NUTRIENT MANAGEMENT FOR BANANA *MUSA* (AB GROUP) NJALIPOOVAN IN *ONATTUKARA* SOILS

By

INDIRA, M.

THESIS
submitted in partial fulfilment of
the requirement for the degree
DOCTOR OF PHILOSOPHY
Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF AGRICULTURE
Vellayani, Thiruvananthapuram

2003

In

memory

of

my Father

DECLARATION

I hereby declare that this thesis entitled **"Nutrient management for banana *Musa* (AB group) Njalipoovan in *Onattukara* soils"** is a bonafide record of research work done by me during the course of research and that 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,
10-3-2003.

INDIRA, M.

CERTIFICATE

Certified that this thesis entitled **"Nutrient management for banana *Musa* (AB group) Njalipoovan in *Onattukara* soils"** is a record of research work done independently by **Smt. Indira, M.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
10-3-2003.

Dr. C. SUNDARESAN NAIR
(Chairman, Advisory Committee)
Associate Director of Research
Kerala Agricultural University
Vellanikkara, Thrissur - 680 656

Approved by

Chairman :

Dr. C. SUNDARESAN NAIR
Associate Director of Research
Kerala Agricultural University
Vellanikkara, Thrissur - 680 656

Members :

1. **Dr. V. K. VENUGOPAL**
   Professor and Head
   Department of Soil Science and
   Agricultural Chemistry
   College of Agriculture, Vellayani

2. **Dr. C. R. SUDHARMAI DEVI**
   Associate Professor
   Department of Soil Science and
   Agricultural Chemistry
   College of Agriculture, Vellayani

3. **Dr. S. JANARDHANAN PILLAI**
   Associate Professor and Head
   Department of Agronomy
   College of Agriculture, Vellayani

4. **Dr. P. SUSHAMAKUMARI**
   Associate Professor
   Onattukara Regional Agricultural Research Station
   Kayamkulam

External Examiner :

Dr K. KUMARASWAMY
PROFESSOR
DEPT OF SS&AC
TNAU, COIMBATORE

ACKNOWLEDGEMENT

I express my deep sense of gratitude and indebtedness to Dr. C. Sundaresan Nair, Associate Director of Research, Kerala Agricultural University and Chairman Advisory Committee for his valuable guidance, sustained enthusiasm and support during the course of the investigation and preparation of the thesis.

I owe my sincere gratitude to Dr. V.K. Venugopal, Professor and Head, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani for his expert guidance, technical advice and timely help rendered throughout the course of the research programme.

My heartfelt thanks are due to Dr.(Mrs.) C. R. Sudharmai Devi, Associate Professor, Department of Soil Science and Agricultural Chemistry, Dr. S. Janardhanan Pillai, Associate Professor and Head, Department of Agronomy, College of Agriculture, Vellayani and Dr. (Mrs.) P. Sushamakumari, Associate Professor, Onattukara Regional Agricultural Research Station, Kayamkulam, members of my advisory committee for their whole hearted sincere help and constructive suggestions on the manuscript.

I am obliged to Dr. P. Rajendran, Managing Director, Kerala Land Development Corporation, Dr. Shyam. S. Kurup, Professor, Onattukara Regional Agricultural Research Station, Kayamkulam and Dr. Thomas Mathew, Assistant Professor (Agronomy), Sugarcane Research Station, Thiruvalla for their valuable suggestions and inspiring advice throughout the course of this research endeavour.

I also wish to place on my record my sincere gratitude to Shri. N. R. Nair, Associate Professor and Head, Sugarcane Research Station, Thiruvalla and Dr. D. Alexander, Associate Director, Onattukara Regional Agricultural Research Station, Kayamkulam for their whole hearted encouragement in the successful completion of the thesis.

I am deeply indebted to Dr. P.J. Joy, Associate Director of Research, Regional Agricultural Research Station, Kumarakom, Dr. P.K. Koshy, Retd. Joint Director, Central Plantation Crops Research Institute, Kayamkulam for extending all possible help during the course of chemical analysis.

My heartfelt thanks are also due to Dr. Sumam George, Dr. Elizabeth K. Syriac, Dr. K. Geetha, Associate Professors, Dr. Usha Mathew, Smt. L. Girija devi, Dr. C. Lekha rani, Assistant Professors for their valuable help and encouragement. A special word of gratitude is extended to Smt. G. Suja, Assistant Professor, Onattukara Regional Agricultural Research Station,kulam and Dr. G. Suja, Scientist, Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram for their willing and generous assistance right from the beginning to the completion of the research work.

I express my sincere thanks to Shri. N. Vasudevan, Farm Supervisor, Onattukara Regional Agricultural Research Station, Kayamkulam for his valuable support and co-operation in the field investigation.

The assistance of Shri. C.E. Ajith Kumar, Computer Programmer, College of Agriculture, Vellayani in the statistical analysis of the data is acknowledged and greatly appreciated.

I extend my sincere thanks to all the teaching and non-teaching and para technical staff of Onattukara Regional Agricultural Research Station, Kayamkulam for their support and co-operation at various stages of study. My heartfelt thanks to all staff, Department of Agricultural Chemistry, College of Agriculture, Vellayani for their sincere co-operation throughout the period of study.

My profound thanks to my friends Rejimol, K.R., Shylaja Kumari, M.S. and Priya Mohan for their prayers and sincere help at one stage or the other.

I am grateful to Kerala Agricultural University for granting me study leave and permitting to conduct the investigation on part time basis at Onattukara Regional Agricultural Research Station, Kayamkulam.

A word of appreciation is also due to M/s. Athira Computers, Kesavadasapuram, Thiruvananthapuram for their neat typesetting and prompt service.

I wish to express my love, affection and indebtedness to my husband Suresh and my daughter Niveditha for their forbearance and patience and my mother and sister for their moral support to make this endeavour a success.

Above all, I am grateful to the Almighty for the blessings in successful completion of the work.

Indira

INDIRA, M.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
BCR	-	Benefit cost ratio
Ca	-	Calcium
CD	-	Critical difference
cm	-	Centimetre
c mol	-	Centi mol
Cu	-	Copper
cv.	-	Cultivar
dS	-	Deci siemens
Fig.	-	Figure
Fe	-	Iron
FYM	-	Farm yard manure
g	-	gram
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potash
kg ha^{-1}	-	Kilogram per hectare
kg	-	Kilogram
LAI	-	Leaf area index
m	-	metre
MAP	-	Month after planting
me	-	milli eqivalents
Mg	-	Magnesium
Mg m^{-3}	-	Mega gram per cubic metre
mg	-	Milligram
mm	-	Milli metre
Mn	-	Manganese
N	-	Nitrogen
^{o}C	-	Degree Celsius
P	-	Phosphorus
P_2O_5	-	Phosphorus pentoxide
$plant^{-1}$	-	Per plant
POP	-	Package of practices
ppm	-	parts per million
S	-	Sulphur
SE_m	-	Standard Error for Mean
sq.m	-	Square metre
t	-	tonnes
var.	-	variety
Zn	-	Zinc

INTRODUCTION

INTRODUCTION

Banana is a unique crop providing food for millions of people in the developing countries of the tropics. It is the fourth important global food commodity after rice, wheat and milk products in terms of gross value of production (Valmayor, 1994). In recent years, there has been a growing recognition of the importance of banana for household food security in many parts of the world.

In India, banana has great socio-economic significance. It is interwoven with the national heritage and with its multi-faceted uses, it is referred to as *Kalpatharu* (Plant of Virtues). Banana is a rich source of starch and minerals. It contains various vitamins and has therapeutic value for the treatment of many diseases. Use of pseudostem core has been well recognized as a medicine in dissolving kidney stones. Banana powder is used as a baby food. With a total annual production of 13.2 million tonnes from 433 thousand hectares, banana contributes 31% of the total fruit production in the country.

Banana is the foremost major fruit crop of Kerala cultivated by marginal and poor farmers. It is cultivated in an area of 92,300 ha with an annual production of 8,08,710 tonnes (FIB, 2002). It can grow well under a wide range of agroclimatic situations and cropping systems. It can be well fitted in crop rotations, multiple cropping, intercropping and companion cropping (Varkey and Pushkaran, 1992).

Among the different cultivars of banana, Njalipoovan (*Musa* AB group) is one of the popular varieties cultivated in the homesteads of Kerala. The variety is assuming importance in commercial cultivation because of its export potential due to high edible and keeping quality. The cultivar can withstand drought to a certain extent and is tolerant to pests and diseases.

Banana is an extremely demanding crop of nutrients. It requires adequate quantity of nutrients throughout its growth period. Therefore addition of mineral nutrients is of importance for its cultivation in many soils. Evidences available on the response of banana to N and K indicate that growth and productivity are affected if nutrients are not applied in optimum quantity (Murray, 1960; Osborne and Hewitt, 1963; Kohli *et al.*, 1984 and Singh *et al.*, 1990). The choice and dosage of nutrients to be applied depends on the variety, initial fertility status, stage of plant growth etc. A judicious application of fertilizers not only gives high yield but also improves the quality of the produce.

Kerala Agricultural University has recommended fertilizer application for cultivars Nendran and Palayankodan (KAU, 1996). Only a general recommendation has been made for other varieties depending on the level of soil fertility. However, under *Onattukara* situation, nutrient requirement for any of the cultivars of banana especially Njalipoovan has not yet been standardised. Hence, the effect of nutrients on growth, yield and quality of banana has to be explored.

Onattukara soil is loamy sand in nature and characterised by low organic matter stauts, fertility, water holding capacity and nutrient retention capacity. So the nutrients applied to the soil is lost by leaching. No work has hitherto been undertaken to quantify the nutrients lost by leaching in these soils. Minimizing the loss of nutrients helps in the effective use of fertilizers thereby reducing the cost of cultivation and increasing the productivity.

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

- To formulate an effective nutrient management schedule for banana cv. Njalipoovan in *Onattukara* soil.
- To evaluate the economics of banana crop production.
- To assess the leaching loss of nutrients in the soil.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana, one of the most important commercial fruit crops of Kerala, requires large amount of mineral nutrients to maintain high yield. Among the different cultivars Njalipoovan has acquired considerable popularity in commercial cultivation because of its superior edible qualities compared to other varieties. Therefore to meet the market demand it is inevitable to increase the production without deterioration in edible qualities. The yield and quality being the primary concerns, nutritional recommendations for the crop assume greater significance in soils where cultivation is carried out on a large scale. In the light of the above it is also worthwhile to consider the different agroclimatic situations in respect of nutrition and its responses.

Hence, the review is presented broadly covering the influence of different nutrients on growth, yield and quality of banana.

2.1 Response of banana to NPK fertilization

Banana is considered as a soil exhaustive crop. Hence continual cropping with banana may lead to severe depletion of essential nutrients from the soil. Supplementing the soil with plant nutrients could overcome this problem to a great extent.

2.1.1 Response to nitrogen

Nitrogen is a key element in banana nutrition and frequent supplementation of the element is required even in fertile soils to elicit better effect on growth and development of the crop.

2.1.1.1 Effect on growth attributes

Mathew (1980) obtained significant increase in the height and girth of pseudostem with higher levels of nitrogen in banana cv. Palayankodan. The positive influence of applied nitrogen on the height and girth of pseudostem of banana and the number of days to flowering was also reported by Chattopadhyay *et al.* (1980).

Sweidon *et al.* (1981) reported that nitrogen at 400 g $plant^{-1}$ induced early differentiation and shortened the vegetative period in banana cv. Dwarf Cavendish. In Hill banana, Mustaffa (1983) observed delayed maturity by the application of nitrogen at high rate and the optimal rate worked out for better growth and development was 160 g N $plant^{-1}$.

The beneficial effect of nitrogen on early growth and development is evident from the studies conducted by Anjorin and Obigbesan (1983). They also observed that nitrogen application upto 300 g $plant^{-1}$ significantly increased plant height, pseudostem girth, pseudostem weight and leaf weight. But higher rates at and above 400 g $plant^{-1}$ depressed all the growth parameters.

In a nutritional trial on banana cv. Robusta, Kohli *et al.* (1984) found that the plant height and pseudostem girth increased significantly with incremental doses of nitrogen (0 to 750 g $plant^{-1}$). However, the effect of different levels of nitrogen on the number of leaves $plant^{-1}$ was not significant. Whereas higher levels of nitrogen reduced the crop duration.

Sharma (1984) reported that the plant height and pseudostem girth were highest at soil application of 187.5g N $plant^{-1}$ along with the foliar application of urea at the rate of 187.5 g $plant^{-1}$ in 12 sprays at biweekly intervals in banana cv. Basrai. Oubahou and Dafiri (1987) recommended upto 425 g N $plant^{-1}$ for banana cv. Giant Cavendish for increasing plant height, pseudostem girth and other yield components. Similar observations were made by Nair (1988), Thangaselvabai (1989) and Prabhuram (1992).

According to Mustaffa (1988), pseudostem height, girth and number of functional leaves showed an increasing trend with increasing levels of nitrogen upto 250 g $plant^{-1}$.

Singh *et al.* (1990) reported that the pseudostem height and girth was increased by the application of nitrogen at 600 g $plant^{-1}$ in banana cv. Dwarf Cavendish. Hazarika and Mohan (1991) reported increase in vegetative growth with increasing nitrogen levels upto 200 g $plant^{-1}$ in banana cv. Jahaji.

Singh and Kashyap (1992) obtained highest plant height with the application of 600 g N $plant^{-1}$ while pseudostem girth and number of leaves were highest at 400 g N $plant^{-1}$.

Highest growth rate of stem with 80g nitrogen plant^{-1} for Dwarf Cavendish and 320 g nitrogen plant^{-1} for Basrai banana was recorded by Gubbuk *et al.* (1993). In banana cv. Hindy plant, Shawky *et al.* (1993) recorded increased vegetative growth with increasing nitrogen application upto 250 g plant^{-1}.

Sheela (1995) studied the response of tissue cultured Nendran banana in reclaimed Kayal lands of Vellayani and reported that nitrogen applied at 400 g plant^{-1} influenced the height of pseudostem at the 5th month stage and girth at early stages of growth. But it had no influence on leaf production month^{-1}, leaf retention month^{-1}, total number of leaves and total duration of the crop.

Srikul and Turner (1995) observed earliness in fruit maturation by the application of 450 kg N ha^{-1} in banana cv. Williams.

According to Geetha (1998), increasing levels of nitrogen applied upto 190 g plant^{-1} significantly increased plant height and girth but shortened the number of days to shooting and total crop duration. But it had no marked influence on fruit maturity commencing from shooting to harvest.

Singh and Suryanarayana (1999) studied the effect of N at 50, 100, 150, 200 and 250 g plant^{-1} levels recorded highest growth by the application of 200 g N plant^{-1} in cv. Cavendish.

2.1.1.2 Effect on yield attributes and yield

In banana cv. Giant Governor, Chattopadhyay *et al.* (1980) reported that by increasing nitrogen dose upto 240 g $plant^{-1}$ annually, the yield increased to 31200 and 30880 kg ha^{-1} in the plant and ratoon crops respectively.

Mathew (1980) in her studies on the yield response of banana cv. Palayankodan to N (0, 100, 200, 300 and 400 g $plant^{-1}$) found that bunch yield significantly increased upto the level of 200 g N $plant^{-1}$. Beyond this level, fruit yield declined.

According to Hernandez *et al.* (1981), yield, number of hands $bunch^{-1}$ and number of fingers $bunch^{-1}$ were highest with 100 g N $plant^{-1}$ in banana cv. Giant Cavendish.

Holder and Gumbs (1983) obtained highest yield with 840 kg N ha^{-1} in banana cv Robusta and Giant Cavendish.

Kohli *et al.* (1984) reported that application of N at the rate of 100 g $plant^{-1}$ resulted in 50 per cent increase in the total dry matter production in banana cv. Robusta. They also observed significant correlation between yield and foliar N level in the 16th leaf. In banana cv. Robusta, Kotur and Mustaffa (1984) observed the highest yield of 44.8 t ha^{-1} by the application of 210 g N $plant^{-1}$.

Hegde (1988) reported that increasing the level of nitrogen from 100-200 g $plant^{-1}$, the fruit yield significantly increased from 45.3 to 49.3 t ha^{-1}.

In banana cv. Jahaji, Hazarika and Mohan (1991) recorded highest number of fingers bunch^{-1} (127.83), bunch weight (20.94 kg plant^{-1}) with 160 g N plant^{-1}.

Singh and Kashyap (1992) obtained an yield of 69.32 t ha^{-1} when 400 g N plant^{-1} was applied in banana cv. Robusta.

A study conducted at the Kerala Agricultural University revealed that the optimum ratio of organic manure to inorganic nitrogen for higher yield in banana was 25:75 (KAU, 1993).

Ray and Yadav (1994) reported highest yield of 92.6 t ha^{-1} with 250 g N plant^{-1} in banana cv. Basrai. The fruit yield declined beyond this level.

Sheela (1995) studied the response of tissue cultured banana cv. Nendran to different levels of N at 200, 300 and 400 g plant^{-1} and observed highest bunch yield of 12.54 kg plant^{-1} and maximum number of fingers 50.02 with 300 g N plant^{-1}.

Investigation on the effect of nitrogen on the yield of two banana cultivars undertaken at Banana Research Station, Kannara (Aravindakshanan and Puskharan, 1996) revealed that highest yield of Palayankodan was obtained at 150 g N plant^{-1} whereas Robusta gave the optimum performance at 100 g N plant^{-1}.

Prabhakar (1996) recorded significant increase in bunch weight and number of hands bunch^{-1} in Nendran banana with 200 g N plant^{-1}.

Tirkey *et al.* (1998) observed that increasing level of nitrogen application from 100 to 300 g plant^{-1} in micro propagated banana significantly increased the bunch weight.

In trials conducted on banana cv. Dwarf Cavendish, Dawood *et al.* (1999) obtained the best rate of growth and yield at 138 g N plant^{-1}.

According to Geetha and Nair (2000), higher level of nitrogen at 143 and 190 g plant^{-1} had significant effect on fruit weight over the lower level of nitrogen at 95 g plant^{-1}.

2.1.1.3 Effect on quality attributes

Studies conducted by Chattopadhyay *et al.* (1980) had shown that the total and reducing sugar content of Cavendish banana fruits can be increased by the application of nitrogen. Similar results were obtained in rainfed banana var. Palayankodan by Mathew (1980). Contrary to these results Mustaffa (1983) described that N application above 150 g plant^{-1} decreased the total soluble solids, total sugars and sugar-acid ratio in Hill banana. Ram and Prasad (1989) indicated that applied N at 100, 200, 300 g plant^{-1} had no effect on starch content and acidity of fruits in banana cv. Cambierganj.

According to Nair (1988), application of 300 g N plant^{-1} increased the total soluble solids of fruits in Nendran.

Hazarika and Mohan (1990) reported highest total soluble solids, total sugars, reducing sugars, non-reducing sugars, sugar-acid ratio, pulp weight and pulp-peel ratio and lowest titrable acidity in banana cv. Jahaji fertilized with 160 g N $plant^{-1}$ when compared with plants without nitrogen application.

Hegde and Srinivas (1991) observed an increase in the percentage of total soluble solids of banana fruits with increase in nitrogen fertilizers from 100 to 300 g $plant^{-1}$. Sankar and Rao (1993) observed that N markedly influenced the quality of fruits in banana cv. Robusta. Starch content increased up to 100 g N $plant^{-1}$ and declined thereafter.

Investigations carried out by Sheela (1995) revealed that N at 300 g and 400 g $plant^{-1}$ decreased the reducing sugar content and increased the acidity in banana fruits.

Geetha (1998) found that N applied at 143 g $plant^{-1}$ recorded the highest sugar content (24.3 %), sugar-acid ratio (46.26) and lowest acidity (0.54 %) in banana cv. Nendran.

2.1.2 Response to phosphorus

The phosphorus requirement of banana is low compared with nitrogen and potassium.

2.1.2.1 Effect on growth attributes

Ramaswamy (1976) reported that in Robusta, height of pseudostem increased with increasing rate of P_2O_5 application. Maximum value was recorded at 60 g $plant^{-1}$.

Shankar (1980) found that the height and girth of pseudostem increased upto 30 g P $plant^{-1}$ further increase led to reduction in plant height.

Bellie (1987) studied the effect of increased dose of phosphorus in banana cv. Nendran and observed early shooting and harvest with highest level of P_2O_5 at 90 g $plant^{-1}$.

According to Sheeja (1990), there was no significant variation in the growth characters and uptake of phosphorus when different phosphatic fertilizers were applied to banana cv. Nendran.

Lin and Fox (1992) in a study on the agronomic effectiveness of rock phosphate in small banana (*Musa paradisiaca* L.) found that the dry matter production, phosphorus content in leaf and total uptake of phosphorus increased with P fertilization.

The favourable influences of P fertilization on general vegetative growth of banana was reported by Shanmugavelu *et al.* (1992).

2.1.2.2 Effect on yield attributes and yield

According to Nambisan *et al.* (1980), individual effect of phosphorus in improving the yield of banana was not significant. Kohli *et al.* (1985) obtained the highest yield in banana cv. Robusta with 50 g P_2O_5 $plant^{-1}$.

Natesh (1987) obtained maximum bunch weight in Nendran (11-13 kg) by the application of 140 g P_2O_5 plant^{-1} in two equal splits at two and four months after planting.

In banana, 0.52 per cent P at shooting was considered as an indication for good productivity (Ray *et al.*, 1988).

Shehana (1997) claimed that phosphorus at 86 g plant^{-1} in combination with phosphobacterin was effective in obtaining maximum yield in banana cv. Nendran.

2.1.2.3 Effect on quality attributes

Reports on the individual effect of phosphorus on the quality attributes of banana fruit are meagre.

2.1.3 Response to potassium

Potassium is the most important element in banana nutrition. It is proved to be the important nutrient influencing both the quantitative and qualitative aspects of the crop (Rajeevan, 1985; George, 1994; Sindhu, 1997).

2.1.3.1 Effect on growth attributes

Bravo *et al.* (1980) observed that in banana grown in Canary Islands, K concentration in the range 78 to 105 me 100 g^{-1} soil correlated with plant growth measured in terms of circumference of pseudostem.

Sheela (1982) conducted investigations on K nutrition in rainfed banana cv. Palayankodan and observed that the height of pseudostem at late vegetative stage and shooting stage were influenced significantly by the application of 400 g and 500 g K_2O plant^{-1} respectively. But the different K levels ranging from 0 to 600 g plant^{-1} did not influence the girth of pseudostem at any stage of plant growth. It was also observed that the different levels of K application did not influence the number of functional leaves. While potassium at the highest level induced early harvest of bunches.

According to Obiefuna (1984), application of 300 g K_2O plant^{-1} at 4 MAP to 5 MAP reduced the time of harvest from planting by more than three months.

In banana cv. Jahaji, Baruah and Mohan (1985) observed maximum height and girth of pseudostem and number of leaves plant^{-1} with 250 g K_2O plant^{-1}.

Mustaffa (1987) from a study on the effect of increasing doses of K fertilizer on banana cv. Robusta found that increased K level of 400 g K_2O plant^{-1} significantly increased the height of plant, girth of pseudostem, leaf number and leaf area.

Obiefuna and Onyete (1987) reported that insufficient doses of K delayed flowering by 2-3 months in plantains.

Oubahou and Dafiri (1987) found positive correlation for K with the height and circumference of the pseudostem which they termed as the productivity index.

Singh *et al.* (1990) reported that potassium application did not favourably increase the leaf area index in Dwarf Cavendish banana.

Hegde and Srinivas (1991) reported significant statistical relationship between increased K levels upto 300 g $plant^{-1}$ and girth of pseudostem.

In Dwarf Cavendish banana, height and basal circumference of pseudostem responded positively to K application upto 500 g $plant^{-1}$ (Khoreiby and Salem, 1991).

Study conducted by George (1994) in banana cv. Nendran revealed that plant height, girth of pseudostem, total number of leaves and number of functional leaves increased with increasing levels of K upto 225 g $plant^{-1}$ application at all growth stages. The effects were more pronounced from shooting stage of the crop.

Sheela (1995) and Sindhu (1997) observed increase in the height and girth of pseudostem with increase in dose of potassium upto 600 g K_2O $plant^{-1}$.

2.1.3.2 Effect on yield attributes and yield

The beneficial effect of potassium in improving the yield of banana has been reported by many workers (Sheela, 1982; Obiefuna, 1984; Cordero, 1985; Mustaffa, 1987; Baruah and Mohan, 1992).

Turner and Barkus (1982) reported that low K supply considerably reduced the bunch weight and various yield components in banana.

In the Carribean coast of Costa Rica, Garita and Jaramillo (1984) found that enhanced K levels at 750 kg ha^{-1} increased bunch size and bunch weight in banana cv. Giant Cavendish.

Investigations on the effect of different methods and times of manuring on the growth and yield of banana, Sharma and Yadav (1987) found that the highest bunch weight of 18.42 kg was obtained by the application of 110 g K $plant^{-1}$.

Obiefuna and Onyete (1987) recommended an annual application of 500 g K $plant^{-1}$ for the heaviest bunch weight, the demand for K being double that of N.

According to Nair *et al.* (1990), though the bunch weight of banana cv. Nendran showed linear response with higher levels of K application upto 600g $plant^{-1}$ the different levels of K did not significantly influence other bunch characters like length of bunch, weight of hand, weight and girth of finger.

Ali *et al.* (1991) observed significant difference in the number of hands and fingers in banana cv. Amrit Sagar between K fertilized and unfertilized plots.

Hegde and Srinivas (1991) observed improvement in yield of banana with increased hands and fingers $bunch^{-1}$ up to a K level of 300 g $plant^{-1}$.

Investigation by Chong *et al.* (1992) revealed that 900-1200 kg K_2O ha^{-1} increased banana yield by 11.6 tonnes ha^{-1} over control.

Sindhu (1997) reported that application of 450 g K_2O $plant^{-1}$ in banana cv. Nendran significantly increased the number of fingers $bunch^{-1}$, number of hands $bunch^{-1}$, weight of hand and bunch.

Kumar *et al.* (1998) studied the effect of potassium on yield of banana cv. Dwarf Cavendesh and worked out the optimal dose of potassium as 200 g $plant^{-1}$ $year^{-1}$ for higher yield.

Experiments undertaken by Lopez and Espinosa (1998) revealed that the best economic responses for yield was obtained with 600-675 kg K_2O ha^{-1}.

Response of Banana cv. Grand Naine to different levels of K_2O at 400, 600, 800 and 1000 g $plant^{-1}$ was studied by Saad and Atawia (1999) and observed that application of 800 g K_2O $plant^{-1}$ increased the bunch weight, number of hands and fingers $bunch^{-1}$.

Lekshmi (2000) reported that the bunch yield and other yield attributing characters of banana cv. Nendran were highest with potassium applied in combination with sodium. Similar results were also obtained by Sunu (2001) in Robusta banana.

2.1.3.3 Effect on quality attributes

It is well documented that potassium has important role in the nutrition of banana which is manifested by its profound influence in improving the quality than on yields.

Zehler *et al.* (1981) reported that potassium had a positive influence in improving storage properties as well as sugar/acid ratio of banana fruit.

Sheela (1982) stated that total soluble solids, total sugar, reducing sugars and sugar/acid ratio increased and acidity decreased with increasing levels of potassium in banana cv. Palayankodan. Similar results were reported by Baruah and Mohan (1986) in banana cv. Jahaji and Mustaffa (1987) in Robusta.

According to Tandon and Sekhon (1988), potassium improves the quality, flavour, sweetness and keeping quality of fruits. Samra and Quadar (1990) stated that soil and foliar application of K increased total and reducing sugars in fruits.

Experiment undertaken by George (1994) to find the effect of K application in banana cv. Nendran revealed that total sugars, non-reducing sugars, shelf life and pulp peel ratio showed an increasing trend with increase in K supply. Similar result of the effect of K on quality of fruits of banana has been reported by Bhargava *et al.* (1993) and Sindhu (1997).

Hassan *et al.* (1999a) reported that higher rates of K application at 500 and 600 g K_2O plant^{-1} resulted in an increase in total sugars, reducing and nonreducing sugars and a decrease in the acidity of fruits in Giant Governor.

2.1.4 Combined effect of NPK on growth, yield and quality

2.1.4.1 Effect on growth attributes

Chattopadhyay and Bose (1986) reported that application of NPK nutrients at 240, 90, 480 g plant^{-1} respectively increased the plant height, stem girth and leaf number significantly.

According to Dagade (1986) the optimum NPK rates with regard to growth and development in banana cv. Robusta were 100 g N, 40 g P_2O_5 and 100 g K_2O plant^{-1}.

The studies with banana cv. Grand Naine, Oubahou and Dafiri (1987) observed increased plant height and pseudostem circumference with increasing levels of N from 225 to 425 g plant^{-1}, P_2O_5 from 320 to 500 g plant^{-1} and K_2O from 320 to 550 g plant^{-1}.

Ram and Prasad (1989) recorded maximum plant growth with 300 g N, 120g P_2O_5 and 200 g K_2O plant^{-1} in Campierganj Local above which flowering was delayed.

Parida *et al.* (1994) recorded increased plant height, stem girth and number of leaves and with increasing rates of N from 75 to 225 g plant^{-1}, P_2O_5 0 to 60 g plant^{-1} and K_2O from 75 to 225 g plant^{-1}. At these levels the number of days taken for shooting was reduced.

According to Anjorin and Obigbesan (1987), application of NPK at 200, 66, 166 g plant^{-1} respectively reduced the number of days to flowering in Basrai Dwarf. But Natesh (1987) reported that the different doses of NPK at different time of application did not influence the crop duration of Nendran.

The experiment conducted by Peters (1997) on maximisation by rescheduling nutrient application in banana cv. Nendran revealed that application of 380, 115, 600 g NPK plant^{-1} in six splits was very effective in producing maximum height, pseudostem girth, number of leaves and LAI.

Agrawal *et al.* (1998) from the study on the influence of higher levels of nitrogen and potassium on growth and yield of *in vitro* banana cv. Robusta revealed that time to flowering was reduced by the application of 450 g K_2O plant^{-1}.

2.1.4.2 Effect on yield attributes and yield

It has been demonstrated that banana responded well to fertilizer application. Increased yields were obtained by the application of N, P and K in combination. The fertilizer studies conducted in Robusta by Pillai and Khader (1980) revealed that plants receiving 100 kg N, 40 kg

P_2O_5 and 400 kg K_2O acre^{-1} in three split doses produced significantly heavier bunches.

Nanjan *et al.* (1980) reported that in Periyar river command area, the optimum dose of nutrients for maximum fruit yield in banana cv. Poovan were, 100 g N, 40g P_2O_5 and 350 g K_2O plant^{-1}. The ratoon crop required 200 g N, 40 g P_2O_5 and 350 g K_2O plant^{-1}.

According to Lahav and Zamet (1982), N:K ratio of 1:6 resulted in the highest number of bunches ha^{-1} in banana. Shaikh *et al.* (1985) worked out the optimum NPK rates for highest yield in Basrai banana as 706, 393 and 706 kg ha^{-1}.

Ray *et al.* (1988) reported that N and K were more effective than P in improving the yield and the highest dose of 225 g each plant^{-1} gave the best results.

While studying the effect of N, P and K on banana cv. Campierganj Local, Ram and Prasad (1989) found that application of 300 g N, 40 g P_2O_5 and 100 g K_2O plant^{-1} resulted in significantly higher bunch weight.

Dave *et al.* (1990) studied the nutritional requirement of Basrai banana in South Gujarat and recommended 150 g each of N, P_2O_5 and K_2O plant^{-1} for increased yield and high nutrient use efficiency.

According to Pandit *et al.* (1992), highest yield of 35 t/ha and number of hands per bunch in Dwarf Cavendish banana were recorded by applying 400 g ammonium sulphate, 300 g super phosphate and 250 g muriate of potash plant^{-1}.

Sanker and Rao (1993) obtained significantly high bunch weight with 100 g N and 15 g P_2O_5 plant^{-1}. Aravindakshan and Pushkaran (1996) found that in Nendran the optimum dose of N, P_2O_5 and K_2O for maximum bunch yield was 150, 150 and 300 g plant^{-1} respectively.

Comparing the effects of fertilizer levels viz., 100:40:100,200:80: 200 and 300:120:300g NPK plant^{-1}, Pawar *et al.* (1997) reported that the yield increase beyond 200:80:200 g N, P_2O_5 and K_2O plant^{-1} was not significant in Basrai banana.

Khandare *et al.* (1998) studied the effect of different fertilizer rates on yield of banana ratoon crop and explained that increasing NPK rate increased yield, total weight bunch^{-1} and average bunch weight.

In a study conducted on *in vitro* banana cv. Robusta, significant increase in yield, number of hands bunch^{-1} and number of fingers bunch^{-1} was recorded by the application of 450 g each of N and K_2O and 200 g P_2O_5 plant^{-1} (Agrawal *et al.*, 1998).

The response of Dwarf Cavendish banana to different levels and combination of nitrogen at 100, 150, 200, 250, 300 and 350 g plant^{-1} phosphorus at 40 g plant^{-1} and K_2O at 100, 150 and 200 g plant^{-1} was studied by Shelke and Nahate (2000) and considered 200, 40 and 200 g of N, P_2O_5 and K_2O plant^{-1} to be optimum for obtaining better yield.

2.1.4.3 Effect on quality attributes

Investigations on the effect of split application of NPK in banana cv. Palayankodan by Rajeevan (1985) revealed that the total sugars, reducing sugars and pulp peel ratio significantly increased with increasing levels of N and K_2O.

Chattopadhyay and Bose (1986) stated that the total sugar content in fruits varied mainly due to different levels of N and K.

In Campierganj Local maximum TSS (21.21%) was recorded with N, P_2O_5 and K_2O at 200:80:200 g plant^{-1} and total sugar was highest (17.3 %) with 300:120:100 g N, P_2O_5 and K_2O plant^{-1} (Ram and Prasad, 1988). Upadhyay (1988) reported that the fruit quality was best with the lower rate of N, P and K in banana cv. Harichal.

Hegde and Srinivas (1991) observed that increasing level of nitrogen increased the total soluble solids while increasing levels of potassium improved the total soluble solids but decreased the pulp/peel ratio in banana.

According to Pandit *et al.* (1992) application of 400 g ammonium sulphate, 300 g single super phosphate and 250 g muriate of potash per plant resulted in highest sugar content and lowest acidity in fruits.

Experiments undertaken in Robusta banana by Agrawal *et al.* (1997) revealed that 450 g each of N and K_2O in five split applications and 200g P_2O_5 plant^{-1} significantly increased the TSS, reducing sugar and total sugars. But the applied fertilizers had no impact on acidity and sugar acid ratio.

2.2 Nutrient uptake of banana

Nambisan *et al.* (1980) worked out the uptake rate of N,P,K and Ca by Robusta banana which produced 55 t fruit ha^{-1} as 325, 75, 1195 and 58 kg ha^{-1} respectively.

The ratios of P and K uptake by different crops relative to N was worked by Goswami and Khera (1981) and reported that for a banana population of 2960 plants ha^{-1}, the ratios were 100N, 44P and 311K.

The study conducted by Godefroy (1982) indicated that a banana crop yielding 40-60 tonnes of bunches ha^{-1} removed 80-120 kg N, 20-30 kg P, 240-360 kg K and 10-15 kg each of Ca and Mg. These results are in conformity to the subsequent report of Mengel and Kirkby (1982).

Irizarry *et al.* (1982) studied the nutrient uptake at different growth stages in banana cv. Grand Naine. The uptake of N, P, K, Ca and Mg at harvest was estimated as 249, 21, 585, 147 and 60 kg ha^{-1} respectively.

Subsequent studies conducted by Irizarry *et al.* (1988) in Grand Naine banana grown in red acid corozal clay showed that the crop uptake was on an average at 276, 23, 711, 152 and 54 kg ha^{-1} of N, P, K, Ca and Mg respectively at harvest of first ratoon crop.

According to Chong *et al.* (1992) the nutrient uptake by banana plants in a plantation with 3000 plants was 448 kg ha^{-1} each for N and P, 1680 and 175 kg ha^{-1} for K and Mg respectively.

The nutrient removal by banana cv. Nendran in Vellayani red loam soil was worked out as 197-349 kg N, 60-68 kg P and 433-706 kg K per hectare (Anil, 1994).

The effect of application of K fertilizer on the nutrient uptake pattern in Cavendish banana was studied by Hassan *et al.* (1999b) and found that uptake of N increased from the vegetative to the shooting stage and decreased thereafter. K uptake showed a similar pattern to N and declined at the shooting stage whereas P uptake showed a reduction from the vegetative to the shooting stage.

A scan of literature indicates that a suitable fertilizer recommendation has not been developed for banana cv. Njalipoovan despite of its superior quality. Hence the present investigation is undertaken to formulate an effective nutrient management schedule for Njalipoovan.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment was conducted in two consecutive cropping seasons of 1998-99 and 1999-00 to study the response of banana cv. Njalipoovan to different levels of nitrogen, phosphorus and potassium. The details of experimental site, season and weather conditions, materials used and methods adopted are presented in this chapter.

3.1 Experimental site

3.1.1 Location

The field experiment was conducted in the garden land of the farm attached to Onattukara Regional Agricultural Research Station, Kayamkulam. Geographically the area is located at 9°30' N latitude and 76°20' E longitude at an altitude of 3.05 m above mean sea level.

3.1.2 Soil

The soil of the experimental site comes under the taxonomic family of Loamy skeletal Kaolinitic Isohyperthermic, *Ustic Quartzi Psamments*. The soil is acidic in reaction with low content of organic carbon, available nitrogen, available phosphorus and exchangeable potassium. The physico-chemical characteristics of the experimental site are presented in Table 1.

Table 1. Physico-chemical characteristics of the soil of the experimental site

Parameters	Unit	Content in soil 98-99	Content in soil 99-00	Method used
A. Mechanical composition				
Coarse sand	%	68.24	66.83	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	%	17.41	17.82	
Silt	%	4.78	5.03	
Clay	%	9.32	10.13	
B. Physical properties				
Bulk density	Mgm^{-3}	1.70	1.67	Core method (Gupta and Dakshinamoorthi, 1980)
Particle density	Mgm^{-3}	2.53	2.60	-do-
Water holding capacity	%	15.92	16.01	-do-
Porosity	%	25.38	24.62	-do-
C. Chemical properties				
Soil reaction (pH)		5.28	5.25	pH meter with glass electrode (Jackson, 1973)
Organic carbon	%	0.25	0.28	Walkley and Black's rapid titration method (Jackson, 1973)
Available N	kg ha^{-1}	186.31	182.85	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P	kg ha^{-1}	9.86	9.54	Bray I method (Jackson, 1973)
Available K	kg ha^{-1}	78.14	75.89	Ammonium acetate method (Jackson, 1973)
Exchangeable Ca	cmol (P^{+}) kg^{-1}	0.06	0.06	-do-
Exchangeable Mg	cmol (P^{+}) kg^{-1}	0.03	0.03	-do-
Avaialble Fe	ppm	20.53	21.18	DTPA extraction (Lindsay and Norvell, 1978)
Available Mn	ppm	1.38	1.41	-do-
Available Cu	ppm	0.12	0.11	-do-
Available Zn	ppm	0.27	0.29	-do-

3.1.3 Cropping history

The land was cropped with banana prior to the commencement of the present investigation.

3.2 Season

The field experiment was conducted during the period from April to May in 1998-99 and 1999-00.

3.3 Weather condition

Typical humid tropical climate is experienced in the area. The data on various weather parameters like maximum temperature, minimum temperature, rainfall and relative humidity during cropping periods and the previous five year average are presented in Appendix-1. The weather parameters of the cropping periods are also depicted graphically in Fig.1a and 1b.

The total rainfall obtained during the first and second year of the cropping period was 3057.8 and 2652.1 mm respectively. The mean monthly minimum and maximum temperature ranged from 20.3°C to 25.2°C and 30.4°C to 35.5°C respectively during 1998-99, while it ranged from 21.1°C to 24.9°C and 29.8°C to 33.2°C respectively during 1999-00. The average monthly relative humidity ranged between 91 to 96 per cent during 1998-99 and between 90 to 96 per cent during 1999-00. In general, the weather conditions were favourable for the satisfactory growth of the crop.

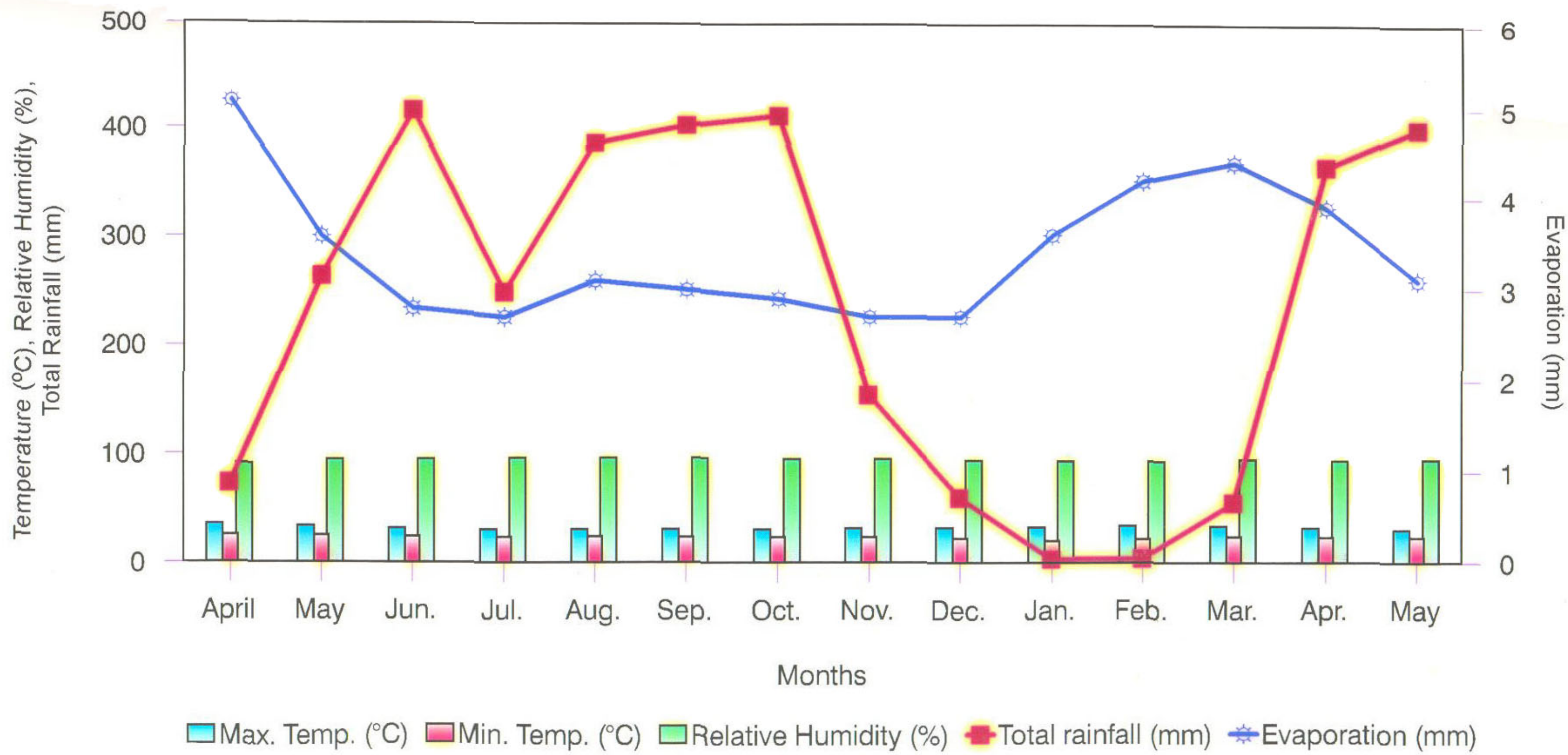

Fig. 1a. Weather parameters during the crop growth period (98-99)

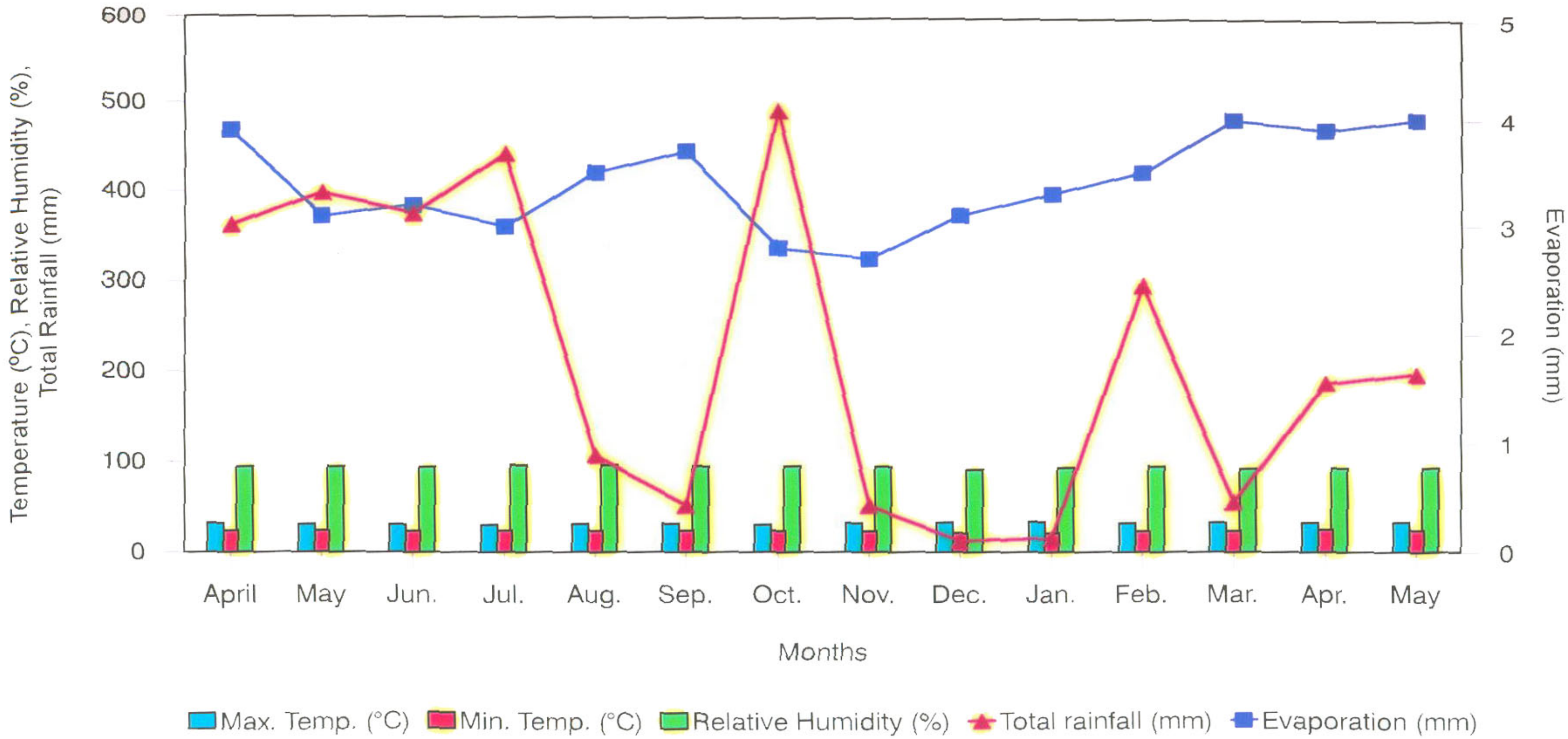

Fig. 1b. Weather parameters during the crop growth period (99-00)

3.4 Materials

3.4.1 Planting materials and variety

Three months old disease free sword suckers of uniform weight were selected for planting to ensure maximum homogenity in physiological maturity. The suckers were obtained from Onattukara Regional Agricultural Research Station, Kayamkulam. The variety used was Njalipoovan.

3.4.2 Manures and fertilizers

Well-decomposed and dried farm yard manure (FYM) @ 10 kg $plant^{-1}$ was used in the experiment. It contained 0.50 per cent nitrogen, 0.20 per cent phosphorus and 0.40 per cent potassium.

Urea (46% N), Mussooriephosphate (20% P_2O_5) and Muriate of potash (60% K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

3.5 Methods

3.5.1 Experimental Design and layout

Lay out plan of the experiment is presented in Fig. 2 (Plate 1). The details of the experimental techniques followed are described below.

Design : Confounded 3^3 factorial, confounding NPK in Replication I and NP^2K in Replication II

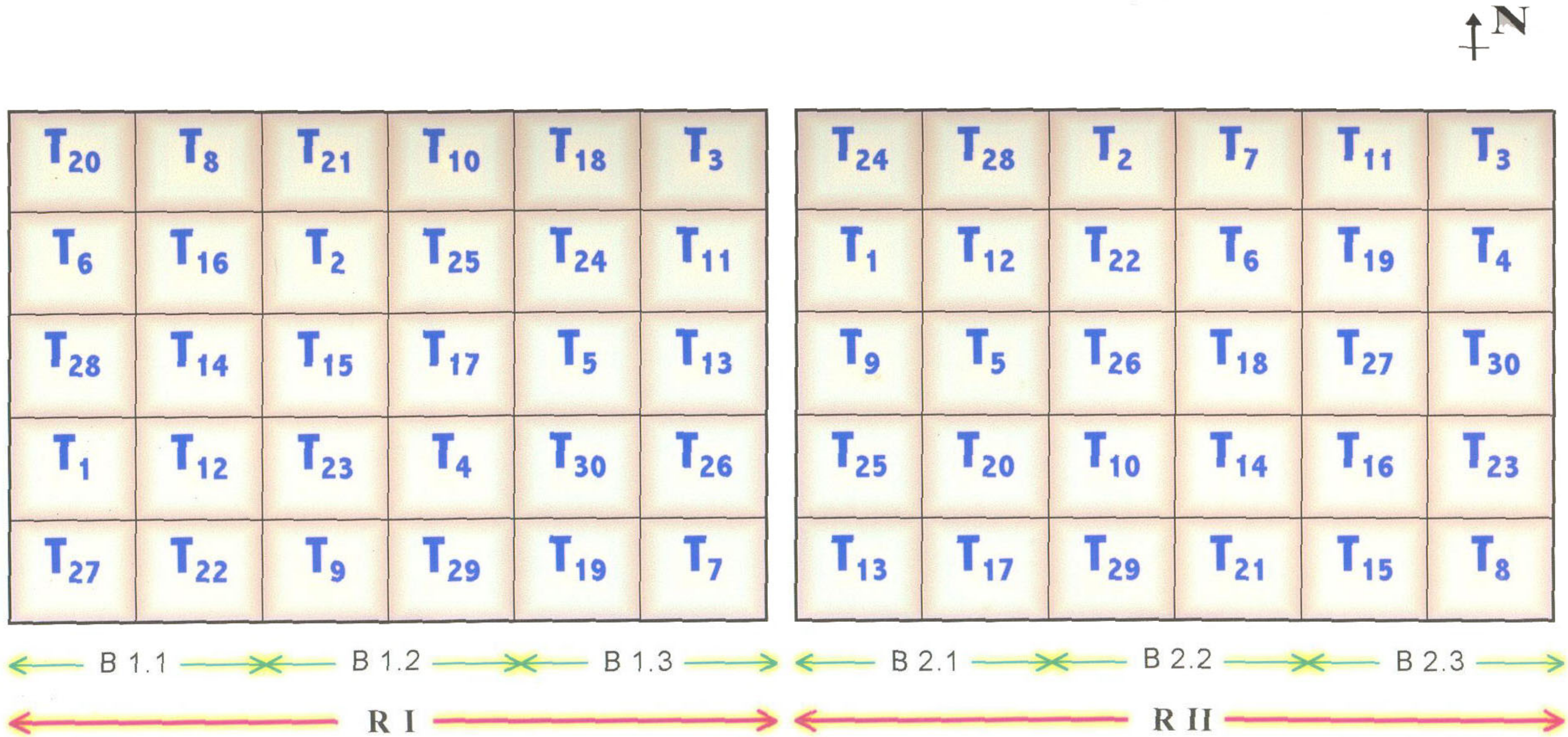

Fig. 2. Layout plan of the experiment

Plate 1. General view of the experiment

Number of treatments	:	27 + 1 = 28
Number of replications	:	2
Number of blocks/replication	:	3
Number of plots/block	:	9+1 = 10
Total number of plots	:	60
Variety	:	*Musa* (AB group) Njalipoovan
Spacing	:	2.13 x 2.13 m
Gross plot size	:	10.70 x 8.50 sq.m

3.5.1.1 Treatments

(i) Levels of nitrogen (N)

n_1 - 100 g $plant^{-1}$

n_2 - 200 g $plant^{-1}$

n_3 - 300 g $plant^{-1}$

(ii) Levels of phosphorus (P_2O_5)

p_1 - 100 g $plant^{-1}$

p_2 - 200 g $plant^{-1}$

p_3 - 300 g $plant^{-1}$

(iii) Levels of potassium (K_2O)

k_1 - 200 g $plant^{-1}$

k_2 - 400 g $plant^{-1}$

k_3 - 600 g $plant^{-1}$

(iv) $n_0p_0k_0$ - absolute control (without N, P and K)

3.5.1.2 Treatment combinations - $3^3+1 = 28$

$n_1p_1k_1$	$n_2p_1k_1$	$n_3p_1k_1$	$n_0p_0k_0$
$n_1p_1k_2$	$n_2p_1k_2$	$n_3p_1k_2$	
$n_1p_1k_3$	$n_2p_1k_3$	$n_3p_1k_3$	
$n_1p_2k_1$	$n_2p_2k_1$	$n_3p_2k_1$	
$n_1p_2k_2$	$n_2p_2k_2$	$n_3p_2k_2$	
$n_1p_2k_3$	$n_2p_2k_3$	$n_3p_2k_3$	
$n_1p_3k_1$	$n_2p_3k_1$	$n_3p_3k_1$	
$n_1p_3k_2$	$n_2p_3k_2$	$n_3p_3k_2$	
$n_1p_3k_3$	$n_2p_3k_3$	$n_3p_3k_3$	

3.5.2 Field preparation and planting

The experimental area was spaded twice, weeds and stubbles were removed. Pits of 50 x 50 x 50 cm size were dug at a spacing of 2.13 x 2.13 m. FYM was applied as basal dose @ 10 kg $plant^{-1}$.

The suckers were dipped in cowdung slurry and dried in sun for three days and stored in shade before planting. The treated suckers were planted upright in the centre of the pits.

3.5.3 Fertilizer incorporation

Fertilizers at the calculated quantities to supply the different levels of nitrogen, phosphorus and potassium as per the treatments were applied in two equal splits. Half the dose of N, P and K was given two months after planting (MAP) and the remaining four MAP.

3.5.4 Maintenance of the crop

Mulching was provided at the basin till the suckers established well. Hand weeding was resorted to as and when required.

3.5.5. Irrigation

The crop was raised as rainfed. However during both the years, life saving irrigations were provided to avoid prolonged dry spells.

3.5.6 Other cultural operations

Field culture other than the treatment requirements were followed as per the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 1996).

3.5.7 General condition of the crop

The establishment of the crop was satisfactory during both the years. Incidence of pests and diseases was also not apparent.

3.5.8 Soil column studies

Undisturbed vertical soil columns from the experimental site were collected (28 numbers) to a depth of 60 cm with slight modification using PVC tubes of 10 cm inner diameter. Calculated amount of FYM and fertilizers as per the treatments for field study were mixed with the soil in the upper 15 cm of the soil column and fixed volume of water was applied to collect the leachate. The leachate from soil column was collected weekly for two months after application of treatments. The leachate was analysed for nitrogen (N), phosphorus (P) and potassium (K). After two months, the soil in the column was cut into segments of 15 cm each for analysis of available N, P and K.

3.6 Biometric observations

3.6.1 Growth characters

3.6.1.1 Height of plant

Height of the plant in centimetre (cm) was measured from the base of the pseudostem at the soil level to the axil of the youngest unopened leaf at 4 MAP, 6 MAP and at harvest.

3.6.1.2 Girth of pseudostem

Girth of pseudostem at 10 cm above the ground level was measured at 4 MAP, 6 MAP and at harvest and expressed in centimetre.

3.6.1.3 Number of leaves plant^{-1}

Total number of leaves including green and senescent ones was recorded at 4 MAP, 6 MAP and at harvest.

3.6.1.4 Number of functional leaves plant^{-1}

Number of photosynthetically active green leaves was recorded at 4 MAP, 6 MAP and at harvest.

3.6.1.5 Days from planting to shooting

The period from planting to visual bunch emergence was recorded and expressed in days.

3.6.1.6 Days from shooting to harvest

The period from shooting to harvest was recorded from the date of visual bunch emergence to the date of harvest and expressed in days.

3.6.2 Physiological characters

3.6.2.1 Total leaf area

The leaf area of each functional leaf was calculated adopting the formula put forward by Murray (1960) and expressed in square metre.

Leaf area of index leaf = l x b x 0.8 (a constant)

where l = length of lamina

b = width of lamina

The length of lamina was measured from the base of the leaf to the tip and width at the broadest point of the leaf in the middle region. The sum of the area of all the functional leaves in a plant was then calculated. These observations were recorded at 4 MAP, 6 MAP and at harvest.

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

3.6.2.2 Leaf area index (LAI)

Leaf area index was determined at 4 MAP, 6 MAP and at harvest using the formula suggested by Watson (1947).

$$\text{LAI} = \frac{\text{Leaf area per plant (cm}^2)}{\text{Land area occupied by the plant (cm}^2)}$$

3.6.2.3 Phyllochron

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

3.6.2.4 Biomass partitioning

One plant each from every treatment of a replication was uprooted at each stage of sampling. The entire plant was separated into rhizome and roots, pseudostem, leaf and the fresh weight was recorded. Fruit was included at the harvest stage. Dry matter content of each analytical part was determined by the method suggested by Piper (1967). Five hundred gram each of fresh sample was taken, washed, sundried and ovendried at 70°C to constant weight and moisture content calculated. From the values of percentage moisture and wet weight of sample, total dry matter production was calculated.

3.6.3 Bunch characters

The bunches were harvested when fully mature as indicated by the disappearance of angles from fingers (Stover and Simmonds, 1987).

3.6.3.1 Length of bunch

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

3.6.3.2 Hands bunch^{-1}

The number of hands in a bunch was counted after harvest.

3.6.3.3 Fingers bunch^{-1}

The total number of fingers in a bunch was counted after harvest.

3.6.3.4 Weight of hand

Each hand on a bunch was weighed separately. The mean value of the weight of different hands on a bunch was calculated and recorded as the weight of the hand for a treatment and expressed in kilogram.

3.6.3.5 Weight of bunch

Weight of bunch including the portion of the peduncle upto the first scar (exposed outside the plant) was recorded and expressed as in kilogram.

3.6.4 Finger characters

The middle finger in the top row of the second hand (from the base of the bunch) was selected as the representative finger or index finger (Gottriech *et al.*, 1964).

3.6.4.1 Length of finger

Length of finger was measured from the tip of the finger to the point of attachment to the peduncle and expressed in centimetre.

3.6.4.2 Girth of finger

Girth of finger was measured at the middle portion and expressed in centimetre.

3.6.4.3 Weight of finger

The weight of the index finger was taken as the mean finger weight.

3.6.5 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 upto a known volume. Aliquots taken from these samples were used for the quality analysis of the fruit.

3.6.5.1 Total soluble solids

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

3.6.5.2 Acidity

Titratable acidity was determined following the procedure proposed by Ranganna (1977). An aliquot from the sample was titrated against 0.1 Normal Sodium Hydroxide and the values were expressed as per cent anhydrous citric acid.

3.6.5.3 Total sugars

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

3.6.5.4 Reducing sugars

The content of reducing sugars of the samples were estimated as per the method described by AOAC (1977) and expressed as percentage on fresh weight basis.

3.6.5.5 Non-reducing sugars

The content of non-reducing sugars was computed from the values estimated for total sugars and reducing sugars (Ranganna, 1977).

3.6.5.6 Vitamin C

Vitamin C was estimated by Redox titration using 2, 6 dichlorophenol indophenol in acid medium as suggested by Ranganna (1977). The results were expressed in mg $100g^{-1}$ of fresh fruit sample.

3.6.5.7 Sugar-acid ratio

Sugar-acid ratio was determined by dividing the value of reducing sugars by the value for the acidity of the corresponding sample.

3.6.5.8 Pulp-peel ratio

The pulp and peel weights of index finger were determined separately and the ratio between these was worked out to arrive at the pulp peel ratio.

3.6.5.9 Shelf life

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

3.6.6 Plant chemical analysis

The different plant parts were separately analysed for their nutrient content. The methods adopted for the chemical analysis are given in Table 2.

3.6.6.1 Uptake of nutrients

Uptake of nutrients by each plant part at 4 MAP, 6 MAP and 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}.

Table 2. Methods adopted for plant analysis

Estimated character	Method adopted	References
N	Micro Kjeldahl digestion in sulphuric acid and distillation	Jackson (1973)
P	Nitric-perchloric - sulphuric acid digestion (10:4:1) and colorimetry (Vanado molybdate yellow colour in nitric acid medium)	Jackson (1973)
K	Nitric-perchloric - sulphuric acid digestion (10:4:1) and flame photometry	Piper (1967)
Ca, Mg	Nitric-perchloric - sulphuric acid digestion (10:4:1) and atomic absorption spectrophotometry	Piper (1967)
Fe, Mn, Cu, Zn	Nitric-perchloric - sulphuric acid digestion (10:4:1) and atomic absorption spectrophotometry	Lindsay and Norvell (1978)

3.6.7 Soil analysis

Soil samples were collected before planting, 4 MAP, 6 MAP and at harvest (Mohan and Rao, 1985). The composite sample drawn from this was air dried, powdered, sieved through 2 mm sieve and analysed for organic carbon available N and P, exchangeable K, calcium (Ca), magnesium (Mg) and available iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) as per the methods described earlier.

3.6.8 Economic analysis

The benefit-cost ratio (BCR) was worked out considering all aspects of the cost of cultivation and income derived from the plant with respect to each treatment. The norms and rates prevalent at Onattukara Regional Agricultural Research Station, Kayamkulam were followed.

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.6.9 Statistical analysis

The data generated were analysed statistically by applying the techniques of analysis of variance as per the lay out of the experiment (Panse and Sukhatme, 1967).

RESULTS

4. RESULTS

The results of the field experiments conducted at Onattukara Regional Agricultural Research Station, Kayamkulam during 1998-99 and 1999-00 to find out the nutritional requirement of banana cv. Njalipoovan and to assess the leaching loss of nutrients are presented in this chapter.

4.1 Growth characters

4.1.1 Height of plant

The main and interaction effects of treatments at various stages of crop growth during 1998-99 and 99-00 are furnished in Tables 3a and 3b respectively.

There was significant difference in the height of the plant throughout crop growth in both the years with the application of different plant nutrients. Increasing levels of nitrogen significantly increased the plant height at all phases with n_3 recording the highest value. Increments in P levels also promoted plant height at most of the stages with p_3 recording the highest value. However, the heights at p_2 and p_3 levels were on par at the initial stages in 98-99. The effect of potassium also was significant at all stages of growth. Significant response was recorded

Table 3a. Effect of nitrogen, phosphorus and potassium on height of plant

Main effect of factors	Height of plant (cm)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	91.22	119.67	282.17	87.17	117.39	271.94
n_2	110.72	139.50	317.67	112.67	142.17	314.72
n_3	122.56	174.94	327.06	123.28	166.44	329.89
$F_{2,27}$	614.77**	2349.02**	375.25**	821.54**	853.24**	446.07**
SE_m	0.638	0.578	1.222	0.647	0.840	1.423
CD(0.05)	1.852	1.677	3.547	1.879	2.437	4.129
p_1	106.83	142.00	306.72	105.06	139.00	303.33
p_2	107.72	144.83	306.78	107.50	141.78	304.33
p_3	108.94	145.28	313.39	110.56	145.22	308.89
$F_{2,27}$	6.31**	20.89**	9.83**	18.11**	13.78**	4.33*
SE_m	0.638	0.578	1.222	0.647	0.840	1.423
CD(0.05)	1.852	1.677	3.547	1.879	2.437	4.129
k_1	106.56	135.78	300.39	105.39	133.83	293.89
k_2	108.17	147.67	311.61	107.94	143.83	308.33
k_3	109.78	150.67	314.89	109.78	148.33	314.33
$F_{2,27}$	6.37**	185.72**	38.71**	11.59**	78.12**	54.56**
SE_m	0.638	0.578	1.222	0.647	0.840	1.423
CD(0.05)	1.852	1.677	3.547	1.879	2.437	4.129

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

Table 3b. Interaction effect of nitrogen, phosphorus and potassium on height of plant

Interaction effects	Height of plant (cm)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	90.00	116.00	277.67	84.67	112.50	268.17
n_1p_2	91.00	122.00	278.67	85.00	117.00	274.33
n_1p_3	92.67	121.00	290.17	91.83	122.67	273.33
n_2p_1	108.67	138.33	317.33	108.50	140.00	313.67
n_2p_2	110.50	137.50	317.33	114.33	140.83	311.50
n_2p_3	113.00	142.67	318.33	115.17	145.67	319.00
n_3p_1	121.83	171.67	325.17	122.00	164.50	328.17
n_3p_2	121.67	175.00	324.33	123.17	162.67	327.17
n_3p_3	124.17	178.17	331.67	124.67	172.17	334.33
$F_{4,27}$	0.33	3.83*	2.31	3.40*	7.46**	1.20
SE_m	1.105	1.001	2.117	1.122	1.455	2.464
CD(0.05)	–	2.904	–	3.255	4.221	–
n_1k_1	90.33	112.67	269.50	85.33	107.17	248.83
n_1k_2	91.67	122.00	287.00	87.50	120.17	275.67
n_1k_3	91.67	124.33	290.00	88.60	124.83	291.33
n_2k_1	107.83	129.50	312.67	109.50	135.83	308.83
n_2k_2	110.67	142.17	318.67	113.17	143.67	316.83
n_2k_3	113.67	146.83	321.67	115.33	147.00	317.50
n_3k_1	121.50	165.17	319.00	121.33	158.50	324.00
n_3k_2	122.17	178.83	329.17	123.17	167.67	331.50
n_3k_3	124.00	180.83	333.00	125.33	173.17	334.17
$F_{4,27}$	1.23	2.62	2.51	0.39	1.49	15.18**
SE_m	1.105	1.001	2.117	1.122	1.455	2.464
CD(0.05)	–	–	–	–	–	7.151
p_1k_1	104.67	134.83	298.00	103.17	134.00	295.00
p_1k_2	107.33	143.00	308.33	105.67	140.33	304.17
p_1k_3	108.50	148.17	313.83	106.33	142.67	310.33
p_2k_1	106.67	133.50	298.00	106.00	133.00	292.50
p_2k_2	107.67	149.17	310.50	107.33	143.00	308.67
p_2k_3	108.83	151.83	311.83	109.17	148.33	311.83
p_3k_1	108.33	139.00	305.17	107.00	134.50	293.67
p_3k_2	109.50	150.83	316.00	110.83	148.17	312.17
p_3k_3	112.00	152.00	319.00	113.83	153.00	320.83
$F_{4,27}$	0.311	4.51**	0.26	0.98	3.48*	2.00
SE_m	1.105	1.001	2.117	1.122	1.455	2.464
CD(0.05)	–	2.904	–	–	4.221	-

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

upto k_3 at 6 MAP in both years and at harvest in 99-00. In the initial stages in two years and at harvest in 98-99, k_2 and k_3 were on par.

The interaction effect of N x P was significant only at 6 MAP in 98-99 and at 4 MAP and 6 MAP in 99-00. In combination with n_1, n_2 and n_3 increasing levels of phosphorus enhanced plant height in both the years. However, with n_1 in 98-99 and with n_2 and n_3 at 6 MAP in 99-00, p_2 and p_3 had similar effect.

Interaction effect of N x K was significant only at harvest stage in 99-00. At this stage in n_1 applied plots increasing rates of potassium resulted in a significant increase in plant height. But in n_2 and n_3 treated plots, k_2 and k_3 recorded similar effect on plant height.

The interaction, P x K was significant only at 6 MAP in both the years. At all levels of P, increasing rates of applied K resulted in an improvement in plant height. In p_2 and p_3 applied plots k_2 and k_3 were on par in 98-99. In 99-00, the general trend of increase in plant height with increase in potassium dosage from k_1 to k_3 was conspicuous in p_2 and p_3 applied plots.

4.1.2 Girth of pseudostem

Different levels of nitrogen, phosphorus and potassium had profound influence on the girth of pseudostem at all stages in both the years (Table 4a). In general, n_3 recorded significantly higher pseudostem girth at most of the stages of growth except at 4 MAP in 99-00.

Table 4a. Effect of nitrogen, phosphorus and potassium on girth of pseudostem

Main effect of factors	Girth of pseudostem (cm)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	26.72	31.89	52.72	28.94	31.00	48.61
n_2	35.06	44.44	57.72	41.33	41.33	55.28
n_3	38.67	47.83	61.50	40.67	44.94	59.67
$F_{2,27}$	181.11**	252.25**	45.25**	216.03**	267.19**	77.85**
SE_m	0.455	0.529	0.654	0.474	0.443	0.631
CD(0.05)	1.321	1.535	1.899	1.375	1.285	1.831
P_1	32.33	39.44	55.83	35.72	37.39	52.44
P_2	33.06	41.72	57.67	37.39	39.50	54.83
P_3	35.06	43.00	58.44	37.83	40.39	56.28
$F_{2,27}$	9.60**	11.60**	4.20*	5.51**	12.11**	9.42**
SE_m	0.455	0.529	0.654	0.474	0.443	0.631
CD(0.05)	1.321	1.535	1.899	1.375	1.285	1.831
k_1	29.11	36.44	50.44	31.78	33.89	49.56
k_2	34.61	42.56	59.83	38.72	40.94	56.39
k_3	36.72	45.17	61.67	40.44	42.44	57.61
$F_{2,27}$	74.51**	71.64**	84.60**	93.65**	106.47**	47.35**
SE_m	0.455	0.529	0.654	0.474	0.443	0.631
CD(0.05)	1.321	1.535	1.899	1.375	1.285	1.831

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

Table 4b. Interaction effect of nitrogen, phosphorus and potassium on girth of pseudostem

Interaction effects	Girth of pseudostem (cm)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	25.67	29.50	52.17	27.33	29.50	46.83
n_1p_2	26.17	32.17	52.50	28.67	31.00	49.00
n_1p_3	28.33	34.00	53.50	30.83	32.50	50.00
n_2p_1	34.33	43.83	56.00	40.33	40.17	52.67
n_2p_2	35.33	44.67	58.33	41.83	40.50	55.33
n_2p_3	35.50	44.83	58.83	41.83	43.33	57.83
n_3p_1	37.00	45.00	59.33	39.50	42.50	57.83
n_3p_2	37.67	48.33	62.17	41.67	44.17	60.17
n_3p_3	41.33	50.17	63.00	40.83	48.17	61.00
$F_{4,27}$	1.52	1.51	0.42	1.00	5.64**	0.31
SE_m	0.788	0.916	1.134	0.821	0.767	1.093
CD(0.05)	–	–	–	–	2.225	–
n_1k_1	23.33	27.67	46.50	24.00	26.83	43.17
n_1k_2	27.33	32.67	55.00	30.67	32.83	50.50
n_1k_3	29.50	35.33	56.67	32.17	33.33	52.17
n_2k_1	31.17	39.83	51.50	37.17	35.17	51.17
n_2k_2	36.17	45.33	60.33	42.83	43.00	57.17
n_2k_3	37.83	48.17	61.33	44.00	45.83	57.50
n_3k_1	32.83	41.83	53.33	34.17	39.67	54.33
n_3k_2	40.33	49.67	64.17	42.67	47.00	61.50
n_3k_3	42.83	52.00	67.00	45.17	48.17	63.17
$F_{4,27}$	2.08	0.80	0.90	1.75	1.89	0.47
SE_m	0.788	0.916	1.134	0.821	0.767	1.093
CD(0.05)	–	–	–	–	–	–
p_1k_1	28.50	35.83	51.00	31.67	33.33	49.50
p_1k_2	33.50	40.33	57.33	36.50	38.83	53.50
p_1k_3	35.00	42.17	59.17	39.00	40.00	54.33
p_2k_1	28.83	37.17	50.83	31.67	34.00	49.17
p_2k_2	34.00	42.00	60.17	40.00	41.50	56.67
p_2k_3	36.33	46.00	62.00	40.50	43.00	58.67
p_3k_1	30.00	36.33	49.50	32.00	34.33	50.00
p_3k_2	36.33	45.33	62.00	39.67	42.50	59.00
p_3k_3	38.83	47.33	63.83	41.83	44.33	59.83
$F_{4,27}$	0.57	2.61	2.47	1.53	1.41	2.07
SE_m	0.788	0.916	1.134	0.821	0.767	1.093
CD(0.05)	–	–	–	–	–	–

** Significant at 1 per cent level

Phosphorus also increased the girth of pseudostem at all the stages in 98-99 and 99-00. During most of the stages p_2 and p_3 were on par. Potassium nutrition profoundly influenced the pseudostem girth at the first and second phase in both the years. Significant response was obtained upto k_3 during these phases. At the final stage k_2 and k_3 were on par.

As depicted in Table 4b, variation in stem girth due to N x P interaction was significant only at 6 MAP in 99-00. Girth of pseudostem was higher at p_3 in n_2 and n_3 applied plots. The N x K and P x K interaction effects were not significant during both the years of experimentation.

4.1.3 Total number of leaves

Perusal of the data in Table 5a clearly indicates that the main effect of nitrogen, phosphorus and potassium had significant influence on total number of leaves per plant at most stages during both the years.

Among the different levels of nitrogen, n_3 recorded significantly higher number of leaves plant^{-1} through out the crop growth. The effect of phosphorus was not significant during the initial phase in 98-99 and 99-00. Significant response was obtained upto p_3 at 6 MAP in 98-99 and at 6 MAP and at harvest in 99-00. No significant difference in the total number of leaves was observed between p_2 and p_3 levels at harvest in 98-99.

Table 5a. Effect of nitrogen, phosphorus and potassium on total number of leaves

Main effect of factors	Total number of leaves					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	10.33	12.22	11.61	8.72	10.17	11.67
n_2	13.11	14.78	13.94	11.56	14.22	13.44
n_3	14.06	16.06	14.83	12.33	14.50	14.22
$F_{2,27}$	54.61**	62.42**	53.04**	46.72**	99.68**	44.71**
SE_m	0.262	0.247	0.228	0.278	0.243	0.196
CD(0.05)	0.760	0.717	0.663	0.807	0.705	0.568
P_1	12.17	13.94	12.89	10.56	12.17	12.67
P_2	12.78	14.11	13.67	10.72	12.94	13.00
P_3	12.56	15.00	13.83	11.33	13.78	13.67
$F_{2,27}$	1.40	5.28*	4.87*	2.17	11.00**	6.76**
SE_m	0.262	0.247	0.228	0.278	0.243	0.196
CD(0.05)	–	0.717	0.663	–	0.705	0.568
k_1	11.89	13.56	12.28	10.11	12.22	11.44
k_2	12.61	14.39	13.78	11.06	13.00	13.67
k_3	13.00	15.11	14.33	11.44	13.67	14.22
$F_{2,27}$	4.64*	9.93**	21.65**	6.08**	8.85**	56.30**
SE_m	0.262	0.247	0.228	0.278	0.243	0.196
CD(0.05)	0.760	0.717	0.663	0.807	0.705	0.568

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

Table 5b. Interaction effect of nitrogen, phosphorus and potassium on total number of leaves

Interaction effects	Total number of leaves					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	9.83	11.67	11.33	8.00	9.17	11.33
n_1p_2	10.83	12.17	11.50	8.67	10.33	11.50
n_1p_3	10.33	12.83	12.00	9.50	11.00	12.17
n_2p_1	13.00	14.50	13.33	11.33	13.67	13.00
n_2p_2	13.33	14.50	14.50	11.50	14.17	13.17
n_2p_3	13.00	15.33	14.00	11.83	14.83	14.17
n_3p_1	13.67	15.67	14.00	12.33	13.67	13.67
n_3p_2	14.17	15.67	15.00	12.00	14.33	14.33
n_3p_3	14.33	16.83	15.50	12.67	15.50	14.67
$F_{4,27}$	0.29	0.17	0.91	0.51	0.33	0.32
SE_m	0.453	0.428	0.396	0.482	0.421	0.339
CD(0.05)	–	–	–	–	–	–
n_1k_1	9.83	11.00	10.83	7.83	9.33	10.50
n_1k_2	10.50	12.50	11.67	9.00	10.17	12.00
n_1k_3	10.67	13.17	12.33	9.33	11.00	12.50
n_2k_1	12.50	14.33	12.67	10.83	13.33	11.67
n_2k_2	13.17	14.67	14.33	12.00	14.50	14.00
n_2k_3	13.67	15.33	14.83	11.67	14.83	14.67
n_3k_1	13.33	15.33	13.33	11.67	14.00	12.17
n_3k_2	14.17	16.00	15.33	13.33	14.33	15.00
n_3k_3	14.67	16.83	15.83	13.17	15.17	15.50
$F_{4,27}$	0.29	0.65	0.67	0.41	0.31	1.37
SE_m	0.453	0.428	0.396	0.482	0.421	0.339
CD(0.05)	–	–	–	–	–	–
p_1k_1	11.67	13.17	12.00	10.17	11.50	11.33
p_1k_2	12.33	14.17	13.00	10.67	12.17	13.00
p_1k_3	12.50	14.50	13.67	10.83	12.83	13.67
p_2k_1	12.17	13.33	12.33	10.00	12.33	11.17
p_2k_2	12.67	14.00	14.00	11.00	13.00	13.50
p_2k_3	13.50	15.00	14.67	11.17	13.50	14.33
p_3k_1	11.83	14.17	12.50	10.17	12.83	11.83
p_3k_2	12.83	15.00	14.33	11.50	13.83	14.50
p_3k_3	13.00	15.83	14.67	12.33	14.67	14.67
$F_{4,27}$	0.09	0.17	0.37	0.65	0.17	0.80
SE_m	0.453	0.428	0.396	0.482	0.421	0.339
CD(0.05)	–	–	–	–	–	–

The response of the crop to potassium was significant upto k_2 level at most of the stages in both the years. But there was no significant difference between k_1 and k_2 and between k_2 and k_3 at the initial phase in 98-99.

The interaction effects of N x P, N x K and P x K did not influence the number of leaves significantly through out the period of experimentation (Table 5b).

4.1.4 Number of functional leaves

The data on the number of functional leaves at various growth stages in 98-99 and 99-00 are presented in Tables 6a and 6b. Increasing levels of nitrogen significantly influenced the number of functional leaves at most of the stages during the period of experimentation with n_3 recording highest number of functional leaves.

The effect of phosphorus was significant in the initial two phases in both the years. In general, significant response was obtained up to p_2 at 4 MAP in 98-99 and at 6 MAP in 99-00. At 6 MAP in 98-99 and at 4 MAP in 99-00, p_3 recorded significantly highest number of functional leaves.

Potassium nutrition significantly influenced the number of functional leaves at almost all phases of growth. The highest level of potassium (k_3) promoted significant leaf retention only at 6 MAP in 98-99. At all other stages, k_2 and k_3 recorded similar effect on leaf retention.

Table 6a. Effect of nitrogen, phosphorus and potassium on the number of functional leaves

Main effect of factors	Number of functional leaves					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	7.11	8.61	3.11	5.83	6.50	3.00
n_2	8.89	10.94	3.28	8.11	9.61	3.33
n_3	10.22	11.83	3.87	8.44	10.78	3.56
$F_{2,27}$	52.56**	71.73**	3.72*	101.07**	97.33**	3.69*
SE_m	0.215	0.196	0.157	0.141	0.224	0.145
CD(0.05)	0.625	0.570	0.457	0.410	0.650	0.422
P_1	8.11	10.22	3.28	7.00	8.33	3.00
P_2	8.83	10.22	3.28	7.39	9.06	3.44
P_3	9.28	10.94	3.50	8.00	9.50	3.44
$F_{2,27}$	7.48**	4.50*	0.67	12.72**	6.90**	3.10
SE_m	0.215	0.196	0.157	0.141	0.224	0.145
CD(0.05)	0.625	0.570	–	0.410	0.650	—
k_1	8.00	9.61	2.78	6.78	8.06	3.06
k_2	9.00	10.39	3.50	7.67	9.22	3.17
k_3	9.22	11.39	3.78	7.94	9.61	3.47
$F_{2,27}$	9.14**	20.57**	10.73**	18.59**	13.04**	4.99*
SE_m	0.215	0.196	0.157	0.141	0.224	0.145
CD(0.05)	0.625	0.570	0.457	0.410	0.650	0.422

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

Table 6b. Interaction effect of nitrogen, phosphorus and potassium on the number of functional leaves

Interaction effects	Number of functional leaves					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	6.83	8.17	3.17	5.17	5.50	2.67
n_1p_2	6.83	8.33	2.83	5.83	6.67	3.67
n_1p_3	7.67	9.33	3.33	6.50	7.33	2.67
n_2p_1	8.00	10.50	3.17	7.67	9.33	2.83
n_2p_2	9.33	11.00	3.33	8.17	9.83	3.50
n_2p_3	9.33	11.33	3.33	8.50	9.67	3.67
n_3p_1	9.50	12.00	3.50	8.17	10.17	3.67
n_3p_2	10.33	11.33	3.67	7.83	10.67	3.83
n_3p_3	10.83	12.17	3.83	9.33	11.50	3.17
$F_{4,27}$	0.85	1.07	0.35	3.99*	1.13	2.59
SE_m	0.373	0.340	0.273	0.245	0.388	0.252
CD(0.05)	–	–	–	0.710	–	–
n_1k_1	6.67	7.50	3.17	5.00	5.51	2.50
n_1k_2	7.33	8.83	3.17	6.00	6.83	3.17
n_1k_3	7.33	9.50	3.00	6.50	7.17	3.33
n_2k_1	7.67	10.17	2.33	7.50	8.33	3.00
n_2k_2	9.33	10.83	3.33	8.33	10.00	3.33
n_2k_3	9.67	11.83	4.17	8.50	10.50	3.67
n_3k_1	9.67	11.17	2.83	7.83	10.33	3.50
n_3k_2	10.33	11.50	4.00	8.67	10.83	3.83
n_3k_3	10.67	12.83	4.17	8.83	11.17	3.33
$F_{4,27}$	1.02	0.59	3.90*	0.36	0.91	1.36
SE_m	0.373	0.340	0.273	0.245	0.388	0.252
CD(0.05)	–	–	0.792	–	–	–
p_1k_1	7.50	9.33	2.67	6.50	7.83	2.50
p_1k_2	8.50	10.17	3.33	7.17	8.50	3.17
p_1k_3	8.33	11.17	3.83	7.33	8.67	3.50
p_2k_1	7.83	9.50	3.00	6.67	8.00	3.33
p_2k_2	9.00	10.00	3.17	7.50	9.33	3.83
p_2k_3	9.67	11.17	3.67	8.00	9.83	3.83
p_3k_1	8.67	10.00	2.67	7.17	8.33	3.17
p_3k_2	9.50	11.00	4.00	8.33	9.83	3.33
p_3k_3	9.67	11.83	3.83	8.50	10.33	3.00
$F_{4,27}$	0.58	0.15	1.28	0.51	0.70	1.36
SE_m	0.373	0.340	0.273	0.245	0.388	0.252
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

Interaction effects presented in Table 6b indicate that N x P interaction was significant only at 4 MAP in 99-00. Highest level of phosphorus at 300g $plant^{-1}$ recorded maximum number of functional leaves in combination with n_3 level. Whereas with n_1 and n_2 levels, p_2 and p_3 showed similar effect. Significant effect of N x K interaction was observed only during the final stage in 98-99. In n_1 and n_3 applied plots, k_2 and k_3 recorded similar effects on leaf retention. The interaction effect of P x K was not significant in either of the years.

4.1.5 Days from planting to shooting

The data on the number of days taken from planting to shooting in 98-99 and 99-00 are presented in Tables 7a and 7b.

Levels of nitrogen exerted a significant influence on the number of days from planting to shooting in both the years of experimentation. Nitrogen application at n_3 significantly lowered the number of days to shooting.

There was no appreciable difference in the number of days to shooting due to different levels of P in 1998-99. However, in the subsequent year a decrease in the trend was observed, though p_1 and p_2 and p_2 and p_3 were on par. Increment in K levels also reduced the number of days from planting to shooting in 1998-99 and 1999-00.

It is evident from Table 7b that none of the interactions were significant in both the years.

Table 7a. Effect of nitrogen, phosphorus and potassium on crop duration

Main effect of factors	Days from planting to shooting		Days from shooting to harvest		Total crop duration (days)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	291.72	297.11	110.44	109.50	402.17	406.06
n_2	281.11	283.89	106.44	106.17	387.56	390.06
n_3	274.17	273.00	106.11	104.11	380.28	377.11
$F_{2,27}$	102.26**	362.89**	7.70**	9.86**	142.38**	264.51**
SE_m	0.874	0.634	0.869	0.866	0.934	0.891
CD(0.05)	2.537	1.839	2.521	2.514	2.711	2.587
P_1	283.89	286.89	107.83	107.72	391.72	394.61
P_2	281.50	285.11	107.61	106.61	389.11	391.72
P_3	281.61	284.43	107.56	105.44	389.17	389.88
$F_{2,27}$	2.36	15.25**	0.03	1.73	2.56	19.15**
SE_m	0.874	0.634	0.869	0.866	0.934	0.891
CD(0.05)	–	1.839	–	–	–	2.587
k_1	284.78	286.11	107.78	107.94	392.56	394.06
k_2	282.33	284.39	107.50	106.22	389.83	390.06
k_3	279.89	283.50	107.72	105.61	387.61	389.11
$F_{2,27}$	7.83**	4.36*	0.03	1.95	7.03**	8.67**
SE_m	0.874	0.634	0.869	0.866	0.934	0.891
CD(0.05)	2.537	1.839	–	–	2.711	2.587

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

Table 7b. Interaction effect of nitrogen, phosphorus and potassium on crop duration

Interaction effects	Days from planting to shooting		Days from shooting to harvest		Total crop duration (days)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	293.67	298.67	110.00	111.50	403.67	410.17
n_1p_2	291.50	298.00	110.67	109.67	402.17	407.67
n_1p_3	290.00	294.67	110.67	107.33	400.67	400.33
n_2p_1	283.17	286.00	106.67	107.00	389.83	393.00
n_2p_2	278.00	284.50	106.17	105.67	381.67	387.00
n_2p_3	282.17	281.17	106.50	105.83	388.67	387.00
n_3p_1	274.83	276.00	106.83	104.67	381.67	380.67
n_3p_2	275.00	272.83	106.00	104.50	381.00	377.33
n_3p_3	272.67	270.17	105.50	103.17	378.17	373.33
$F_{4,27}$	1.57	0.36	0.13	0.37	1.50	0.62
SE_m	1.514	1.098	1.505	1.500	1.618	1.544
CD(0.05)	–	–	–	–	–	–
n_1k_1	294.50	298.00	109.83	110.67	404.33	408.67
n_1k_2	292.67	298.17	110.33	109.33	403.00	405.83
n_1k_3	288.00	295.17	111.17	108.50	399.17	403.67
n_2k_1	283.33	286.50	106.83	107.00	390.17	393.50
n_2k_2	280.33	282.00	106.00	105.83	386.33	387.83
n_2k_3	279.67	283.17	106.50	105.67	386.17	388.83
n_3k_1	276.50	273.83	106.67	106.17	383.17	380.00
n_3k_2	274.00	273.00	106.17	103.50	380.17	376.50
n_3k_3	272.00	272.17	105.50	102.67	377.50	374.83
$F_{4,27}$	0.47	1.54	0.20	1.54	0.34	0.35
SE_m	1.514	1.098	1.505	1.500	1.618	1.544
CD(0.05)	–	–	–	–	–	–
p_1k_1	285.83	288.33	106.67	108.83	393.50	397.17
p_1k_2	284.33	286.67	107.50	107.33	391.83	394.00
p_1k_3	281.50	285.67	108.33	107.00	389.83	392.67
p_2k_1	285.17	286.33	107.17	108.17	392.33	394.50
p_2k_2	281.50	284.50	107.33	105.83	388.83	390.33
p_2k_3	277.83	284.50	108.33	105.83	306.17	390.33
p_3k_1	283.33	283.67	108.50	106.83	391.83	390.50
p_3k_2	281.17	282.00	107.67	105.50	388.83	385.83
p_3k_3	280.33	280.33	106.50	104.00	386.83	384.33
$F_{4,27}$	0.60	0.19	0.34	0.19	0.15	0.17
SE_m	1.514	1.098	1.505	1.500	1.618	1.544
CD(0.05)	–	–	–	–	–	–

4.1.6 Days from shooting to bunch maturation

It is clear from Table 7a that the application of nitrogen significantly reduced the number of days from shooting to harvest in both the years. Significant decrease was observed only upto n_2. Different levels of phosphorus or potassium had no impact on the days to bunch maturation in either of the years.

As depicted in Table 7b, the interactions N x P, N x K and P x K also could not significantly influence the days taken from shooting to harvest during the two years of experimentation.

4.1.7 Total crop duration

The main effects of treatments on the total duration of the crop are furnished in Table 7a.

Application of nitrogen significantly influenced the number of days from planting to harvest. In both the years, n_3 recorded least number of days. The influence of phosphorus was not significant during 98-99. But during 99-00, application of p_2 and p_3 had the same effect in reducing the total crop duration.

Response of potassium was significant in 1998-99 and 99-00. Higher rates of potassium (k_2 or k_3) were found to reduce the total crop duration. None of the interaction effects could significantly influence the total crop duration in the first or second year of experimentation (Table 7b).

4.2 Physiological characters

4.2.1 Total leaf area

As shown in Table 8a, different levels of nitrogen, phosphorus and potassium had profound influence on the total leaf area. Increments in N levels significantly enhanced the total leaf area at most stages with maximum value at n_3. However n_2 and n_3 proved to be equally effective at harvest stage in 99-00.

The effect of both phosphorus and potassium was significant in the initial st ages in both the years with maximum values at p_3 and k_3 respectively. However at the final stage no significant difference was observed between different levels of P and K.

Interaction effects furnished in Table 8b indicated that N x P interaction was significant only at certain stages (4MAP and 6MAP in 98-99 and 4MAP in 99-00). In combination with n_1 and n_2, higher levels of phosphorus (p_2 or p_3) resulted in higher leaf area at the initial stages in 98-99. However, n_3 promoted the leaf area with increase in P at initial stages in 98-99 and first phase of 99-00. At n_1 level also increments in phosphorus improved the leaf area in 99-00.

The interaction N x K, was significant only in the initial stages of 98-99. Increasing levels of potassium resulted in a significant higher leaf area with n_1 at 4 MAP and with n_2 and n_3 at 6MAP. In the case of n_2 or n_3 level at 4MAP and n_1 level at 6 MAP k_2 and k_3 were on par.

Table 8a. Effect of nitrogen, phosphorus and potassium on total leaf area

Main effect of factors	Total leaf area (m^2)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	2.29	3.36	2.44	1.79	3.10	2.11
n_2	2.74	5.58	2.51	2.65	5.11	2.71
n_3	3.79	8.03	3.11	3.57	7.31	2.82
$F_{2,27}$	240.76**	118.38**	41.96**	451.09**	436.71**	5.67**
SE_m	0.050	0.068	0.057	0.042	0.101	0.160
CD(0.05)	0.144	0.197	0.166	0.122	0.293	0.463
P_1	2.70	5.04	2.64	2.44	4.68	2.36
P_2	2.91	5.79	2.71	2.65	5.23	2.54
P_3	3.21	6.14	2.71	2.91	5.61	2.74
$F_{2,27}$	26.79**	69.37**	0.56	31.67**	21.57**	1.38
SE_m	0.050	0.068	0.057	0.042	0.101	0.160
CD(0.05)	0.144	0.197	–	0.122	0.293	–
k_1	2.45	4.52	2.68	2.20	4.46	2.53
k_2	3.09	6.06	2.65	2.79	5.36	2.47
k_3	3.28	6.39	2.73	3.02	5.71	2.64
$F_{2,27}$	75.55**	217.48**	0.43	98.75**	41.02**	0.31
SE_m	0.050	0.068	0.057	0.042	0.101	0.160
CD(0.05)	0.144	0.197	–	0.122	0.293	–

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

Table 8b. Interaction effect of nitrogen, phosphorus and potassium on total leaf area

Interaction effects	Total leaf area (m^2)					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	2.03	3.10	2.52	1.49	2.73	2.01
n_1p_2	2.33	3.33	2.48	1.80	3.17	2.13
n_1p_3	2.50	3.66	2.31	2.06	3.40	2.20
n_2p_1	2.61	4.78	2.40	2.56	4.50	2.37
n_2p_2	2.73	5.93	2.47	2.68	5.23	2.72
n_2p_3	2.88	6.03	2.66	2.71	5.60	3.04
n_3p_1	3.46	7.23	2.99	3.27	6.81	2.71
n_3p_2	3.65	8.11	3.18	3.48	7.30	2.78
n_3p_3	4.26	8.74	3.17	3.97	7.83	2.97
$F_{4,27}$	3.42*	6.58**	1.86	4.53**	0.52	0.23
SE_m	0.086	0.118	0.099	0.073	0.175	0.276
CD(0.05)	0.250	0.341	–	0.212	–	–
n_1k_1	1.83	2.80	2.42	1.29	2.48	2.02
n_1k_2	2.33	3.56	2.44	1.94	3.31	2.14
n_1k_3	2.70	3.73	2.46	2.13	3.52	2.19
n_2k_1	2.41	4.20	2.47	2.30	4.31	2.54
n_2k_2	2.89	6.08	2.44	2.75	5.36	2.64
n_2k_3	2.93	6.45	2.62	2.91	5.65	2.95
n_3k_1	3.12	6.55	3.16	3.03	6.58	3.04
n_3k_2	4.04	8.54	3.08	3.68	7.41	2.63
n_3k_3	4.21	8.99	3.10	4.01	7.96	2.79
$F_{4,27}$	3.99*	14.23**	0.38	1.78	0.45	0.48
SE_m	0.086	0.118	0.099	0.073	0.175	0.276
CD(0.05)	0.250	0.341	–	–	–	–
p_1k_1	2.34	4.40	2.59	2.16	4.24	2.48
p_1k_2	2.78	5.12	2.67	2.49	4.80	2.30
p_1k_3	2.98	5.58	2.65	2.68	5.00	2.31
p_2k_1	2.43	4.55	2.69	2.23	4.48	2.51
p_2k_2	3.07	6.32	2.72	2.73	5.41	2.42
p_2k_3	3.22	6.50	2.72	3.00	5.81	2.70
p_3k_1	2.59	4.60	2.76	2.23	4.66	2.61
p_3k_2	3.41	6.74	2.57	3.15	5.86	2.68
p_3k_3	3.63	7.10	2.81	3.37	6.31	2.92
$F_{4,27}$	1.81	12.07**	0.70	5.97**	1.78	0.21
SE_m	0.086	0.118	0.099	0.073	0.175	0.276
CD(0.05)	–	0.341	–	0.212	–	–

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

The significant effect of P x K was evident at the second phase of 98-99 and first phase of 99-00. In combination with p_3 increasing levels of potassium significantly enhanced the leaf area. The effect of k_2 and k_3 was same in p_2 applied plots during the first year and p_1 applied plots in the subsequent year.

4.2.2 Leaf area index (LAI)

Different levels of nitrogen, phosphorus and potassium had remarkable influence on LAI at almost all stages in 98-99 and 99-00 (Table 9a).

Incremental doses of nitrogen significantly enhanced LAI at most stages, with highest values obtained at n_3. However, at harvest stage in 99-00 no significant difference was observed between n_2 and n_3 levels. The effect of phosphorus and potassium was significant in the early stages in both the years. Increasing rates of both P and K resulted in a significant increase in LAI. But towards the final stage phosphorus or potassium could not have any influence on LAI.

A close scrutiny of data in Table 9b indicated that the interaction between nitrogen and phosphorus had significant effect at 4 MAP and 6 MAP in 98-99 and at 4 MAP in 99-00. In combination with n_1 and n_2 at 4 MAP, with n_2 at 6 MAP in 98-99 and also with n_2 at 4 MAP in 99-00, p_2 and p_3 exerted similar effect on LAI. On the whole, p_3 had a significant effect in combination with n_1 and n_3.

Table 9a. Effect of nitrogen, phosphorus and potassium on leaf area index

Main effect of factors	Leaf area index					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1	0.50	0.74	0.54	0.39	0.68	0.47
n_2	0.60	1.23	0.55	0.58	1.13	0.60
n_3	0.83	1.77	0.69	0.79	1.61	0.62
$F_{2,27}$	232.25**	118.79**	41.74**	440.39**	428.83**	5.56**
SE_m	0.011	0.015	0.013	0.009	0.022	0.035
CD(0.05)	0.032	0.043	0.037	0.027	0.065	0.103
p_1	0.59	1.11	0.58	0.54	1.03	0.52
p_2	0.64	1.28	0.60	0.58	1.15	0.60
p_3	0.71	1.35	0.60	0.64	1.24	0.60
$F_{2,27}$	26.32**	68.71**	0.51	31.93**	21.23**	1.35
SE_m	0.011	0.015	0.013	0.009	0.022	0.035
CD(0.05)	0.032	0.043	–	0.027	0.065	–
k_1	0.54	1.00	0.59	0.49	0.98	0.56
k_2	0.68	1.33	0.58	0.61	1.18	0.54
k_3	0.72	1.41	0.60	0.66	1.26	0.58
$F_{2,27}$	73.46**	215.35**	0.43	96.44**	40.06**	0.31
SE_m	0.011	0.015	0.013	0.009	0.022	0.035
CD(0.05)	0.032	0.043	–	0.027	0.065	–

** Significant at 1 per cent level

Table 9b. Interaction effect of nitrogen, phosphorus and potassium on leaf area index

Interaction effects	Leaf area index					
	98-99			99-00		
	4MAP	6MAP	Harvest	4MAP	6MAP	Harvest
n_1p_1	0.44	0.68	0.56	0.33	0.60	0.44
n_1p_2	0.52	0.73	0.54	0.40	0.70	0.47
n_1p_3	0.55	0.81	0.51	0.46	0.75	0.49
n_2p_1	0.58	1.05	0.53	0.56	0.99	0.52
n_2p_2	0.60	1.30	0.55	0.59	1.15	0.60
n_2p_3	0.63	1.33	0.59	0.60	1.23	0.67
n_3p_1	0.76	1.59	0.66	0.72	1.50	0.60
n_3p_2	0.80	1.79	0.70	0.76	1.61	0.61
n_3p_3	0.94	1.93	0.70	0.88	1.73	0.65
$F_{4,27}$	3.37*	6.41**	1.78	4.59**	0.51	0.23
SE_m	0.019	0.026	0.002	0.016	0.039	0.061
CD(0.05)	0.056	0.075	–	0.047	–	–
n_1k_1	0.40	0.62	0.53	0.29	0.55	0.45
n_1k_2	0.51	0.78	0.53	0.43	0.73	0.47
n_1k_3	0.60	0.82	0.54	0.47	0.78	0.48
n_2k_1	0.53	0.92	0.54	0.51	0.95	0.56
n_2k_2	0.64	1.34	0.54	0.61	1.18	0.58
n_2k_3	0.65	1.42	0.58	0.64	1.24	0.65
n_3k_1	0.69	1.44	0.70	0.67	1.45	0.67
n_3k_2	0.89	1.88	0.68	0.81	1.63	0.58
n_3k_3	0.93	1.98	0.68	0.88	1.75	0.61
$F_{4,27}$	3.51*	14.23**	0.40	1.77	0.42	0.48
SE_m	0.019	0.026	0.002	0.016	0.039	0.061
CD(0.05)	0.056	0.075	–	–	–	–
p_1k_1	0.51	0.97	0.57	0.48	0.93	0.55
p_1k_2	0.61	1.13	0.59	0.55	1.06	0.51
p_1k_3	0.66	1.23	0.58	0.59	1.10	0.51
p_2k_1	0.54	1.00	0.59	0.49	0.99	0.55
p_2k_2	0.68	1.39	0.60	0.60	1.19	0.53
p_2k_3	0.71	1.43	0.60	0.66	1.28	0.59
p_3k_1	0.57	1.01	0.61	0.49	1.03	0.58
p_3k_2	0.75	1.48	0.57	0.69	1.29	0.59
p_3k_3	0.80	1.56	0.62	0.74	1.39	0.64
$F_{4,27}$	1.70	12.24**	0.70	5.85**	1.73	0.22
SE_m	0.019	0.026	0.002	0.016	0.039	0.061
CD(0.05)	–	0.075	–	0.047	–	–

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

The effect of N x K was significant only at the initial stages in 98-99. In combination with n_1 at 4 MAP and with n_2 and n_3 at 6 MAP, higher levels of potassium resulted in an increase in LAI. But k_2 and k_3 exerted similar effect in n_2 and n_3 treated plots at 4 MAP and n_1 treated plots at 6 MAP.

The interaction P x K was significant at 6 MAP in 98-99 and 4 MAP in 99-00. At all levels of phosphorus, LAI was increased with increase in dose of potassium. However, in combination with p_1 at 4 MAP in 99-00 and p_2 at 6 MAP in 98-99, k_2 and k_3 were on par.

4.2.3 Phyllochron

Table 10a clearly depicts that different levels of nitrogen and potassium had significant impact on phyllochron during both the years of experimentation. With regard to the applied nitrogen, the highest level n_3 significantly reduced the phyllochron. Potassium nutrition also had a marked influence on phyllochron. Higher levels of K (k_2 or k_3) had the same effect in reducing the number of days between successive leaf emergence. None of the interaction effects could significantly influence the phyllochron in the first or second year of field investigation (Table 10b).

4.2.4 Dry matter accumulation and partitioning

4.2.4.1 Total dry matter

Different levels of nitrogen, phosphorus and potassium had profound influence on total dry matter at almost all stages of growth (Table 11a).

Table 10a. Effect of nitrogen, phosphorus and potassium on phyllochron

Main effect of factors	Phyllochron (days)	
	98-99	99-00
n_1	15.33	15.50
n_2	13.50	12.50
n_3	11.39	10.28
$F_{2,27}$	55.81**	145.03**
SE_m	0.264	0.218
CD(0.05)	0.767	0.632
p_1	13.50	12.78
p_2	13.50	12.50
p_3	13.22	12.50
$F_{2,27}$	0.37	3.26
SE_m	0.264	0.218
CD(0.05)	–	–
k_1	14.11	13.22
k_2	13.33	12.78
k_3	12.78	12.78
$F_{2,27}$	6.43**	4.71*
SE_m	0.264	0.218
CD(0.05)	0.767	0.632

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

Table 10b. Interaction effect of nitrogen, phosphorus and potassium on phyllochron

Interaction effect	Phyllochron (days)	
	98-99	99-00
n_1p_1	15.67	16.00
n_1p_2	15.50	15.17
n_1p_3	14.83	15.33
n_2p_1	13.67	12.83
n_2p_2	13.33	12.33
n_2p_3	13.50	12.33
n_3p_1	11.17	11.00
n_3p_2	11.67	10.00
n_3p_3	11.33	9.83
$F_{4,27}$	0.50	0.25
SE_m	0.458	0.377
CD(0.05)	–	–
n_1k_1	15.83	16.00
n_1k_2	15.33	15.67
n_1k_3	14.83	14.83
n_2k_1	14.17	13.00
n_2k_2	13.50	12.50
n_2k_3	12.83	12.00
n_3k_1	12.33	10.67
n_3k_2	11.17	10.17
n_3k_3	10.67	10.00
$F_{4,27}$	0.19	0.22
SE_m	0.458	0.377
CD(0.05)	–	–
p_1k_1	14.00	13.83
p_1k_2	13.33	13.33
p_1k_3	13.17	12.67
p_2k_1	14.33	12.67
p_2k_2	13.50	12.50
p_2k_3	12.67	12.33
p_3k_1	14.00	13.17
p_3k_2	13.17	12.50
p_3k_3	12.50	11.83
$F_{4,27}$	0.26	0.51
SE_m	0.458	0.377
CD(0.05)	–	–

Table 11a. Effect of nitrogen, phosphorus and potassium on total dry matter

Main effect of factors	Total dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	834.54	2069.43	6546.94	780.39	2059.59	6036.65
n_2	982.85	2225.30	8335.32	918.25	2184.34	7491.17
n_3	1102.11	2485.28	8848.68	1024.55	2366.17	8382.74
$F_{2,27}$	2404.29**	1332.61**	1009.73**	3416.39**	1179.77**	1934.20**
SE_m	2.734	5.755	38.025	2.094	4.489	26.927
CD(0.05)	7.933	16.701	110.348	6.078	13.026	78.142
p_1	953.35	2212.62	7495.42	889.69	2163.24	6973.45
p_2	972.71	2266.44	8021.26	906.79	2198.51	7400.62
p_3	993.45	2300.95	8214.25	926.72	2248.35	7536.49
$F_{2,27}$	53.79**	59.82**	95.74**	78.38**	90.86**	119.02**
SE_m	2.734	5.755	38.025	2.094	4.489	26.927
CD(0.05)	7.933	16.701	110.348	6.078	13.026	78.142
k_1	953.60	2223.46	7515.47	891.61	2168.36	6947.98
k_2	973.90	2268.14	8051.34	910.73	2212.43	7368.86
k_3	992.00	2288.41	8164.12	920.84	2229.31	7593.71
$F_{2,27}$	49.38**	33.33**	83.07**	50.38**	49.21**	148.17**
SE_m	2.734	5.755	38.025	2.094	4.489	26.927
CD(0.05)	7.933	16.701	110.348	6.078	13.026	78.142

** Significant at 1 per cent level

Table 11b. Interaction effect of nitrogen, phosphorus and potassium on total dry matter

Interaction effects	Total dry matter (g $plant^{-1}$)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	814.38	2040.82	6354.55	770.46	2032.89	5903.25
n_1p_2	840.17	2068.55	6547.45	782.09	2059.91	6068.81
n_1p_3	849.07	2098.93	6738.80	788.63	2085.98	6137.89
n_2p_1	962.52	2175.76	7756.53	900.62	2150.06	6969.76
n_2p_2	977.65	2237.11	8527.12	912.22	2178.48	7675.30
n_2p_3	1008.40	2263.02	8722.31	941.92	2224.47	7828.43
n_3p_1	1083.14	2421.28	8375.16	997.98	2306.75	8047.33
n_3p_2	1100.30	2493.65	8989.22	1026.06	2357.15	8457.74
n_3p_3	1122.87	2540.91	9181.65	1049.62	2434.61	8643.14
$F_{4,27}$	1.38	2.72	6.89**	6.66**	6.36**	13.41**
SE_m	4.735	9.968	65.861	3.628	7.775	46.639
CD(0.05)	–	–	191.129	10.528	22.562	135.345
n_1k_1	823.18	2043.72	6331.87	768.53	2029.41	5864.76
n_1k_2	827.54	2076.74	6571.72	782.39	2062.29	6062.63
n_1k_3	852.92	2087.84	6737.22	790.26	2087.08	6182.55
n_2k_1	960.99	2191.18	7775.84	907.72	2155.59	6939.44
n_2k_2	987.63	2229.49	8239.01	919.47	2192.59	7646.94
n_2k_3	999.95	2255.23	8691.10	927.58	2204.84	7887.11
n_3k_1	1076.64	2435.49	8438.70	998.58	2320.09	8039.75
n_3k_2	1106.54	2498.19	9043.29	998.58	2382.40	8397.00
n_3k_3	1123.14	2522.17	9064.04	1030.33	2396.02	8711.47
$F_{4,27}$	2.30	1.30	5.52**	4.41**	1.32	13.58**
SE_m	4.735	9.968	65.861	3.628	7.775	46.639
CD(0.05)	–	–	191.129	10.528	–	135.345
p_1k_1	940.53	2170.78	7260.57	877.83	2135.41	6765.95
p_1k_2	951.71	2223.92	7584.13	890.17	2168.16	6900.29
p_1k_3	967.80	2243.18	7641.55	901.06	2186.13	7254.10
p_2k_1	951.54	2234.16	7499.84	889.19	2165.89	6932.23
p_2k_2	976.58	2275.54	8192.71	911.07	2206.51	7545.05
p_2k_3	990.00	2289.63	8371.24	920.11	2223.13	7674.57
p_3k_1	968.73	2265.45	7785.99	907.81	2203.78	7145.77
p_3k_2	993.41	2304.97	8377.19	930.94	2262.61	7661.23
p_3k_3	1018.20	2332.43	8449.57	941.42	2278.67	7795.47
$F_{4,27}$	1.66	0.30	3.91*	0.81	0.88	7.68**
SE_m	4.735	9.968	65.861	3.628	7.775	46.639
CD(0.05)	–	–	191.129	–	–	135.345

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

Increased rates of these three nutrients significantly enhanced total dry matter through the growth period. At all these stages maximum value was recorded by n_3, p_3 and k_3 respectively.

The interaction effect, N x P was significant at harvest stage in 98-99 and at all stages in 99-00. Incremental doses of phosphorus enhanced total dry matter production in n_1, n_2 or n_3 applied plots at these stages. However, at the initial stage and final stage in 99-00, phosphorus responded upto p_2 in n_1 treated plots (Table 11b).

The interaction N x K was significant at 4 MAP in 99-00 and at harvest stage in both the years. At these stages k_2 and k_3 were on par in combination with n_1 and n_2. At 4 MAP and harvest stage in 99-00, k_3 produced significantly high total dry matter in n_3 applied plots. The interaction between phosphorus and potassium was significant only at the final stages in both the years. At harvest stage in 99-00, k_3 level of potassium recorded the highest total dry matter in combination with p_1. Whereas in p_2 and p_3 applied plots potassium responded significantly upto k_2.

4.2.4.2 Leaf dry matter

Application of nitrogen, phosphorus and potassium at different levels significantly influenced the leaf dry matter throughout the crop growth. Incremental doses of nitrogen and phosphorus significantly increased the leaf dry matter at all stages in 98-99 and 99-00 with the highest values at n_3 and p_3 respectively. Increasing levels of potassium significantly increased the leaf dry matter at all stages except at 6 MAP in 99-00. At this stage k_2 and k_3 were on par (Table 12a).

Table 12a. Effect of nitrogen, phosphorus and potassium on leaf dry matter

Main effect of factors	Leaf dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	225.53	610.19	296.49	207.95	575.82	261.91
n_2	240.39	661.18	313.21	223.40	614.53	286.15
n_3	272.86	719.09	322.15	257.50	676.31	306.28
$F_{2,27}$	1161.41**	926.55**	377.54**	1453.29**	448.28**	282.84**
SE_m	0.710	1.242	0.671	0.665	2.394	1.321
CD(0.05)	2.061	3.603	1.946	1.930	6.947	3.833
p_1	239.92	649.67	305.80	222.07	610.54	279.33
p_2	244.55	666.04	310.86	231.93	620.74	284.87
p_3	254.30	674.74	315.19	234.86	635.37	290.13
$F_{2,27}$	106.88**	10.51**	49.12**	101.45**	16.92**	16.72**
SE_m	0.710	1.242	0.671	0.665	2.394	1.321
CD(0.05)	2.061	3.603	1.946	1.930	6.947	3.833
k_1	238.71	655.75	304.92	221.94	611.36	278.62
k_2	247.11	663.11	311.37	231.99	624.73	285.58
k_3	252.96	671.60	315.55	234.92	630.57	290.13
$F_{2,27}$	101.76**	40.77**	63.85**	104.66**	27.17**	19.27**
SE_m	0.710	1.242	0.671	0.665	2.394	1.321
CD(0.05)	2.061	3.603	1.946	1.930	6.947	3.833

** Significant at 1 per cent level

Table 12b. Interaction effect of nitrogen, phosphorus and potassium on leaf dry matter

Interaction effects	Leaf dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	222.84	600.48	289.96	203.24	564.59	253.46
n_1p_2	225.46	609.75	298.54	209.73	577.66	261.97
n_1p_3	228.28	620.33	300.96	210.89	585.20	270.29
n_2p_1	233.93	645.66	307.12	220.42	609.14	279.68
n_2p_2	238.37	669.05	312.84	224.42	611.14	285.87
n_2p_3	248.86	668.82	319.66	225.38	623.33	292.91
n_3p_1	262.97	702.88	320.32	242.55	657.91	304.85
n_3p_2	269.83	719.33	321.20	261.63	673.42	306.77
n_3p_3	285.76	735.08	324.94	268.33	697.58	307.20
$F_{4,27}$	13.58**	2.29	4.66*	25.65**	0.71	0.82
SE_m	1.230	2.150	1.161	1.152	4.146	2.288
CD(0.05)	3.570	–	3.370	3.343	–	–
n_1k_1	221.43	603.65	291.50	203.24	563.92	257.94
n_1k_2	225.67	610.67	295.68	208.97	576.56	261.12
n_1k_3	229.50	616.23	302.28	211.64	586.87	266.67
n_2k_1	233.33	656.08	306.24	219.65	607.37	277.55
n_2k_2	240.99	658.86	315.04	225.00	616.46	288.21
n_2k_3	246.84	668.59	318.34	225.57	619.78	292.69
n_3k_1	261.36	707.51	317.02	242.94	662.78	300.37
n_3k_2	274.67	719.79	323.40	262.02	681.18	307.41
n_3k_3	282.54	729.98	326.04	267.55	684.95	311.04
$F_{4,27}$	7.53**	5.68**	3.24*	21.43**	2.92*	2.75*
SE_m	1.230	2.150	1.161	1.152	4.146	2.288
CD(0.05)	3.570	6.240	3.370	3.343	12.032	6.639
p_1k_1	236.35	640.56	301.84	215.07	604.93	275.86
p_1k_2	239.78	650.06	306.90	223.47	611.14	278.40
p_1k_3	243.61	658.40	308.66	227.67	615.57	283.73
p_2k_1	237.36	661.64	304.24	223.85	607.81	277.76
p_2k_2	245.03	664.42	310.20	235.11	623.55	285.65
p_2k_3	251.28	672.07	318.12	236.83	630.86	291.20
p_3k_1	242.40	665.04	308.66	226.91	621.33	282.24
p_3k_2	256.52	674.85	317.02	237.40	639.51	292.69
p_3k_3	263.98	684.34	319.88	240.26	645.27	295.47
$F_{4,27}$	9.23**	1.44	1.50	0.49	0.95	0.91
SE_m	1.230	2.150	1.161	1.152	4.146	2.288
CD(0.05)	3.570	–	–	–	–	–

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

Interaction effects furnished in Table 12b indicated that N x P interaction was significant at 4 MAP in both the years and at harvest stage in 98-99. At 4 MAP in 98-99, increasing levels of phosphorus significantly increased the leaf dry matter in combination with n_2 and n_3. In the subsequent year, significant response to p_3 was obtained in n_3 applied plots only. At the harvest stage in 98-99, higher phosphorus nutrition (p_3) resulted in significantly higher leaf dry matter in combination with n_2 and n_3.

The significant effect of N x K interaction is evident at all stages of growth. At all levels of nitrogen, incremental doses of potassium significantly increased the leaf dry matter at 4 MAP in 98-99. However, in the subsequent year, k_3 produced significantly higher leaf dry matter when combined with n_3 level only. At 6 MAP in 98-99, in n_2 and n_3 applied plots, k_3 produced significantly higher leaf dry matter. But during 99-00, k_2 and k_3 were on par at all levels of nitrogen. At harvest stage in both the years, in n_2 and n_3 treated plots, significant response to potassium was obtained only upto k_2 level.

The interaction, P x K was significant only at 4 MAP in 98-99. At all levels of phosphorus, higher leaf dry matter could be obtained in combination with the highest level of K (Table 12b).

4.2.4.3 Pseudostem dry matter

The main effect of treatments on pseudostem dry matter during the two years of experimentation are summarised in Table 13a.

Table 13a. Effect of nitrogen, phosphorus and potassium on pseudostem dry matter

Main effect of factors	Pseudostem dry matter (g $plant^{-1}$)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	397.44	902.96	3070.79	382.88	919.96	2909.93
n_2	515.43	944.84	3591.94	492.60	958.42	3350.54
n_3	592.56	1067.14	3842.98	554.63	1026.72	3724.52
$F_{2,27}$	397.56**	312.80**	376.46**	342.45**	191.15**	221.29**
SE_m	1.559	4.824	20.300	1.486	3.911	8.667
CD(0.05)	4.523	13.998	58.912	4.313	11.350	25.153
p_1	492.05	954.73	3398.50	468.90	952.60	3255.69
p_2	501.86	972.89	3511.86	473.48	965.45	3345.21
p_3	511.52	987.31	3595.35	487.73	987.06	3384.08
$F_{2,27}$	39.04**	11.46**	23.68**	43.63**	19.83**	57.67**
SE_m	1.559	4.824	20.300	1.486	3.911	8.667
CD(0.05)	4.523	13.998	58.912	4.313	11.350	25.153
k_1	497.03	957.79	3390.71	471.98	954.27	3248.24
k_2	501.25	976.39	3547.06	477.23	971.27	3350.71
k_3	507.15	980.76	3567.94	480.90	979.58	3386.04
$F_{2,27}$	10.67**	6.39**	22.76**	9.09**	10.90**	68.20**
SE_m	1.559	4.824	20.300	1.486	3.911	8.667
CD(0.05)	4.523	13.998	58.912	4.313	11.350	25.153

** Significant at 1 per cent level

Table 13b. Interaction effect of nitrogen, phosphorus and potassium on pseudostem dry matter

Interaction effects	Pseudostem dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	385.94	891.46	2999.04	379.58	912.11	2851.49
n_1p_2	399.51	904.55	3042.37	382.05	917.32	2940.56
n_1p_3	406.87	912.86	3170.96	387.00	930.47	2937.74
n_2p_1	503.47	932.39	3456.42	482.63	945.20	3241.83
n_2p_2	513.36	944.95	3633.52	485.33	956.99	3377.61
n_2p_3	529.46	957.17	3685.88	509.85	973.08	3432.18
n_3p_1	586.73	1040.36	3740.05	544.50	1000.51	3673.76
n_3p_2	592.71	1069.18	3859.68	553.05	1022.04	3717.47
n_3p_3	598.23	1091.89	3929.20	566.33	1057.63	3782.33
$F_{4,27}$	2.29	0.98	0.94	1.99	2.26	4.80**
SE_m	2.700	8.355	35.161	2.574	6.774	15.013
CD(0.05)	–	–	–	–	–	43.567
n_1k_1	395.83	891.67	2971.10	380.03	906.21	2857.84
n_1k_2	393.07	907.18	3090.55	383.40	920.04	2916.12
n_1k_3	403.42	910.02	3150.72	385.20	933.64	2955.83
n_2k_1	508.30	933.48	3437.06	489.15	950.19	3218.99
n_2k_2	517.04	948.01	3641.88	492.53	960.39	3396.46
n_2k_3	520.95	953.03	3696.88	496.13	964.69	3436.17
n_3k_1	586.96	1048.22	3763.98	546.75	1006.40	3667.88
n_3k_2	593.63	1073.98	3908.74	555.75	1033.37	3739.56
n_3k_3	597.08	1079.22	3856.21	561.38	1040.40	3766.11
$F_{4,27}$	1.34	0.21	2.76*	5.35**	0.72	6.70**
SE_m	2.700	8.355	35.161	2.574	6.774	15.013
CD(0.05)	–	–	102.038	7.470	–	43.567
p_1k_1	488.98	937.63	3313.64	467.55	936.81	3226.55
p_1k_2	489.21	961.98	3461.04	468.68	955.40	3248.41
p_1k_3	497.95	964.60	3420.83	470.48	965.60	3292.12
p_2k_1	494.50	960.89	3397.90	466.88	955.17	3243.43
p_2k_2	503.24	977.26	3547.05	474.08	966.96	3378.13
p_2k_3	507.84	980.53	3590.62	479.47	974.21	3414.08
p_3k_1	507.61	974.86	3460.60	481.50	970.81	3274.73
p_3k_2	511.29	989.92	3633.08	488.93	991.44	3425.60
p_3k_3	515.66	997.14	3692.36	492.75	998.92	3451.92
$F_{4,27}$	0.72	0.11	0.96	1.11	0.19	6.61**
SE_m	2.700	8.355	35.161	2.574	6.774	15.013
CD(0.05)	–	–	–	–	–	43.567

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

The effect of nitrogen, phosphorus and potassium was significant at all phases of growth. Increasing levels of both nitrogen and phosphorus significantly increased the pseudostem dry matter with the maximum values at n_3 and p_3 respectively in 98-99 and 99-00. Potassium also exerted marked influence on pseudostem dry matter. Significant response was obtained upto k_2 in most of the stages except at 4 MAP in 98-99 and harvest stage in 99-00. At these two stages the level k_3 recorded the highest pseudostem dry matter.

Interaction effects are furnished in Table 13b. The variation in pseudostem dry matter due to N x P interaction was significant only at harvest stage in 99-00. In combination with n_2 and n_3, increasing levels of phosphorus significantly increased the pseudostem dry matter. But in n_1 applied plots p_2 and p_3 showed similar effect.

The interaction between nitrogen and potassium was significant at 4 MAP in 99-00 and at harvest stage in both the years. At all levels of nitrogen significant response was obtained upto k_2 level. At 4 MAP in 99-00, k_1 and k_2 produced similar effect in combination with n_1 and n_2.

Significant difference in pseudostem dry matter due to P x K interaction was significant only at harvest stage in 99-00. At this stage in p_1 applied plots highest pseudostem dry matter was obtained at k_3 level of potassium. But there was no significant difference between k_1 and k_2. On the other hand in combination with p_2 and p_3, significant response was obtained upto k_2 level.

4.2.4.4 Rhizome dry matter

The effect of treatments on rhizome dry matter at different growth stages during the two years are presented in Tables 14a and 14b.

In general, n_3 recorded significantly highest rhizome dry matter at all stages of growth. Incremental doses of phosphorus significantly enhanced the rhizome dry matter at most of the growth stages except at 4 MAP in 98-99 and 99-00. At these stages, the levels p_1 and p_2 as well as p_2 and p_3 were on par.

The effect of potassium was significant in both the years. Application of k_3 resulted in significantly higher rhizome dry matter at most stages of growth except at 6 MAP in 99-00. At this stage significant response was obtained only upto k_2 level.

As depicted in Table 14b, the interactions N x P, N x K or P x K could not significantly effect the rhizome dry matter at all the stages during the two years of experimentation.

4.2.4.5 Bunch dry matter

The main and interaction effects of treatments in bunch dry matter during the different growth phases in both the years are presented in Tables 15a and 15b respectively.

Table 14a. Effect of nitrogen, phosphorus and potassium on rhizome dry matter

Main effect of factors	Rhizome dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	211.57	556.29	888.37	189.57	563.81	881.46
n_2	227.04	619.29	978.34	202.25	611.38	968.84
n_3	236.69	699.05	1076.09	212.42	663.14	1065.67
$F_{2,27}$	55.68**	101.65**	291.59**	91.52**	167.62**	107.86**
SE_m	1.698	2.244	5.498	1.197	3.844	2.806
CD(0.05)	4.928	6.512	15.956	3.473	11.156	8.142
p_1	221.39	608.22	955.15	198.72	600.09	945.16
p_2	226.29	627.51	978.49	201.39	612.32	972.65
p_3	227.63	638.90	1009.16	204.14	625.92	998.16
$F_{2,27}$	3.74*	4.77*	24.27**	5.14*	11.31**	8.93**
SE_m	1.698	2.244	5.498	1.197	3.844	2.806
CD(0.05)	4.928	6.512	15.956	3.473	11.156	8.142
k_1	217.87	609.93	947.45	197.69	602.74	951.04
k_2	225.55	628.65	989.41	201.51	616.43	977.72
k_3	231.89	636.05	1005.94	205.05	619.17	987.21
$F_{2,27}$	17.11**	35.97**	30.08**	9.45**	5.24*	4.47*
SE_m	1.698	2.244	5.498	1.197	3.844	2.806
CD(0.05)	4.928	6.512	15.956	3.473	11.156	8.142

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

Table 14b. Interaction effect of nitrogen, phosphorus and potassium on rhizome dry matter

Interaction effects	Rhizome dry matter (g plant^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	205.60	548.88	875.25	187.64	556.20	861.30
n_1p_2	215.20	554.26	887.11	190.31	564.92	874.65
n_1p_3	213.92	565.73	902.75	190.76	570.31	908.43
n_2p_1	225.12	597.72	943.46	197.58	595.72	940.00
n_2p_2	225.92	623.11	974.96	202.48	610.35	972.23
n_2p_3	230.08	637.03	1016.60	206.70	628.06	994.22
n_3p_1	233.44	678.05	1046.73	210.93	648.34	1034.09
n_3p_2	237.76	705.15	1073.41	211.38	661.69	1071.07
n_3p_3	238.88	713.94	1108.14	214.97	679.40	1091.85
$F_{4,27}$	0.59	2.31	1.56	0.75	0.61	1.64
SE_m	2.941	3.887	9.523	2.073	6.658	4.860
CD(0.05)	–	–	–	–	–	–
n_1k_1	205.92	548.40	874.00	185.27	559.28	866.62
n_1k_2	208.80	558.89	890.89	190.02	565.69	883.83
n_1k_3	220.00	561.58	900.22	193.43	566.46	893.73
n_2k_1	219.36	601.63	933.34	198.92	598.03	944.68
n_2k_2	229.60	622.62	986.23	201.95	615.74	977.30
n_2k_3	232.16	633.61	1015.45	205.89	620.36	984.55
n_3k_1	228.32	679.76	1035.00	208.89	650.91	1041.83
n_3k_2	238.24	704.42	1091.12	212.56	667.85	1072.03
n_3k_3	243.52	712.97	1102.16	215.83	670.67	1083.15
$F_{4,27}$	0.74	2.21	2.64	0.05	0.41	0.90
SE_m	2.941	3.887	9.523	2.073	6.658	4.860
CD(0.05)	–	–	–	–	–	–
p_1k_1	215.20	592.59	918.39	195.21	593.67	929.21
p_1k_2	222.72	611.88	960.35	198.03	601.63	949.75
p_1k_3	226.24	620.18	986.70	202.92	604.96	956.52
p_2k_1	219.68	611.63	941.85	198.47	602.91	947.58
p_2k_2	228.32	633.86	992.90	201.88	616.00	980.74
p_2k_3	230.88	637.03	1000.73	203.81	618.05	989.63
p_3k_1	218.72	625.55	982.10	199.39	611.64	976.33
p_3k_2	225.60	640.20	1014.99	204.62	631.66	1002.68
p_3k_3	238.56	650.95	1030.40	208.41	634.48	1015.48
$F_{4,27}$	1.14	0.37	0.50	0.28	0.27	0.75
SE_m	2.941	3.887	9.523	2.073	6.658	4.860
CD(0.05)	–	–	–	–	–	–

Table 15a. Effect of nitrogen, phosphorus and potassium on bunch dry matter

Main effect of factors	Bunch dry matter (g plant^{-1})	
	98-99	99-00
n_1	2290.56	1986.67
n_2	3480.56	2885.00
n_3	3607.22	3288.33
$F_{2,27}$	123.97**	77.66**
SE_m	20.426	23.910
CD(0.05)	59.277	69.388
p_1	2837.22	2493.33
p_2	3218.33	2800.00
p_3	3292.78	2866.67
$F_{2,27}$	14.31**	6.93**
SE_m	20.426	23.910
CD(0.05)	59.277	69.388
k_1	2873.81	2470.00
k_2	3224.67	2756.67
k_3	3272.78	2933.33
$F_{2,27}$	10.85**	9.56**
SE_m	20.426	23.910
CD(0.05)	59.277	69.388

** Significant at 1 per cent level

Table 15b. Interaction effect of nitrogen, phosphorus and potassium on bunch dry matter

Interaction effects	Bunch dry matter (g $plant^{-1}$)	
	98-99	99-00
n_1p_1	2191.67	1940.33
n_1p_2	2318.33	1995.00
n_1p_3	2361.67	2025.00
n_2p_1	3050.00	2505.00
n_2p_2	3693.33	3040.00
n_2p_3	3698.33	3110.33
n_3p_1	3270.00	3035.00
n_3p_2	3733.33	3365.00
n_3p_3	3818.33	3465.00
$F_{4,27}$	5.31**	7.56**
Se_m	35.380	41.414
CD(0.05)	102.672	120.183
n_1k_1	2196.67	1885.00
n_1k_2	2293.33	2005.00
n_1k_3	2381.67	2070.00
n_2k_1	3100.00	2495.00
n_2k_2	3656.33	2985.33
n_2k_3	3658.33	3175.00
n_3k_1	3325.00	3030.33
n_3k_2	3718.33	3280.00
n_3k_3	3778.33	3555.00
$F_{4,27}$	4.63**	5.74**
SE_m	35.380	41.414
CD(0.05)	102.672	120.183
p_1k_1	2728.33	2333.33
p_1k_2	2856.67	2423.33
p_1k_3	2926.67	2723.33
p_2k_1	2856.67	2463.33
p_2k_2	3340.00	2903.33
p_2k_3	3458.33	3033.33
p_3k_1	3036.67	2613.33
p_3k_2	3408.33	2943.00
p_3k_3	3433.33	3043.00
$F_{4,27}$	4.09*	5.11**
SE_m	35.380	41.414
CD(0.05)	102.672	120.183

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

The effect of nitrogen, phosphorus and potassium was significant in 98-99 and 99-00. Significantly highest bunch dry matter was observed in n_3 applied plots. In the case of phosphorus, p_3 recorded the highest bunch dry matter only during the first year. Whereas k_3 recorded maximum value during the second year.

It is clear from Table 15b that interactions, N x P, N x K and P x K were significant in 98-99 and in 99-00 also. At all levels of nitrogen, p_2 and p_3 had similar effect on bunch dry matter in both the years. In the case of N x K interaction, irrespective of the levels of nitrogen, potassium responded upto k_2 during the first year. Whereas during the suceeding year, increasing rates of potassium significantly increased the dry matter in n_2 and n_3 applied plots. The highest level of potassium k_3 produced significant highest dry matter in combination with p_1 during 99-00 and with p_2 in both the years.

4.3 Bunch characters

4.3.1 Length of bunch

The effect of treatments on length of bunch for two years of experimentation are presented in Tables 16a and 16b.

The effect of nitrogen was significant in both the years. In 98-99 an increasing trend was observed with increase in nitrogen levels, though n_2 (91.83 cm) and n_3 (93.83 cm) were on a par. Applied phosphorus did not

Table 16a. Effect of nitrogen, phosphorus and potassium on bunch characters

Main effect of factors	Length of bunch (cm)		No. of hands bunch^{-1}		No. of fingers bunch^{-1}		Weight of hand (kg)	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
n_1	82.66	71.61	7.06	7.33	111.78	111.94	0.66	0.52
n_2	91.83	83.56	8.50	8.44	131.39	128.89	1.01	0.87
n_3	93.83	93.44	9.33	9.11	142.56	138.50	1.07	1.02
$F_{2,27}$	4.06*	102.77**	103.84**	26.07**	189.65**	41.01**	188.35**	330.70**
SE_m	2.957	1.079	0.113	0.176	1.131	2.100	0.016	0.014
CD(0.05)	8.580	3.130	0.328	0.510	3.283	6.093	0.047	0.041
p_1	87.00	80.72	7.83	7.78	120.83	118.72	0.84	0.72
p_2	90.50	82.17	8.33	8.50	129.94	128.72	0.94	0.84
p_3	90.82	85.72	8.72	8.61	134.94	131.89	0.96	0.86
$F_{2,27}$	0.51	5.69**	15.52**	6.62**	39.99**	10.71**	16.58**	27.02**
SE_m	2.957	1.079	0.113	0.176	1.131	2.100	0.016	0.014
CD(0.05)	–	3.130	0.328	0.510	3.283	6.093	0.047	0.041
k_1	88.71	79.72	7.72	7.83	121.44	119.72	0.85	0.72
k_2	90.56	84.06	8.39	8.39	130.28	128.50	0.94	0.82
k_3	89.06	84.83	8.78	8.67	134.00	131.11	0.95	0.86
$F_{2,27}$	0.11	6.52**	22.28**	5.82**	32.49**	8.07**	12.06**	31.39**
SE_m	2.957	1.079	0.113	0.176	1.131	2.100	0.016	0.014
CD(0.05)	–	3.130	0.328	0.510	3.283	6.093	0.047	0.041

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

Table 16b. Interaction effect of nitrogen, phosphorus and potassium on bunch characters

Interaction effects	Length of bunch (cm)		No. of hands bunch^{-1}		No. of fingers bunch^{-1}		Weight of hand (kg)	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	78.83	69.00	7.00	7.00	106.50	106.33	0.62	0.52
n_1p_2	81.67	70.17	7.00	7.50	113.83	114.00	0.67	0.51
n_1p_3	87.47	75.67	7.17	7.50	115.00	115.50	0.68	0.53
n_2p_1	88.50	82.17	7.83	7.67	121.17	118.33	0.92	0.72
n_2p_2	94.17	81.67	8.83	8.83	135.67	133.17	1.06	0.90
n_2p_3	92.83	86.83	8.83	8.83	137.33	135.17	1.07	1.00
n_3p_1	93.67	91.00	8.67	8.67	134.83	131.50	0.98	0.92
n_3p_2	95.67	94.67	9.17	9.17	140.33	139.00	1.09	1.10
n_3p_3	92.17	94.67	10.17	9.50	152.50	145.00	1.14	1.05
$F_{4,27}$	0.34	0.78	4.30**	0.53	3.70*	0.48	1.24	9.44**
SE_m	5.121	1.868	0.196	0.305	1.960	3.636	0.028	0.025
CD(0.05)	–	–	0.568	–	5.687	–	–	0.072
n_1k_1	81.80	69.33	6.83	7.17	109.00	109.17	0.62	0.48
n_1k_2	81.50	72.33	7.00	7.33	110.67	112.50	0.67	0.53
n_1k_3	84.67	73.17	7.33	7.50	115.67	114.17	0.68	0.55
n_2k_1	88.50	79.67	7.67	7.83	122.00	120.00	0.94	0.73
n_2k_2	94.00	85.00	8.67	8.50	135.00	131.50	1.05	0.91
n_2k_3	93.00	86.00	9.17	9.00	137.17	135.17	1.05	0.98
n_3k_1	95.83	90.17	8.67	8.50	133.33	130.00	0.98	0.94
n_3k_2	96.17	94.83	9.50	9.33	145.17	141.50	1.11	1.03
n_3k_3	89.50	95.33	9.83	9.50	149.17	144.00	1.11	1.10
$F_{4,27}$	0.44	0.15	2.01	0.63	2.90*	0.68	0.75	3.82*
SE_m	5.121	1.868	0.196	0.305	1.960	3.636	0.028	0.025
CD(0.05)	–	–	–	–	5.687	–	–	0.072
p_1k_1	85.00	78.83	7.50	7.50	116.17	114.83	0.82	0.67
p_1k_2	88.17	80.67	7.83	7.83	121.00	120.33	0.86	0.70
p_1k_3	87.83	82.67	8.17	8.00	125.33	121.00	0.84	0.79
p_2k_1	90.00	78.83	7.67	7.83	122.33	119.67	0.84	0.72
p_2k_2	89.50	84.17	8.50	8.67	132.17	132.17	0.98	0.89
p_2k_3	92.00	83.50	8.83	9.00	135.33	134.33	0.99	0.89
p_3k_1	91.14	81.50	8.00	8.17	125.83	124.67	0.89	0.76
p_3k_2	94.00	87.33	8.83	8.67	137.67	133.00	0.99	0.88
p_3k_3	87.33	88.33	9.33	9.00	141.33	138.00	1.01	0.94
$F_{4,27}$	0.25	0.43	0.92	0.33	1.02	0.48	1.53	2.26
SE_m	5.121	1.868	0.196	0.305	1.960	3.636	0.028	0.025
CD(0.05)	–	–	–	–	–	–	–	–

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

have any effect on the length of bunch in 98-99. However, in the subsequent year, phosphorus at the highest level p_3 produced maximum length (85.72 cm).

Like phosphorus, the effect of potassium was also not significant during the first year. During the second year, the length of bunch increased with increasing levels of potassium. The higher doses of potassium (k_2 and k_3) showed similar effects (84.06 cm and 84.83 cm respectively).

As depicted in Table 16b, the interactions N x P, N x K and P x K also could not significantly effect the length of bunch during the two years of experimentation.

4.3.2 Number of hands bunch^{-1}

It is clear from Table 16a that nitrogen had a significant influence on the number of hands in a bunch. With increase in levels of nitrogen, there was significant increase in the number of hands bunch^{-1}. Maximum number was observed at n_3 level in 98-99 and 99-00 (9.33 and 9.11 respectively).

Response of phosphorus also was significant in both the years. Applied phosphorus at the highest level p_3 produced maximum number of hands bunch^{-1} (8.72) in 98-99. During the succeeding year, though yield due to p_3 was highest, it was on par with p_2. In the case of potassium, k_3 recorded the highest number during 98-99 (8.78) whereas in the subsequent year k_2 and k_3 were on par..

As furnished in Table 16b, the interaction between nitrogen and phosphorus significantly influenced the number of hands bunch^{-1} in 98-99. In combination with n_1 and n_2, the higher levels of phosphorus (p_2 and p_3) had similar effect. But in n_3 treated plots, the highest level of phosphorus (p_3) tended to enhance the number of hands. The interactions, N x K and P x K were not significant in either of the years.

4.3.3 Number of fingers bunch^{-1}

Table 16a clearly depicts the significant effect of different levels of nitrogen on the number of fingers bunch^{-1}. In both the years of experimentation, number of fingers increased with increasing rates of nitrogen with the maximum number at n_3 (142.56 and 138.50 respectively). Incremental dose of both phosphorus and potassium application significantly enhanced the number of fingers in a bunch in 98-99 with the highest values at p_3 (134.94) and k_3 (134.00). However, in 99-00, the higher levels of phosphorus (p_2 and p_3) and potassium (k_2 and k_3) were on par.

Considering N x P interactions, significantly higher response was observed in 98-99. In n_1 and n_2 applied plots, higher levels of phosphorus (p_2 or p_3) tended to increase the number of fingers in a bunch. But in n_3 applied plots, maximum value was attained at p_3 level (152.50). The interaction N x K was significant only in the first year. Higher levels of K (k_2 and k_3) resulted in maximum number of fingers bunch^{-1} irrespective of applied nitrogen. The interaction between phosphorus and potassium was not significant in both the years of study (Table 16b).

4.3.4 Weight of hand

It is evident from Table 16a that different levels of nitrogen had similar effect in both the years. Application of nitrogen at the highest level (n_3) enhanced the weight of hand considerably during 98-99 and 99-00 (1.07 kg and 1.02 kg respectively).

The response of phosphorus on weight of hand was significant in two years of study. Though an increasing trend was noticed with increase in level of phosphorus the higher levels (p_2 and p_3) were on par. Similar effect was imparted by potassium also. Significant response was obtained only upto k_2 level of potassium.

The interaction, N x P was significant only during 99-00. At n_1 and n_3 levels of nitrogen, higher levels of phosphorus (p_2 and p_3) had similar effect on weight of hand. In n_2 applied plots, increasing rate of phosphorus significantly enhanced the weight of hand with the highest values recorded at n_2p_3 (1.00 kg). Influence of N x K interaction was also significant during the second year. At all levels of nitrogen, higher levels of K (k_2 and k_3) resulted in maximum weight of hand. The interaction, P x K could not influence the weight of hand during two years of experimentation.

4.3.5 Weight of bunch

Perusal of the data in Table 17a indicates that nitrogen nutrition profoundly influenced the weight of bunch in both the years.

Table 17a. Effect of nitrogen, phosphorus and potassium on weight of bunch

Main effect of factors	Weight of bunch (kg)	
	98-99	99-00
n_1	7.69	6.66
n_2	11.68	9.68
n_3	12.11	11.03
$F_{2,27}$	826.52**	649.42**
SE_m	0.084	0.088
CD(0.05)	0.244	0.255
p_1	9.52	8.37
p_2	10.81	9.39
p_3	11.05	9.61
$F_{2,27}$	96.78**	57.04**
SE_m	0.084	0.088
CD(0.05)	0.244	0.255
k_1	9.64	8.29
k_2	10.82	9.24
k_3	10.99	9.83
$F_{2,27}$	73.65**	78.67**
SE_m	0.084	0.088
CD(0.05)	0.244	0.255

** Significant at 1 per cent level

Table 17b. Interaction effect of nitrogen, phosphorus and potassium on weight of bunch

Interaction effects	Weight of bunch (kg)	
	98-99	99-00
n_1p_1	7.35	6.50
n_1p_2	7.78	6.68
n_1p_3	7.93	6.78
n_2p_1	10.23	8.42
n_2p_2	12.40	10.20
n_2p_3	12.42	10.43
n_3p_1	10.97	10.18
n_3p_2	12.53	11.28
n_3p_3	12.82	11.62
$F_{4,27}$	10.18**	10.33**
SE_m	0.145	0.152
CD(0.05)	0.422	0.442
n_1k_1	7.37	6.32
n_1k_2	7.70	6.72
n_1k_3	8.00	6.93
n_2k_1	10.40	8.38
n_2k_2	12.27	10.02
n_2k_3	12.28	10.65
n_3k_1	11.15	10.17
n_3k_2	12.48	11.00
n_3k_3	12.68	11.92
$F_{4,27}$	7.10**	8.83**
SE_m	0.145	0.152
CD(0.05)	0.422	0.442
p_1k_1	9.15	7.83
p_1k_2	9.58	8.13
p_1k_3	9.82	9.13
p_2k_1	9.58	8.27
p_2k_2	11.22	9.76
p_2k_3	11.62	10.17
p_3k_1	10.18	8.77
p_3k_2	11.45	9.87
p_3k_3	11.53	10.20
$F_{4,27}$	6.86**	4.20**
SE_m	0.145	0.152
CD(0.05)	0.422	0.442

** Significant at 1 per cent level

Table 17c. Influence of N x P x K interaction on weight of bunch

P x K interaction	Bunch weight (kg $plant^{-1}$)					
	98-99			99-00		
	n_1	n_2	n_3	n_1	n_2	n_3
p_1k_1	7.10	10.00	10.35	6.25	7.95	9.30
p_1k_2	7.30	10.25	11.20	6.60	8.05	9.75
p_1k_3	7.65	10.45	11.35	6.65	9.25	11.50
p_2k_1	7.50	9.95	11.30	6.15	8.20	10.45
p_2k_2	7.75	12.95	12.95	6.90	12.15	12.20
p_2k_3	8.10	13.05	13.30	7.00	12.25	12.35
p_3k_1	7.50	11.25	11.80	6.55	9.00	10.75
p_3k_2	8.05	13.00	13.30	6.65	11.85	11.90
p_3k_3	8.25	13.00	13.40	7.15	12.25	12.60
$F_{8,27}$	2.72^*			2.34^*		
SE_m	0.252			0.264		
CD (0.05)	0.731			0.765		

* Significant at 5 per cent level

Incremental doses of nitrogen significantly increased the weight of bunch with n_3 recording the highest bunch weight (12.11 kg in 98-99 and 11.03 kg in 99-00).

The influence of phosphorus on bunch weight was significant in 98-99 and 99-00. During these periods, phosphorus responded significantly upto p_2 (10.81 and 9.39 kg respectively). Further increase to p_3 did not bring any significant increase. Response of potassium was also significant in both the years. During 98-99, though an increasing trend was noticed with increase in rates of potassium, k_2 and k_3 were on par (10.82 and 10.99 kg respectively). However, in 99-00 increasing rates of potassium significantly enhanced bunch weight. Maximum weight was observed at k_3 level (9.83 kg).

Table 17b depicts the significant N x P, N x K and P x K interaction effects on weight of bunch in 98-99 and 99-00. The effect of phosphorus was evident upto p_2 irrespective of the levels of nitrogen. The interaction N x K was significant in 98-99 and 99-00. During the first year, at all levels of nitrogen, k_2 and k_3 were on par. But during the suceeding year k_2 and k_3 exerted similar effect on bunch weight only at n_1 level. However at n_2 and n_3 levels, incremental doses of potassium significantly increased the weight of bunch.

The interaction, P x K was significant in both the years. At all levels of phosphorus in 98-99 and at p_2 and p_3 levels in 99-00 significant increase in the weight of bunch was observed upto k_2. At p_1 level k_3 recorded significantly higher bunch weight in 99-00.

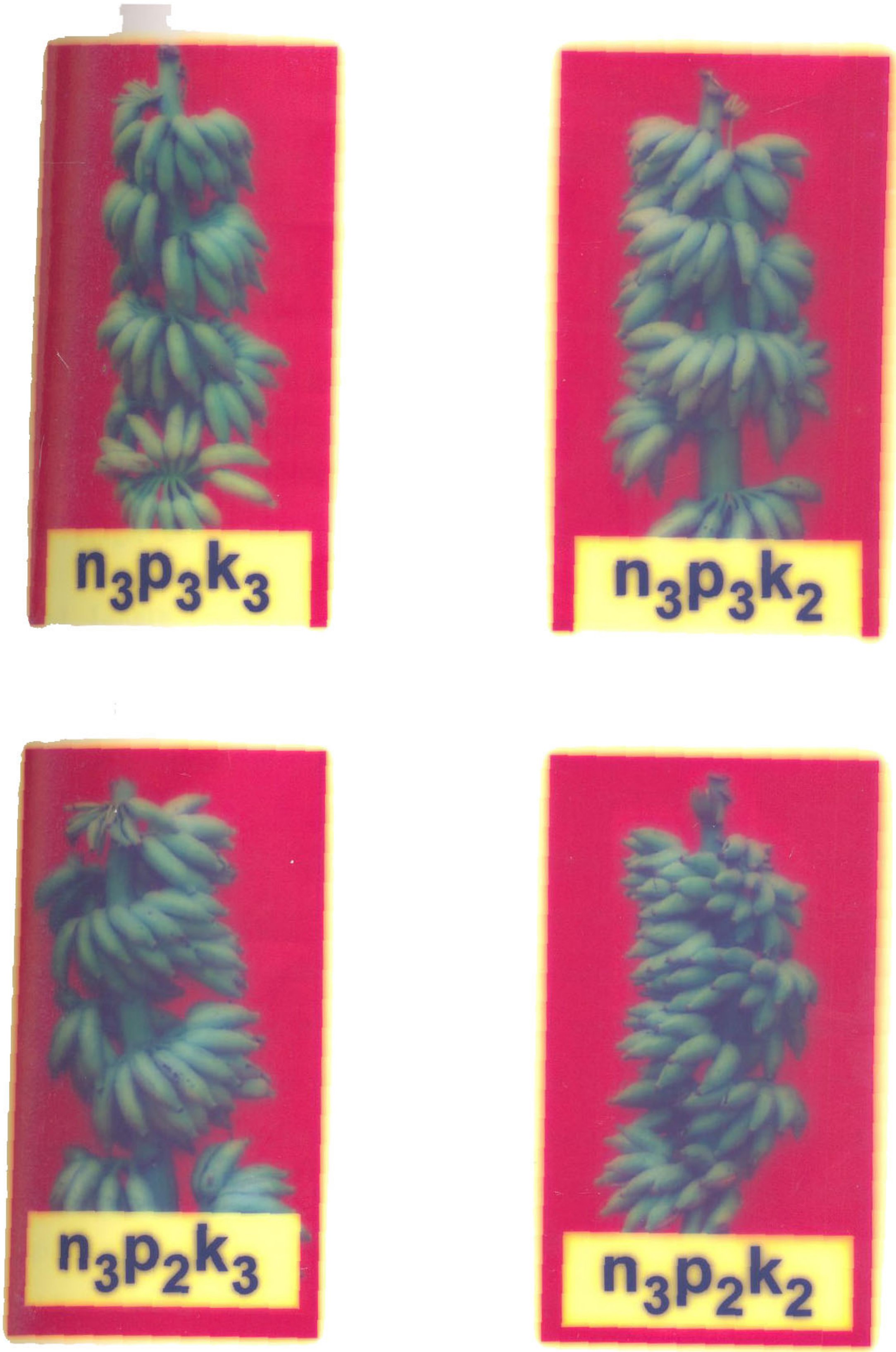

Plate 2a. Effect of graded levels of N, P and K on size of bunch

The interaction of nitrogen with phosphorus and potassium was significant in 98-99 and 99-00 (Table 17c). During both the years, the weight of bunch recorded from the treatments $n_3p_3k_3$ (13.40 and 12.60 kg), $n_3p_3k_2$ (13.30 and 11.90 kg), $n_3p_2k_3$ (13.30 and 12.35 kg), $n_3p_2k_2$ (12.95 and 12.20 kg), $n_2p_3k_3$ (13.00 and 12.25 kg), $n_2p_3k_2$ (13.00 and 11.85 kg), $n_2p_2k_3$ (13.05 and 12.25 kg) and $n_2p_2k_2$ (12.95 and 12.15 kg) were statistically on par. Effect of different levels of N, P and K on the size of bunch are depicted in Plates 2a and 2b.

4.4 Finger characters

4.4.1 Length of finger

The effect of treatments on the length of finger for the two years of experimentation are presented in Table 18a and 18b.

Nitrogen nutrition at different levels had similar effects in enhancing the length of finger in both the years of experimentation. Application of n_3 resulted in higher finger length (11.44 cm and 11.00 cm respectively). The effect of phosphorus was significant in both the years. During first year appreciable increase in the length of finger was noticed only upto p_2. However, in the subsequent year an increasing trend was obtained with increase in P levels. Potassium also exerted a significant effect on finger length. In 98-99, the higher doses (k_2 and k_3) had similar effects. But in 99-00, k_3 produced significantly longer fingers (9.75 cm). Influence of graded levels of N, P and K on the size of finger is presented in Plate 3. Table 18b clearly reveals that none of the interaction effects are significant in either of the years.

Plate 2b. Effect of graded levels of N, P and K on size of bunch

Table 18a. Effect of nitrogen, phosphorus and potassium on finger characters

Main effect of factors	Length of finger (cm)		Girth of finger (cm)		Weight of finger (g)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	7.92	7.36	8.08	8.36	45.81	35.67
n_2	9.58	9.53	8.68	8.99	68.03	60.31
n_3	11.44	11.00	9.58	9.37	73.61	71.47
$F_{2,27}$	133.81**	344.68**	96.79**	79.09**	222.96**	693.13**
SE_m	0.153	0.099	0.077	0.058	0.985	0.696
CD(0.05)	0.443	0.286	0.224	0.167	2.859	2.019
p_1	9.14	8.86	8.62	8.77	58.31	49.83
p_2	9.72	9.25	8.76	8.90	64.25	58.08
p_3	10.08	9.78	8.98	9.04	64.89	59.53
$F_{2,27}$	9.76**	21.84**	5.44*	5.39*	13.58**	56.49**
SE_m	0.153	0.099	0.077	0.058	0.985	0.696
CD(0.05)	0.443	0.286	0.224	0.167	2.859	2.019
k_1	8.94	8.72	8.52	8.73	57.78	50.14
k_2	9.83	9.42	8.91	8.97	64.75	57.33
k_3	10.17	9.75	8.92	9.01	64.92	59.97
$F_{2,27}$	17.15**	28.67**	8.74**	6.68**	17.11**	53.49**
SE_m	0.153	0.099	0.077	0.058	0.985	0.696
CD(0.05)	0.443	0.286	0.224	0.167	2.859	2.019

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

Table 18b. Interaction effect of nitrogen, phosphorus and potassium on finger characters

Interaction effects	Length of finger (cm)		Girth of finger (cm)		Weight of finger (g)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	7.75	7.08	8.00	8.33	45.25	34.75
n_1p_2	7.92	7.33	8.07	8.35	46.58	35.92
n_1p_3	8.08	7.67	8.18	8.38	45.58	36.33
n_2p_1	9.00	9.08	8.55	8.72	61.50	50.08
n_2p_2	9.67	9.50	8.58	9.02	70.83	63.08
n_2p_3	10.08	10.00	8.92	9.23	71.75	67.75
n_3p_1	10.67	10.42	9.32	9.27	68.17	64.67
n_3p_2	11.58	10.92	9.62	9.33	75.33	75.25
n_3p_3	12.08	11.67	9.83	9.50	77.33	74.50
$F_{4,27}$	1.15	0.98	0.57	1.47	2.81*	12.84**
SE_m	0.264	0.171	0.133	0.100	1.706	1.205
CD(0.05)	–	–	–	–	4.951	3.498
n_1k_1	7.67	7.08	7.95	8.27	43.92	33.08
n_1k_2	7.92	7.42	8.12	8.37	46.75	36.58
n_1k_3	8.17	7.58	8.18	8.43	46.75	37.33
n_2k_1	8.83	8.83	8.30	8.78	63.00	51.92
n_2k_2	9.75	9.75	8.80	9.07	70.83	63.00
n_2k_3	10.17	10.00	8.95	9.12	70.25	66.00
n_3k_1	10.33	10.25	9.32	9.15	66.42	65.42
n_3k_2	11.83	11.08	9.82	9.48	76.67	72.42
n_3k_3	12.17	11.67	9.63	9.47	77.75	76.58
$F_{4,27}$	2.00	2.14	1.08	0.43	1.89	4.93**
SE_m	0.264	0.171	0.133	0.100	1.706	1.205
CD(0.05)	–	–	–	–	–	3.498
p_1k_1	8.67	8.50	8.52	8.48	56.17	46.92
p_1k_2	9.17	8.92	8.72	8.83	59.83	49.33
p_1k_3	9.58	9.17	8.63	9.00	58.92	53.25
p_2k_1	8.83	8.67	8.52	8.93	57.00	50.25
p_2k_2	10.08	9.42	8.82	8.87	66.58	61.17
p_2k_3	10.25	9.67	8.93	8.90	69.17	62.83
p_3k_1	9.33	9.00	8.53	8.78	60.17	53.25
p_3k_2	10.25	9.92	9.20	9.22	67.83	61.50
p_3k_3	10.67	10.42	9.20	9.12	66.67	63.83
$F_{4,27}$	2.03	1.30	1.37	1.82	2.06	2.49
SE_m	0.264	0.171	0.133	0.100	1.706	1.205
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

** Significant at 1 per cent level

Plate 3. Effect of graded levels of N, P and K on size of finger

4.4.2 Girth of finger

As shown in Table 18a, different levels of nitrogen had significant effect on girth of finger with n_3 giving higher values in both the years (9.58 cm and 9.37 cm respectively). Though the effect due to P nutrition was significant, the doses p_1 and p_2 had same effect in 98-99 and 99-00. The difference between p_2 and p_3 was also not significant in either of the years. Application of potassium also resulted in appreciable increase in finger girth. During the first and second year k_2 and k_3 levels were on par.

Critical review of the data furnished the Table 18b revealed that N x P, N x K and P x K interactions were not significant in both the years.

4.4.3 Weight of finger

It is evident from Table 18a that incremental doses of nitrogen resulted in remarkable increase in weight of hand. During both the years, highest value was recorded by n_3 (73.61 g and 71.47 g respectively). Phosphorus also had significant effect in these years. The levels p_2 and p_3 had similar effect on finger weight. In the case of potassium also k_2 and k_3 were on par.

Weight of finger was significantly influenced by the interaction, N x P in 98-99 and 99-00. At all levels of nitrogen except at n_1 in 98-99, increase in finger weight due to increase in phosphorus was noticed upto p_2. The interaction N x K was significant only during second year. When combined with nitrogen at n_1 and n_2, k_2 and k_3 had same effect on weight of finger. The interaction P x K was not significant in either of the years (Table 18b).

4.5 Quality attributes of ripe fruits

4.5.1 Total soluble solids

The data on total soluble solids for 98-99 and 99-00 are presented in Tables 19a and 19b.

The main effect of nitrogen and potassium was significant in both the years. Incremental doses of nitrogen significantly enhanced TSS of ripe fruits during 98-99 and 99-00 (Table 19a). In 98-99, potassium application upto k_3 significantly increased the TSS. However in the subsequent year the levels k_2 and k_3 were on par. There was no appreciable difference in TSS of ripe fruits due to different levels of phosphorus.

The interactions, N x P, N x K and P x K were not significant in either of the years (Table 19b).

4.5.2 Acidity

As shown in Table 19a, applied nitrogen had significant impact on acidity of ripe fruits in 98-99 and 99-00. Increased rates of nitrogen application significantly reduced the acidity with n_3 recording the lowest value. Response to applied phosphorus was not significant in both the years of experimentation.

The influence of applied potassium on acidity was significant during the period of study. Remarkable response was obtained upto k_2 level in 98-99 as well as in 99-00 (Table 19a).

Table 19a. Effect of nitrogen, phosphorus and potassium on TSS, acidity and vitamin C content of fruits

Main effect of factors	TSS (%)		Acidity (%)		Vitamin C (mg 100 g^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	17.16	17.11	0.33	0.33	3.25	3.24
n_2	17.75	17.39	0.26	0.26	3.30	3.26
n_3	18.03	17.87	0.23	0.22	3.36	3.28
$F_{2,27}$	193.76**	175.50**	233.54**	665.52**	1.11	2.34
SE_m	0.010	0.029	0.003	0.002	0.012	0.014
CD(0.05)	0.029	0.084	0.010	0.006	–	–
p_1	17.62	17.38	0.28	0.29	3.30	3.24
p_2	17.64	17.45	0.27	0.27	3.30	3.26
p_3	17.65	17.49	0.27	0.26	3.30	3.27
$F_{2,27}$	2.64	2.60	3.32	3.18	0.04	2.09
SE_m	0.010	0.029	0.003	0.002	0.012	0.014
CD(0.05)	–	–	–	–	–	–
k_1	17.57	17.34	0.29	0.29	3:29	3.24
k_2	17.67	17.48	0.26	0.27	3.30	3.27
k_3	17.71	17.55	0.25	0.26	3.31	3.27
F2,27	50.82**	13.89**	32.82**	49.74**	0.30	1.12
SE_m	0.010	0.029	0.003	0.002	0.012	0.014
CD(0.05)	0.029	0.084	0.010	0.006	–	–

** Significant at 1 per cent level

Table 19b. Interaction effect of nitrogen, phosphorus and potassium on TSS, acidity and vitamin C content of fruits

Interaction effects	TSS (%)		Acidity (%)		Vitamin C (mg 100 g^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	17.06	17.06	0.34	0.36	3.23	3.22
n_1p_2	17.22	17.10	0.33	0.33	3.25	3.25
n_1p_3	17.20	17.18	0.31	0.31	3.26	3.24
n_2p_1	17.67	17.20	0.26	0.27	3.31	3.23
n_2p_2	17.75	17.39	0.25	0.25	3.31	3.25
n_2p_3	17.85	17.58	0.26	0.26	3.28	3.30
n_3p_1	17.98	17.76	0.23	0.23	3.37	3.26
n_3p_2	18.03	17.96	0.23	0.22	3.34	3.28
n_3p_3	18.08	17.88	0.22	0.21	3.37	3.30
$F_{4,27}$	2.50	2.19	2.62	2.31	0.85	0.44
SE_m	0.018	0.050	0.006	0.004	0.021	0.024
CD(0.05)	–	–	–	–	–	–
n_1k_1	17.12	17.07	0.35	0.36	3.24	3.22
n_1k_2	17.15	17.10	0.32	0.33	3.24	3.24
n_1k_3	17.21	17.17	0.31	0.31	3.26	3.26
n_2k_1	17.74	17.35	0.27	0.27	3.29	3.23
n_2k_2	17.75	17.34	0.25	0.26	3.30	3.27
n_2k_3	17.77	17.47	0.24	0.25	3.30	3.27
n_3k_1	18.00	17.72	0.24	0.23	3.35	3.27
n_3k_2	18.04	17.90	0.23	0.22	3.36	3.31
n_3k_3	18.06	17.98	0.21	0.21	3.37	3.27
$F_{4,27}$	1.06	1.14	1.27	2.23	0.03	0.40
SE_m	0.018	0.050	0.006	0.004	0.021	0.024
CD(0.05)	–	–	–	–	–	–
p_1k_1	17.54	17.25	0.29	0.30	3.28	3.23
p_1k_2	17.57	17.32	0.28	0.29	3.32	3.24
p_1k_3	17.60	17.44	0.26	0.27	3.31	3.25
p_2k_1	17.64	17.47	0.29	0.28	3.29	3.24
p_2k_2	17.67	17.44	0.26	0.27	3.30	3.28
p_2k_3	17.70	17.54	0.25	0.25	3.30	3.27
p_3k_1	17.69	17.42	0.29	0.28	3.32	3.26
p_3k_2	17.71	17.58	0.26	0.25	3.28	3.30
p_3k_3	17.74	17.64	0.25	0.25	3.31	3.28
$F_{4,27}$	0.27	0.88	1.97	1.35	0.89	0.07
SE_m	0.018	0.050	0.006	0.004	0.021	0.024
CD(0.05)	–	–	–	–	–	–

The N x P, N x K and P x K interaction effects were not significant in either of the years (Table 19b).

4.5.3 Vitamin C

Different levels of nitrogen, phosphorus and potassium, either independently or in combination did not significantly influence the vitamin C content of ripe fruits in both the years (Table 19a and 19b).

4.5.4 Total sugar

Perusal of the data in Table 20a indicates that different levels of applied nitrogen significantly influenced the total sugar content of ripe fruits. Among the different levels, n_3 recorded significantly higher values in 98-99 and 99-00.

Different levels of phosphorus could not significantly effect the total sugar content in either of the years. But applied potassium at the highest level, k_3 produced fruits with highest total sugar content in 98-99 and 99-00.

It is clear from Table 20b that none of the interaction effects could significantly influence the total sugar content in the first and second year of experimentation.

4.5.5 Reducing sugar

The main and interaction effects of treatments on reducing sugar content of fruits in 98-99 and 99-00 are presented in Tables 20a and 20b respectively.

Table 20a. Effect of nitrogen, phosphorus and potassium on total, reducing and non-reducing sugar content of fruits

Main effect of factors	Total sugar (%)		Reducing sugar (%)		Non-reducing sugar (%)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	12.91	12.69	9.45	9.33	3.46	3.36
n_2	14.97	14.79	11.22	11.07	3.75	3.73
n_3	16.13	15.98	12.18	12.13	3.94	3.85
$F_{2,27}$	38.38**	48.64**	60.76**	62.39**	3.18	2.72
SE_m	0.008	0.008	0.006	0.006	0.007	0.009
CD(0.05)	0.024	0.022	0.016	0.016	–	–
p_1	14.58	14.41	10.89	10.80	3.69	3.61
p_2	14.65	14.47	10.94	10.83	3.71	3.64
p_3	14.77	14.58	11.02	10.90	3.75	3.68
$F_{2,27}$	1.24	1.42	2.41	1.89	1.36	1.50
SE_m	0.008	0.008	0.006	0.006	0.007	0.009
CD(0.05)	–	–	–	–	–	–
k_1	14.59	14.42	10.89	10.80	3.69	3.62
k_2	14.69	14.51	10.96	10.85	3.72	3.66
k_3	14.73	14.54	10.99	10.88	3.74	3.66
$F_{2,27}$	7.75**	6.82**	79.71**	45.56**	2.79	2.07
SE_m	0.008	0.008	0.006	0.006	0.007	0.009
CD(0.05)	0.024	0.022	0.016	0.016	–	–

** Significant at 1 per cent level

Table 20b. Interaction effect of nitrogen, phosphorus and potassium on total, reducing and non reducing sugar content of fruits

Interaction effects	Total sugar (%)		Reducing sugar (%)		Non-reducing sugar (%)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	12.83	12.63	9.40	9.30	3.44	3.33
n_1p_2	12.89	12.69	9.42	9.33	3.47	3.36
n_1p_3	13.00	12.75	9.53	9.35	3.47	3.40
n_2p_1	14.88	14.68	11.14	11.00	3.74	3.69
n_2p_2	14.97	14.76	11.23	11.04	3.74	3.72
n_2p_3	15.05	14.93	11.27	11.16	3.78	3.77
n_3p_1	16.03	15.91	12.13	12.09	3.90	3.82
n_3p_2	16.11	15.98	12.17	12.13	3.94	3.85
n_3p_3	16.25	16.07	12.26	12.18	3.99	3.87
$F_{4,27}$	1.96	1.71	2.42	1.91	2.54	0.11
SE_m	0.014	0.013	0.010	0.010	0.012	0.017
CD(0.05)	–	–	–	–	–	–
n_1k_1	12.83	12.63	9.39	9.31	3.44	3.33
n_1k_2	12.91	12.70	9.45	9.33	3.46	3.37
n_1k_3	12.98	12.73	9.50	9.35	3.48	3.39
n_2k_1	14.87	14.71	11.16	11.01	3.73	3.70
n_2k_2	14.99	14..82	11.24	11.08	3.76	3.74
n_2k_3	15.02	14.85	11.25	11.11	3.77	3.75
n_3k_1	16.04	15.92	12.13	12.09	3.91	3.83
n_3k_2	16.16	16.00	12.21	12.14	3.96	3.86
n_3k_3	16.19	16.03	12.22	12.17	3.97	3.86
$F_{4,27}$	0.98	0.47	3.86*	3.69*	0.17	0.30
SE_m	0.014	0.013	0.010	0.010	0.012	0.017
CD(0.05)	–	–	0.028	0.029	–	–
p_1k_1	14.50	14.36	10.83	10.77	3.67	3.59
p_1k_2	14.59	14.42	10.89	10.80	3.73	3.62
p_1k_3	14.66	14.44	10.95	10.82	3.71	3.62
p_2k_1	14.59	14.40	10.90	10.79	3.69	3.61
p_2k_2	14.67	14.49	10.96	10.84	3.72	3.65
p_2k_3	14.69	14.54	10.96	10.87	3.73	3.67
p_3k_1	14.67	14.51	11.95	10.85	3.72	3.65
p_3k_2	14.80	14.61	11.05	10.91	3.75	3.70
p_3k_3	14.84	14.64	11.07	10.94	3.77	3.70
$F_{4,27}$	2.54	1.42	2.58	0.422	0.15	0.21
SE_m	0.014	0.013	0.010	0.010	0.012	0.017
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

The reducing sugar content of ripe fruits was significantly influenced by different levels of nitrogen and potassium. Increasing rates of nitrogen and potassium application significantly enhanced the reducing sugar content.

Interaction effects are furnished in Table 20b. The variation in reducing sugar content due to N x K interaction was significant during both the years. During the first year, incremental doses of potassium significantly increased the reducing sugar content only at n_1 level, whereas at n_2 and n_3 levels the higher levels of K (k_2 and k_3) showed similar effect. But during the succeeding year at n_1 level of nitrogen k_2 and k_3 were on par. At n_2 and n_3 levels, significant response in total sugar content was observed upto k_3 level.

The interactions N x P and P x K could not profoundly influence the reducing sugar content in 98-99 and 99-00.

4.5.6 Non-reducing sugar

The variation in the non reducing sugar content of fruits due to effect of different levels of nigrogen, phosphorus and potassium was not significant in either of the years (Table 20a).

The interactions also had no significant effect on the non-reducing sugar content of fruits (Table 20b).

4.5.7 Sugar-acid ratio

As shown in Table 21a, applied nitrogen and potassium had significant effect on sugar-acid ratio of fruits. Increasing levels of both nitrogen and potassium significantly increased the sugar-acid ratio of fruits. But applied phosphorus had no significant effect on sugar-acid ratio in two years of experimentation.

The N x P, N x K and P x K interaction effects were not significant during both the years (Table 21b).

4.5.8 Pulp-peel ratio

It is evident from Table 21a that the effect of different levels of nitrogen on pulp-peel ratio was significant in both the years. During 98-99 and 99-00, higher doses of nitrogen (n_2 and n_3) was found to enhance the pulp-peel ratio of fruits. Variation in pulp-peel ratio due to applied phosphorus was not significant in either of years.

Potassium also exerted marked influence on pulp-peel ratio with the maximum value at k_3 level.

As presented in Table 21b, the interactions, N x P, N x K and P x K could not significantly effect the pulp-peel ratio during two years of experimentation.

Table 21a. Effect of nitrogen, phosphorus and potassium on sugar acid ratio, pulp-peel ratio and shelf life of fruits

Main effect of factors	Sugar-acid ratio		Pulp-peel ratio		Shelf life (days)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	40.06	38.77	3.53	3.51	5.80	5.83
n_2	57.74	57.01	3.68	3.60	6.47	6.48
n_3	71.17	72.31	3.69	3.63	5.88	5.89
$F_{2,27}$	91.94**	168.30**	18.21**	13.37**	16.60**	121.25**
SE_m	0.514	0.409	0.018	0.018	0.009	0.022
CD(0.05)	1.493	1.188	0.051	0.052	0.026	0.064
p_1	53.75	53.03	3.54	3.55	6.04	6.09
p_2	57.62	56.38	3.61	3.61	6.05	6.04
p_3	57.60	58.69	3.64	3.60	6.06	6.06
$F_{2,27}$	1.88	2.84	2.98	3.34	1.04	0.73
SE_m	0.514	0.409	0.018	0.018	0.009	0.022
CD(0.05)	–	–	–	–	–	–
k_1	52.30	53.06	3.52	3.49	6.00	6.01
k_2	57.03	55.93	3.59	3.59	6.02	6.03
k_3	59.65	59.11	3.69	3.67	6.13	6.11
$F_{2,27}$	52.43**	54.62**	22.60**	24.79**	64.47**	17.93**
SE_m	0.514	0.409	0.018	0.018	0.009	0.022
CD(0.05)	1.493	1.188	0.051	0.052	0.026	0.064

** Significant at 1 per cent level

Table 21b. Interaction effect of nitrogen, phosphorus and potassium on sugar acid ratio, pulp-peel ratio and shelf life of fruits

Interaction effects	Sugar acid ratio		Pulp-peel ratio		Shelf life (days)	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	37.80	35.77	3.47	3.45	5.79	5.93
n_1p_2	39.97	38.71	3.54	3.52	5.79	5.78
n_1p_3	41.42	41.84	3.58	3.56	5.80	5.78
n_2p_1	54.48	54.11	3.61	3.59	6.44	6.47
n_2p_2	61.49	58.70	3.69	3.64	6.47	6.46
n_2p_3	57.24	58.24	3.73	3.59	6.51	6.50
n_3p_1	68.96	69.21	3.54	3.60	5.89	5.88
n_3p_2	71.40	71.73	3.59	3.67	5.89	5.88
n_3p_3	73.15	76.00	3.63	3.64	5.87	5.91
$F_{4,27}$	2.59	2.06	0.06	1.01	2.42	1.02
SE_m	0.891	0.709	0.030	0.031	0.016	0.056
CD(0.05)	–	–	–	–	–	–
n_1k_1	36.38	35.67	3.42	3.43	5.73	5.90
n_1k_2	40.91	39.01	3.51	3.49	5.78	5.75
n_1k_3	42.90	41.64	3.66	3.61	5.88	5.84
n_2k_1	54.48	54.20	3.61	3.51	6.42	6.43
n_2k_2	58.61	56.46	3.67	3.61	6.43	6.44
n_2k_3	60.13	60.38	3.75	3.70	6.57	6.56
n_3k_1	66.03	69.32	3.53	3.54	5.84	5.85
n_3k_2	71.57	72.31	3.58	3.67	5.86	5.88
n_3k_3	75.91	35.31	3.65	3.70	5.95	5.93
$F_{4,27}$	1.64	0.25	1.33	0.49	0.90	1.13
SE_m	0.891	0.709	0.030	0.031	0.016	0.056
CD(0.05)	–	–	–	–	–	–
p_1k_1	52.07	50.95	3.46	3.47	5.99	6.18
p_1k_2	52.37	52.44	3.53	3.56	6.03	6.03
p_1k_3	56.81	55.70	3.64	3.62	6.10	6.08
p_2k_1	52.05	52.88	3.52	3.49	6.00	6.00
p_2k_2	59.39	55.79	3.61	3.61	6.01	6.01
p_2k_3	61.42	60.44	3.70	3.71	6.14	6.11
p_3k_1	52.77	55.34	3.58	3.51	6.00	6.00
p_3k_2	59.33	59.54	3.63	3.60	6.03	6.04
p_3k_3	60.72	61.19	3.73	3.67	6.16	6.14
$F_{4,27}$	2.48	2.02	0.21	0.41	1.73	1.44
SE_m	0.891	0.709	0.030	0.031	0.016	0.056
CD(0.05)	–	–	–	–	–	–

4.5.9 Shelf life

Table 21a clearly depicts that nitrogen had significant impact on shelf life of fruits. In 98-99 as well as in 99-00, n_2 produced fruits with significantly longer shelf life. Further increase to n_3 level reduced shelf life considerably. In 99-00, n_1 and n_3 were on par. The rates of applied phosphorus did not exert any influence on shelf life.

The effect of potassium on shelf life was also significant with k_3 producing the longest shelf life.

The interaction effects N x P, N x K and P x K could not profoundly influence the shelf life in either of the years (Table 21b).

4.6 Uptake of nutrients

4.6.1 Nitrogen

4.6.1.1 Leaf

Perusal of the data in Table 22a indicates that different levels of nitrogen, phosphorus and potassium significantly increased the uptake of nitrogen in leaf at all the stages. Nitrogen uptake was significantly increased by increasing the levels of N, P and K.

As shown in Table 22b, N x P interaction was significant at 4 MAP and at harvest stage in both the years. During 98-99, in n_2 and n_3 applied plots, significantly high leaf N uptake was noticed with p_3 level of phosphorus. At 4 MAP in 99-00, p_3 recorded higher N uptake in leaf only at n_3 level of nitrogen. At harvest stage in 99-00, in n_3 applied plots, p_2 and p_3 were on par.

Table 22a. Effect of nitrogen, phosphorus and potassium on uptake of nitrogen in leaf

Main effect of factors	N uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	9.54	32.76	11.44	8.82	30.69	10.00
n_2	10.79	36.92	12.41	9.97	34.03	11.25
n_3	12.78	42.98	13.72	12.12	40.44	13.09
$F_{2,27}$	191.32**	219.72**	117.81**	130.80**	734.50**	869.35**
SE_m	0.038	0.110	0.033	0.046	0.183	0.053
CD(0.05)	0.109	0.318	0.097	0.134	0.531	0.153
p_1	10.73	36.53	12.22	9.90	34.16	11.04
p_2	10.96	37.62	12.54	10.41	35.00	11.48
p_3	11.42	38.51	12.81	10.59	36.01	11.82
$F_{2,27}$	86.89**	81.53**	79.12**	58.72**	25.84**	55.15**
SE_m	0.038	0.110	0.033	0.046	0.183	0.053
CD(0.05)	0.109	0.318	0.097	0.134	0.531	0.153
k_1	10.62	36.83	12.17	9.91	34.12	11.08
k_2	11.09	37.57	12.56	10.40	35.26	11.51
k_3	11.40	38.26	12.83	10.60	35.78	11.76
$F_{2,27}$	108.40**	42.81**	100.33**	58.91**	21.64**	42.61**
SE_m	0.038	0.110	0.033	0.046	0.183	0.053
CD(0.05)	0.109	0.318	0.097	0.134	0.531	0.153

** Significant at 1 per cent level

Table 22b. Interaction effect of nitrogen, phosphorus and potassium on uptake of nitrogen in leaf

Interaction effect	N uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	9.47	32.03	11.09	8.59	29.97	9.52
n_1p_2	9.52	32.68	11.59	8.90	30.77	10.01
n_1p_3	9.61	33.57	11.63	8.97	31.32	10.48
n_2p_1	10.41	35.72	12.04	9.74	33.35	10.73
n_2p_2	10.71	37.18	12.32	10.04	34.01	11.26
n_2p_3	11.25	37.87	12.86	10.13	34.74	11.76
n_3p_1	12.32	41.85	13.52	11.39	39.15	12.88
n_3p_2	12.64	42.99	13.70	12.30	40.20	13.17
n_3p_3	13.40	44.10	13.93	12.67	41.98	13.23
$F_{4,27}$	15.01**	1.65	6.87**	10.78**	1.95	4.42**
SE_m	0.065	0.190	0.058	0.080	0.317	0.091
CD(0.05)	0.188	–	0.167	0.233	–	0.265
n_1k_1	9.31	32.06	11.17	8.58	29.83	9.74
n_1k_2	9.55	32.84	11.42	8.84	30.75	9.98
n_1k_3	9.74	33.37	11.73	9.03	31.48	10.28
n_2k_1	10.41	36.35	11.94	9.75	33.16	10.78
n_2k_2	10.83	36.74	12.51	10.03	34.28	11.36
n_2k_3	11.13	37.68	12.77	10.13	34.65	11.62
n_3k_1	12.15	42.08	13.40	11.40	39.37	12.71
n_3k_2	12.89	43.12	13.74	12.34	40.74	13.19
n_3k_3	13.31	43.74	14.00	12.62	41.22	13.38
$F_{4,27}$	8.66**	0.89	3.75*	9.67**	0.19	1.12
SE_m	0.065	0.190	0.058	0.080	0.317	0.091
CD(0.05)	0.188	–	0.167	0.233	–	–
p_1k_1	10.49	35.84	11.98	9.55	33.39	10.80
p_1k_2	10.74	36.70	12.24	9.96	34.34	11.02
p_1k_3	10.97	37.07	12.43	10.20	34.74	11.31
p_2k_1	10.57	37.15	12.11	9.99	33.97	11.06
p_2k_2	11.01	37.58	12.54	10.57	35.27	11.53
p_2k_3	11.30	38.13	12.97	10.68	35.75	11.85
p_3k_1	10.81	37.50	12.42	10.18	35.01	11.38
p_3k_2	11.52	38.43	12.90	10.68	36.17	11.97
p_3k_3	13.32	39.60	13.11	10.90	36.87	12.12
$F_{4,27}$	6.42**	2.71	2.66	0.38	0.22	1.33
SE_m	0.065	0.190	0.058	0.080	0.317	0.091
CD(0.05)	0.188	–	–	–	–	–

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

Considering N x K interaction, significantly higher response was noticed at 4 MAP in two years and at harvest stage in 98-99. During the first year, increasing level of potassium significantly increased the N uptake at all levels of nitrogen. However, in the subsequent year at 4 MAP, k_2 and k_3 exerted similar effects in combination with n_1 and n_2.

The interaction P x K was significant only at 4 MAP in 98-99. At this stage at all levels of phosphorus, increasing levels of potassium significantly increased the nitrogen uptake (Table 22b).

4.6.1.2 Pseudostem

It is clear from Table 23a that different levels of nitrogen, phosphorus and potassium profoundly influenced the uptake of nitrogen in pseudostem at various growth stages. Increasing the dose of both nitrogen and phosphorus significantly increased the N uptake in 98-99 and 99-00. Significant increase in the uptake of N due to increase in the levels of potassium was evident at 4 MAP in 98-99 and at all stages in 99-00.

Interaction effects are furnished in Table 23b. The interaction N x P was significant only at 4 MAP in 99-00. In combination with n_2 and n_3 levels of nitrogen, p_3 recorded significantly high pseudostem N uptake.

The interaction N x K was significant at 4 MAP in 98-99 and at all stages in the subsequent year. At 4 MAP in 98-99, k_3 recorded significantly high pseudostem N uptake in combination with n_1 only, whereas in combination with n_2 and n_3, k_2 and k_3 were on par.

Table 23a. Effect of nitrogen, phosphorus and potassium on uptake of nitrogen in pseudostem

Main effect of factors	N uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	13.43	40.18	84.51	12.74	41.12	79.02
n_2	17.79	42.89	100.50	16.80	43.34	93.30
n_3	21.65	56.44	117.17	19.86	53.64	112.60
$F_{2,27}$	473.74**	158.80**	401.87**	296.48**	106.80**	229.27**
SE_m	0.060	0.218	0.815	0.065	0.204	0.352
CD(0.05)	0.173	0.634	2.364	0.190	0.593	1.021
p_1	17.21	45.64	96.60	16.07	44.98	91.69
p_2	17.62	46.44	101.08	16.39	45.97	95.69
p_3	18.04	47.43	104.51	16.94	47.15	97.53
$F_{2,27}$	47.78**	16.82**	23.73**	44.97**	28.12**	72.12**
SE_m	0.060	0.218	0.815	0.065	0.204	0.352
CD(0.05)	0.173	0.634	2.364	0.190	0.593	1.021
k_1	17.21	45.24	94.64	16.02	44.70	90.24
k_2	17.66	46.85	103.25	16.56	46.39	96.47
k_3	17.99	47.42	104.30	16.82	47.02	98.21
$F_{2,27}$	42.84**	26.74**	42.34**	39.04**	34.34**	141.64**
SE_m	0.060	0.218	0.815	0.065	0.204	0.352
CD(0.05)	0.173	0.634	2.364	0.190	0.593	1.021

** Significant at 1 per cent level

Table 23b. Interaction effect of nitrogen, phosphorus and potassium on uptake of nitrogen in pseudostem

Interaction effects	N uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	12.94	39.66	81.75	12.56	40.58	76.04
n_1p_2	13.52	40.14	83.74	12.70	41.04	79.73
n_1p_3	13.84	40.74	88.03	12.95	41.74	81.28
n_2p_1	17.27	42.23	95.92	16.36	42.33	89.69
n_2p_2	17.75	42.67	101.26	16.60	43.52	94.37
n_2p_3	18.34	43.78	104.33	17.44	44.18	95.84
n_3p_1	21.42	55.03	112.11	19.28	52.05	109.33
n_3p_2	21.58	56.52	118.24	19.87	53.36	112.98
n_3p_3	21.93	57.76	121.16	20.43	55.53	115.48
$F_{4,27}$	2.35	1.38	0.63	4.12**	1.45	0.45
SE_m	0.103	0.378	1.411	0.114	0.354	0.610
CD(0.05)	–	–	–	0.330	–	–
n_1k_1	13.26	39.34	79.67	12.52	40.11	76.11
n_1k_2	13.30	40.22	85.96	12.73	41.17	79.62
n_1k_3	13.74	40.98	87.89	12.96	42.08	81.34
n_2k_1	17.31	41.53	92.94	16.35	42.20	87.62
n_2k_2	17.91	43.39	103.03	16.90	43.78	95.30
n_2k_3	18.14	43.76	105.54	17.15	44.05	97.06
n_3k_1	21.06	54.86	111.29	19.18	51.79	106.99
n_3k_2	21.79	56.93	120.77	20.05	54.22	114.59
n_3k_3	22.09	57.52	119.46	20.36	54.92	116.22
$F_{4,27}$	3.42*	0.80	1.25	3.16*	3.17*	5.05**
SE_m	0.103	0.378	1.411	0.114	0.354	0.610
CD(0.05)	0.300	–	–	0.330	1.028	1.769
p_1k_1	16.96	44.37	91.54	15.76	43.78	88.61
p_1k_2	17.16	46.03	99.72	16.15	45.12	91.99
p_1k_3	17.52	46.51	98.53	16.29	46.05	94.46
p_2k_1	17.07	45.22	95.63	15.86	44.72	89.83
p_2k_2	17.73	46.76	103.04	16.48	46.36	97.74
p_2k_3	18.05	47.34	104.56	16.84	46.85	99.51
p_3k_1	17.61	46.13	96.73	16.44	45.60	92.28
p_3k_2	18.10	47.75	107.00	17.05	47.69	99.67
p_3k_3	18.40	48.41	109.79	17.33	48.16	100.66
$F_{4,27}$	1.54	0.01	1.33	1.15	0.34	2.72
SE_m	0.103	0.378	1.411	0.114	0.354	0.610
CD(0.05)	–	–	–	–	–	–

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

However, in the subsequent year k_2 and k_3 exerted similar effects in combination with all levels of nitrogen. The interaction between phosphorus and potassium could not markedly influence the pseudostem N uptake throughout the period of experimentation (Table 23b).

4.6.1.3 Rhizome

The data on the uptake of nitrogen in rhizome during 98-99 and 99-00 are given in Table 24a and 24b respectively.

Application of nitrogen, phosphorus and potassium significantly influenced the uptake of nitrogen in rhizome at all stages of growth during 98-99 and 99-00. Incremental doses of these nutrients significantly increased the uptake of nitrogen at all stages except at 4 MAP in 98-99 and at 6 MAP in 99-00. At 4 MAP in 98-99 p_2 and p_3 were on par whereas at 6 MAP in 99-00, k_2 and k_3 levels of potassium exerted similar effects.

It is evident from Table 24b that the interactions N x P and P x K were not significant in either of the years. The interaction N x K was significant only at 6 MAP in 98-99. At this stage increasing levels of potassium significantly increased the N uptake in n_2 and n_3 applied plots. In n_1 applied plots k_1 and k_2 were on par and again k_2 and k_3 were on par.

4.6.2 Phosphorus

4.6.2.1 Leaf

Different levels of nitrogen, phosphorus and potassium had profound influence on the uptake of P in leaf at all stages of growth.

Table 24a. Effect of nitrogen, phosphorus and potassium on uptake of nitrogen in rhizome

Main effect of factors	N uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	6.05	23.26	22.04	5.47	23.03	21.74
n_2	6.71	27.34	24.44	5.97	26.11	24.37
n_3	7.30	34.29	27.78	6.60	31.69	26.92
$F_{2,27}$	151.34**	182.67**	459.44**	214.31**	545.18**	107.71**
SE_m	0.051	0.131	0.134	0.039	0.188	0.079
CD(0.05)	0.147	0.379	0.390	0.112	0.546	0.229
p_1	6.57	27.40	24.03	5.89	26.17	23.63
p_2	6.72	28.45	24.68	6.01	26.85	24.31
p_3	6.78	29.04	25.55	6.13	27.81	25.09
$F_{2,27}$	4.88*	40.37**	32.20**	9.48**	19.27**	85.11**
SE_m	0.051	0.131	0.134	0.039	0.188	0.079
CD(0.05)	0.147	0.379	0.390	0.112	0.546	0.229
k_1	6.42	27.23	23.84	5.84	26.07	23.68
k_2	6.71	28.49	24.96	6.02	27.21	24.46
k_3	6.94	29.18	25.46	6.17	27.56	24.88
$F_{2,27}$	27.28**	57.38**	37.85**	18.78**	17.13**	59.90**
SE_m	0.051	0.131	0.134	0.039	0.188	0.079
CD(0.05)	0.147	0.379	0.390	0.112	0.546	0.229

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

Table 24b. Interaction effect of nitrogen, phosphorus and potassium on uptake of nitrogen in rhizome

Interaction effects	N uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	5.86	22.76	21.60	5.39	22.74	21.14
n_1p_2	6.16	23.19	22.00	5.47	23.04	21.56
n_1p_3	6.15	23.82	22.52	5.54	23.32	22.53
n_2p_1	6.66	26.31	23.49	5.77	25.12	23.59
n_2p_2	6.67	27.68	24.32	6.00	25.93	24.50
n_2p_3	6.82	28.04	25.51	6.13	27.30	25.02
n_3p_1	7.18	33.14	26.99	6.51	30.65	26.17
n_3p_2	7.34	34.48	27.72	6.57	31.60	26.88
n_3p_3	7.38	35.25	28.62	6.71	32.83	27.71
$F_{4,27}$	0.67	2.05	1.48	0.80	2.06	1.09
SE_m	0.088	0.226	0.234	0.067	0.326	0.137
CD(0.05)	–	–	–	–	–	–
n_1k_1	5.85	22.70	21.57	5.30	22.43	21.17
n_1k_2	5.98	23.28	22.09	5.47	23.19	21.82
n_1k_3	6.33	23.79	22.46	5.63	23.47	22.23
n_2k_1	6.41	26.12	23.38	5.78	25.20	23.71
n_2k_2	6.80	27.56	24.60	5.98	26.31	24.55
n_2k_3	6.93	28.35	25.33	6.14	26.83	24.85
n_3k_1	6.99	32.86	26.57	6.43	30.58	26.17
n_3k_2	7.34	34.63	28.18	6.61	32.12	27.02
n_3k_3	7.57	35.38	28.58	6.75	32.38	27.58
$F_{4,27}$	0.72	3.21*	2.29	0.04	0.52	0.56
SE_m	0.088	0.226	0.234	0.067	0.326	0.137
CD(0.05)	–	0.656	–	–	–	–
p_1k_1	6.36	26.47	23.16	5.74	25.54	23.13
p_1k_2	6.60	27.57	24.06	5.88	26.32	23.67
p_1k_3	6.73	28.17	24.86	6.05	26.66	24.00
p_2k_1	6.46	27.29	23.69	5.85	26.00	23.54
p_2k_2	6.80	28.73	25.09	6.04	27.11	24.51
p_2k_3	6.90	29.33	25.25	6.15	27.45	24.88
p_3k_1	6.43	27.93	24.67	5.92	26.68	24.37
p_3k_2	6.72	29.17	25.72	6.15	28.19	25.21
p_3k_3	7.19	30.02	26.26	6.32	28.58	25.68
$F_{4,27}$	1.93	0.31	0.55	0.23	0.45	0.85
SE_m	0.088	0.226	0.234	0.067	0.326	0.137
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

Application of n_3, p_3 and k_3 resulted in highest P uptake in leaf in 98-99 and 99-00 (Table 25a).

The interaction N x P was significant throughout crop growth. Incremental doses of phosphorus enhanced the P uptake in n_1, n_2 and n_3 applied plots at most of the growth stages. However, towards the final stage in 99-00, p_3 responded significantly upto n_2 (Table 25b).

The interaction effect, N x K was significant at 4 MAP in both the years and at 6 MAP in 98-99. At all levels of nitrogen, k_3 recorded significantly higher P uptake. But k_1 and k_2 were on par in n_1 applied plots at 4 MAP and in n_2 applied plots at 6 MAP during 98-99. The interaction between phosphorus and potassium was significant only at 4 MAP in 98-99. In combination with p_1, significant response was obtained upto k_2 whereas in p_2 and p_3 treated plots, k_3 resulted in highest P uptake.

4.6.2.2 Pseudostem

The main and interaction effects of treatments on uptake of phosphorus in pseudostem at different stages of growth in 98-99 and 99-00 are presented in Table 26a and 26b respectively.

The effect of nitrogen, phosphorus and potassium on P uptake was significant at all stages in both the years. With regard to nitrogen and phosphorus highest values were recorded by n_3 and p_3 respectively at all stages. But in the case of potassium, except at 6 MAP in 98-99, k_3 recorded the highest P uptake.

Table 25a. Effect of nitrogen, phosphorus and potassium on uptake of phosphorus in leaf

Main effect of factors	P uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	1.34	6.04	0.68	1.23	5.64	0.59
n_2	1.45	6.73	0.76	1.33	6.23	0.70
n_3	1.68	7.60	0.78	1.58	7.10	0.75
$F_{2,27}$	1613.03**	415.05**	368.92**	1938.18**	864.13**	863.80**
SE_m	0.004	0.012	0.003	0.004	0.025	0.003
CD(0.05)	0.013	0.035	0.008	0.012	0.073	0.008
p_1	1.40	6.48	0.68	1.28	6.05	0.62
p_2	1.49	6.84	0.74	1.39	6.33	0.69
p_3	1.59	7.06	0.80	1.46	6.60	0.73
$F_{2,27}$	486.10**	58.77**	430.07**	517.12**	120.62**	408.97**
SE_m	0.004	0.012	0.003	0.004	0.025	0.003
CD(0.05)	0.013	0.035	0.008	0.012	0.073	0.008
k_1	1.44	6.70	0.72	1.33	6.20	0.70
k_2	1.50	6.79	0.74	1.39	6.35	0.68
k_3	1.59	6.90	0.76	1.42	6.43	0.70
$F_{2,27}$	128.73**	70.22**	45.33**	126.81**	21.87**	57.49**
SE_m	0.004	0.012	0.003	0.004	0.025	0.003
CD(0.05)	0.013	0.035	0.008	0.012	0.073	0.008

** Significant at 1 per cent level

Table 25b. Interaction effect of nitrogen, phosphorus and potassium on uptake of phosphorus in leaf

Interaction effects	P uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	1.29	5.83	0.62	1.17	5.40	0.52
n_1p_2	1.34	6.03	0.68	1.25	5.65	0.59
n_1p_3	1.40	6.28	0.75	1.28	5.88	0.67
n_2p_1	1.36	6.43	0.69	1.27	6.05	0.63
n_2p_2	1.43	6.81	0.76	1.32	6.20	0.71
n_2p_3	1.55	6.96	0.82	1.40	6.45	0.75
n_3p_1	1.54	7.17	0.74	1.41	6.70	0.71
n_3p_2	1.69	7.70	0.79	1.62	7.14	0.77
n_3p_3	1.83	7.94	0.83	1.70	7.47	0.78
$F_{4,27}$	3.49*	3.55*	5.18**	6.39**	5.83**	16.52**
SE_m	0.008	0.021	0.005	0.007	0.043	0.005
CD(0.05)	0.022	0.061	0.014	0.020	0.126	0.014
n_1k_1	1.32	5.97	0.66	1.20	5.51	0.57
n_1k_2	1.34	6.05	0.68	1.24	5.66	0.59
n_1k_3	1.37	6.12	0.70	1.26	5.76	0.61
n_2k_1	1.39	6.67	0.74	1.30	6.15	0.68
n_2k_2	1.45	6.71	0.76	1.34	6.25	0.70
n_2k_3	1.49	6.83	0.77	1.34	6.30	0.72
n_3k_1	1.61	7.45	0.77	1.48	6.94	0.73
n_3k_2	1.69	7.61	0.79	1.60	7.15	0.76
n_3k_3	1.75	7.75	0.80	1.64	7.22	0.77
$F_{4,27}$	9.14**	4.28**	0.20	4.18**	0.87	0.40
SE_m	0.008	0.021	0.005	0.007	0.043	0.005
CD(0.05)	0.022	0.061	–	0.020	–	–
p_1k_1	1.37	6.37	0.67	1.24	5.98	0.61
p_1k_2	1.40	6.47	0.68	1.29	8.06	0.62
p_1k_3	1.42	6.59	0.69	1.32	6.12	0.64
p_2k_1	1.43	6.78	0.72	1.34	6.17	0.66
p_2k_2	1.49	6.83	0.74	1.41	6.36	0.69
p_2k_3	1.53	6.93	0.76	1.43	6.45	0.71
p_3k_1	1.61	6.94	0.77	1.41	6.44	0.71
p_3k_2	1.60	7.06	0.77	1.48	6.64	0.74
p_3k_3	1.65	7.18	0.79	1.64	6.71	0.76
$F_{4,27}$	8.49**	1.64	2.29	0.97	0.97	1.54
SE_m	0.008	0.021	0.005	0.007	0.043	0.005
CD(0.05)	0.022	–	–	–	–	–

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

Table 26a. Effect of nitrogen, phosphorus and potassium on uptake of phosphorus in pseudostem

Main effect of factors	P uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	1.81	5.51	9.22	1.71	5.65	5.89
n_2	2.39	6.17	10.02	2.29	6.21	7.65
n_3	2.79	7.07	10.75	2.59	6.78	10.20
$F_{2,27}$	383.56**	773.52**	207.55**	323.48**	589.43**	509.18**
SE_m	0.008	0.028	0.017	0.008	0.023	0.030
CD(0.05)	0.023	0.081	0.048	0.022	0.067	0.088
p_1	2.23	6.02	8.45	2.11	5.99	7.27
p_2	2.34	6.29	9.02	2.20	6.20	7.94
p_3	2.42	6.44	9.52	2.28	6.46	8.52
$F_{2,27}$	139.11**	57.40**	58.46**	122.03**	105.09**	42.59**
SE_m	0.008	0.028	0.017	0.008	0.023	0.030
CD(0.05)	0.023	0.081	0.048	0.022	0.067	0.088
k_1	2.28	6.12	8.51	2.15	6.08	7.58
k_2	2.34	6.29	9.09	2.21	6.24	7.97
k_3	2.37	6.34	12.40	2.24	6.32	8.18
$F_{2,27}$	27.35**	16.77**	15.61**	34.31**	27.69**	10.17**
SE_m	0.008	0.028	0.017	0.008	0.023	0.030
CD(0.05)	0.023	0.081	0.048	0.022	0.067	0.088

** Significant at 1 per cent level

Table 26b. Interaction effect of nitrogen, phosphorus and potassium on uptake of phosphorus in pseudostem

Interaction effects	P uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	1.72	5.35	6.83	1.66	5.41	5.28
n_1p_2	1.82	5.54	6.80	1.71	5.57	5.92
n_1p_3	1.88	5.65	7.44	1.77	5.97	6.48
n_2p_1	2.27	6.02	8.50	2.19	6.09	6.73
n_2p_2	2.41	6.20	9.41	2.28	6.26	7.63
n_2p_3	2.50	6.28	9.75	2.40	6.29	8.58
n_3p_1	2.70	6.69	10.03	2.48	6.45	9.81
n_3p_2	2.81	7.13	10.86	2.61	6.76	10.26
n_3p_3	2.87	7.38	11.36	2.69	7.13	10.52
$F_{4,27}$	2.44	6.11**	1.26	4.79**	11.68**	2.99*
SE_m	0.014	0.049	0.029	0.014	0.040	0.052
CD(0.05)	–	0.141	–	0.040	0.117	0.152
n_1k_1	1.79	5.43	6.50	1.68	5.53	5.63
n_1k_2	1.79	5.54	6.89	1.72	5.66	5.89
n_1k_3	1.83	5.58	8.67	1.73	5.77	6.16
n_2k_1	2.33	6.05	8.65	2.24	6.14	7.27
n_2k_2	2.41	6.20	9.40	2.30	6.23	7.73
n_2k_3	2.44	6.25	9.62	2.32	6.27	7.93
n_3k_1	2.73	6.88	10.39	2.52	6.58	7.84
n_3k_2	2.80	7.12	10.97	2.60	6.84	10.30
n_3k_3	2.83	7.20	10.89	2.65	6.92	10.45
$F_{4,27}$	2.74*	0.95	1.26	2.48	2.13	1.36
SE_m	0.014	0.049	0.029	0.014	0.040	0.052
CD(0.05)	0.040	–	–	–	–	–
p_1k_1	2.20	5.87	7.95	2.08	5.84	7.10
p_1k_2	2.22	6.07	8.43	2.11	6.00	7.28
p_1k_3	2.27	6.12	7.97	2.13	6.11	7.44
p_2k_1	2.30	6.19	8.59	2.15	6.08	7.57
p_2k_2	2.35	6.31	9.15	2.20	6.22	8.01
p_2k_3	2.38	6.37	9.33	2.40	6.29	8.23
p_3k_1	2.36	6.31	8.98	2.21	6.32	8.07
p_3k_2	2.43	6.47	9.68	2.30	6.51	8.63
p_3k_3	2.45	6.54	9.88	2.35	6.56	8.87
$F_{4,27}$	0.83	0.22	1.13	1.78	0.26	2.62
SE_m	0.014	0.049	0.029	0.014	0.040	0.052
CD(0.05)	–	–	–	–	–	–

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

Considering N x P interaction at 6 MAP in 98-99, p_3 imparted significantly higher response in combination with n_3 only. At this stage in the subsequent year, in n_1 and n_3 applied plots, the highest rate of phosphorus nutrition (p_3) tended to enhance the uptake of phosphorus in pseudostem. At 4 MAP and at harvest stage in 99-00, p_3 produced significantly higher P uptake with all levels of nitrogen. The N x K interaction was significant only at 4 MAP in 98-99. At all levels of nitrogen, k_2 and k_3 had similar effect on P uptake. The interaction P x K was not significant in both the years.

4.6.2.3 Rhizome

The main effect of treatments on uptake of phosphorus during the two years of experimentation are summarised in Table 27a.

The effect of different levels of nitrogen, phosphorus and potassium was significant at all the stages of growth in 98-99 and 99-00. Increasing the levels of both N and P significantly increased the P uptake in rhizome. Except at 6 MAP in 99-00 incremental doses of K increased the P uptake. At this stage k_2 and k_3 had similar effect.

As depicted in Table 27b, uptake of phosphorus due to N x P interaction was significant at 6 MAP in 98-99 and at harvest stage in 99-00. With all levels of nitrogen, increasing levels of phosphorus significantly increased the uptake of phosphorus. The interaction N x K was significant only at 6 MAP in 98-99. At n_2 and n_3 levels of nitrogen, significantly higher P uptake was obtained at k_3 level. But at n_1 level, k_2 and k_3 were on par. The interaction between phosphorus and potassium was not significant in either of the years.

Table 27a. Effect of nitrogen, phosphorus and potassium on uptake of phosphorus in rhizome

Main effect of factors	P uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.91	2.65	3.01	0.81	2.69	2.89
n_2	0.99	3.03	3.41	0.88	2.99	3.34
n_3	1.04	3.54	3.84	0.93	3.35	3.73
$F_{2,27}$	68.94**	1681.22**	337.15**	134.79**	342.58**	1263.66**
SE_m	0.008	0.011	0.022	0.005	0.018	0.012
CD(0.05)	0.023	0.032	0.065	0.015	0.052	0.035
p_1	0.95	2.90	3.22	0.84	2.86	3.13
p_2	0.98	3.09	3.41	0.87	3.01	3.31
p_3	1.01	3.23	3.62	0.91	3.15	3.53
$F_{2,27}$	18.68**	219.90**	78.70**	39.12**	65.02**	283.27**
SE_m	0.008	0.011	0.022	0.005	0.018	0.012
CD(0.05)	0.023	0.032	0.065	0.015	0.052	0.035
k_1	0.94	2.98	3.29	0.85	2.94	3.23
k_2	0.98	3.10	3.44	0.87	3.03	3.34
k_3	1.02	3.15	3.52	0.90	3.05	3.39
$F_{2,27}$	20.73**	59.60**	27.18**	16.55**	11.08**	46.62**
SE_m	0.008	0.011	0.022	0.005	0.018	0.012
CD(0.05)	0.023	0.032	0.065	0.015	0.052	0.035

** Significant at 1 per cent level

Table 27b. Interaction effect of nitrogen, phosphorus and potassium on uptake of phosphorus in rhizome

Interaction effects	P uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.87	2.55	2.85	0.79	2.59	2.75
n_1p_2	0.92	2.64	3.02	0.81	2.69	2.83
n_1p_3	0.94	2.75	3.18	0.84	2.78	3.09
n_2p_1	0.96	2.84	3.19	0.83	2.81	3.13
n_2p_2	0.99	3.04	3.40	0.88	2.99	3.35
n_2p_3	1.02	3.21	3.64	0.92	3.16	3.55
n_3p_1	1.00	3.31	3.63	0.90	3.18	3.50
n_3p_2	1.04	3.60	3.83	0.93	3.35	3.76
n_3p_3	1.08	3.71	4.05	0.97	3.52	3.94
$F_{4,27}$	0.30	10.50**	0.67	1.07	1.96	5.00**
SE_m	0.014	0.018	0.039	0.009	0.031	0.021
CD(0.05)	–	0.051	–	–	–	0.060
n_1k_1	0.88	2.60	2.97	0.79	2.65	2.82
n_1k_2	0.90	2.66	3.01	0.81	2.70	2.89
n_1k_3	0.95	2.68	3.07	0.83	2.70	2.96
n_2k_1	0.95	2.92	3.24	0.86	2.90	3.24
n_2k_2	1.00	3.05	3.42	0.87	3.02	3.37
n_2k_3	1.02	3.12	3.56	0.90	3.04	3.41
n_3k_1	1.00	3.42	3.68	0.91	3.26	3.64
n_3k_2	1.05	3.57	3.89	0.93	3.38	3.76
n_3k_3	1.08	3.63	3.94	0.95	3.41	3.80
$F_{4,27}$	0.62	3.81*	2.72	0.07	0.78	0.62
SE_m	0.014	0.018	0.039	0.009	0.031	0.021
CD(0.05)	–	0.051	–	–	–	–
p_1k_1	0.91	2.81	3.09	0.82	2.82	3.06
p_1k_2	0.95	2.93	3.22	0.84	2.87	3.14
p_1k_3	0.97	2.97	3.36	0.86	2.90	3.17
p_2k_1	0.95	3.00	3.28	0.85	2.95	3.21
p_2k_2	0.99	3.13	3.47	0.87	3.03	3.34
p_2k_3	1.01	3.15	3.49	0.89	3.04	3.39
p_3k_1	0.97	3.14	3.51	0.88	3.05	3.42
p_3k_2	1.00	3.23	3.64	0.91	3.19	3.54
p_3k_3	1.07	3.31	3.71	0.93	3.21	3.62
$F_{4,27}$	1.43	0.64	0.66	0.36	0.65	1.31
SE_m	0.014	0.018	0.039	0.009	0.031	0.021
CD(0.05)	–	–	–	–	–	–

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

4.6.3 Potassium

4.6.3.1 Leaf

As depicted in Table 28a, nitrogen, phosphorus and potassium significantly influenced the uptake of potassium at all stages of growth throughout the period of experimentation. Incremental doses of nitrogen, phosphorus and potassium significantly increased the uptake of K in leaf with the maximum values at n_3, p_3 and k_3 respectively.

Interaction effects furnished in Table 28b indicated that N x P interaction was significant at all stages except at harvest stage in 99-00. At these stages, p_3 recorded maximum K uptake in combination with n_3. Similarly, p_3 recorded highest K uptake at all levels of nitrogen at 4 MAP, with n_1 at 6 MAP and with n_2 at harvest stage during the first year. But at 4 MAP and 6 MAP in 99-00, p_2 and p_3 were on par with n_1 and n_2.

The interaction between N x K was significant at 4 MAP and 6 MAP in 98-99 and at 4 MAP in 99-00. During the first year at all levels of nitrogen, K uptake was significantly increased by increasing the levels of potassium. In the subsequent year in n_1 treated plots significant response was obtained upto k_3. Significant P x K interaction occured only at 4 MAP in 98-99. At all levels of phosphorus, increasing rates of potassium significantly promoted the K uptake.

4.6.3.2 Pseudostem

Different levels nitrogen, phosphorous and potassium had significant influence on the uptake of K in pseudostem in both the years.

Table 28a. Effect of nitrogen, phosphorus and potassium on uptake of potassium in leaf

Main effect of factors	K uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	10.73	38.50	12.40	9.87	36.21	10.88
n_2	11.48	41.83	13.11	10.69	38.84	11.87
n_3	13.15	45.65	13.43	12.39	42.80	12.70
$F_{2,27}$	143.09**	208.90**	217.81**	155.35**	419.31**	273.23**
SE_m	0.033	0.078	0.036	0.033	0.162	0.055
CD(0.05)	0.095	0.227	0.104	0.095	0.470	0.160
p_1	11.46	40.97	12.76	10.58	38.43	11.60
p_2	11.70	42.14	12.99	11.09	39.23	11.82
p_3	12.20	42.88	13.18	11.27	40.19	12.04
$F_{2,27}$	134.51**	151.60**	34.80**	120.52**	29.40**	15.88**
SE_m	0.033	0.078	0.036	0.033	0.162	0.055
CD(0.05)	0.095	0.227	0.104	0.095	0.470	0.160
k_1	11.30	41.05	12.53	10.49	38.24	11.38
k_2	11.82	41.94	13.00	11.10	39.41	11.88
k_3	12.23	42.99	13.40	11.36	40.20	12.19
$F_{2,27}$	202.03**	152.62**	146.39**	185.76**	36.76**	54.92**
SE_m	0.033	0.078	0.036	0.033	0.162	0.055
CD(0.05)	0.095	0.227	0.104	0.095	0.470	0.160

** Significant at 1 per cent level

Table 28b. Interaction effect of nitrogen, phosphorus and potassium on uptake of potassium in leaf

Interaction effects	K uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	10.59	37.63	12.13	9.59	35.30	10.57
n_1p_2	10.71	38.44	12.47	9.95	36.42	10.89
n_1p_3	10.89	39.42	12.58	10.07	36.91	11.19
n_2p_1	11.12	40.77	12.80	10.53	38.42	11.62
n_2p_2	11.40	42.30	13.15	10.73	38.68	11.84
n_2p_3	11.92	42.43	13.38	10.80	39.41	12.13
n_3p_1	12.67	44.49	13.34	10.90	41.57	12.60
n_3p_2	12.99	45.69	13.36	11.55	42.61	12.74
n_3p_3	13.80	46.77	13.57	12.62	44.24	12.78
$F_{4,27}$	14.85**	4.58**	3.18*	26.71**	2.74*	1.57
SE_m	0.057	0.135	0.062	0.057	0.281	0.096
CD(0.05)	0.165	0.393	0.180	0.164	0.815	–
n_1k_1	10.42	37.65	12.04	9.53	35.17	10.58
n_1k_2	10.71	38.54	12.34	9.91	36.26	10.87
n_1k_3	11.05	39.30	12.81	10.17	37.19	11.19
n_2k_1	11.05	41.07	12.58	10.39	38.02	11.62
n_2k_2	11.49	41.70	13.21	10.77	38.88	11.84
n_2k_3	11.91	42.73	13.54	10.90	39.61	12.13
n_3k_1	12.44	44.44	12.98	11.55	41.54	12.60
n_3k_2	13.27	45.58	13.46	12.62	43.09	12.74
n_3k_3	13.74	46.93	13.83	12.99	43.78	12.78
$F_{4,27}$	10.09**	3.39*	1.77	22.62**	0.51	1.22
SE_m	0.057	0.135	0.062	0.057	0.281	0.096
CD(0.05)	0.165	0.393	–	0.164	–	–
p_1k_1	11.15	40.01	12.43	10.15	37.65	11.28
p_1k_2	11.46	40.92	12.76	10.65	38.42	11.57
p_1k_3	11.76	41.97	13.08	10.95	39.22	11.93
p_2k_1	11.25	41.40	12.48	10.57	38.11	11.34
p_2k_2	11.70	42.01	13.00	11.24	39.40	11.91
p_2k_3	12.15	43.01	13.50	11.45	40.19	12.21
p_3k_1	11.51	41.75	12.69	10.76	38.97	11.52
p_3k_2	12.31	42.90	13.24	11.40	40.41	12.15
p_3k_3	12.79	43.97	13.60	11.66	41.18	13.31
$F_{4,27}$	9.69**	1.50	2.51	0.69	0.50	1.01
SE_m	0.057	0.135	0.062	0.057	0.281	0.096
CD(0.05)	0.165	–	–	–	–	–

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

At all stages, n_3 and p_3 recorded significantly highest K uptake. Increasing rates of K enhanced the uptake of potassium at all stages except at 6 MAP in 98-99. At this stage k_2 and k_3 were on par (Table 29a).

As shown in Table 29b significant difference in the uptake of potassium due to N x P interaction was evident at 4 MAP in 98-99 and at all stages in the subsequent year. At 4 MAP in both the years and at harvest stage in 99-00, p_3 produced significantly highest K uptake in combination with n_2 and n_3. At n_1 level of nitrogen, p_2 and p_3 were on par. At 6 MAP in 99-00, p_2 and p_3 produced similar effects in combination with n_1 and n_2.

The interaction N x K was significant at 4 MAP in both the years and at harvest stage in 99-00. At all levels of nitrogen, k_3 produced significantly highest K uptake at 4 MAP in first year and at harvest stage in the second year. At 4 MAP in 99-00, incremental doses of potassium significantly increased the uptake of potassium in combination with n_2 and n_3.

The interaction P x K was significant at 4 MAP and at harvest stage in 99-00. The highest level of potassium k_3 produced significantly highest K uptake at all levels of phosphorous.

4.6.3.3 Rhizome

Perusal of the data in Table 30a clearly indicates that the different of levels of nitrogen, phosphorus and potassium had significant influence

Table 29a. Effect of nitrogen, phosphorus and potassium on uptake of potassium in pseudostem

Main effect of factors	K uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	19.38	58.69	133.03	18.54	59.71	124.91
n_2	25.02	61.61	155.46	23.69	62.42	145.36
n_3	29.18	70.27	167.96	27.18	67.26	161.83
$F_{2,27}$	271.81**	374.06**	396.33**	411.92**	239.52**	215.75**
SE_m	0.094	0.312	0.889	0.068	0.247	0.398
CD(0.05)	0.274	0.904	2.580	0.196	0.717	1.156
p_1	24.15	62.23	147.41	22.59	61.97	140.23
p_2	24.40	63.55	152.54	23.02	62.97	144.90
p_3	25.04	64.78	156.51	23.80	64.44	146.96
$F_{2,27}$	23.47**	16.71**	26.35**	81.13**	25.28**	74.98**
SE_m	0.094	0.312	0.889	0.068	0.247	0.398
CD(0.05)	0.274	0.904	2.580	0.196	0.717	1.156
k_1	23.78	62.16	145.61	22.51	61.70	130.71
k_2	24.45	63.82	154.18	23.20	63.29	145.05
k_3	25.34	64.58	156.67	23.70	64.44	148.35
$F_{2,27}$	68.86**	15.77**	42.61**	78.88**	29.89**	151.55**
SE_m	0.094	0.312	0.889	0.068	0.247	0.398
CD(0.05)	0.274	0.904	2.580	0.196	0.717	1.156

** Significant at 1 per cent level

Table 29b. Interaction effect of nitrogen, phosphorus and potassium on uptake of potassium in pseudostem

Interaction effect	K uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	18.87	57.86	129.45	18.35	58.94	121.40
n_1p_2	19.54	58.75	131.89	18.48	59.65	126.73
n_1p_3	19.73	59.46	137.75	18.79	60.54	126.60
n_2p_1	24.58	60.70	150.00	23.01	61.73	140.18
n_2p_2	24.69	61.65	157.12	23.43	62.26	146.82
n_2p_3	25.79	62.48	159.27	24.63	63.27	149.08
n_3p_1	28.99	68.14	162.77	26.42	65.24	159.12
n_3p_2	28.96	70.27	168.61	27.15	67.02	161.16
n_3p_3	29.58	72.40	172.50	27.97	69.51	165.22
$F_{4,27}$	2.75*	1.91	0.69	8.70**	3.38*	4.83**
SE_m	0.163	0.539	1.540	0.117	0.428	0.690
CD(0.05)	0.474	–	–	0.340	1.242	2.002
n_1k_1	19.03	57.65	127.14	18.23	58.32	121.25
n_1k_2	19.03	58.98	134.08	18.53	59.65	125.02
n_1k_3	20.08	59.44	137.87	18.86	60.54	128.46
n_2k_1	24.16	60.42	147.21	23.20	61.73	137.76
n_2k_2	24.96	61.78	157.58	23.63	62.26	147.60
n_2k_3	25.95	62.63	161.60	24.24	63.27	150.71
n_3k_1	28.16	68.43	162.47	26.09	65.24	157.11
n_3k_2	29.37	70.70	170.87	27.44	67.02	162.51
n_3k_3	30.00	71.69	170.54	28.01	69.51	165.88
$F_{4,27}$	3.95*	0.54	1.34	9.49**	1.09	6.57**
SE_m	0.163	0.539	1.540	0.117	0.428	0.690
CD(0.05)	0.474	–	–	0.340	–	2.002
p_1k_1	23.42	60.80	142.26	22.26	60.50	137.19
p_1k_2	24.10	62.67	150.08	22.54	62.22	139.95
p_1k_3	24.93	62.23	149.87	22.99	63.18	143.56
p_2k_1	23.67	62.31	145.98	22.27	61.83	138.48
p_2k_2	24.22	63.85	154.13	23.11	62.99	146.57
p_2k_3	25.30	64.50	157.50	23.68	64.10	149.66
p_3k_1	24.27	63.38	148.57	22.99	62.78	140.44
p_3k_2	25.04	64.94	158.32	23.96	64.66	148.61
p_3k_3	25.80	66.02	162.64	24.44	65.88	151.84
$F_{4,27}$	0.29	0.10	1.22	3.60*	0.30	6.22**
SE_m	0.163	0.539	1.540	0.117	0.428	0.690
CD(0.05)	–	–	–	0.340	–	2.002

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

Table 30a. Effect of nitrogen, phosphorus and potassium on uptake of potassium in rhizome

Main effect of factors	K uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	8.70	29.89	42.53	7.73	30.16	41.90
n_2	9.28	33.34	47.02	8.26	33.02	46.13
n_3	9.67	37.84	51.71	8.73	35.92	51.04
$F_{2,27}$	45.56**	116.21**	267.25**	109.40**	173.09**	321.28**
SE_m	0.072	0.119	0.281	0.048	0.219	0.126
CD(0.05)	0.209	0.346	0.815	0.139	0.636	0.365
p_1	8.98	32.65	45.74	8.09	32.30	44.98
p_2	9.24	33.86	46.85	8.24	33.00	46.00
p_3	9.33	34.56	48.66	8.39	33.81	47.70
$F_{2,27}$	3.37*	65.57**	27.64**	9.54**	11.88**	116.64**
SE_m	0.072	0.119	0.281	0.048	0.219	0.126
CD(0.05)	0.209	0.346	0.815	0.139	0.636	0.365
k_1	8.82	32.54	45.02	7.99	32.03	44.81
k_2	9.17	33.84	47.51	8.21	33.21	46.57
k_3	9.65	34.70	48.73	8.53	33.86	47.68
$F_{2,27}$	33.42**	83.54**	45.39**	31.89**	17.90**	132.00**
SE_m	0.072	0.119	0.281	0.048	0.219	0.126
CD(0.05)	0.209	0.346	0.815	0.139	0.636	0.365

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

Table 30b. Interaction effect of nitrogen, phosphorus and potassium on uptake of potassium in rhizome

Interaction effects	K uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	8.54	29.24	41.74	7.59	29.63	40.88
n_1p_2	8.80	29.87	42.39	7.81	30.24	41.48
n_1p_3	8.76	30.58	43.45	7.79	30.61	43.32
n_2p_1	9.21	32.17	45.41	8.04	32.17	44.62
n_2p_2	9.23	33.54	46.65	8.27	33.08	46.40
n_2p_3	9.40	34.31	49.01	8.47	33.81	47.38
n_3p_1	9.49	36.55	50.08	8.65	35.09	49.43
n_3p_2	9.68	38.19	51.51	8.65	35.69	51.31
n_3p_3	9.83	38.79	53.53	8.90	36.99	52.39
$F_{4,27}$	0.40	2.04	1.20	1.23	0.55	1.14
SE_m	0.125	0.207	0.486	0.083	0.379	0.218
CD(0.05)	–	–	–	–	–	–
n_1k_1	8.35	29.07	41.51	7.47	29.44	40.65
n_1k_2	8.56	30.06	42.65	7.72	30.30	42.01
n_1k_3	9.19	30.55	43.42	8.00	30.74	43.02
n_2k_1	8.93	32.13	44.29	8.01	31.81	44.42
n_2k_2	9.31	33.44	47.49	8.23	33.30	46.39
n_2k_3	9.60	34.45	49.28	8.55	33.96	47.59
n_3k_1	9.19	36.41	49.24	8.49	34.84	49.37
n_3k_2	9.65	38.01	52.39	8.68	36.04	51.31
n_3k_3	10.16	39.10	53.48	9.03	36.89	52.44
$F_{4,27}$	0.73	2.26	2.98*	0.05	0.41	2.78*
SE_m	0.125	0.207	0.486	0.083	0.379	0.218
CD(0.05)	–	–	1.411	–	–	0.633
p_1k_1	8.71	31.59	43.62	7.85	31.57	43.70
p_1k_2	9.10	32.72	45.93	8.04	32.34	45.05
p_1k_3	9.43	33.65	47.67	8.39	32.97	46.18
p_2k_1	8.90	32.66	44.63	8.01	32.04	44.68
p_2k_2	9.23	34.13	47.49	8.23	33.20	46.78
p_2k_3	9.58	34.80	48.43	8.49	33.77	47.74
p_3k_1	8.86	33.36	46.80	8.10	32.49	46.06
p_3k_2	9.18	34.66	49.11	8.39	34.09	47.89
p_3k_3	9.95	35.66	50.08	8.71	34.84	49.13
$F_{4,27}$	1.19	0.29	0.32	0.19	0.48	1.01
SE_m	0.125	0.207	0.486	0.083	0.379	0.218
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

on the uptake of potassium in rhizome throughout the crop growth in 98-99 and 99-00.

Among the different levels of nitrogen and potassium n_3 and k_3 produced significantly highest K uptake at all stages. The highest level of phosphorus p_3 also promoted highest K uptake at most of the stages except at 4 MAP in 98-99. At this stage p_2 and p_3 had similar effect.

Interaction effects presented in Table 30b, indicated that N x P and P x K interactions were not significant in both the years. The interaction N x K was significant only at harvest stage in 98-99 and 99-00. At this stage in 98-99, k_3 produced significantly highest K uptake in combination with n_2 only. At n_1 and n_3 levels of nitrogen, k_2 and k_3 exerted similar effect. In the subsequent year, at all levels of nitrogen, incremental doses of potassium significantly increased the K uptake in rhizome.

4.6.4 Calcium

4.6.4.1 Leaf

The effect of treatments on calcium uptake in leaf for the two years of experimentation are presented in Tables 31a and 31b. N, P and K had significant effect on uptake of calcium in 98-99 and 99-00. Except at harvest stage in 98-99, increasing the levels of N and P resulted in an increase in the uptake of Ca. But in the case of potassium beyond the level k_2, there was a reduction in calcium uptake.

Table 31a. Effect of nitrogen, phosphorus and potassium on uptake of calcium in leaf

Main effect of factors	Ca uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	3.24	12.69	2.30	2.94	11.78	2.03
n_2	3.51	13.88	2.52	3.27	12.93	2.31
n_3	3.98	15.26	2.68	3.75	14.35	2.56
$F_{2,27}$	627.01**	849.76**	297.70**	1021.99**	752.76**	315.89**
SE_m	0.015	0.044	0.111	0.013	0.047	0.015
CD(0.05)	0.043	0.128	0.321	0.037	0.136	0.044
p_1	3.48	13.59	2.42	3.17	12.69	2.20
p_2	3.55	14.00	2.51	3.36	13.00	2.32
p_3	3.70	14.23	2.57	3.43	13.37	2.38
$F_{2,27}$	58.92**	54.53**	44.56**	109.52**	52.86**	37.58**
SE_m	0.015	0.044	0.111	0.013	0.047	0.015
CD(0.05)	0.043	0.128	0.321	0.037	0.136	0.044
k_1	3.36	13.55	2.33	3.10	12.53	2.12
k_2	3.77	14.30	2.63	3.48	13.41	2.45
k_3	3.60	13.98	2.54	3.37	13.11	2.33
$F_{2,27}$	189.26**	72.63**	201.64**	237.09**	89.81**	120.61**
SE_m	0.015	0.044	0.111	0.013	0.047	0.015
CD(0.05)	0.043	0.128	0.321	0.037	0.136	0.044

** Significant at 1 per cent level

Table 31b. Interaction effect of nitrogen, phosphorus and potassium on uptake of calcium in leaf

Interaction effects	Ca uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	3.19	12.40	2.19	2.82	11.35	1.87
n_1p_2	3.26	12.66	2.32	2.97	11.80	2.06
n_1p_3	3.28	13.01	2.39	3.04	12.19	2.15
n_2p_1	3.42	13.47	2.45	3.21	12.82	2.22
n_2p_2	3.46	14.11	2.53	3.29	12.89	2.35
n_2p_3	3.64	14.05	2.59	3.30	13.08	2.37
n_3p_1	3.82	14.90	2.62	3.48	13.90	2.46
n_3p_2	3.94	15.25	2.68	3.82	14.30	2.55
n_3p_3	4.18	15.64	2.74	3.96	14.82	2.63
$F_{4,27}$	8.53**	3.02*	1.38	22.01**	5.41**	3.50*
SE_m	0.026	0.076	0.019	0.022	0.081	0.026
CD(0.05)	0.075	0.222	–	0.064	0.236	0.076
n_1k_1	3.09	12.40	2.18	2.79	11.35	1.88
n_1k_2	3.41	12.97	2.41	3.07	12.21	2.16
n_1k_3	3.23	12.70	2.30	2.96	11.78	2.04
n_2k_1	3.31	13.55	2.33	3.10	12.47	2.13
n_2k_2	3.69	14.25	2.67	3.38	13.27	2.47
n_2k_3	3.52	13.84	2.57	3.32	13.04	2.34
n_3k_1	3.69	14.71	2.47	3.42	13.78	2.35
n_3k_2	4.21	15.69	2.83	4.00	14.74	2.72
n_3k_3	4.04	15.39	2.74	3.83	14.51	2.62
$F_{4,27}$	5.75**	2.69	5.42**	17.02**	1.10	1.53
SE_m	0.026	0.076	0.019	0.022	0.081	0.026
CD(0.05)	0.075	–	0.056	0.064	–	–
p_1k_1	3.33	13.18	2.30	2.98	12.35	2.06
p_1k_2	3.63	13.94	2.52	3.35	12.99	2.32
p_1k_3	3.47	13.65	2.45	3.19	12.72	2.22
p_2k_1	3.34	13.69	2.32	3.13	12.45	2.14
p_2k_2	3.74	14.33	2.65	3.51	13.40	2.48
p_2k_3	3.58	14.00	2.56	3.44	13.14	2.34
p_3k_1	3.42	13.78	2.37	3.20	12.81	2.17
p_3k_2	3.94	14.64	2.73	4.00	13.83	2.54
p_3k_3	3.75	14.29	2.61	3.49	13.47	2.43
$F_{4,27}$	4.92**	0.69	3.74*	1.73	1.82	1.60
SE_m	0.026	0.076	0.019	0.022	0.081	0.026
CD(0.05)	0.075	–	0.056	–	–	–

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

As presented in Table 31b, N x P interaction was significant at 4 MAP, 6 MAP in both the years and also at harvest stage in 99-00. At all these stages, p_3 had maximum Ca uptake in combination with n_1 (except at 4 MAP in 98-99) and n_3. At 6 MAP in 98-99 and at all stages in the subsequent year, p_2 and p_3 exerted similar effect in n_2 applied plots.

The N x K interaction was significant at 4 MAP in 98-99 and 99-00 and at harvest stage in 98-99. During first year, at all levels of N, increasing the rate of K upto k_2 significantly enhanced the Ca uptake in leaf. There was significant reduction in Ca uptake beyond k_2. However, in the subsequent year, k_2 and k_3 were on par in n_2 applied plots. Whereas k_2 produced maximum uptake in combination with n_1 and n_3. Interaction effect between phosphorus and potassium was significant at 4 MAP and harvest stage in 98-99. At all levels of phosphorus, k_2 retained maximum Ca uptake.

4.6.4.2 Pseudostem

Variation in calcium uptake due to different levels of nitrogen, phosphorus and potassium was significant in both the years with the maximum values at n_3, p_3 and k_2 respectively (Table 32a). Ca uptake increased with increasing levels of N and P. In case of potassium there was reduction beyond k_2 level.

Significant N x P interaction occurred at 4 MAP and harvest stage in 99-00. At 4 MAP, p_3 recorded significantly highest calcium uptake at all levels of nitrogen whereas at harvest stage p_3 recorded maximum uptake in combination with n_3 only (Table 32b).

Table 32a. Effect of nitrogen, phosphorus and potassium on uptake of calcium in pseudostem

Main effect of factors	Ca uptake in pseudostem ($kg\ ha^{-1}$)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	7.00	16.80	25.44	6.76	17.24	26.51
n_2	9.12	17.75	29.35	8.81	18.12	27.15
n_3	10.70	20.22	31.73	10.04	19.47	27.82
$F_{2,27}$	368.53**	342.50**	238.50**	367.74**	203.73**	571.46**
SE_m	0.031	0.165	0.206	0.027	0.079	0.146
CD(0.05)	0.089	0.480	0.597	0.079	0.228	0.423
p_1	8.71	17.96	27.80	8.34	17.85	26.51
p_2	8.95	18.26	29.00	8.50	18.23	27.15
p_3	9.16	18.54	29.72	8.77	18.74	27.82
$F_{2,27}$	56.47**	9.08**	22.26**	64.24**	32.12**	20.05**
SE_m	0.031	0.165	0.206	0.027	0.079	0.146
CD(0.05)	0.089	0.480	0.597	0.079	0.228	0.423
k_1	8.70	17.59	26.94	8.31	17.72	25.50
k_2	9.15	18.79	30.27	8.75	18.82	28.46
k_3	8.97	18.38	29.32	8.55	18.29	27.51
$F_{2,27}$	56.02**	40.70**	69.61**	64.58**	49.22**	107.32**
SE_m	0.031	0.165	0.206	0.027	0.079	0.146
CD(0.05)	0.089	0.480	0.597	0.079	0.228	0.423

** Significant at 1 per cent level

Table 32b. Interaction effect of nitrogen, phosphorus and potassium on uptake of calcium in pseudostem

Interaction effects	Ca uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	6.76	16.77	24.58	6.61	16.99	22.84
n_1p_2	7.02	16.75	25.16	6.76	17.19	23.56
n_1p_3	7.22	16.87	26.59	6.90	17.54	24.29
n_2p_1	8.88	17.47	28.33	8.62	17.74	26.33
n_2p_2	9.09	17.77	30.06	8.67	18.07	27.82
n_2p_3	7.39	18.00	29.66	9.16	18.55	28.03
n_3p_1	10.48	19.65	30.50	9.78	18.82	30.37
n_3p_2	10.74	20.27	31.78	10.08	19.45	30.05
n_3p_3	10.88	20.74	32.93	10.26	20.13	31.13
$F_{4,27}$	0.62	2.33	2.11	5.39**	2.03	3.27*
SE_m	0.053	0.165	0.356	0.647	0.136	0.252
CD(0.05)	–	–	–	0.137	–	0.732
n_1k_1	6.89	16.34	23.68	6.60	16.71	22.36
n_1k_2	7.19	17.21	26.97	6.86	17.87	24.54
n_1k_3	6.92	16.83	25.67	6.80	17.14	23.78
n_2k_1	8.87	17.15	27.26	8.59	17.66	25.18
n_2k_2	9.32	18.27	30.96	9.06	18.57	29.03
n_2k_3	9.17	17.83	29.84	8.79	18.13	27.96
n_3k_1	10.33	19.29	29.87	9.74	18.78	28.97
n_3k_2	10.95	20.89	32.88	10.33	20.03	31.82
n_3k_3	10.82	20.47	32.46	10.04	19.59	30.77
$F_{4,27}$	5.12**	1.63	0.60	3.53*	0.92	3.19*
SE_m	0.053	0.165	0.356	0.647	0.136	0.252
CD(0.05)	0.154	–	–	0.137	–	0.732
p_1k_1	8.52	17.22	26.28	8.20	17.31	25.38
p_1k_2	8.90	18.57	28.76	8.49	18.45	27.62
p_1k_3	8.69	18.10	28.37	8.31	17.79	26.54
p_2k_1	8.67	17.72	28.96	8.19	17.69	25.27
p_2k_2	9.18	18.68	30.86	8.75	18.75	28.61
p_2k_3	8.99	18.39	29.17	8.57	18.27	27.56
p_3k_1	8.90	17.84	27.57	8.54	18.16	25.86
p_3k_2	9.37	19.13	32.88	9.01	19.26	29.16
p_3k_3	9.22	18.64	30.42	8.76	18.80	28.42
$F_{4,27}$	0.65	0.41	1.53	2.68	0.14	2.55
SE_m	0.053	0.165	0.356	0.647	0.136	0.252
CD(0.05)	–	–	–	–	–	–

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

The interaction N x K was significant at 4 MAP in both the years and at harvest stage in 99-00. During the first year, in n_2 and n_3 applied plots significant response was noticed upto k_2. The medium level of potassium (k_2) recorded significantly high Ca uptake in combination with n_1 during 98-99, with n_2 and n_3 at 4 MAP and with all levels of N at harvest stage during the second year. The interaction between phosphorus and potassium could not profoundly influence the calcium uptake throughout the period of experimentation.

4.6.4.3 Rhizome

The uptake of calcium at various growth stages in 98-99 and 99-00 are presented in Tables 33a and 33b.

As shown in Table 33a, nitrogen influenced the uptake of calcium in rhizome throughout crop growth with n_3 giving significantly highest value. Different levels of phosphorus significantly influenced the calcium uptake at all stages except at 4 MAP in 98-99. During most of the stages p_3 recorded the highest value. But at 4 MAP in 99-00, p_2 and p_3 had similar effect. The effect of potassium was also significant in both the years with k_2 recording highest Ca uptake in most of the stages. Further increase in K supply resulted in a reduction in Ca uptake throughout the period of experimentation.

It is evident from Table 33b that the effect of N x P interaction was significant at 6 MAP in 98-99 and at harvest stage in both the years. At these stage p_2 and p_3 resulted in higher Ca uptake in n_3 treated plots.

Table 33a. Effect of nitrogen, phosphorus and potassium on uptake of calcium in rhizome

Main effect of factors	Ca uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	3.12	9.31	7.93	2.77	9.38	7.65
n_2	3.27	10.35	8.96	2.96	10.28	8.73
n_3	3.48	11.65	10.00	3.11	11.13	9.73
$F_{2,27}$	34.13**	92.95**	234.23**	67.12**	181.92**	625.39**
SE_m	0.031	0.038	0.066	0.021	0.065	0.042
CD(0.05)	0.089	0.111	0.196	0.060	0.188	0.121
p_1	3.24	10.10	8.59	2.90	10.03	8.37
p_2	3.29	10.49	8.98	2.94	10.25	8.75
p_3	3.34	10.71	9.32	3.00	10.51	8.99
$F_{2,27}$	2.35	6.52**	29.16**	5.29**	14.25**	56.22**
SE_m	0.031	0.038	0.066	0.021	0.065	0.042
CD(0.05)	–	0.111	0.196	0.060	0.188	0.121
k_1	3.08	10.00	8.25	2.80	9.88	8.08
k_2	3.52	10.87	9.56	3.12	10.60	9.21
k_3	3.27	10.44	9.08	2.92	10.29	8.82
$F_{2,27}$	47.95**	12.51**	25.99**	60.75**	29.99**	189.90**
SE_m	0.031	0.038	0.066	0.021	0.065	0.042
CD(0.05)	0.089	0.111	0.196	0.060	0.188	0.121

** Significant at 1 per cent level

Table 33b. Interaction effect of nitrogen, phosphorus and potassium on uptake of calcium in rhizome

Interaction effects	Ca uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	3.10	9.19	7.56	2.77	9.21	7.37
n_1p_2	3.12	9.24	8.05	2.75	9.42	7.58
n_1p_3	3.14	9.50	8.19	2.80	9.51	7.98
n_2p_1	3.23	9.97	8.79	2.87	10.05	8.57
n_2p_2	3.27	10.39	8.79	2.98	10.23	8.65
n_2p_3	3.32	10.67	9.31	3.02	10.57	8.95
n_3p_1	3.41	11.14	9.43	3.07	10.82	9.16
n_3p_2	3.47	11.84	10.17	3.10	11.11	10.00
n_3p_3	3.56	11.96	10.47	3.17	11.46	10.03
$F_{4,27}$	0.26	7.14**	2.86*	0.98	0.74	8.38**
SE_m	0.533	0.067	0.117	0.036	0.112	0.072
CD(0.05)	–	0.193	0.340	–	–	0.210
n_1k_1	2.96	9.06	7.61	2.63	9.16	7.26
n_1k_2	3.36	9.55	8.34	2.92	9.61	7.99
n_1k_3	3.04	9.32	7.85	2.77	9.37	7.40
n_2k_1	3.07	9.86	8.10	2.79	9.86	7.98
n_2k_2	3.47	10.82	9.73	3.15	10.64	9.30
n_2k_3	3.27	10.36	9.05	2.93	10.34	8.90
n_3k_1	3.22	11.09	9.05	2.98	10.66	9.00
n_3k_2	3.72	12.21	10.61	3.29	11.56	10.35
n_3k_3	3.49	11.65	10.25	3.07	11.16	9.85
$F_{4,27}$	1.06	6.15**	7.10**	0.44	1.11	6.45**
SE_m	0.533	0.067	0.117	0.036	0.112	0.072
CD(0.05)	–	0.193	0.340	–	–	0.210
p_1k_1	3.06	9.72	7.90	2.76	9.75	7.85
p_1k_2	3.42	10.54	9.22	3.07	10.29	8.76
p_1k_3	3.24	10.13	8.65	2.87	10.03	8.48
p_2k_1	3.10	10.04	9.23	2.81	9.90	8.05
p_2k_2	3.49	10.91	9.61	3.10	10.61	9.26
p_2k_3	3.28	10.53	9.11	2.92	10.25	8.93
p_3k_1	3.09	10.25	8.62	2.83	10.04	8.33
p_3k_2	3.64	11.22	9.85	3.19	10.91	9.60
p_3k_3	3.27	10.67	9.49	2.98	10.59	9.03
$F_{4,27}$	1.23	1.11	0.26	0.24	0.60	2.43
SE_m	0.533	0.067	0.117	0.036	0.112	0.072
CD(0.05)	–	–	–	–	–	–

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

But p_3 resulted in significantly high Ca uptake when combined with n_1 and n_2 at 6 MAP in 98-99 and at harvest stage in the subsequent year.

The significant effect of N x K was evident at 6 MAP in 98-99 and at harvest stage in both the years. In general, at all levels of N, higher Ca uptake was obtained at k_2 level of potassium beyond which there was a decline in uptake. The interaction between phosphorus and potassium was not significant in either of the years.

4.6.5 Magnesium

4.6.5.1 Leaf

The data on uptake of magnesium at different stages of growth in each year are presented in Tables 34a and 34b. Magnesium uptake was profoundly influenced by N, P and K. Increasing levels of both N and P increased the uptake of Mg. With regard to potassium, significant increase was obtained upto k_2 beyond which there was not much variation.

As indicated in Table 34b, N x P interaction was significant at 4 MAP and 6 MAP in 98-99, 4 MAP and at harvest stage in 99-00. At 4 MAP in the first year, p_3 recorded higher Mg uptake with all levels of nitrogen. In the subsequent year phosphorus significantly influenced the Mg uptake in combination with n_3 only.

The difference in Mg uptake due to N x K interaction was significant only at the initial stage in both the years. Irrespective of the

Table 34a. Effect of nitrogen, phosphorus and potassium on uptake of magnesium in leaf

Main effect of factors	Mg uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	2.18	7.37	0.41	1.99	6.92	0.36
n_2	2.41	8.09	0.45	2.19	7.52	0.41
n_3	2.83	8.84	0.45	2.60	8.33	0.45
$F_{2,27}$	105.29**	472.31**	77.96**	109.79**	300.14**	290.63**
SE_m	0.010	0.034	0.003	0.009	0.041	0.003
CD(0.05)	0.029	0.098	0.009	0.027	0.119	0.008
p_1	2.38	7.87	0.44	2.17	7.41	0.39
p_2	2.46	8.12	0.44	2.28	7.60	0.41
p_3	2.59	8.31	0.45	2.33	7.77	0.42
$F_{2,27}$	10.54**	41.84**	9.92**	6.62**	19.74**	22.09**
SE_m	0.010	0.034	0.003	0.009	0.041	0.003
CD(0.05)	0.029	0.098	0.009	0.027	0.119	0.008
k_1	2.30	7.79	0.42	2.13	7.27	0.38
k_2	2.50	8.15	0.45	2.29	7.69	0.41
k_3	2.52	8.22	0.45	2.30	7.80	0.40
$F_{2,27}$	26.59**	75.30**	49.52**	14.38**	49.34**	64.18**
SE_m	0.010	0.034	0.003	0.009	0.041	0.003
CD(0.05)	0.029	0.098	0.009	0.027	0.119	0.008

** Significant at 1 per cent level

Table 34b. Interaction effect of nitrogen, phosphorus and potassium on uptake of magnesium in leaf

Interaction effects	Mg uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	2.13	7.20	0.40	1.93	6.69	0.33
n_1p_2	2.18	7.34	0.41	2.00	7.01	0.37
n_1p_3	2.25	7.56	0.43	2.03	7.05	0.38
n_2p_1	2.33	7.92	0.44	2.14	7.44	0.40
n_2p_2	2.40	8.21	0.45	2.20	7.50	0.41
n_2p_3	2.50	8.16	0.46	2.23	7.63	0.42
n_3p_1	2.69	8.50	0.47	2.45	8.09	0.45
n_3p_2	2.80	8.81	0.47	2.63	8.28	0.45
n_3p_3	3.00	9.21	0.48	2.72	8.62	0.45
$F_{4,27}$	8.43**	5.69**	0.96	9.95**	2.24	7.87**
SE_m	0.018	0.059	0.006	0.016	0.071	0.004
CD(0.05)	0.051	0.170	–	0.047	–	0.013
n_1k_1	2.11	7.14	0.39	1.91	6.66	0.34
n_1k_2	2.20	7.39	0.42	1.99	6.95	0.37
n_1k_3	2.25	7.57	0.44	2.03	7.14	0.37
n_2k_1	2.23	7.80	0.40	2.10	7.22	0.40
n_2k_2	2.42	8.15	0.46	2.22	7.64	0.42
n_2k_3	2.38	8.33	0.46	2.25	7.71	0.43
n_3k_1	2.55	8.41	0.45	2.38	7.92	0.43
n_3k_2	2.89	8.90	0.48	2.67	8.49	0.46
n_3k_3	2.94	9.20	0.49	2.70	8.59	0.46
$F_{4,27}$	2.77*	2.65	0.40	18.78**	1.17	1.92
SE_m	0.018	0.059	0.006	0.016	0.071	0.004
CD(0.05)	0.051	–	–	0.047	–	–
p_1k_1	2.26	7.59	0.41	2.08	7.17	0.37
p_1k_2	2.40	7.92	0.44	2.19	7.48	0.40
p_1k_3	2.45	8.10	0.45	2.26	7.57	0.41
p_2k_1	2.28	7.86	0.42	2.14	7.24	0.38
p_2k_2	2.48	8.11	0.44	2.31	7.70	0.42
p_2k_3	2.51	8.39	0.47	2.38	7.86	0.43
p_3k_1	2.35	7.91	0.43	2.18	7.39	0.39
p_3k_2	2.63	8.41	0.46	2.37	7.90	0.43
p_3k_3	2.67	8.61	0.47	2.43	8.02	0.44
$F_{4,27}$	8.49**	1.38	0.60	2.09	0.98	0.52
SE_m	0.018	0.059	0.006	0.016	0.071	0.004
CD(0.05)	0.051	–	–	–	–	–

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

levels of N, potassium responded upto k_2 in increasing the Mg uptake. Considering P x K interaction which was significant only at 4 MAP in 98-99, at all levels of P higher response was noticed with k_2 level.

4.6.5.2 Pseudostem

Table 35a depicts the effect of different levels of nitrogen, phosphorus and potassium on uptake of magnesium in pseudostem. Increasing the levels of nitrogen and phosphorus significantly increased the uptake of magnesium in pseudostem in both the years with the maximum values at n_3 and p_3 respectively. Potassium responded only upto k_2 level.

A close scrutiny of the data in Table 35b indicated that the interaction between nitrogen and phosphorus had significant influence on Mg uptake at 4 MAP in 98-99, 6 MAP in 99-00 and at harvest stage in both the years. During the first year, p_2 and p_3 had similar effects with n_1 and n_2 at 4 MAP and with all levels of nitrogen at harvest stage. In the subsequent year, p_3 recorded significantly highest uptake in combination with n_1 and n_3 at 6 MAP and with n_2 and n_3 at harvest stage.

The interaction between nitrogen and potassium was significant at 4 MAP in 99-00 and at harvest stage in both the years. At all the levels of N in these stages k_2 and k_3 exerted similar effect on magnesium uptake.

The interaction P x K was not significant in either of the years.

Table 35a. Effect of nitrogen, phosphorous and potassium on uptake of magnesium in pseudostem

Main effect of factors	Mg uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	3.04	10.08	3.66	2.91	10.26	3.42
n_2	4.07	11.01	4.42	4.02	11.23	4.03
n_3	4.79	12.74	5.02	4.56	12.31	4.63
$F_{2,27}$	73.35**	715.95**	339.37**	167.35**	283.41**	638.46**
SE_m	0.032	0.050	0.037	0.021	0.061	0.024
CD(0.05)	0.094	0.146	0.107	0.060	0.177	0.070
p_1	3.82	10.87	4.17	3.71	10.94	3.88
p_2	3.99	11.33	4.39	3.82	11.30	4.04
p_3	4.09	11.63	4.54	3.96	11.57	4.17
$F_{2,27}$	17.39**	58.21**	25.65**	37.86**	26.46**	35.97**
SE_m	0.032	0.050	0.037	0.021	0.061	0.024
CD(0.05)	0.094	0.146	0.107	0.060	0.177	0.070
k_1	3.76	10.75	4.03	3.56	10.68	3.78
k_2	3.98	11.41	4.42	3.90	11.37	4.08
k_3	4.06	11.53	4.51	3.95	11.54	4.14
$F_{2,27}$	37.38**	90.94**	72.06**	138.87**	79.32**	84.89**
SE_m	0.032	0.050	0.037	0.021	0.061	0.024
CD(0.05)	0.094	0.146	0.107	0.060	0.177	0.070

** Significant at 1 per cent level

Table 35b. Interaction effect of nitrogen, phosphorus and potassium on uptake of magnesium in pseudostem

Interaction effects	Mg uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	2.78	9.62	3.59	2.76	9.81	3.31
n_1p_2	3.12	10.07	3.78	2.93	10.22	3.45
n_1p_3	3.21	10.55	3.80	3.03	10.76	3.50
n_2p_1	3.92	10.71	4.11	3.92	11.07	3.88
n_2p_2	4.17	11.12	4.50	3.98	11.36	4.03
n_2p_3	4.13	11.23	4.64	4.16	11.27	4.18
n_3p_1	4.68	12.29	4.80	4.44	11.95	4.44
n_3p_2	4.76	12.81	5.07	4.56	12.31	4.65
n_3p_3	4.93	13.13	5.19	4.70	12.67	4.82
$F_{4,27}$	4.55**	1.80	6.85**	0.67	3.97*	3.53*
SE_m	0.056	0.088	0.064	0.036	0.105	0.042
CD(0.05)	0.163	–	0.185	–	0.306	0.121
n_1k_1	2.88	9.70	3.45	2.71	9.74	3.26
n_1k_2	3.00	10.14	3.70	2.93	10.27	3.46
n_1k_3	3.23	10.40	3.84	3.03	10.77	3.53
n_2k_1	3.88	10.43	4.03	3.75	10.66	3.74
n_2k_2	4.06	11.14	4.43	4.11	11.32	4.09
n_2k_3	4.20	11.46	4.60	4.20	11.72	4.21
n_3k_1	4.52	12.11	4.62	4.23	11.64	4.35
n_3k_2	4.89	12.95	5.14	4.65	12.53	4.70
n_3k_3	4.96	13.17	5.30	4.71	12.76	4.60
$F_{4,27}$	1.43	1.76	2.97*	2.81*	0.79	3.15*
SE_m	0.056	0.088	0.064	0.036	0.105	0.042
CD(0.05)	–	–	0.185	0.104	–	0.121
p_1k_1	3.69	10.42	4.04	3.50	10.39	3.73
p_1k_2	3.76	10.94	4.16	3.72	11.05	3.40
p_1k_3	4.02	11.24	4.31	3.90	11.39	4.01
p_2k_1	3.77	10.82	4.99	3.54	10.73	3.78
p_2k_2	4.04	11.45	4.49	3.91	11.41	4.12
p_2k_3	4.15	11.73	4.69	4.02	11.75	4.23
p_3k_1	3.82	11.00	4.06	3.64	10.93	3.84
p_3k_2	4.15	11.84	4.62	4.07	11.66	4.24
p_3k_3	4.30	12.07	4.95	4.17	12.11	4.42
$F_{4,27}$	1.59	0.94	2.57	2.53	0.22	1.46
SE_m	0.056	0.088	0.064	0.036	0.105	0.042
CD(0.05)	–	–	–	–	–	–

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

4.6.5.3 Rhizome

It is clear from Table 36a that uptake of magnesium in rhizome was significantly influenced by different levels of nitrogen, phosphorus and potassium. Increased rates of nitrogen and phosphorus application significantly enhanced magnesium uptake at all stages. In the case of potassium, maximum values were recorded at k_2 level beyond which there was no significant variation in Mg uptake.

The interactions N x P, N x K and P x K could not significantly effect the uptake of magnesium in rhizome during the two years of experimentation (Table 36b).

4.6.6 Iron

4.6.6.1 Leaf

The effect of treatments on uptake of iron in leaf for the two years of experimentation are presented in Tables 37a and 37b.

Application of nitrogen at different levels had significant effect in promoting the iron uptake in leaf with n_3 giving the highest value. The effect of phosphorus and potassium was also significant at all stages. Highest value for iron uptake was recorded at p_3 and k_3 level of phosphorus and potassium respectively at most of the stages.

As presented in Table 37b, N x P interaction was significant at all the stages in both the years. At the lowest and highest levels of nitrogen,

Table 36a. Effect of nitrogen, phosphorus and potassium on uptake of magnesium in rhizome

Main effect of factors	Mg uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	1.07	3.97	1.26	0.96	4.05	1.23
n_2	1.20	4.68	1.42	1.05	4.59	1.41
n_3	1.35	5.38	1.59	1.19	5.06	1.59
$F_{2,27}$	132.10**	655.12**	255.06**	154.12**	232.54**	97.54**
SE_m	0.012	0.028	0.010	0.009	0.033	0.006
CD(0.05)	0.036	0.080	0.029	0.027	0.096	0.016
p_1	1.16	4.47	1.37	1.05	4.40	1.35
p_2	1.20	4.69	1.42	1.06	4.56	1.41
p_3	1.26	4.86	1.48	1.09	4.75	1.47
$F_{2,27}$	14.73**	50.10**	25.79**	5.07**	28.89**	11.56**
SE_m	0.012	0.028	0.010	0.009	0.033	0.006
CD(0.05)	0.036	0.080	0.029	0.027	0.096	0.016
k_1	1.10	4.37	1.34	0.98	4.34	1.34
k_2	1.22	4.77	1.44	1.08	4.65	1.43
k_3	1.25	4.74	1.46	1.09	4.71	1.44
$F_{2,27}$	69.77**	95.42**	64.02**	7.58**	35.81**	12.44**
SE_m	0.012	0.028	0.010	0.009	0.033	0.006
CD(0.05)	0.036	0.080	0.029	0.027	0.096	0.016

** Significant at 1 per cent level

Table 36b. Interaction effect of nitrogen, phosphorus and potassium on uptake of magnesium in rhizome

Interaction effects	Mg uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	1.00	3.78	1.23	0.94	3.87	1.16
n_1p_2	1.09	4.01	1.27	0.96	4.10	1.22
n_1p_3	1.10	4.12	1.30	0.98	4.20	1.32
n_2p_1	1.18	4.52	1.37	1.05	4.44	1.36
n_2p_2	1.16	4.67	1.41	1.04	4.57	1.42
n_2p_3	1.27	4.84	1.47	1.06	4.75	1.46
n_3p_1	1.31	5.12	1.53	1.16	4.89	1.54
n_3p_2	1.35	5.39	1.58	1.17	5.01	1.59
n_3p_3	1.39	5.64	1.65	1.23	5.30	1.64
$F_{4,27}$	2.09	1.51	0.63	1.06	0.77	2.47
SE_m	0.021	0.048	0.018	0.016	0.057	0.010
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.98	3.75	1.21	0.90	3.91	1.17
n_1k_2	1.06	4.02	1.26	0.96	4.09	1.24
n_1k_3	1.16	4.14	1.33	1.02	4.16	1.29
n_2k_1	1.10	4.36	1.31	0.97	4.34	1.35
n_2k_2	1.22	4.76	1.43	1.05	4.67	1.43
n_2k_3	1.29	4.91	1.50	1.13	4.75	1.46
n_3k_1	1.21	5.01	1.48	1.07	4.78	1.51
n_3k_2	1.39	5.52	1.62	1.22	5.19	1.62
n_3k_3	1.45	5.62	1.66	1.27	5.23	1.64
$F_{4,27}$	1.84	1.99	2.28	2.60	1.38	1.36
SE_m	0.021	0.048	0.018	0.016	0.057	0.010
CD(0.05)	–	–	–	–	–	–
p_1k_1	1.08	4.22	1.29	0.98	4.23	1.30
p_1k_2	1.17	4.55	1.38	1.05	4.45	1.35
p_1k_3	1.24	4.65	1.45	1.12	4.51	1.40
p_2k_1	1.10	4.35	1.32	0.97	4.34	1.34
p_2k_2	1.22	4.81	1.44	1.07	4.64	1.43
p_2k_3	1.28	4.91	1.49	1.13	4.71	1.46
p_3k_1	1.12	4.55	1.39	0.99	4.47	1.39
p_3k_2	1.27	4.93	1.48	1.11	4.87	1.50
p_3k_3	1.38	5.11	1.55	1.17	4.92	1.53
$F_{4,27}$	1.67	0.89	0.22	0.58	0.75	2.05
SE_m	0.021	0.048	0.018	0.016	0.057	0.010
CD(0.05)	–	–	–	–	–	–

Table 37a. Effect of nitrogen, phosphorus and potassium on uptake of iron in leaf

Main effect of factors	Fe uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.13	0.38	0.16	0.12	0.36	0.14
n_2	0.14	0.41	0.17	0.13	0.38	0.16
n_3	0.16	0.45	0.18	0.15	0.42	0.17
$F_{2,27}$	104.59**	206.21**	50.92**	138.23**	486.45**	34.73**
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.001
CD(0.05)	0.001	0.002	0.001	0.001	0.004	0.002
p_1	0.14	0.40	0.17	0.13	0.38	0.15
p_2	0.14	0.41	0.17	0.13	0.39	0.16
p_3	0.15	0.42	0.18	0.14	0.40	0.16
$F_{2,27}$	9.15**	12.88**	6.98**	9.86**	33.07**	3.36*
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.001
CD(0.05)	0.001	0.002	0.001	0.001	0.004	0.002
k_1	0.14	0.41	0.17	0.13	0.38	0.15
k_2	0.14	0.41	0.17	0.13	0.39	0.16
k_3	0.15	0.42	0.18	0.14	0.39	0.16
$F_{2,27}$	11.19**	6.91**	11.93**	13.26**	27.10**	4.01*
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.001
CD(0.05)	0.001	0.002	0.001	0.001	0.004	0.002

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

Table 37b. Interaction effect of nitrogen, phosphorus and potassium on uptake of iron in leaf

Interaction effects	Fe uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.13	0.37	0.16	0.12	0.35	0.14
n_1p_2	0.13	0.37	0.16	0.12	0.36	0.14
n_1p_3	0.14	0.38	0.17	0.13	0.36	0.15
n_2p_1	0.13	0.40	0.17	0.13	0.38	0.15
n_2p_2	0.14	0.42	0.17	0.13	0.38	0.16
n_2p_3	0.14	0.42	0.18	0.14	0.39	0.16
n_3p_1	0.15	0.44	0.17	0.14	0.41	0.17
n_3p_2	0.16	0.45	0.17	0.15	0.42	0.17
n_3p_3	0.17	0.46	0.18	0.16	0.44	0.18
$F_{4,27}$	12.27**	6.67**	6.20**	23.66**	2.78*	3.59*
SE_m	0.001	0.001	0.001	0.001	0.003	0.001
CD(0.05)	0.002	0.004	0.002	0.002	0.008	0.004
n_1k_1	0.12	0.37	0.16	0.12	0.35	0.14
n_1k_2	0.13	0.38	0.16	0.12	0.36	0.14
n_1k_3	0.13	0.38	0.17	0.13	0.36	0.15
n_2k_1	0.13	0.40	0.17	0.12	0.38	0.15
n_2k_2	0.14	0.41	0.17	0.13	0.38	0.16
n_2k_3	0.14	0.42	0.18	0.13	0.39	0.16
n_3k_1	0.15	0.44	0.17	0.14	0.41	0.17
n_3k_2	0.16	0.45	0.17	0.15	0.43	0.17
n_3k_3	0.17	0.46	0.18	0.16	0.43	0.17
$F_{4,27}$	7.41**	3.94*	4.57**	22.03**	0.71	1.31
SE_m	0.001	0.001	0.001	0.001	0.003	0.001
CD(0.05)	0.002	0.004	0.002	0.002	–	–
n_1k_1	0.13	0.39	0.17	0.12	0.37	0.15
n_1k_2	0.14	0.40	0.17	0.13	0.38	0.15
n_1k_3	0.14	0.41	0.17	0.13	0.38	0.16
n_2k_1	0.14	0.41	0.17	0.13	0.38	0.15
n_2k_2	0.14	0.41	0.17	0.14	0.39	0.16
n_2k_3	0.15	0.42	0.18	0.14	0.39	0.16
n_3k_1	0.14	0.41	0.17	0.13	0.38	0.16
n_3k_2	0.15	0.42	0.18	0.14	0.40	0.16
n_3k_3	0.15	0.43	0.18	0.14	0.40	0.17
$F_{4,27}$	9.18**	1.65	1.73	0.54	1.04	1.04
SE_m	0.001	0.001	0.001	0.001	0.003	0.001
CD(0.05)	0.002	–	–	–	–	–

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

higher iron uptake in leaf could be obtained in combination with the highest level of phosphorus at all stages except at 6 MAP in 99-00. At this stage p_2 and p_3 had similar effect in n_1 applied plots. But with the medium level of N (n_2), p_2 and p_3 produced similar effect at the initial stages during first year and at harvest stage in the subsequent year.

The interaction, N x K was significant at all stages in 98-99 and at 4 MAP in 99-00. Only at n_3 level, incremental dose of potassium significantly increased the uptake of iron in leaf. The interaction, P x K was significant only at the initial stage in 98-99. At p_1 and p_3 level of phosphorus, significantly higher iron uptake was obtained only upto k_2 level whereas in p_2 applied plots k_3 produced the highest iron uptake in leaf.

4.6.6.2 Pseudostem

Perusal of the data in Table 38a indicates that the variation in uptake of iron due to the effect of different levels of nitrogen, phosphorus and potassium was significant at various growth stages in 98-99 and 99-00.

Different levels of nitrogen significantly increased the iron uptake in pseudostem. Increasing the rate of N significantly increased the uptake of iron at all stages in both the years. Except at 4 MAP in both the years incremental doses of phosphorus significantly increased the iron uptake. Similarly highest rate of potassium also significantly enhanced the values at all stages except at 6 MAP in 99-00.

Table 38a. Effect of nitrogen, phosphorus and potassium on uptake of iron in pseudostem

Main effect of factors	Fe uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.17	0.44	1.24	0.16	0.45	1.17
n_2	0.22	0.46	1.47	0.21	0.47	1.36
n_3	0.25	0.53	1.56	0.24	0.50	1.52
$F_{2,27}$	413.39**	345.57**	43.15**	251.14**	256.60**	199.22**
SE_m	0.001	0.002	0.008	0.001	0.002	0.004
CD(0.05)	0.002	0.007	0.024	0.002	0.005	0.011
p_1	0.21	0.47	1.38	0.20	0.46	1.32
p_2	0.21	0.48	1.43	0.20	0.47	1.36
p_3	0.22	0.49	1.47	0.21	0.48	1.38
$F_{2,27}$	4.10*	13.63**	3.90*	35.91**	30.94**	5.96**
SE_m	0.001	0.002	0.008	0.001	0.002	0.004
CD(0.05)	0.002	0.007	0.024	0.002	0.005	0.011
k_1	0.21	0.46	1.35	0.20	0.46	1.30
k_2	0.21	0.48	1.45	0.20	0.48	1.36
k_3	0.22	0.49	1.47	0.21	0.48	1.38
$F_{2,27}$	3.58*	23.63**	5.80**	23.14**	37.74**	13.20**
SE_m	0.001	0.002	0.008	0.001	0.002	0.004
CD(0.05)	0.002	0.007	0.024	0.002	0.005	0.011

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

Table 38b. Interaction effect of nitrogen, phosphorous and potassium on uptake of iron in pseudostem

Interaction effects	Fe uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.16	0.43	1.20	0.16	0.44	1.15
n_1p_2	0.17	0.44	1.22	0.16	0.45	1.18
n_1p_3	0.17	0.45	1.28	0.16	0.46	1.18
n_2p_1	0.21	0.46	1.42	0.20	0.46	1.31
n_2p_2	0.22	0.46	1.49	0.21	0.47	1.37
n_2p_3	0.22	0.47	1.51	0.22	0.48	1.40
n_3p_1	0.25	0.51	1.52	0.23	0.49	1.49
n_3p_2	0.25	0.53	1.57	0.24	0.50	1.51
n_3p_3	0.26	0.54	1.61	0.24	0.52	1.54
$F_{4,27}$	2.24	0.98	0.92	2.46	2.05	1.76
SE_m	0.001	0.004	0.014	0.001	0.003	0.007
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.17	0.43	1.18	0.16	0.44	1.14
n_1k_2	0.17	0.44	1.26	0.16	0.45	1.18
n_1k_3	0.17	0.45	1.28	0.17	0.46	1.20
n_2k_1	0.21	0.45	1.38	0.21	0.46	1.29
n_2k_2	0.22	0.47	1.51	0.21	0.47	1.39
n_2k_3	0.22	0.47	1.53	0.21	0.48	1.41
n_3k_1	0.25	0.51	1.50	0.23	0.49	1.47
n_3k_2	0.25	0.53	1.60	0.24	0.51	1.53
n_3k_3	0.26	0.54	1.59	0.24	0.52	1.55
$F_{4,27}$	2.37	0.75	2.16	0.77	1.37	2.22
SE_m	0.001	0.004	0.014	0.001	0.003	0.007
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.21	0.45	1.32	0.20	0.45	1.29
n_1k_2	0.21	0.47	1.41	0.20	0.47	1.32
n_1k_3	0.21	0.48	1.40	0.20	0.47	1.34
n_2k_1	0.21	0.46	1.35	0.20	0.46	1.30
n_2k_2	0.22	0.48	1.45	0.20	0.47	1.38
n_2k_3	0.22	0.49	1.48	0.21	0.48	1.40
n_3k_1	0.21	0.47	1.30	0.20	0.47	1.31
n_3k_2	0.22	0.49	1.49	0.21	0.49	1.40
n_3k_3	0.21	0.49	1.52	0.21	0.49	1.41
$F_{4,27}$	0.85	0.04	1.41	0.81	0.33	2.24
SE_m	0.001	0.004	0.014	0.001	0.003	0.007
CD(0.05)	–	–	–	–	–	–

The interactions, N x P, N x K and P x K were not significant in both the years (Table 38b).

4.6.6.3 Rhizome

Table 39a clearly indicates the effect of different levels of nitrogen, phosphorus and potassium on uptake of iron in rhizome.

The effect of nitrogen was significant in both the years of experimentation. Application of n_3 resulted in significantly highest iron uptake in rhizome at all stages except at 4 MAP in 99-00. The influence of phosphorus was significant at all stages except at the initial stage during first year. Increasing rates of phosphorous significantly increased the uptake of iron at 6 MAP in 99-00 and at harvest stage in both the years. Potassium exerted profound influence on iron uptake both in 98-99 and 99-00. At almost all stages except at harvest stage in 98-99, higher rates of applied potassium (k_2 or k_3) was found to enhance the iron uptake in rhizome.

None of the interaction effects were significant in either of the years (Table 39b).

4.6.7 Manganese

4.6.7.1 Leaf

The main and interaction effects of treatments on Mn uptake in leaf at different growth stages in 98-99 and 99-00 are presented in Tables 40a and 40b respectively.

Table 39a. Effect of nitrogen, phosphorus and potassium on uptake of iron in rhizome

Main effect of factors	Fe uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.10	0.27	0.38	0.09	0.27	0.39
n_2	0.11	0.30	0.42	0.10	0.30	0.41
n_3	0.12	0.34	0.46	0.10	0.33	0.46
$F_{2,27}$	36.88**	907.36**	316.40**	121.55**	185.08**	132.27**
SE_m	0.001	0.001	0.002	0.0003	0.002	0.001
CD(0.05)	0.003	0.003	0.007	0.001	0.006	0.003
p_1	0.11	0.30	0.41	0.09	0.29	0.40
p_2	0.11	0.31	0.42	0.10	0.30	0.41
p_3	0.11	0.31	0.43	0.10	0.31	0.42
$F_{2,27}$	2.35	47.56**	27.07**	8.20**	13.45**	10.46**
SE_m	0.001	0.001	0.002	0.0003	0.002	0.001
CD(0.05)	–	0.003	0.007	0.001	0.006	0.003
k_1	0.10	0.30	0.40	0.09	0.29	0.40
k_2	0.11	0.31	0.42	0.10	0.30	0.42
k_3	0.11	0.31	0.43	0.10	0.30	0.42
$F_{2,27}$	15.95**	66.88**	57.49**	25.90**	12.68**	10.00**
SE_m	0.001	0.001	0.002	0.0003	0.002	0.001
CD(0.05)	0.003	0.003	0.007	0.001	0.006	0.003

** Significant at 1 per cent level

Table 39b. Interaction effect of nitrogen, phosphorous and potassium on uptake of iron in rhizome

Interaction effects	Fe uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.10	0.27	0.37	0.09	0.27	0.36
n_1p_2	0.10	0.27	0.38	0.09	0.27	0.37
n_1p_3	0.10	0.28	0.38	0.09	0.28	0.38
n_2p_1	0.11	0.29	0.40	0.10	0.29	0.40
n_2p_2	0.11	0.31	0.42	0.10	0.30	0.41
n_2p_3	0.11	0.31	0.44	0.10	0.31	0.42
n_3p_1	0.11	0.33	0.45	0.10	0.32	0.44
n_3p_2	0.12	0.35	0.46	0.10	0.32	0.46
n_3p_3	0.12	0.35	0.47	0.10	0.33	0.47
$F_{4,27}$	0.24	1.74	1.11	0.56	0.52	1.91
SE_m	0.002	0.002	0.004	0.001	0.003	0.002
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.10	0.27	0.37	0.09	0.27	0.36
n_1k_2	0.10	0.28	0.38	0.09	0.27	0.37
n_1k_3	0.11	0.28	0.38	0.09	0.27	0.38
n_2k_1	0.11	0.29	0.39	0.09	0.29	0.40
n_2k_2	0.11	0.30	0.42	0.10	0.30	0.42
n_2k_3	0.12	0.31	0.44	0.10	0.30	0.42
n_3k_1	0.11	0.33	0.44	0.10	0.31	0.44
n_3k_2	0.12	0.35	0.47	0.10	0.33	0.46
n_3k_3	0.12	0.35	0.48	0.11	0.33	0.47
$F_{4,27}$	0.72	2.50	2.25	0.03	0.67	1.13
SE_m	0.002	0.002	0.004	0.001	0.003	0.002
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.10	0.29	0.39	0.09	0.29	0.39
p_1k_2	0.11	0.30	0.41	0.09	0.29	0.40
p_1k_3	0.11	0.31	0.42	0.10	0.29	0.41
p_2k_1	0.11	0.30	0.40	0.09	0.29	0.40
p_2k_2	0.11	0.31	0.43	0.10	0.30	0.42
p_2k_3	0.11	0.32	0.43	0.10	0.30	0.42
p_3k_1	0.11	0.30	0.41	0.10	0.29	0.41
p_3k_2	0.11	0.32	0.44	0.10	0.31	0.43
p_3k_3	0.12	0.32	0.44	0.10	0.31	0.43
$F_{4,27}$	0.65	0.28	0.33	0.49	0.38	1.15
SE_m	0.002	0.002	0.004	0.001	0.003	0.002
CD(0.05)	–	–	–	–	–	–

Table 40a. Effect of nitrogen, phosphorus and potassium on uptake of manganese in leaf

Main effect of factors	Mn uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.08	0.24	0.09	0.07	0.22	0.08
n_2	0.09	0.25	0.09	0.08	0.24	0.09
n_3	0.10	0.28	0.10	0.09	0.26	0.09
$F_{2,27}$	111.88**	110.09**	37.61**	206.39**	598.82**	397.57**
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.003	0.001
p_1	0.08	0.25	0.09	0.08	0.23	0.08
p_2	0.09	0.26	0.09	0.09	0.24	0.09
p_3	0.09	0.26	0.10	0.09	0.25	0.09
$F_{2,27}$	11.07**	10.61**	5.68**	15.52**	56.48**	25.41**
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.003	0.001
k_1	0.08	0.25	0.09	0.08	0.23	0.08
k_2	0.09	0.26	0.09	0.09	0.24	0.09
k_3	0.09	0.26	0.10	0.09	0.25	0.09
$F_{2,27}$	18.10**	13.86**	15.82**	27.29**	70.10**	71.92**
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.003	0.001

** Significant at 1 per cent level

Table 40b. Interaction effect of nitrogen, phosphorous and potassium on uptake of manganese in leaf

Interaction effects	Mn uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.08	0.23	0.09	0.07	0.21	0.08
n_1p_2	0.08	0.24	0.09	0.07	0.22	0.08
n_1p_3	0.08	0.24	0.09	0.08	0.22	0.08
n_2p_1	0.08	0.25	0.09	0.08	0.23	0.08
n_2p_2	0.09	0.26	0.10	0.08	0.24	0.08
n_2p_3	0.09	0.26	0.10	0.08	0.24	0.09
n_3p_1	0.09	0.27	0.09	0.09	0.25	0.09
n_3p_2	0.10	0.28	0.10	0.10	0.26	0.09
n_3p_3	0.10	0.29	0.10	0.10	0.27	0.09
$F_{4,27}$	3.40*	4.70**	2.75*	3.08*	4.10*	2.37
SE_m	0.0003	0.001	0.0003	0.0003	0.002	0.001
CD(0.05)	0.001	0.003	0.001	0.001	0.005	–
n_1k_1	0.08	0.23	0.09	0.07	0.21	0.07
n_1k_2	0.08	0.24	0.09	0.07	0.22	0.08
n_1k_3	0.08	0.24	0.09	0.07	0.22	0.08
n_2k_1	0.08	0.25	0.09	0.07	0.23	0.08
n_2k_2	0.09	0.25	0.09	0.08	0.24	0.09
n_2k_3	0.09	0.26	0.10	0.08	0.24	0.09
n_3k_1	0.09	0.27	0.09	0.09	0.25	0.09
n_3k_2	0.10	0.28	0.10	0.10	0.27	0.09
n_3k_3	0.10	0.29	0.10	0.10	0.27	0.09
$F_{4,27}$	9.82**	7.13**	1.85	3.74*	1.99	2.27
SE_m	0.0003	0.001	0.0003	0.0003	0.002	0.001
CD(0.05)	0.001	0.003	–	0.001	–	–
p_1k_1	0.08	0.24	0.09	0.08	0.22	0.08
p_1k_2	0.09	0.25	0.09	0.08	0.23	0.08
p_1k_3	0.09	0.25	0.09	0.08	0.24	0.08
p_2k_1	0.08	0.25	0.09	0.08	0.23	0.08
p_2k_2	0.09	0.26	0.10	0.08	0.24	0.09
p_2k_3	0.09	0.26	0.10	0.08	0.25	0.09
p_3k_1	0.08	0.25	0.09	0.08	0.24	0.08
p_3k_2	0.09	0.26	0.10	0.08	0.25	0.09
p_3k_3	0.10	0.27	0.10	0.09	0.25	0.09
$F_{4,27}$	10.06**	3.44*	5.39**	2.23	2.74*	2.11
SE_m	.0.0003	0.001	0.0003	0.0003	0.002	0.001
CD(0.05)	0.001	0.003	0.001	–	0.005	–

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

Increasing rates of nitrogen application significantly enhanced the uptake of Mn at most of the stages. However, at harvest stage in 99-00, n_2 and n_3 were on par. The effect of phosphorus and potassium was significant only upto p_2 and k_2 respectively at most of the stages except at harvest stage in 98-99 and 6 MAP in 99-00. At these stages highest uptake was recorded by p_3 and k_3 respectively.

The interaction N x P was significant throughout except at harvest stage in 99-00. At 4 MAP and harvest stage in 98-99, in plots that received n_1, p_1 was sufficient for enhancing the Mn uptake in leaf. Whereas at 6 MAP in both the years, p_2 and p_3 turned equally effective in n_1 applied plots. The higher levels of phosphorus p_2 and p_3 exerted similar effect in combination with n_2. At 6 MAP in both the years p_3 recorded significantly higher Mn uptake in n_3 treated plots (Table 40b).

The N x K interaction was significant at 4 MAP in both the years and at 6 MAP in 98-99. At all levels of nitrogen, k_2 and k_3 were on par during the first phase in 98-99 and 99-00. At 6 MAP in 98-99, k_3 recorded significantly higher Mn uptake in n_2 and n_3 treated plots.

The variation in the uptake of Mn due to P x K interaction was significant at all stages in the first year and 6 MAP in the second year. During 98-99, significantly higher response was obtained upto k_2 in p_1 and p_2 applied plots whereas during subsequent year the response was significant upto k_3. In p_3 treated plots, increasing levels of potassium significantly increased the Mn uptake at the initial two stages during the first year.

4.6.7.2 Pseudostem

Table 41a clearly depicts that nitrogen, phosphorous and potassium applied at different doses significantly influenced the uptake of Mn in pseudostem. Increasing the rate of nitrogen from n_1 to n_3 resulted in a significant increase in Mn uptake in pseudostem. At 6 MAP in 98-99 and at harvest stage in both the years incremental doses of phosphorus and potassium significantly increased the Mn uptake.

As shown in Table 41b, N x K interaction was significant at the initial stage in both the years. At n_1 and n_3 levels k_2 and k_3 were on par. The interactions N x P and P x K were not significant in either of the years.

4.6.7.3 Rhizome

It is clear from Table 42a that different levels of N, P and K profoundly influenced the uptake of manganese in rhizome. Except at the initial stage in both the years Mn uptake significantly increased with increasing levels of N and P with the maximum values at n_3 and p_3 respectively. But in the case of potassium, the higher levels, k_2 and k_3 had similar effect at all stages except at 6 MAP in 98-99.

Interaction effects are furnished in Table 42b. The interaction between nitrogen and potassium was significant at 4 MAP and harvest stage in 98-99. In combination with all levels of nitrogen, k_3 resulted in significantly higher values. The interactions, N x P and P x K were not significant in either of the years.

Table 41a. Effect of nitrogen, phosphorus and potassium on uptake of manganese in pseudostem

Main effect of factors	Mn uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.12	0.28	0.83	0.11	0.29	0.78
n_2	0.15	0.30	0.98	0.14	0.30	0.91
n_3	0.18	0.34	1.06	0.16	0.33	1.02
$F_{2,27}$	352.04**	332.00**	417.90**	269.05**	143.97**	235.58**
SE_m	0.0003	0.002	0.006	0.0003	0.001	0.002
CD(0.05)	0.001	0.005	0.016	0.001	0.004	0.007
p_1	0.14	0.30	0.93	0.13	0.30	0.88
p_2	0.15	0.31	0.96	0.14	0.31	0.91
p_3	0.15	0.32	0.99	0.14	0.31	0.92
$F_{2,27}$	3.90*	17.94**	28.30**	3.30*	21.20**	79.72**
SE_m	0.0003	0.002	0.006	0.0003	0.001	0.002
CD(0.05)	0.001	0.005	0.016	0.001	0.004	0.007
k_1	0.14	0.30	0.90	0.13	0.30	0.86
k_2	0.15	0.31	0.98	0.14	0.31	0.92
k_3	0.15	0.32	0.99	0.14	0.31	0.93
$F_{2,27}$	5.21*	30.75**	67.97**	4.99*	31.31**	21.03**
SE_m	0.0003	0.002	0.006	0.0003	0.001	0.002
CD(0.05)	0.001	0.005	0.016	0.001	0.004	0.007

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

Table 41b. Interaction effect of nitrogen, phosphorus and potassium on uptake of manganese in pseudostem

Interaction effects	Mn uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.11	0.28	0.81	0.11	0.29	0.76
n_1p_2	0.12	0.28	0.82	0.11	0.29	0.79
n_1p_3	0.12	0.29	0.86	0.11	0.29	0.79
n_2p_1	0.15	0.30	0.94	0.14	0.30	0.87
n_2p_2	0.15	0.30	0.99	0.14	0.30	0.91
n_2p_3	0.16	0.31	1.01	0.15	0.31	0.93
n_3p_1	0.17	0.33	1.03	0.16	0.32	1.00
n_3p_2	0.17	0.34	1.06	0.16	0.32	1.01
n_3p_3	0.18	0.35	1.09	0.17	0.33	1.04
$F_{4,27}$	1.25	2.02	1.31	2.70	1.17	1.90
SE_m	0.001	0.003	0.010	0.001	0.002	0.004
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.11	0.28	0.78	0.11	0.28	0.75
n_1k_2	0.12	0.29	0.85	0.11	0.29	0.78
n_1k_3	0.12	0.29	0.87	0.11	0.30	0.80
n_2k_1	0.15	0.29	0.91	0.14	0.29	0.85
n_2k_2	0.15	0.30	1.00	0.14	0.30	0.93
n_2k_3	0.16	0.31	1.02	0.15	0.31	0.94
n_3k_1	0.17	0.33	1.01	0.16	0.31	0.98
n_3k_2	0.18	0.35	1.09	0.17	0.33	1.03
n_3k_3	0.18	0.35	1.08	0.17	0.33	1.04
$F_{4,27}$	3.51*	1.11	1.83	4.47**	0.60	2.18
SE_m	0.001	0.003	0.010	0.001	0.002	0.004
CD(0.05)	0.002	–	–	0.003	–	–
p_1k_1	0.14	0.29	0.88	0.13	0.29	0.85
p_1k_2	0.14	0.30	0.95	0.14	0.30	0.88
p_1k_3	0.15	0.31	0.95	0.14	0.30	0.90
p_2k_1	0.14	0.30	0.91	0.13	0.30	0.86
p_2k_2	0.15	0.31	0.98	0.14	0.31	0.92
p_2k_3	0.15	0.31	1.00	0.14	0.31	0.93
p_3k_1	0.15	0.30	0.92	0.14	0.30	0.87
p_3k_2	0.15	0.32	1.01	0.14	0.32	0.91
p_3k_3	0.15	0.32	1.03	0.15	0.33	0.95
$F_{4,27}$	1.06	0.15	1.24	1.16	0.27	2.46
SE_m	0.001	0.003	0.010	0.001	0.002	0.004
CD(0.05)	–	–	–	–	–	–

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

Table 42a. Effect of nitrogen, phosphorus and potassium on uptake of manganese in rhizome

Main effect of factors	Mn uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.06	0.18	0.25	0.05	0.18	0.24
n_2	0.07	0.21	0.27	0.06	0.20	0.26
n_3	0.07	0.24	0.30	0.06	0.22	0.29
$F_{2,27}$	85.53**	126.48**	292.44**	131.77**	220.94**	61.83**
SE_m	0.001	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	0.002	0.002	0.004	0.001	0.004	0.003
p_1	0.06	0.20	0.26	0.05	0.20	0.25
p_2	0.07	0.21	0.27	0.06	0.20	0.26
p_3	0.07	0.22	0.28	0.06	0.21	0.27
$F_{2,27}$	5.42*	7.30**	27.23**	9.59**	20.17**	5.21*
SE_m	0.001	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	0.002	0.002	0.004	0.001	0.004	0.003
k_1	0.06	0.20	0.26	0.05	0.20	0.25
k_2	0.07	0.21	0.28	0.06	0.21	0.27
k_3	0.07	0.22	0.28	0.06	0.21	0.27
$F_{2,27}$	37.69**	15.12**	58.99**	30.36**	37.19**	9.70**
SE_m	0.001	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	0.002	0.002	0.004	0.001	0.004	0.003

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

Table 42b. Interaction effect of nitrogen, phosphorus and potassium on uptake of manganese in rhizome

Interaction effects	Mn uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.06	0.18	0.24	0.05	0.18	0.23
n_1p_2	0.06	0.18	0.25	0.05	0.18	0.24
n_1p_3	0.06	0.19	0.25	0.05	0.19	0.24
n_2p_1	0.07	0.20	0.26	0.06	0.20	0.25
n_2p_2	0.07	0.21	0.27	0.06	0.20	0.26
n_2p_3	0.07	0.21	0.28	0.06	0.21	0.26
n_3p_1	0.07	0.23	0.29	0.06	0.22	0.28
n_3p_2	0.07	0.24	0.30	0.06	0.22	0.29
n_3p_3	0.07	0.24	0.31	0.06	0.23	0.30
$F_{4,27}$	0.47	2.28	1.89	0.59	0.20	0.54
SE_m	0.001	0.001	0.003	0.001	0.002	0.002
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.06	0.18	0.24	0.05	0.18	0.23
n_1k_2	0.06	0.18	0.24	0.05	0.18	0.24
n_1k_3	0.06	0.19	0.25	0.06	0.19	0.24
n_2k_1	0.06	0.20	0.25	0.06	0.19	0.25
n_2k_2	0.07	0.21	0.27	0.06	0.21	0.27
n_2k_3	0.07	0.22	0.28	0.06	0.21	0.27
n_3k_1	0.07	0.22	0.28	0.06	0.21	0.28
n_3k_2	0.07	0.24	0.30	0.06	0.23	0.29
n_3k_3	0.07	0.25	0.31	0.06	0.23	0.30
$F_{4,27}$	1.56	6.03**	2.85*	0.09	2.37	1.31
SE_m	0.001	0.001	0.003	0.001	0.002	0.002
CD(0.05)	–	0.004	0.008	–	–	–
p_1k_1	0.06	0.19	0.25	0.05	0.19	0.24
p_1k_2	0.06	0.21	0.27	0.06	0.20	0.26
p_1k_3	0.07	0.21	0.27	0.06	0.20	0.26
p_2k_1	0.06	0.20	0.26	0.06	0.19	0.25
p_2k_2	0.07	0.20	0.27	0.06	0.21	0.27
p_2k_3	0.07	0.22	0.28	0.06	0.21	0.27
p_3k_1	0.06	0.21	0.27	0.06	0.20	0.26
p_3k_2	0.07	0.22	0.28	0.06	0.21	0.27
p_3k_3	0.07	0.22	0.29	0.06	0.21	0.28
$F_{4,27}$	1.13	0.22	0.30	0.34	0.70	1.42
SE_m	0.001	0.001	0.003	0.001	0.002	0.002
CD(0.05)	–	–	–	–	–	–

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

4.6.8 Zinc

4.6.8.1 Leaf

As depicted in Table 43a uptake of zinc in leaf was significantly influenced by different levels of N, P and K. Except at 6 MAP, n_2 and n_3 had similar effect on Zn uptake. The higher levels of phosphorus (p_2 and p_3) and potassium (k_2 and k_3) were on par at all stages during 98-99 and at 4 MAP during 99-00. At 6 MAP in 99-00 maximum value was recorded by p_3 and k_3 respectively. The effect of P was not significant at harvest stage in 99-00. The interactions, N x P, N x K and P x K were not significant in both the years (Table 43b).

4.6.8.2 Pseudostem

The data on the uptake of zinc in pseudostem at various growth stages in 98-99 and 99-00 are furnished in Table 44a and Table 44b. The effect of nitrogen was significant throughout the period of experimentation. Increments in N levels significantly promoted Zn uptake with n_3 recording highest value. But n_2 and n_3 were on par at 4 MAP in 99-00. The effect of phosphorus was significant at all stages except at 6 MAP in 98-99. In the initial stages of crop growth p_2 and p_3 were on par. Potassium nutrition influenced Zn uptake at 4 MAP in 98-99, 6 MAP in 99-00 and at harvest stage in two years. Increasing levels of K significantly increased Zn uptake during 99-00.

None of the interaction effects were significant in either of the years (Table 44b).

Table 43a. Effect of nitrogen, phosphorus and potassium on uptake of zinc in leaf

Main effect of factors	Zn uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.01	0.07	0.01	0.01	0.06	0.01
n_2	0.02	0.08	0.02	0.02	0.07	0.02
n_3	0.02	0.09	0.02	0.02	0.08	0.02
$F_{2,27}$	165.83**	292.46**	72.52**	131.89**	220.97**	55.79**
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.001	0.001	0.001	0.001
p_1	0.01	0.07	0.01	0.01	0.07	0.02
p_2	0.02	0.08	0.02	0.02	0.07	0.02
p_3	0.02	0.08	0.02	0.02	0.08	0.02
$F_{2,27}$	33.39**	17.55**	14.26**	27.74**	23.91**	2.29
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.001	0.001	0.001	—
k_1	0.01	0.07	0.01	0.01	0.07	0.01
k_2	0.02	0.08	0.02	0.02	0.07	0.02
k_3	0.02	0.08	0.02	0.02	0.08	0.02
$F_{2,27}$	27.40**	11.38**	22.72**	25.79**	24.12**	6.97**
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.001	0.001	0.001	0.001

** Significant at 1 per cent level

Table 43b. Interaction effect of nitrogen, phosphorus and potassium on uptake of zinc in leaf

Interaction effects	Zn uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.01	0.07	0.02	0.01	0.07	0.01
n_1p_2	0.02	0.07	0.02	0.02	0.07	0.02
n_1p_3	0.02	0.07	0.02	0.02	0.07	0.02
n_2p_1	0.01	0.08	0.02	0.01	0.07	0.02
n_2p_2	0.02	0.08	0.02	0.02	0.07	0.02
n_2p_3	0.02	0.08	0.02	0.02	0.07	0.02
n_3p_1	0.02	0.08	0.02	0.02	0.08	0.02
n_3p_2	0.02	0.08	0.02	0.02	0.08	0.02
n_3p_3	0.02	0.09	0.02	0.02	0.08	0.02
$F_{4,27}$	2.67	2.55	0.15	2.31	0.65	1.80
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.01	0.07	0.02	0.01	0.07	0.02
n_1k_2	0.02	0.07	0.02	0.01	0.07	0.02
n_1k_3	0.02	0.07	0.02	0.02	0.07	0.02
n_2k_1	0.02	0.08	0.02	0.01	0.07	0.02
n_2k_2	0.02	0.08	0.02	0.02	0.07	0.02
n_2k_3	0.02	0.08	0.02	0.02	0.07	0.02
n_3k_1	0.02	008	0.02	0.02	0.08	0.02
n_3k_2	0.02	0.09	0.02	0.02	0.08	0.02
n_3k_3	0.02	0.09	0.02	0.02	0.08	0.02
$F_{4,27}$	2.68	1.55	1.18	2.14	0.77	0.19
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.02	0.07	0.02	0.02	0.07	0.02
p_1k_2	0.02	0.07	0.02	0.02	0.07	0.02
p_1k_3	0.02	0.08	0.02	0.02	0.07	0.02
p_2k_1	0.02	0.07	0.02	0.02	0.07	0.02
p_2k_2	0.02	0.08	0.02	0.02	0.07	0.02
p_2k_3	0.02	0.08	0.02	0.02	0.07	0.02
p_3k_1	0.02	0.08	0.02	0.02	0.07	0.02
p_3k_2	0.02	0.08	0.02	0.02	0.08	0.02
p_3k_3	0.02	0.08	0.02	0.02	0.08	0.02
$F_{4,27}$	0.92	0.44	1.02	0.74	2.01	0.98
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–

Table 44a. Effect of nitrogen, phosphorous and potassium on uptake of zinc in pseudostem

Main effect of factors	Zn uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.03	0.08	0.17	0.03	0.08	0.16
n_2	0.04	0.09	0.21	0.04	0.09	0.19
n_3	0.05	0.10	0.23	0.04	0.10	0.22
$F_{2,27}$	56.28**	96.86**	112.28**	22.20**	138.73**	307.93**
SE_m	0.0003	0.001	0.002	0.0003	0.001	0.002
CD(0.05)	0.001	0.003	0.007	0.001	0.002	0.005
p_1	0.03	0.09	0.20	0.03	0.08	0.19
p_2	0.04	0.09	0.20	0.04	0.09	0.19
p_3	0.04	0.09	0.21	0.04	0.09	0.20
$F_{2,27}$	7.19**	2.97	4.35*	4.08*	21.63**	8.18**
SE_m	0.0003	0.001	0.002	0.0003	0.001	0.002
CD(0.05)	0.001	–	0.007	0.001	0.002	0.005
k_1	0.03	0.09	0.19	0.03	0.08	0.18
k_2	0.04	0.09	0.21	0.03	0.09	0.19
k_3	0.04	0.09	0.21	0.03	0.10	0.20
$F_{2,27}$	45.41**	0.64	12.61**	2.03	51.74**	23.72**
SE_m	0.0003	0.001	0.002	0.0003	0.001	0.002
CD(0.05)	0.001	–	0.007	–	0.002	0.005

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

Table 44b. Interaction effect of nitrogen, phosphorus and potassium on uptake of zinc and pseudostem

Interaction effects	Zn uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.03	0.08	0.17	0.03	0.08	0.15
n_1p_2	0.03	0.08	0.17	0.03	0.08	0.16
n_1p_3	0.03	0.08	0.18	0.03	0.09	0.16
n_2p_1	0.04	0.08	0.20	0.04	0.09	0.19
n_2p_2	0.04	0.08	0.21	0.04	0.09	0.20
n_2p_3	0.04	0.09	0.22	0.04	0.09	0.20
n_3p_1	0.04	0.10	0.22	0.04	0.10	0.22
n_3p_2	0.05	0.10	0.23	0.04	0.10	0.22
n_3p_3	0.05	0.10	0.23	0.04	0.10	0.22
$F_{4,27}$	0.69	0.28	0.26	0.70	2.15	0.92
SE_m	0.001	0.002	0.004	0.001	0.001	0.003
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.03	0.08	0.17	0.03	0.08	0.15
n_1k_2	0.03	0.08	0.18	0.03	0.08	0.16
n_1k_3	0.03	0.08	0.18	0.03	0.09	0.16
n_2k_1	0.04	0.09	0.20	0.04	0.09	0.18
n_2k_2	0.04	0.09	0.21	0.04	0.09	0.20
n_2k_3	0.04	0.09	0.22	0.04	0.09	0.20
n_3k_1	0.04	0.10	0.21	0.04	0.09	0.21
n_3k_2	0.05	0.10	0.23	0.04	0.10	0.22
n_3k_3	0.05	0.10	0.23	0.04	0.10	0.23
$F_{4,27}$	2.62	1.52	0.66	0.39	1.20	1.22
SE_m	0.001	0.002	0.004	0.001	0.001	0.003
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.04	0.09	0.19	0.03	0.08	0.18
p_1k_2	0.04	0.09	0.20	0.03	0.09	0.19
p_1k_3	0.04	0.09	0.20	0.03	0.09	0.19
p_2k_1	0.04	0.09	0.19	0.03	0.09	0.18
p_2k_2	0.04	0.09	0.20	0.04	0.09	0.19
p_2k_3	0.04	0.09	0.21	0.04	0.09	0.20
p_3k_1	0.04	0.09	0.20	0.04	0.09	0.18
p_3k_2	0.04	0.09	0.21	0.04	0.10	0.20
p_3k_3	0.04	0.09	0.21	0.04	0.10	0.20
$F_{4,27}$	1.59	0.90	0.48	0.25	1.66	2.00
SE_m	0.001	0.002	0.004	0.001	0.001	0.003
CD(0.05)	–	–	–	–	–	–

4.6.8.3 Rhizome

Nitrogen, phosphorus and potassium applied at different levels had significant influence on uptake of zinc in rhizome (Table 45a). At all stages except at 4 MAP in 98-99 and 6 MAP in 99-00, n_3 produced significantly highest Zn uptake. At most of the stages p_2 and p_3 as well as k_2 and k_3 were on par. The interactions N x P, N x K and P x K were not significant in either of the years (Table 45b).

4.6.9 Copper

4.6.9.1 Leaf

The uptake of copper in leaf at various growth stages in 98-99 and 99-00 are presented in Tables 46a and 46b.

As shown in Table 46a, different levels of nitrogen, phosphorous and potassium significantly influenced the Cu uptake in leaf at all stages. The highest level of nitrogen (n_3) and phosphorus (p_3) produced significantly higher uptake at 4 MAP in both years and at harvest stage in 99-00. Except at 4 MAP in both the years, higher levels of potassium (k_2 and k_3) exerted similar effect on Cu uptake. None of the interactions were significant in either of the years (Table 46b).

4.6.9.2 Pseudostem

It is evident from Table 47a, different levels of N, P and K profoundly influenced the uptake of copper in pseudostem. At all stages

Table 45a. Effect of nitrogen, phosphorus and potassium on uptake of zinc in rhizome

Main effect of factors	Zn uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.01	0.05	0.06	0.01	0.05	0.06
n_2	0.02	0.06	0.07	0.01	0.06	0.07
n_3	0.02	0.07	0.08	0.02	0.06	0.08
$F_{2,27}$	55.99**	259.19**	170.72**	89.03**	132.31**	363.21**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.002	0.001	0.001	0.001
p_1	0.01	0.05	0.06	0.01	0.05	0.06
p_2	0.02	0.06	0.07	0.01	0.06	0.07
p_3	0.02	0.06	0.07	0.02	0.06	0.07
$F_{2,27}$	6.02**	9.34**	11.41**	3.95*	8.75**	41.45**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.002	0.001	0.001	0.001
k_1	0.01	0.05	0.06	0.01	0.05	0.06
k_2	0.02	0.06	0.07	0.01	0.06	0.07
k_3	0.02	0.06	0.08	0.02	0.06	0.07
$F_{2,27}$	22.56**	43.29**	93.59**	15.38**	30.91**	125.36**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.001	0.002	0.001	0.001	0.001

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

Table 45b. Interaction effect of nitrogen, phosphorus and potassium on uptake of zinc in rhizome

Interaction effects	Zn uptake of rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.01	0.05	0.06	0.01	0.05	0.06
n_1p_2	0.01	0.05	0.06	0.01	0.05	0.06
n_1p_3	0.02	0.05	0.06	0.01	0.05	0.06
n_2p_1	0.02	0.06	0.07	0.01	0.06	0.07
n_2p_2	0.02	0.06	0.07	0.01	0.06	0.07
n_2p_3	0.02	0.06	0.07	0.01	0.06	0.07
n_3p_1	0.02	0.06	0.08	0.02	0.06	0.08
n_3p_2	0.02	0.07	0.08	0.02	0.06	0.08
n_3p_3	0.02	0.07	0.08	0.02	0.06	0.08
$F_{4,27}$	0.17	1.18	0.36	2.48	0.17	2.54
SE_m	0.0003	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.01	0.05	0.06	0.01	0.05	0.06
n_1k_2	0.01	0.05	0.06	0.01	0.05	0.06
n_1k_3	0.02	0.05	0.07	0.01	0.05	0.06
n_2k_1	0.02	0.06	0.06	0.01	0.05	0.06
n_2k_2	0.02	0.06	0.07	0.01	0.06	0.07
n_2k_3	0.02	0.06	0.07	0.01	0.06	0.07
n_3k_1	0.02	0.06	0.07	0.01	0.06	0.07
n_3k_2	0.02	0.07	0.08	0.01	0.06	0.08
n_3k_3	0.02	0.07	0.08	0.01	0.06	0.08
$F_{4,27}$	0.87	2.52	2.06	1.72	1.27	2.67
SE_m	0.0003	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.01	0.06	0.06	0.01	0.06	0.06
p_1k_2	0.02	0.06	0.07	0.01	0.06	0.07
p_1k_3	0.02	0.06	0.07	0.01	0.06	0.07
p_2k_1	0.02	0.06	0.06	0.01	0.06	0.06
p_2k_2	0.02	0.06	0.07	0.01	0.06	0.07
p_2k_3	0.02	0.06	0.07	0.01	0.06	0.07
p_3k_1	0.01	0.06	0.07	0.01	0.06	0.07
p_3k_2	0.02	0.06	0.08	0.01	0.06	0.07
p_3k_3	0.02	0.06	0.08	0.01	0.06	0.07
$F_{4,27}$	1.59	0.33	0.68	0.43	1.10	0.38
SE_m	0.0003	0.001	0.001	0.0003	0.001	0.001
CD(0.05)	–	–	–	–	–	–

Table 46a. Effect of nitrogen, phosphorus and potassium on uptake of copper in leaf

Main effect of factors	Cu uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.01	0.04	0.01	0.01	0.04	0.01
n_2	0.01	0.05	0.02	0.01	0.05	0.01
n_3	0.02	0.05	0.02	0.02	0.05	0.02
$F_{2,27}$	21.53**	47.22**	24.69**	25.32**	40.09**	14.34**
SE_m	0.0003	0.001	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.001	0.001
p_1	0.01	0.04	0.01	0.01	0.04	0.01
p_2	0.01	0.05	0.02	0.01	0.05	0.01
p_3	0.02	0.05	0.02	0.02	0.05	0.02
$F_{2,27}$	3.87*	4.64*	4.72*	3.97*	3.37*	3.08*
SE_m	0.0003	0.001	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.001	0.001
k_1	0.01	0.04	0.01	0.01	0.04	0.01
k_2	0.01	0.05	0.02	0.01	0.05	0.02
k_3	0.02	0.05	0.02	0.02	0.05	0.02
$F_{2,27}$	3.55*	22.97**	14.90**	4.35*	7.81**	5.53**
SE_m	0.0003	0.001	0.0003	0.0003	0.0003	0.0003
CD(0.05)	0.001	0.002	0.001	0.001	0.001	0.001

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

Table 46b. Interaction effect of nitrogen, phosphorus and potassium on copper uptake in leaf

Interaction effects	Cu uptake in leaf (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.01	0.04	0.01	0.01	0.04	0.01
n_1p_2	0.01	0.05	0.01	0.01	0.04	0.01
n_1p_3	0.01	0.05	0.01	0.01	0.04	0.01
n_2p_1	0.01	0.05	0.01	0.01	0.05	0.01
n_2p_2	0.01	0.05	0.01	0.01	0.05	0.01
n_2p_3	0.01	0.05	0.01	0.01	0.05	0.01
n_3p_1	0.02	0.05	0.02	0.01	0.05	0.02
n_3p_2	0.02	0.05	0.02	0.01	0.05	0.02
n_3p_3	0.02	0.05	0.02	0.01	0.05	0.02
$F_{4,27}$	0.53	0.96	1.51	2.71	1.93	2.50
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.01	0.04	0.01	0.01	0.04	0.01
n_1k_2	0.01	0.04	0.01	0.01	0.04	0.01
n_1k_3	0.01	0.05	0.01	0.01	0.04	0.01
n_2k_1	0.01	0.05	0.01	0.01	0.04	0.01
n_2k_2	0.01	0.05	0.01	0.01	0.05	0.01
n_2k_3	0.01	0.05	0.01	0.01	0.05	0.01
n_3k_1	0.01	0.05	0.02	0.01	0.05	0.01
n_3k_2	0.02	0.05	0.02	0.01	0.05	0.02
n_3k_3	0.02	0.06	0.02	0.01	0.05	0.02
$F_{4,27}$	1.01	0.62	2.52	2.67	1.46	1.09
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.01	0.04	0.01	0.01	0.04	0.01
p_1k_2	0.01	0.05	0.01	0.01	0.05	0.01
p_1k_3	0.01	0.05	0.01	0.01	0.05	0.01
p_2k_1	0.01	0.05	0.01	0.01	0.04	0.01
p_2k_2	0.01	0.05	0.01	0.01	0.05	0.01
p_2k_3	0.01	0.05	0.01	0.01	0.05	0.01
p_3k_1	0.01	0.05	0.01	0.01	0.04	0.01
p_3k_2	0.01	0.05	0.02	0.01	0.05	0.02
p_3k_3	0.01	0.05	0.02	0.01	0.05	0.02
$F_{4,27}$	0.73	0.32	2.70	2.29	1.03	2.05
SE_m	0.0003	0.001	0.0003	0.0003	0.001	0.0003
CD(0.05)	–	–	–	–	–	–

Table 47a. Effect of nitrogen, phosphorus and potassium on uptake of copper in pseudostem

Main effect of factors	Cu uptake in pseudostem (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.02	0.07	0.15	0.02	0.07	0.14
n_2	0.03	0.07	0.19	0.03	0.07	0.18
n_3	0.04	0.09	0.20	0.03	0.08	0.20
$F_{2,27}$	34.62**	119.80**	92.16**	41.89**	72.26**	227.66**
SE_m	0.0003	0.001	0.003	0.0003	0.001	0.002
CD(0.05)	0.001	0.003	0.008	0.001	0.002	0.006
p_1	0.02	0.07	0.17	0.02	0.07	0.17
p_2	0.03	0.08	0.18	0.03	0.07	0.17
p_3	0.03	0.08	0.19	0.03	0.08	0.18
$F_{2,27}$	5.03*	8.62**	9.26**	11.65**	13.90**	18.45**
SE_m	0.0003	0.001	0.003	0.0003	0.001	0.002
CD(0.05)	0.001	0.003	0.008	0.001	0.002	0.006
k_1	0.02	0.07	0.17	0.02	0.07	0.16
k_2	0.03	0.08	0.18	0.03	0.08	0.18
k_3	0.03	0.08	0.19	0.03	0.08	0.18
$F_{2,27}$	23.60**	11.88**	18.19**	25.08**	13.10**	16.61**
SE_m	0.0003	0.001	0.003	0.0003	0.001	0.002
CD(0.05)	0.001	0.003	0.008	0.001	0.002	0.006

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

Table 47b. Interaction effect of nitrogen, phosphorus and potassium on uptake of copper in pseudostem

Interaction effects	Cu uptake in pseudostem ($kg\ ha^{-1}$)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.02	0.07	0.14	0.02	0.07	0.13
n_1p_2	0.02	0.07	0.15	0.02	0.07	0.14
n_1p_3	0.02	0.07	0.16	0.02	0.07	0.15
n_2p_1	0.03	0.07	0.18	0.03	0.07	0.18
n_2p_2	0.03	0.07	0.19	0.03	0.07	0.18
n_2p_3	0.03	0.07	0.19	0.03	0.08	0.19
n_3p_1	0.03	0.08	0.20	0.03	0.08	0.20
n_3p_2	0.04	0.08	0.20	0.03	0.08	0.19
n_3p_3	0.04	0.09	0.21	0.03	0.08	0.21
$F_{4,27}$	1.05	0.92	0.44	0.11	1.97	1.38
SE_m	0.001	0.001	0.004	0.0003	0.001	0.003
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.02	0.07	0.15	0.02	0.07	0.13
n_1k_2	0.02	0.07	0.15	0.02	0.07	0.14
n_1k_3	0.02	0.07	0.16	0.02	0.07	0.15
n_2k_1	0.03	0.07	0.18	0.03	0.07	0.17
n_2k_2	0.03	0.07	0.19	0.03	0.07	0.18
n_2k_3	0.03	0.07	0.20	0.03	0.07	0.18
n_3k_1	0.03	0.08	0.19	0.03	0.08	0.19
n_3k_2	0.03	0.09	0.21	0.03	0.08	0.20
n_3k_3	0.04	0.09	0.21	0.03	0.08	0.21
$F_{4,27}$	1.27	0.24	0.46	1.85	2.49	0.22
SE_m	0.001	0.001	0.004	0.0003	0.001	0.003
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.03	0.07	0.16	0.03	0.07	0.16
p_1k_2	0.03	0.07	0.18	0.03	0.07	0.17
p_1k_3	0.03	0.08	0.18	0.03	0.07	0.17
p_2k_1	0.03	0.07	0.17	0.03	0.07	0.16
p_2k_2	0.03	0.08	0.18	0.03	0.07	0.17
p_2k_3	0.03	0.08	0.19	0.03	0.07	0.18
p_3k_1	0.03	0.08	0.17	0.03	0.07	0.17
p_3k_2	0.03	0.08	0.19	0.03	0.08	0.19
p_3k_3	0.03	0.08	0.20	0.03	0.08	0.19
$F_{4,27}$	0.07	0.63	0.61	0.51	1.28	1.07
SE_m	0.001	0.001	0.004	0.0003	0.001	0.003
CD(0.05)	–	–	–	–	–	–

except at 4 MAP in 99-00, n_3 produced maximum uptake of copper whereas p_3 gave significantly high value only at harvest stage in both the years and at 6 MAP in 99-00. The higher levels k_2 and k_3 were on par at all stages except at harvest stage in 98-99. The interactions, N x P, N x K and P x K were not significant in either of the years (Table 47b).

4.6.9.3 Rhizome

The main effect of treatments on copper uptake in rhizome in 98-99 and 99-00 are furnished in Table 48a. Application of nitrogen, phosphorus and potassium at different levels significantly influenced the copper uptake. In the case of nitrogen, maximum value was recorded by n_3. Only at 6 MAP in both the years, p_3 produced significantly higher Cu uptake. But with regard to potassium, k_3 recorded the highest uptake at the initial two stages. The interactions were not significant in 98-99 as well as in 99-00 (Table 48b).

4.7 Nutrient uptake in bunch

4.7.1 Nitrogen

Perusal of the data in Table 49a clearly indicates that the main effect of nitrogen, phosphorus and potassium had significant influence on uptake of nitrogen in bunch.

In general, increasing levels of nitrogen and phosphorus significantly enhanced the N uptake with the maximum value at n_3 and p_3 respectively. The highest level of potassium promoted N uptake significantly during 99-00 only. During 98-99 k_2 and k_3 had similar effect.

Table 48a. Effect of nitrogen, phosphorus and potassium on uptake of copper in rhizome

Main effect of factors	Cu uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.01	0.03	0.04	0.01	0.04	0.04
n_2	0.01	0.04	0.05	0.01	0.04	0.05
n_3	0.02	0.05	0.06	0.02	0.05	0.06
$F_{2,27}$	9.09**	52.15**	81.10**	17.67**	136.87**	101.28**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.001
CD(0.05)	0.001	0.001	0.002	0.001	0.001	0.002
p_1	0.01	0.04	0.04	0.01	0.04	0.04
p_2	0.01	0.04	0.05	0.01	0.04	0.05
p_3	0.01	0.05	0.05	0.01	0.05	0.05
$F_{2,27}$	1.05	20.21**	8.52**	1.83	12.12**	11.91**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.001
CD(0.05)	–	0.001	0.002	–	0.001	0.002
k_1	0.01	0.04	0.04	0.01	0.04	0.04
k_2	0.01	0.04	0.05	0.01	0.04	0.05
k_3	0.02	0.05	0.05	0.02	0.05	0.05
$F_{2,27}$	19.12**	26.54**	13.14**	10.20**	13.47**	16.48**
SE_m	0.0003	0.0003	0.001	0.0003	0.0003	0.001
CD(0.05)	0.001	0.001	0.002	0.001	0.001	0.002

** Significant at 1 per cent level

Table 48b. Interaction effect of nitrogen, phosphorus and potassium on uptake of copper in rhizome

Interaction effects	Cu uptake in rhizome (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.01	0.04	0.04	0.01	0.04	0.04
n_1p_2	0.01	0.04	0.04	0.01	0.04	0.04
n_1p_3	0.01	0.04	0.04	0.01	0.04	0.04
n_2p_1	0.01	0.04	0.05	0.01	0.04	0.05
n_2p_2	0.01	0.04	0.05	0.01	0.04	0.05
n_2p_3	0.01	0.04	0.05	0.01	0.04	0.05
n_3p_1	0.01	0.05	0.05	0.01	0.05	0.05
n_3p_2	0.01	0.05	0.05	0.01	0.05	0.06
n_3p_3	0.01	0.05	0.05	0.01	0.05	0.06
$F_{4,27}$	0.94	2.69	0.61	0.49	0.43	0.14
SE_m	0.0003	0.0003	0.001	0.0003	0.001	0.001
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.01	0.04	0.04	0.01	0.04	0.04
n_1k_2	0.01	0.04	0.04	0.01	0.04	0.04
n_1k_3	0.01	0.04	0.04	0.01	0.04	0.05
n_2k_1	0.01	0.04	0.05	0.01	0.04	0.05
n_2k_2	0.01	0.04	0.05	0.01	0.04	0.05
n_2k_3	0.01	0.04	0.05	0.01	0.04	0.05
n_3k_1	0.01	0.05	0.05	0.01	0.05	0.05
n_3k_2	0.01	0.05	0.05	0.01	0.05	0.05
n_3k_3	0.01	0.05	0.06	0.01	0.05	0.06
$F_{4,27}$	1.59	2.50	0.91	0.13	0.95	0.32
SE_m	0.0003	0.0003	0.001	0.0003	0.001	0.001
CD(0.0.5)	–	–	–	–	–	–
p_1k_1	0.01	0.04	0.05	0.01	0.04	0.05
p_1k_2	0.01	0.04	0.05	0.01	0.04	0.05
p_1k_3	0.01	0.04	0.05	0.01	0.04	0.05
p_2k_1	0.01	0.04	0.05	0.01	0.04	0.05
p_2k_2	0.01	0.04	0.05	0.01	0.04	0.05
p_2k_3	0.01	0.04	0.05	0.01	0.04	0.05
p_3k_1	0.01	0.04	0.05	0.01	0.04	0.05
p_3k_2	0.01	0.04	0.05	0.01	0.04	0.05
p_3k_3	0.01	0.04	0.05	0.01	0.04	0.05
$F_{4,27}$	0.28	0.57	0.55	0.80	0.79	0.95
SE_m	0.0003	0.0003	0.001	0.0003	0.001	0.001
CD(0.05)	–	–	–	–	–	–

Table 49a. Effect of nitrogen, phosphorus and potassium on uptake of nitrogen, phosphorus and potassium in bunch

Main effect of factors	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1	40.48	35.00	1.65	1.40	57.32	49.35
n_2	68.08	56.33	2.71	2.20	91.06	75.46
n_3	78.21	70.89	2.89	2.57	100.40	90.69
$F_{2,27}$	140.21**	124.20**	49.36**	48.83**	110.28**	110.13**
SE_m	0.521	0.512	0.030	0.027	0.682	0.630
CD(0.05)	1.513	1.486	0.087	0.079	1.980	1.828
p_1	56.34	49.06	1.99	1.74	75.22	65.45
p_2	64.15	55.69	2.51	2.10	85.33	73.54
p_3	66.27	57.47	2.74	2.33	88.23	76.51
$F_{2,27}$	100.57**	74.93**	16.03**	12.03**	10.03**	8.25**
SE_m	0.521	0.512	0.030	0.027	0.682	0.630
CD(0.05)	1.513	1.486	0.087	0.079	1.980	1.828
k_1	57.14	48.75	2.19	1.85	72.18	61.66
k_2	61.12	54.80	2.49	2.11	85.57	73.00
k_3	65.52	58.67	2.57	2.21	91.04	80.84
$F_{2,24}$	74.07**	95.40**	4.38*	4.70*	20.23**	23.44**
SE_m	0.521	0.512	0.030	0.027	0.682	0.630
CD(0.05)	1.513	1.486	0.087	0.079	1.980	1.828

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

Table 49b. Interaction effect of nitrogen, phosphorus and potassium on uptake of nitrogen, phosphorus and potassium in bunch

Interaction effects	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	38.80	33.92	1.31	1.16	55.85	48.96
n_1p_2	40.40	35.27	1.67	1.38	57.22	48.83
n_1p_3	42.25	35.79	1.96	1.66	58.91	50.27
n_2p_1	59.72	48.13	2.25	1.80	79.38	64.48
n_2p_2	70.86	59.24	2.82	2.37	95.49	79.41
n_2p_3	73.45	61.62	3.04	2.41	98.31	82.48
n_3p_1	70.51	65.11	2.41	2.25	90.42	82.92
n_3p_2	81.20	72.56	3.05	2.56	103.30	92.37
n_3p_3	82.92	74.99	3.21	2.90	107.47	96.77
$F_{4,27}$	12.57**	12.89**	1.92	4.79**	16.32**	19.03**
SE_m	0.903	0.887	0.052	0.047	1.182	1.091
CD(0.05)	2.621	2.575	–	0.136	3.430	3.166
n_1k_1	38.89	32.82	1.54	1.32	51.47	44.03
n_1k_2	40.95	35.29	1.64	1.41	57.07	49.41
n_1k_3	41.61	36.88	1.76	1.47	63.43	54.61
n_2k_1	60.70	48.41	2.39	1.90	76.12	61.00
n_2k_2	70.80	58.24	2.85	2.30	95.37	78.16
n_2k_3	72.74	62.34	2.89	2.38	101.69	87.21
n_3k_1	71.82	65.01	2.63	2.33	88.93	79.94
n_3k_2	80.60	70.87	2.99	2.64	104.26	91.42
n_3k_3	82.20	76.79	3.05	2.77	108.00	100.70
$F_{4,27}$	8.93**	9.58**	3.59*	4.62**	11.68**	14.41**
SE_m	0.903	0.887	0.052	0.047	1.182	1.091
CD(0.05)	2.621	2.575	0.152	0.136	3.430	3.166
p_1k_1	53.92	45.77	1.90	1.62	67.99	58.01
p_1k_2	56.78	47.46	2.04	1.72	75.49	63.07
p_1k_3	58.33	53.94	2.05	1.84	82.17	75.28
p_2k_1	56.88	48.64	2.17	1.80	72.28	61.81
p_2k_2	66.84	57.71	2.61	2.19	88.39	76.15
p_2k_3	68.73	60.23	2.76	2.32	95.32	82.64
p_3k_1	60.61	51.83	2.50	2.13	76.25	66.15
p_3k_2	68.72	59.21	2.83	2.41	92.82	79.77
p_3k_3	69.48	61.36	2.89	2.43	95.62	84.61
$F_{4,27}$	5.70**	5.11**	4.58**	6.61**	6.11**	6.70**
SE_m	0.903	0.887	0.052	0.047	1.182	1.091
CD(0.05)	2.621	2.575	0.152	0.136	3.430	3.166

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

Interaction effects furnished in Table 49b indicated that N x P interaction was significant in 98-99 and 99-00. With all levels of nitrogen, the higher levels of phosphorus p_2 and p_3 were on par.

The interactions, N x K and P x K were also significant in both the years. With regard to N x K interaction, k_2 and k_3 exerted similar effect with all levels of nitrogen during first year and with n_1 only during the second year. In the case of P x K interaction, k_3 produced significantly higher N uptake in combination with p_1 during 99-00.

4.7.2 Phosphorus

Nitrogen, phosphorus and potassium applied at different levels significantly influenced the phosphorus uptake in bunch (Table 49a). The uptake of phosphorus was significantly high at n_3 and p_3 respectively. But k_3 produced significantly high uptake during the second year only.

The interaction effect, N x P was significant in 99-00 only. In combination with n_1 and n_3, highest level of phosphorus produced highest P uptake. With n_2, higher levels p_2 and p_3 were on par (Table 49b).

The interaction, N x K and P x K were significant in both the years. With all levels of nitrogen, k_2 and k_3 exerted similar effect. Similarly with all levels of phosphorus also, k_2 and k_3 had similar effect on P uptake.

4.7.3 Potassium

The data on K uptake in bunch during 98-99 and 99-00 are furnished in Tables 49a and 49b.

The difference in K uptake due to different levels of nitrogen, phosphorus and potassium was significant in 98-99 and 99-00. Increasing the levels of these nutrients significantly increased the K uptake with the maximum values at n_3, p_3 and k_3 respectively.

As depicted in Table 49b, N x P, N x K and P x K interactions were significant in both the years. In n_1 and n_2 treated plots, phosphorus application responded upto p_2. Whereas in n_3 treated plots p_3 recorded significantly high K uptake. With all levels of nitrogen incremental doses of potassium significantly increased the K uptake.

With regard to P x K interaction, higher K uptake was obtained due to the application of p_1 and p_2 in combination with k_3. In p_3 treated plots significant response was obtained upto k_2 during first year.

4.7.4 Calcium

It is clear from Table 50a that nitrogen, phosphorus and potassium had significant effect on Ca uptake in bunch. Nitrogen applied at n_2 level significantly increased the calcium uptake in 98-99. Further increase had a significant negative effect on uptake of calcium. Whereas during 99-00, incremental doses of nitrogen significantly increased the calcium

Table 50a. Effect of nitrogen, phosphorus and potassium on uptake of calcium and magnesium in bunch

Main effect of factors	Ca uptake (kg ha^{-1})		Mg uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00
n_1	3.68	3.68	0.91	0.74
n_2	8.59	6.56	1.75	1.17
n_3	7.89	7.11	1.37	1.19
$F_{2,27}$	468.47**	313.99**	391.92**	351.83**
SE_m	0.123	0.104	0.021	0.014
CD(0.05)	0.356	0.301	0.062	0.040
p_1	5.94	5.26	1.25	0.97
p_2	6.99	5.90	1.39	1.09
p_3	7.23	6.20	1.40	1.05
$F_{2,27}$	31.23**	21.25**	16.25**	20.54**
SE_m	0.123	0.104	0.021	0.014
CD(0.05)	0.356	0.301	0.062	0.040
k_1	6.27	5.42	1.28	1.01
k_2	7.07	6.19	1.39	1.07
k_3	6.82	5.75	1.32	1.02
$F_{2,27}$	11.21**	13.92**	7.02**	5.08*
SE_m	0.123	0.104	0.021	0.014
CD(0.05)	0.356	0.301	0.062	0.040

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

Table 50b. Interaction effect of nitrogen, phosphorus and potassium on uptake of calcium and magnesium in bunch

Interaction effect	Ca uptake (kg ha^{-1})		Mg uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00
n_1p_1	3.47	3.35	0.84	0.73
n_1p_2	3.66	3.68	0.88	0.76
n_1p_3	3.91	4.02	1.00	0.73
n_2p_1	5.95	4.95	1.60	1.03
n_2p_2	9.71	6.75	1.86	1.23
n_2p_3	10.10	7.99	1.82	1.25
n_3p_1	8.40	7.48	1.30	1.14
n_3p_2	7.61	7.26	1.41	1.27
n_3p_3	7.67	6.58	1.28	1.16
$F_{4,27}$	45.42**	30.70**	4.56**	7.75**
SE_m	0.212	0.180	0.037	0.023
CD(0.05)	0.616	0.522	0.107	0.068
n_1k_1	3.56	3.26	0.88	0.72
n_1k_2	3.63	3.68	0.93	0.74
n_1k_3	3.85	4.11	0.93	0.76
n_2k_1	6.97	5.88	1.64	1.08
n_2k_2	9.95	7.65	1.84	1.20
n_2k_3	8.83	6.46	1.77	1.22
n_3k_1	8.28	7.11	1.33	1.22
n_3k_2	7.99	7.41	1.40	1.23
n_3k_3	7.34	6.80	1.40	1.13
$F_{4,27}$	22.00**	2.97*	1.20	5.16**
SE_m	0.212	0.180	0.037	0.023
CD(0.05)	0.616	0.522	–	0.068
p_1k_1	5.68	4.91	1.24	0.94
p_1k_2	5.96	5.02	1.27	0.93
p_1k_3	6.17	5.85	1.24	1.03
p_2k_1	6.46	5.51	1.23	1.03
p_2k_2	7.22	6.05	1.46	1.11
p_2k_3	7.29	6.14	1.47	1.12
p_3k_1	6.66	5.84	1.40	1.06
p_3k_2	7.26	6.18	1.45	1.03
p_3k_3	7.76	6.58	1.39	1.06
$F_{4,27}$	0.74	1.09	3.64*	2.24
SE_m	0.212	0.180	0.037	0.023
CD(0.05)	–	–	0.107	–

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

uptake. In both the years response to applied phosphorus was noticed upto p_2 level. In the case of potassium also k_2 and k_3 were on par in 98-99. In the subsequent year k_2 had significantly high Ca uptake. Significant reduction was noticed with further increase in potassium.

As presented in Table 50b the interaction between nitrogen and phosphorus significantly influenced the calcium uptake in 98-99 as well as in 99-00. In combination with n_1 in both the years and with n_2 in 98-99, p_2 and p_3 had similar effect. With n_3, increasing rates of phosphorus resulted in a decrease in calcium uptake.

The interaction effect N x K was significant in both the years. At the lowest level of N, k_2 and k_3 were on par. At the highest levels increase of K from k_2 to k_3 significantly reduced the calcium uptake.

The interaction between phosphorus and potassium was not significant in either of the years.

4.7.5 Magnesium

As depicted in Table 50a, the main effect of nitrogen, phosphorus and potassium was significant in 98-99 and 99-00. During the first year, application of nitrogen at n_2 resulted in higher uptake of Mg beyond which there was significant reduction. Whereas in 99-00 n_2 and n_3 were on par. Application of phosphorus at higher levels (p_2 and p_3) had similar effect on Mg uptake. But increasing the dose of potassium beyond k_2 resulted in a significant reduction in the uptake of magnesium.

The interaction between nitrogen and phosphorus was significant in both the years. In n_1 applied plots, p_3 recorded the highest value in 98-99. In n_3 treated plots, there was significant reduction in Mg uptake beyond p_2.

The interaction effect N x K was present in 99-00. The levels k_2 and k_3 had similar effect in n_1 and n_2 applied plots. But with the highest level of nitrogen, there was a reduction in Mg uptake beyond k_2. The interaction P x K was significant in 98-99. Irrespective of the levels of phosphorus, k_2 and k_3 proved to be equally good in increasing the Mg uptake.

4.7.6 Iron

The effect of treatments on iron uptake in bunch during the two years are presented in Tables 51a and 51b. Incremental doses of nitrogen, phosphorus and potassium significantly increased the iron uptake with maximum values at n_3, p_3 and k_3 respectively.

The interactions N x P, N x K and P x K were significant in both the years (Table 51b). In the case of N x P interaction, p_3 recorded significantly highest uptake in combinations with all levels of nitrogen during first year and with n_2 and n_3 during the second year. But with regard to N x K interaction, k_3 recorded the highest uptake in n_2 treated plots in 98-99 and in n_2 and n_3 treated plots in 99-00. Increasing rate of potassium significantly increased the iron uptake in combination with p_1 and p_2 in 98-99 and with all the three levels in 99-00.

Table 51a. Effect of nitrogen, phosphorus and potassium on uptake of iron, manganese, zinc and copper in bunch

Main effect of factors	Fe uptake (kg ha^{-1})		Mn uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})		Cu uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
n_1	0.08	0.07	0.04	0.04	0.02	0.02	0.01	0.01
n_2	0.17	0.14	0.08	0.07	0.03	0.03	0.03	0.02
n_3	0.19	0.17	0.10	0.09	0.04	0.03	0.03	0.03
$F_{2,27}$	82.80**	114.06**	40.90**	31.96**	81.66**	81.95**	124.46**	122.85**
SE_m	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
CD(0.05)	0.006	0.004	0.004	0.005	0.003	0.003	0.002	0.002
p_1	0.13	0.11	0.06	0.06	0.02	0.02	0.02	0.01
p_2	0.15	0.13	0.08	0.07	0.03	0.03	0.03	0.02
p_3	0.16	0.14	0.08	0.07	0.03	0.03	0.03	0.02
$F_{2,27}$	5.42*	7.06**	6.60**	3.85*	15.80**	7.29**	7.58**	17.20**
SE_m	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
CD(0.05)	0.006	0.004	0.004	0.005	0.003	0.003	0.002	0.002
k_1	0.13	0.10	0.06	0.05	0.02	0.02	0.02	0.01
k_2	0.16	0.13	0.08	0.07	0.03	0.03	0.03	0.02
k_3	0.17	0.15	0.09	0.08	0.03	0.03	0.03	0.02
$F_{2,27}$	8.31**	20.48**	10.43**	7.41**	4.72*	4.65*	3.67*	3.66*
SE_m	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
CD(0.05)	0.006	0.004	0.004	0.005	0.003	0.003	0.002	0.002

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

Table 51b. Interaction effect of nitrogen, phosphorus and potassium on uptake on iron, manganese, zinc and copper in bunch

Interaction effects	Fe uptake (kg ha^{-1})		Mn uptake (kg ha^{-1})		Zn uptake (kg ha^{-1})		Cu uptake (kg ha^{-1})	
	98-99	99-00	98-99	99-00	98-99	99-00	98-99	99-00
n_1p_1	0.08	0.06	0.04	0.03	0.02	0.02	0.01	0.01
n_1p_2	0.08	0.07	0.04	0.04	0.02	0.02	0.01	0.01
n_1p_3	0.09	0.07	0.04	0.04	0.02	0.02	0.02	0.01
n_2p_1	0.15	0.12	0.07	0.06	0.03	0.02	0.02	0.01
n_2p_2	0.18	0.15	0.09	0.08	0.03	0.02	0.03	0.02
n_2p_3	0.19	0.16	0.09	0.08	0.04	0.03	0.03	0.02
n_3p_1	0.18	0.16	0.08	0.08	0.03	0.03	0.03	0.03
n_3p_2	0.20	0.18	0.10	0.09	0.04	0.03	0.03	0.03
n_3p_3	0.21	0.19	0.11	0.10	0.94	0.04	0.03	0.03
$F_{4,27}$	6.00**	11.31**	11.41**	3.66*	2.01	0.59	0.63	1.17
SE_m	0.003	0.003	0.002	0.003	0.002	0.002	0.001	0.001
CD(0.05)	0.001	0.008	0.007	0.008	–	–	–	–
n_1k_1	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.01
n_1k_2	0.09	0.07	0.04	0.03	0.02	0.02	0.01	0.01
n_1k_3	0.09	0.07	0.05	0.04	0.02	0.02	0.01	0.01
n_2k_1	0.15	0.11	0.06	0.05	0.02	0.02	0.02	0.01
n_2k_2	0.18	0.15	0.09	0.07	0.03	0.03	0.03	0.02
n_2k_3	0.19	0.17	0.10	0.09	0.04	0.03	0.03	0.02
n_3k_1	0.16	0.14	0.07	0.07	0.03	0.02	0.02	0.02
n_3k_2	0.21	0.18	0.10	0.10	0.04	0.04	0.03	0.03
n_3k_3	0.21	0.20	0.11	0.11	0.04	0.04	0.04	0.03
$F_{4,27}$	10.62**	22.39**	12.04**	11.30**	2.66	2.68	2.57	1.62
SE_m	0.003	0.003	0.002	0.003	0.002	0.002	0.001	0.001
CD(0.05)	0.001	0.008	0.007	0.008	–	–	–	–
p_1k_1	0.12	0.09	0.05	0.05	0.02	0.02	0.02	0.01
p_1k_2	0.14	0.11	0.06	0.06	0.02	0.02	0.02	0.02
p_1k_3	0.15	0.13	0.07	0.07	0.03	0.03	0.02	0.02
p_2k_1	0.13	0.10	0.06	0.05	0.02	0.02	0.02	0.01
p_2k_2	0.16	0.14	0.08	0.07	0.03	0.03	0.03	0.02
p_2k_3	0.17	0.15	0.09	0.08	0.04	0.03	0.03	0.02
p_3k_1	0.14	0.11	0.06	0.06	0.02	0.02	0.02	0.02
p_3k_2	0.18	0.15	0.09	0.08	0.03	0.03	0.03	0.02
p_3k_3	0.18	0.16	0.10	0.09	0.04	0.03	0.03	0.03
$F_{4,27}$	3.44*	4.73**	8.82**	2.32	1.81	1.96	1.37	0.95
SE_m	0.003	0.003	0.002	0.003	0.002	0.002	0.001	0.001
CD(0.05)	0.001	0.008	0.007	–	–	–	–	–

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

4.7.7 Manganese

It is clear from Table 51a that nitrogen, phosphorus and potassium had profound influence on manganese uptake in bunch. Highest rate of nitrogen and potassium significantly enhanced the uptake of manganese. But in the case of phosphorus significant response was obtained upto p_2.

Interaction effects furnished in Table 51b indicated that all the three interactions N x P, N x K and P x K were significant in both the years. In n_1 and n_2 treated plots significant response was obtained upto p_2. But with n_3, p_3 recorded the maximum value. In the case of N x K interaction, significantly high Mn uptake was recorded by k_3 with all levels of nitrogen. Irrespective of the levels of applied phosphorus increasing the rate of potassium significantly increased the Mn uptake.

4.7.8 Zinc

Table 51a clearly indicates that zinc uptake was significantly increased by nitrogen, phosphorus and potassium. The highest level of nitrogen n_3 recorded maximum uptake in 98-99. Response to applied phosphorus and potassium was obtained upto p_2 and k_2 respectively. None of the interactions were significant in either of the years (Table 51b).

4.7.9 Copper

The uptake of copper in both the years was influenced by nitrogen, phosphorus and potassium (Table 51a). The response to applied N was significant upto n_2 during first year and upto n_3 in the subsequent year. Phosphorus as well as potassium responded upto the medium level. The interactions N x P, N x K and P x K were not significant in both the years (Table 51b).

4.8 Nutrient status of soil

4.8.1 Organic carbon

Organic carbon content did not vary significantly due to different levels of nitrogen, phosphorus or potassium in either of the years. None of the interaction effects were significant in 98-99 or 99-00 (Tables 52a and 52b).

4.8.2 Available nitrogen

The data on available nitrogen content of the soil at different stages of growth in both the years are furnished in Tables 53a and 53b.

Available nitrogen content of the soil vary due to the application of different levels of nitrogen. At all stages of growth in both the years the highest value was recorded by n_3. The effect of phosphorus was significant at 4 MAP and 6 MAP in both the years. The highest level p_3 recorded maximum value at 6 MAP in 98-99 and at 4 MAP in 99-00. Potassium fertilization also significantly enhanced the available N. The level k_3 recorded high available N content at 6 MAP and harvest stage in 98-99.

Table 52a. Effect of nitrogen, phosphorus and potassium on organic carbon content of soil

Main effect of factors	Organic carbon content (%)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.29	0.33	0.33	0.27	0.30	0.30
n_2	0.30	0.35	0.34	0.28	0.32	0.31
n_3	0.31	0.36	0.36	0.28	0.32	0.32
$F_{2,27}$	3.18	3.11	2.58	2.57	2.10	2.63
SE_m	0.003	0.002	0.003	0.002	0.002	0.001
CD(0.05)	–	–	–	–	–	–
p_1	0.28	0.32	0.34	0.26	0.29	0.31
p_2	0.29	0.33	0.34	0.27	0.30	0.32
p_3	0.29	0.33	0.34	0.27	0.31	0.32
$F_{2,27}$	2.59	3.25	0.24	2.01	1.70	1.65
SE_m	0.003	0.002	0.003	0.002	0.002	0.001
CD(0.05)	–	–	–	–	–	–
k_1	0.29	0.32	0.31	0.27	0.30	0.30
k_2	0.29	0.34	0.33	0.27	0.31	0.30
k_3	0.30	0.34	0.33	0.27	0.31	0.31
$F_{2,27}$	2.52	1.78	3.07	1.42	2.65	2.72
SE_m	0.003	0.002	0.003	0.002	0.002	0.001
CD(0.05)	–	–	–	–	–	–

Table 52b. Interaction effect of nitrogen, phosphorus and potassium on organic carbon content of soil

Interaction effects	Organic carbon content (%)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	0.28	0.32	0.31	0.26	0.29	0.29
n_1p_2	0.28	0.33	0.33	0.26	0.30	0.30
n_1p_3	0.29	0.33	0.33	0.27	0.30	0.30
n_2p_1	0.29	0.34	0.33	0.27	0.31	0.30
n_2p_2	0.29	0.34	0.34	0.28	0.32	0.31
n_2p_3	0.30	0.35	0.34	0.28	0.32	0.31
n_3p_1	0.31	0.36	0.34	0.28	0.32	0.32
n_3p_2	0.31	0.36	0.34	0.28	0.32	0.32
n_3p_3	0.31	0.36	0.36	0.28	0.32	0.32
$F_{4,27}$	2.63	1.45	1.61	1.77	1.13	1.75
SE_m	0.006	0.003	0.006	0.003	0.003	0.002
CD(0.05)	–	–	–	–	–	–
n_1k_1	0.27	0.32	0.33	0.26	0.27	0.29
n_1k_2	0.28	0.33	0.33	0.26	0.29	0.30
n_1k_3	0.29	0.33	0.34	0.27	0.29	0.30
n_2k_1	0.29	0.32	0.34	0.27	0.29	0.30
n_2k_2	0.29	0.33	0.34	0.27	0.29	0.30
n_2k_3	0.30	0.33	0.34	0.27	0.30	0.31
n_3k_1	0.29	0.32	0.33	0.26	0.30	0.30
n_3k_2	0.29	0.33	0.33	0.27	0.30	0.31
n_3k_3	0.30	0.34	0.34	0.27	0.31	0.32
$F_{4,27}$	2.42	1.29	1.17	1.62	1.60	1.21
SE_m	0.006	0.003	0.006	0.003	0.003	0.002
CD(0.05)	–	–	–	–	–	–
p_1k_1	0.28	0.32	0.30	0.26	0.29	0.29
p_1k_2	0.28	0.33	0.30	0.26	0.29	0.31
p_1k_3	0.29	0.33	0.31	0.26	0.30	0.31
p_2k_1	0.29	0.32	0.32	0.27	0.31	0.30
p_2k_2	0.29	0.33	0.33	0.27	0.31	0.32
p_2k_3	0.29	0.33	0.33	0.27	0.31	0.32
p_3k_1	0.29	0.33	0.33	0.27	0.31	0.32
p_3k_2	0.30	0.33	0.33	0.27	0.31	0.32
p_3k_3	0.30	0.34	0.33	0.27	0.32	0.32
$F_{4,27}$	1.50	0.49	0.52	0.71	1.00	1.20
SE_m	0.006	0.003	0.006	0.003	0.003	0.002
CD(0.05)	–	–	–	–	–	–

Table 53a. Effect of nitrogen, phosphorus and potassium on available nitrogen in soil

Main effect of factors	Available nitrogen (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	193.78	222.71	236.80	191.99	221.35	233.05
n_2	206.94	245.41	251.88	205.32	242.67	250.31
n_3	241.93	265.71	269.23	234.49	261.69	262.99
$F_{2,27}$	40.25**	79.08**	32.19**	40.96**	45.30**	20.03**
SE_m	0.737	0.586	0.766	0.684	0.989	1.062
CD(0.05)	2.138	1.702	2.222	1.986	2.870	3.082
p_1	211.44	242.63	249.44	207.90	239.97	246.63
p_2	214.98	244.59	251.05	210.32	245.65	249.75
p_3	216.24	246.60	252.41	213.57	243.09	249.97
$F_{2,27}$	4.03*	6.76**	2.78	7.13**	3.82*	3.11
SE_m	0.737	0.586	0.766	0.684	0.989	1.062
CD(0.05)	2.138	1.702	–	1.986	2.870	–
k_1	211.88	242.79	249.38	207.73	239.54	246.53
k_2	214.93	244.97	250.60	211.10	242.57	248.24
k_3	215.85	246.86	252.92	212.96	243.60	251.08
$F_{2,27}$	2.82*	4.79*	5.54**	6.13**	4.98*	5.86**
SE_m	0.737	0.586	0.766	0.684	0.989	1.062
CD(0.05)	2.138	1.702	2.222	1.986	2.870	3.082

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

Table 53b. Interaction effect of nitrogen, phosphorus and potassium on available nitrogen in soil

Interaction effects	Available nitrogen (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	192.36	221.36	235.75	190.02	220.14	231.98
n_1p_2	193.88	222.76	236.53	192.26	222.29	230.24
n_1p_3	195.12	224.00	238.11	193.68	221.63	236.92
n_2p_1	203.40	242.13	249.56	202.73	234.97	246.38
n_2p_2	207.86	245.27	253.30	203.97	243.73	251.97
n_2p_3	209.57	248.85	252.79	209.24	244.30	252.57
n_3p_1	238.56	264.41	263.02	230.96	259.80	261.23
n_3p_2	243.19	265.74	263.32	234.72	261.94	262.51
n_3p_3	244.02	266.96	266.33	237.79	263.35	265.24
$F_{4,27}$	2.35	7.98**	0.65	2.10	2.45	1.91
SE_m	0.981	0.419	0.679	0.806	0.519	0.588
CD(0.05)	–	1.216	–	–	–	–
n_1k_1	192.40	221.54	235.40	191.22	220.62	230.59
n_1k_2	194.25	222.76	236.63	192.17	221.27	234.47
n_1k_3	194.70	223.82	238.36	192.58	222.17	234.08
n_2k_1	204.56	243.92	250.13	203.68	240.08	249.14
n_2k_2	207.48	246.05	251.97	205.59	243.48	250.78
n_2k_3	208.79	246.27	252.54	206.67	244.43	250.99
n_3k_1	238.67	262.91	262.60	228.29	257.92	260.14
n_3k_2	243.06	266.12	263.20	235.55	262.96	262.99
n_3k_3	244.05	268.08	266.87	239.63	264.21	264.85
$F_{4,27}$	1.51	4.06*	0.21	2.14	6.47**	0.19
SE_m	0.981	0.419	0.679	0.806	0.519	0.588
CD(0.05)	–	1.216	–	–	1.507	–
p_1k_1	209.87	240.89	248.66	206.50	238.19	245.37
p_1k_2	212.06	242.52	248.76	207.16	240.03	246.51
p_1k_3	212.39	244.49	250.90	210.05	241.70	247.70
p_2k_1	212.61	242.55	249.82	207.13	239.64	245.46
p_2k_2	215.63	245.59	249.59	211.09	243.76	250.45
p_2k_3	216.69	245.64	253.74	212.73	244.56	248.81
p_3k_1	213.14	244.93	249.65	209.55	240.79	249.05
p_3k_2	217.10	246.82	253.46	215.06	243.93	252.29
p_3k_3	218.47	248.05	254.13	216.10	244.56	253.41
$F_{4,27}$	1.09	1.33	0.88	2.43	1.27	0.36
SE_m	0.981	0.419	0.679	0.806	0.519	0.588
CD(0.05)	–	–	–	–	–	–

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

It is evident from Table 53b that the combined effect of nitrogen and phosphorus was significant only at 6 MAP in 98-99, with p_3 registering the higher content at all levels of N. The interaction effect N x K was significant at 6 MAP in both the years. At n_1 and n_2 levels of N, significant response was noticed upto k_2 which registered the same content as that of k_3. However at n_3 level, increasing levels of N significantly increased the available N content in 98-99. The interaction P x K not significant in either of the years.

4.8.3 Available phosphorus

The data on available phosphorus content of the soil at different stages of growth are presented in Tables 54a and 54b.

Different levels of nitrogen had significant influence on available P status of the soil at most of the stages except at 6 MAP in 98-99. Plots that received n_3 recorded the highest P content at most of the stages. The effect of phosphorus was significant throughout the period of experimentation. Except at harvest stages in 99-00, p_3 recorded significantly higher P content. The effect of potassium was significant at 4 MAP in 98-99 and 99-00, 6 MAP in 99-00 and at harvest stage in 98-99. At the initial stage, k_3 recorded maximum P content.

It is evident from Table 54b that N x P interaction was significant at 4 MAP and harvest stage in 98-99. Irrespective of the levels of nitrogen, increasing rates of phosphorus significantly increased the P content. Available P content of the soil did not vary significantly due to the interaction effects N x K and P x K in 98-99 or 99-00.

Table 54a. Effect of nitrogen, phosphorus and potassium on available phosphorus in soil

Main effect of factors	Available phosphorus (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	10.42	12.14	13.04	10.30	11.86	12.83
n_2	11.20	12.15	13.80	11.03	11.74	13.63
n_3	11.71	13.21	14.51	11.65	13.01	13.80
$F_{2,27}$	7.97**	2.65	23.37**	18.96**	13.43**	3.82*
SE_m	0.023	0.378	0.048	0.049	0.061	0.266
CD(0.05)	0.067	–	0.140	0.142	0.176	0.773
p_1	10.81	11.94	12.92	10.79	11.57	12.44
p_2	11.11	11.88	13.82	10.94	12.26	13.62
p_3	11.41	13.68	14.60	11.26	12.78	14.19
$F_{2,27}$	6.53**	7.29**	30.39**	24.46**	10.04**	11.25**
SE_m	0.023	0.378	0.048	0.049	0.061	0.266
CD(0.05)	0.067	1.097	0.140	0.142	0.176	0.773
k_1	11.04	12.20	13.51	10.90	12.10	12.95
k_2	11.11	12.88	13.86	10.97	12.19	13.58
k_3	11.18	12.43	13.96	11.12	12.31	13.72
$F_{2,27}$	9.99**	0.84	24.55**	5.29*	3.15*	2.36
SE_m	0.023	0.378	0.048	0.049	0.061	0.266
CD(0.05)	0.067	–	0.140	0.142	0.176	–

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

Table 54b. Interaction effect of nitrogen, phosphorus and potassium on available phosphorus in soil

Interaction effects	Available phosphorus (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	10.12	11.36	12.06	10.06	11.34	12.02
n_1p_2	10.47	12.08	13.14	10.29	11.89	12.95
n_1p_3	10.66	12.99	13.90	10.56	11.34	13.50
n_2p_1	10.90	11.65	12.90	10.76	11.24	13.08
n_2p_2	11.13	11.01	13.75	10.99	11.92	13.75
n_2p_3	11.58	13.78	14.74	11.34	12.06	14.05
n_3p_1	11.42	12.82	13.80	11.54	12.13	12.23
n_3p_2	11.74	12.55	14.57	11.53	12.96	14.16
n_3p_3	11.99	11.36	15.17	11.88	13.94	15.03
$F_{4,27}$	3.02*	0.57	3.17*	0.85	2.41	1.11
SE_m	0.040	0.382	0.080	0.105	0.461	0.085
CD(0.05)	0.116	–	0.243	–	–	–
n_1k_1	10.35	12.06	12.96	10.25	11.78	12.75
n_1k_2	10.43	12.13	13.05	10.31	11.79	12.81
n_1k_3	10.47	12.24	13.10	10.35	12.01	12.91
n_2k_1	11.10	12.37	13.46	10.93	11.72	13.56
n_2k_2	11.20	12.69	13.93	10.95	11.74	13.53
n_2k_3	11.31	11.39	14.01	11.22	11.76	13.78
n_3k_1	11.66	12.16	14.12	11.51	12.81	12.54
n_3k_2	11.70	13.83	14.59	11.64	13.04	14.39
n_3k_3	11.77	14.65	14.82	11.78	13.18	14.48
$F_{4,27}$	0.53	1.09	2.41	0.65	0.82	1.68
SE_m	0.040	0.382	0.080	0.105	0.461	0.085
CD(0.05)	–	–	–	–	–	–
p_1k_1	10.75	11.84	12.82	10.70	11.46	11.28
p_1k_2	10.80	12.00	12.96	10.79	11.52	12.89
p_1k_3	10.89	12.00	12.99	10.87	11.72	13.16
p_2k_1	11.05	11.16	13.51	10.84	12.20	13.59
p_2k_2	11.11	12.96	13.89	10.86	12.23	13.61
p_2k_3	11.18	11.52	14.05	11.11	12.34	13.65
p_3k_1	11.31	13.60	14.21	11.16	12.63	13.99
p_3k_2	11.43	13.68	14.21	11.25	12.82	14.23
p_3k_3	11.48	13.76	14.89	11.37	12.88	14.36
$F_{4,27}$	0.29	0.66	2.66	0.31	0.26	1.35
SE_m	0.040	0.382	0.080	0.105	0.461	0.085
CD(0.05)	–	–	–	–	–	–

* Significant at 5 per cent level

4.8.4 Available potassium

The effect of different levels of nitrogen, phosphorus and potassium on available K status of the soil are presented in Tables 55a and 55b.

Application of nitrogen profoundly influenced the available K status of the soil at all stages of growth in both the years. At these stage, the effect of applied nitrogen was significant upto n_2. The effect of phosphorus was significant only at 6 MAP in 99-00. At this stage p_2 was on par with p_1 and with p_3. Applications of different levels of potassium also influenced the available K content of soil. Except at harvest stage in 99-00, significant response was obtained upto k_2.

Table 55b clearly indicates that the interaction N x P was significant only at 6 MAP in 99-00. At n_1 level, p_3 recorded the highest value. Whereas at n_2 and n_3 level, p_2 and p_3 were on par. The interaction between nitrogen and potassium was significant throughout the growth period. At all levels of N, k_2 and k_3 produced similar effect. The K status was highest with k_3 in combination with n_1 at harvest stage in 98-99 and with n_1 and n_2 at 6 MAP in the subsequent year. The interaction P x K was not significant in either of the years.

4.8.5 Exchangeable calcium

The influence of levels of nitrogen, phosphorus and potassium on available calcium content of soil was not significant either in 98-99 or 99-00 (Table 56). None of the interaction effects were significant in either of the years.

Table 55a. Effect of nitrogen, phosphorus and potassium on available potassium in soil

Main effect of factors	Available potassium (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	83.44	108.94	119.67	82.11	106.00	118.05
n_2	96.22	135.67	147.28	95.67	131.11	145.67
n_3	95.89	133.81	146.33	95.11	130.17	143.05
$F_{2,27}$	15.13**	45.27**	92.61**	50.18**	81.01**	116.95**
SE_m	0.592	0.699	0.498	0.343	0.500	0.446
CD(0.05)	1.718	2.028	1.446	0.994	1.451	1.293
p_1	91.50	125.55	137.00	91.11	121.39	135.00
p_2	91.78	126.55	136.78	90.67	122.44	135.39
p_3	92.28	126.11	137.50	91.11	123.44	136.39
$F_{2,27}$	0.44	0.51	0.55	0.56	4.23*	2.03
SE_m	0.592	0.699	0.498	0.343	0.500	0.446
CD(0.05)	–	–	–	–	1.451	–
k_1	89.17	116.22	127.83	87.50	113.39	125.44
k_2	93.22	130.83	140.55	92.28	125.83	139.28
k_3	93.17	131.17	141.89	93.11	127.05	142.06
$F_{2,27}$	15.42**	14.91**	26.45**	7.82**	24.99**	13.69**
SE_m	0.592	0.699	0.498	0.343	0.500	0.446
CD(0.05)	1.718	2.028	1.446	0.994	1.451	1.293

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

Table 55b. Interaction effect of nitrogen, phosphorus and potassium on available potassium in soil

Interaction effects	Available potassium (kg ha^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	82.17	106.67	119.17	81.83	103.83	116.67
n_1p_2	82.00	109.67	119.33	81.67	105.17	118.00
n_1p_3	86.17	110.50	120.50	82.83	109.00	119.50
n_2p_1	95.67	135.50	146.67	95.33	129.67	144.83
n_2p_2	96.17	136.17	147.00	95.33	132.00	145.00
n_2p_3	96.83	135.33	148.17	96.33	131.67	147.17
n_3p_1	96.67	134.50	145.17	96.17	130.67	143.50
n_3p_2	97.17	133.83	144.00	95.00	130.17	143.17
n_3p_3	93.83	132.50	143.83	94.17	129.67	142.50
$F_{4,27}$	0.89	1.55	0.85	2.19	3.91*	2.03
SE_m	1.025	1.211	0.863	0.593	0.866	0.772
CD(0.05)	–	–	–	–	2.513	–
n_1k_1	82.00	105.83	114.17	80.67	101.50	110.83
n_1k_2	84.50	109.50	118.83	82.67	106.67	118.67
n_1k_3	83.83	111.50	126.00	83.00	109.83	120.67
n_2k_1	93.00	120.50	133.50	91.00	118.67	133.00
n_2k_2	97.67	142.33	153.00	97.50	134.67	150.67
n_2k_3	98.00	144.17	155.33	98.50	140.00	152.33
n_3k_1	92.50	122.33	135.83	90.83	120.00	132.50
n_3k_2	97.50	140.67	149.83	96.67	136.17	148.50
n_3k_3	97.67	137.83	147.33	97.83	134.33	148.17
$F_{4,27}$	4.12**	20.66**	25.52**	6.73**	21.23**	13.69**
SE_m	1.025	1.211	0.863	0.593	0.866	0.772
CD(0.05)	2.976	3.513	2.504	1.721	2.513	2.240
p_1k_1	88.83	115.83	127.67	87.50	113.33	125.67
p_1k_2	92.17	130.00	140.50	92.50	123.50	138.17
p_1k_3	93.50	130.83	142.83	93.33	127.33	141.17
p_2k_1	90.00	115.67	127.67	87.50	113.17	124.83
p_2k_2	93.33	131.00	140.33	91.67	124.50	139.50
p_2k_3	92.00	133.00	142.33	92.83	129.67	141.83
p_3k_1	88.67	117.17	128.17	87.50	113.67	125.83
p_3k_2	94.17	131.50	140.83	92.67	129.50	140.17
p_3k_3	94.00	129.67	143.50	93.17	127.17	143.17
$F_{4,27}$	1.02	1.15	0.05	0.22	2.12	0.22
SE_m	1.025	1.211	0.863	0.593	0.866	0.772
CD(0.05)	–	–	–	–	–	–

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

Table 56. Effect of nitrogen, phosphorus and potassium on exchangeable calcium in soil

Main effect of factors	Exchangeable calcium content (c mol (p^+) kg^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.07	0.06	0.07	0.07	0.06	0.06
n_2	0.08	0.07	0.07	0.08	0.07	0.07
n_3	0.07	0.07	0.07	0.07	0.07	0.07
$F_{2,27}$	0.002	0.02	0.003	0.005	0.29	0.001
SE_m	0.086	0.043	0.111	0.040	0.010	0.121
CD(0.05)	–	–	–	–	–	–
p_1	0.07	0.07	0.07	0.07	0.07	0.07
p_2	0.08	0.07	0.07	0.07	0.07	0.07
p_3	0.07	0.07	0.07	0.07	0.07	0.07
$F_{2,27}$	0.0001	0.0001	0.0001	0.0001	0.03	0.001
SE_m	0.086	0.043	0.111	0.040	0.010	0.121
CD(0.05)	–	–	–	–	–	–
k_1	0.08	0.07	0.07	0.07	0.07	0.07
k_2	0.07	0.07	0.07	0.07	0.07	0.07
k_3	0.07	0.07	0.07	0.07	0.07	0.07
$F_{2,27}$	0.001	0.003	0.0004	0.003	0.003	0.002
SE_m	0.086	0.043	0.111	0.040	0.010	0.121
CD(0.05)	–	–	–	–	–	–

4.8.6 Exchangeable magnesium

Neither the independent nor the combined effects of levels of nitrogen, phosphorus and potassium had significant influence on available magnesium content of the soil in 98-99 and 99-00 (Table 57).

4.8.7 Available iron

The data on available iron content of the soil at different stages of growth are provided in Tables 58a and 58b.

The influence of different levels of nitrogen was significant at most of the stages except at 4 MAP in 99-00. At 4 MAP in 98-99 and 6 MAP in 99-00, there was a significant reduction in the available iron content of the soil when nitrogen level was increased from n_1 to n_2. The effect of phosphorus was not significant in 98-99 and 99-00. In both the years, increased rates of K fertilization significantly decreased the available iron content.

Table 58b depicts that the interaction, N x K was significant at 4 MAP and 6 MAP in 98-99 and at the initial stage in 99-00. At n_1 level, k_2 and k_3 were on par during the first year. Whereas in the subsequent year, there was significant reduction in the available iron content when the rate of K was increased from 400 to 600 g plant^{-1}. Throughout the period, incremental doses of potassium significantly reduced the available iron content in combination with n_2 and n_3. The interactions N x P and P x K were not significant in either of the years.

Table 57. Effect of nitrogen, phosphorus and potassium on exchangeable magnesium in soil

Main effect of factors	Exchangeable magnesium (c mol (p^+) kg^{-1})					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.03	0.03	0.02	0.03	0.02	0.02
n_2	0.03	0.03	0.03	0.03	0.03	0.02
n_3	0.03	0.03	0.03	0.03	0.02	0.02
$F_{2,27}$	0.0001	0.001	0.003	0.001	0.003	0.01
SE_m	0.038	0.018	0.009	0.007	0.014	0.013
CD(0.05)	–	–	–	–	–	–
p_1	0.03	0.03	0.02	0.03	0.03	0.02
p_2	0.03	0.03	0.02	0.03	0.03	0.02
p_3	0.03	0.03	0.02	0.03	0.03	0.02
$F_{2,27}$	0.0001	0.0002	0.0004	0.001	0.001	0.0001
SE_m	0.038	0.018	0.009	0.007	0.014	0.013
CD(0.05)	–	–	–	–	–	–
k_1	0.03	0.03	0.02	0.03	0.03	0.02
k_2	0.03	0.03	0.02	0.03	0.03	0.02
k_3	0.03	0.03	0.02	0.03	0.03	0.02
$F_{2,27}$	0.00001	0.0001	0.0002	0.009	0.0001	0.0001
SE_m	0.038	0.018	0.009	0.007	0.014	0.013
CD(0.05)	–	–	–	–	–	–

Table 58a. Effect of nitrogen, phosphorus and potassium on available iron in soil

Main effect of factors	Available iron (ppm)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	23.33	19.94	25.22	22.72	20.33	23.78
n_2	22.17	21.72	24.22	23.11	21.22	24.22
n_3	23.17	21.39	23.22	23.44	22.05	23.78
$F_{2,27}$	3.41*	8.64**	13.33**	2.12	4.15*	5.78**
SE_m	0.341	0.219	0.274	0.248	0.254	0.217
CD(0.05)	0.991	0.635	0.795	–	0.736	0.630
p_1	22.89	20.89	24.11	22.89	20.94	24.28
p_2	22.56	21.00	24.39	23.11	21.67	23.39
p_3	23.22	21.17	24.17	23.28	21.00	23.61
$F_{2,27}$	0.95	0.41	0.29	0.62	2.51	2.73
SE_m	0.341	0.219	0.274	0.248	0.254	0.217
CD(0.05)	–	–	–	–	–	–
k_1	24.39	23.44	26.89	24.94	22.94	26.55
k_2	22.78	20.72	25.05	23.39	21.89	23.78
k_3	21.50	18.89	20.72	20.94	18.78	20.94
$F_{2,27}$	7.98**	10.97**	13.37**	6.59**	7.29**	16.69**
SE_m	0.341	0.219	0.274	0.248	0.254	0.217
CD(0.05)	0.991	0.635	0.795	0.721	0.736	0.630

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

Table 58b. Interaction effect of nitrogen, phosphorus and potassium on available iron in soil

Interaction effect	Available iron (ppm)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1p_1	23.00	19.50	23.33	22.00	18.67	23.50
n_1p_2	23.00	20.17	24.62	23.33	21.17	23.17
n_1p_3	24.00	20.17	24.83	22.83	21.17	23.17
n_2p_1	22.33	21.33	24.67	23.33	21.33	24.00
n_2p_2	21.50	22.17	24.50	22.50	21.33	24.00
n_2p_3	22.67	21.67	23.50	23.50	21.00	23.83
n_3p_1	23.33	21.83	24.33	23.33	22.83	24.50
n_3p_2	23.17	20.67	22.67	23.50	22.50	23.00
n_3p_3	23.00	21.67	22.67	23.50	20.83	23.83
$F_{4,27}$	0.55	2.31	2.69	1.72	2.70	0.87
SE_m	0.591	0.379	0.475	0.430	0.440	0.376
CD(0.05)	–	–	–	–	–	–
n_1k_1	23.17	21.17	26.83	23.67	20.83	26.33
n_1k_2	23.87	19.67	27.00	23.17	21.00	22.83
n_1k_3	23.00	19.00	21.83	21.33	21.17	20.67
n_2k_1	24.50	24.17	27.00	25.00	23.83	26.83
n_2k_2	21.33	22.17	24.83	23.50	21.17	24.50
n_2k_3	20.67	18.83	20.83	20.83	21.17	21.33
n_3k_1	25.50	25.00	26.83	26.17	24.17	26.50
n_3k_2	23.17	20.33	23.33	23.50	23.50	24.00
n_3k_3	20.83	18.83	19.50	20.67	23.50	20.83
$F_{4,27}$	5.07**	6.68**	2.61	3.59*	2.33	0.87
SE_m	0.591	0.379	0.475	0.430	0.440	0.376
CD(0.05)	1.716	1.100	–	1.248	–	–
p_1k_1	24.00	23.17	26.67	24.00	22.33	27.17
p_1k_2	23.17	20.83	24.67	23.33	21.83	24.83
p_1k_3	21.50	18.67	21.00	21.33	18.67	20.83
p_2k_1	24.67	23.83	26.50	25.83	23.17	26.33
p_2k_2	21.67	20.33	25.67	22.67	22.50	23.00
p_2k_3	21.33	18.83	21.00	20.83	19.33	20.83
p_3k_1	24.50	23.33	27.50	25.00	23.33	26.17
p_3k_2	23.50	21.00	24.83	24.17	21.33	23.50
p_3k_3	21.67	19.17	20.17	20.67	18.33	21.17
$F_{4,27}$	1.10	0.86	1.64	2.61	1.05	2.05
SE_m	0.591	0.379	0.475	0.430	0.440	0.376
CD(0.05)	–	–	–	–	–	–

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

4.8.8 Available manganese

No significant differences were found in the available manganese content due to the independent or combined effects of levels of nitrogen, phosphorus and potassium at various growth stages during the period of experimentation (Table 59).

4.8.9 Available zinc

It is clear from Table 60 that there was no variation in the available zinc content due to the effect of nitrogen, phosphorus and potassium. None of the interactions could also significantly influence the available zinc status in both the years.

4.8.10 Available copper

Neither the independent nor the combined effects of levels of nitrogen, phosphorus and potassium had significant influence on available copper content of the soil in 98-99 and 99-00 (Table 61).

4.9 Economic analysis

4.9.1 Benefit-cost Ratio (BCR)

The data on BCR in each year are furnished in Tables 62a and 62b.

Benefit-cost ratio increased with increasing levels of nitrogen. In the case of phosphorus significant response was obtained upto p_2.

Table 59. Effect of nitrogen, phosphorus and potassium on available manganese in soil

Main effects of factors	Available manganese (ppm)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	1.43	1.45	1.45	1.42	1.43	1.43
n_2	1.44	1.47	1.44	1.43	1.44	1.44
n_3	1.47	1.47	1.45	1.45	1.44	1.44
$F_{2,27}$	2.70	1.55	1.74	1.53	2.14	2.45
SE_m	0.002	0.002	0.002	0.002	0.002	0.002
CD(0.05)	–	–	–	–	–	–
p_1	1.44	1.43	1.46	1.43	1.44	1.44
p_2	1.43	1.44	1.46	1.43	1.45	1.45
p_3	1.45	1.44	1.45	1.43	1.45	1.46
$F_{2,27}$	2.82	0.18	2.71	0.14	2.97	0.43
SE_m	0.002	0.002	0.002	0.002	0.002	0.002
CD(0.05)	–	–	–	–	–	–
k_1	1.45	1.43	1.45	1.44	1.44	1.44
k_2	1.45	1.44	1.43	1.45	1.45	1.46
k_3	1.46	1.44	1.46	1.43	1.45	1.46
$F_{2,27}$	3.22	2.08	1.04	2.20	2.51	2.25
SE_m	0.002	0.002	0.002	0.002	0.002	0.002
CD(0.05)	–	–	–	–	–	–

Table 60. Effect of nitrogen, phosphorus and potassium on available zinc in soil

Main effect of factors	Available zinc (ppm)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.27	0.28	0.34	0.26	0.27	0.27
n_2	0.28	0.28	0.34	0.28	0.28	0.31
n_3	0.28	0.31	0.36	0.27	0.28	0.31
$F_{2,27}$	2.68	1.04	2.65	1.77	2.39	2.59
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–
p_1	0.26	0.29	0.34	0.25	0.28	0.30
p_2	0.27	0.31	0.36	0.26	0.29	0.32
p_3	0.27	0.31	0.35	0.27	0.29	0.30
$F_{2,27}$	1.69	3.32	2.17	2.91	3.16	2.47
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–
k_1	0.28	0.28	0.34	0.27	0.29	0.31
k_2	0.24	0.33	0.35	0.27	0.28	0.31
k_3	0.28	0.33	0.35	0.26	0.29	0.32
$F_{2,27}$	0.92	2.18	2.42	3.18	3.15	1.30
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–

Table 61. Effect of nitrogen, phosphorus and potassium on available copper in soil

Main effect of factors	Available copper (ppm)					
	98-99			99-00		
	4 MAP	6 MAP	Harvest	4 MAP	6 MAP	Harvest
n_1	0.12	0.12	0.15	0.12	0.13	0.14
n_2	0.13	0.12	0.14	0.12	0.12	0.14
n_3	0.13	0.13	0.14	0.13	0.13	0.15
$F_{2,27}$	2.24	2.55	1.54	1.92	2.43	2.07
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–
p_1	0.12	0.12	0.13	0.12	0.13	0.15
p_2	0.12	0.12	0.13	0.12	0.12	0.14
p_3	0.12	0.12	0.13	0.13	0.13	0.14
$F_{2,27}$	2.99	2.96	1.76	1.27	2.03	2.61
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–
k_1	0.12	0.13	0.11	0.13	0.13	0.14
k_2	0.14	0.13	0.11	0.13	0.13	0.14
k_3	0.14	0.12	0.12	0.12	0.12	0.14
$F_{2,27}$	2.76	2.53	1.25	2.70	3.31	2.38
SE_m	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
CD(0.05)	–	–	–	–	–	–

Table 62a. Effect of nitrogen, phosphorus and potassium on benefit cost ratio

Main effect of factors	Benefit cost ratio	
	98-99	99-00
n_1	1.18	1.05
n_2	1.75	1.53
n_3	1.81	1.66
$F_{2,27}$	23.10**	37.56**
SE_m	0.013	0.017
CD(0.05)	0.037	0.049
p_1	1.47	1.31
p_2	1.63	1.46
p_3	1.64	1.46
$F_{2,27}$	56.19**	26.18**
SE_m	0.013	0.017
CD(0.05)	0.037	0.049
k_1	1.49	1.30
k_2	1.62	1.44
k_3	1.62	1.50
$F_{2,27}$	37.86**	38.80**
SE_m	0.013	0.017
CD(0.05)	0.037	0.049

** Significant at 1 per cent level

Table 62b. Interaction effect of nitrogen, phosphorus and potassium on benefit cost ratio

Interaction effects	Benefit cost ratio	
	98-99	99-00
n_1p_1	1.15	1.09
n_1p_2	1.20	1.03
n_1p_3	1.20	1.02
n_2p_1	1.58	1.30
n_2p_2	1.81	1.64
n_2p_3	1.85	1.64
n_3p_1	1.67	1.55
n_3p_2	1.87	1.72
n_3p_3	1.88	1.72
$F_{4,27}$	7.88**	16.88**
SE_m	0.022	0.029
CD(0.05)	0.065	0.084
n_1k_1	1.15	1.05
n_1k_2	1.18	1.03
n_1k_3	1.21	1.06
n_2k_1	1.61	1.30
n_2k_2	1.83	1.62
n_2k_3	1.81	1.67
n_3k_1	1.70	1.55
n_3k_2	1.86	1.66
n_3k_3	1.86	1.78
$F_{4,27}$	5.43**	13.12**
SE_m	0.022	0.029
CD(0.05)	0.065	0.084
p_1k_1	1.44	1.29
p_1k_2	1.48	1.25
p_1k_3	1.48	1.39
p_2k_1	1.48	1.27
p_2k_2	1.70	1.55
p_2k_3	1.70	1.56
p_3k_1	1.54	1.33
p_3k_2	1.70	1.50
p_3k_3	1.68	1.55
$F_{4,27}$	5.65**	7.93**
SE_m	0.022	0.029
CD(0.05)	0.065	0.084

** Significant at 1 per cent level

Table 62c. Influence of N x P x K interaction on benefit cost ratio

P x K interaction	Benefit cost ratio					
	98-99			99-00		
	n_1	n_2	n_3	n_1	n_2	n_3
p_1k_1	1.14	1.58	1.61	1.18	1.25	1.45
p_1k_2	1.14	1.58	1.71	1.03	1.24	1.49
p_1k_3	1.17	1.58	1.70	1.06	1.40	1.72
p_2k_1	1.18	1.54	1.72	0.96	1.27	1.59
p_2k_2	1.19	1.96	1.94	1.06	1.84	1.76
p_2k_3	1.22	1.94	1.95	1.05	1.82	1.81
p_3k_1	1.15	1.71	1.77	1.01	1.36	1.61
p_3k_2	1.21	1.93	1.95	1.00	1.76	1.75
p_3k_3	1.22	1.90	1.93	1.06	1.79	1.81
$F_{4,27}$	2.47*			2.82*		
SE_m	0.039			0.050		
CD(0.05)	0.112			0.146		

* Significant at 5 per cent level

But potassium significantly responded upto k_2 level during 98-99 and upto k_3 in the suceeding year.

It is evident from Table 62b that the combined effect of nitrogen and phosphorus was significant in both the years. At n_1 level, phosphorus did not significantly effect BCR. Whereas at n_2 and n_3 levels, phosphorus responded upto p_2 level. A significant N x K interaction occurred in 98-99 as well as in 99-00. At n_1 and n_2 level, k_2 and k_3 were on par. But in combination with n_3, increasing levels of K significantly increased BCR in 99-00. The interaction between P x K was also significant in both the years. Irrespective of the levels of P during 98-99 and with p_2 and p_3 during 99-00, k_2 and k_3 had similar effect on BCR.

Considering the interaction N x P x K which was significant in both the years (Table 62c) highest BCR was recorded by $n_2p_2k_2$ (1.96 and 1.84 respectively) for first and second year. This treatment was on par with $n_3p_3k_3$, $n_3p_3k_2$, $n_3p_2k_3$, $n_3p_2k_2$, $n_2p_3k_3$, $n_2p_3k_2$ and $n_2p_2k_3$. Similar trend was observed in the second year also.

4.10 Soil column studies

4.10.1 Leaching loss of nutrients

The data on the per cent loss of nitrogen, phosphorus and potassium from applied fertilizers are furnished in Table 63. The results indicated that application of N, P and K at different levels did not produce any significant effect on the loss of these nutrients in leachate collected

Table 63. Leaching loss of nitrogen, phosphorus and potassium

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
$n_1p_1k_1$	23.36	1.74	15.95
$n_1p_1k_2$	23.30	1.71	16.06
$n_1p_1k_3$	23.67	1.76	16.06
$n_1p_2k_1$	23.38	1.71	16.00
$n_1p_2k_2$	23.58	1.74	16.16
$n_1p_2k_3$	23.83	1.67	16.05
$n_1p_3k_1$	23.37	1.79	16.04
$n_1p_3k_2$	23.68	1.77	16.19
$n_1p_3k_3$	23.78	1.78	16.39
$n_2p_1k_1$	23.17	1.77	16.38
$n_2p_1k_2$	23.28	1.78	16.21
$n_2p_1k_3$	23.29	1.77	16.30
$n_2p_2k_1$	23.24	1.75	16.16
$n_2p_2k_2$	23.60	1.76	16.42
$n_2p_2k_3$	23.25	1.76	16.53
$n_2p_3k_1$	23.31	1.81	16.08
$n_2p_3k_2$	23.24	1.81	16.11
$n_2p_3k_3$	23.31	1.79	16.17
$n_3p_1k_1$	23.75	1.78	16.11
$n_3p_1k_2$	23.91	1.78	16.26
$n_3p_1k_3$	23.98	1.74	16.34
$n_3p_2k_1$	23.48	1.66	16.19
$n_3p_2k_2$	23.84	1.67	16.26
$n_3p_2k_3$	23.89	1.72	16.22
$n_3p_3k_1$	23.96	1.81	16.27
$n_3p_3k_2$	23.94	1.80	16.42
$n_3p_3k_3$	23.92	1.81	16.40
$F_{26,27}$	1.66	1.50	1.32
SE_m	0.216	0.032	0.130
CD(0.05)	–	–	–

from the soil. The nitrogen loss was estimated in the range of 23.17 to 23.98 per cent, phosphorus 1.66 to 1.81 per cent and potassium 15.95 to 16.53 per cent.

4.10.2 Nutrient retention at different depths

4.10.2.1 Nitrogen

It is evident from Table 64 that the treatment effect due to different mineral nutrition of N, P and K had not influenced the retention of nitrogen in the soil at different depths studied. However, it ranged between 21.75 to 23.69 per cent at 0-15 cm, 18.20 to 19.69 per cent at 15-30 cm, 10.69 to 12.33 per cent at 30-45 cm and 9.75 to 10.92 per cent at 45-60 cm.

4.10.2.2 Phosphorus

There was no significant difference between the treatment combination in retaining P at different depths in the soil column (Table 65). It ranged between 14.46 to 18.12 per cent at 0-15 cm, 13.01 to 13.79 per cent at 15-30 cm, 9.19 to 9.77 per cent at 30-45 cm and 6.40 to 7.55 per cent at 45-60 cm.

4.10.2.3 Potassium

Table 66 clearly depicts that the K retention at different depths in the soil column was not significantly influenced by the different

Table 64. Retention of nitrogen in the soil column at different depths

Treatment	Nitrogen (%)			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
$n_1p_1k_1$	23.69	18.68	11.65	9.75
$n_1p_1k_2$	22.82	19.16	11.00	10.34
$n_1p_1k_3$	22.82	19.69	10.69	10.63
$n_1p_2k_1$	21.75	19.36	12.25	10.35
$n_1p_2k_2$	22.61	18.69	12.03	10.38
$n_1p_2k_3$	22.76	19.09	11.73	10.39
$n_1p_3k_1$	23.65	18.20	11.48	10.37
$n_1p_3k_2$	23.00	18.92	11.80	10.73
$n_1p_3k_3$	23.31	19.12	11.14	10.25
$n_2p_1k_1$	23.55	18.44	11.32	10.25
$n_2p_1k_2$	23.67	18.78	11.35	10.21
$n_2p_1k_3$	22.80	18.53	11.36	10.12
$n_2p_2k_1$	23.07	18.65	11.74	10.61
$n_2p_2k_2$	23.04	18.75	12.14	10.58
$n_2p_2k_3$	22.53	18.55	12.16	10.85
$n_2p_3k_1$	23.03	18.71	12.17	10.54
$n_2p_3k_2$	23.46	19.02	11.86	10.30
$n_2p_3k_3$	23.47	18.66	11.89	10.39
$n_3p_1k_1$	23.08	18.63	12.30	10.47
$n_3p_1k_2$	23.32	18.83	11.76	10.92
$n_3p_1k_3$	23.09	18.32	12.12	10.57
$n_3p_2k_1$	23.63	18.58	11.84	10.58
$n_3p_2k_2$	23.14	18.30	12.30	10.30
$n_3p_2k_3$	23.42	18.60	11.86	10.42
$n_3p_3k_1$	23.60	18.80	11.35	10.67
$n_3p_3k_2$	23.10	18.71	12.33	10.53
$n_3p_3k_3$	23.40	18.56	12.33	10.76
$F_{26,27}$	0.47	0.64	1.14	0.49
SE_m	0.637	0.411	0.412	0.349
CD(0.05)	–	–	–	–

Table 65. Retention of phosphorus in the soil column at different depths

Treatment	Phosphorus (%)			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
$n_1p_1k_1$	16.95	13.01	9.44	6.86
$n_1p_1k_2$	18.12	13.37	9.39	7.25
$n_1p_1k_3$	18.07	13.70	9.48	6.83
$n_1p_2k_1$	16.78	13.37	9.35	7.28
$n_1p_2k_2$	14.69	13.39	9.62	7.00
$n_1p_2k_3$	14.84	13.47	9.38	7.15
$n_1p_3k_1$	14.64	13.02	9.21	7.78
$n_1p_3k_2$	15.16	13.56	9.74	6.59
$n_1p_3k_3$	15.51	13.24	9.77	7.00
$n_2p_1k_1$	15.04	13.49	9.42	7.06
$n_2p_1k_2$	15.59	13.78	9.27	7.55
$n_2p_1k_3$	14.74	13.76	9.42	6.83
$n_2p_2k_1$	15.66	13.56	9.53	7.26
$n_2p_2k_2$	15.29	13.17	9.66	7.08
$n_2p_2k_3$	15.42	13.56	9.46	7.04
$n_2p_3k_1$	14.76	13.59	9.68	6.74
$n_2p_3k_2$	14.46	13.51	9.52	7.12
$n_2p_3k_3$	14.86	13.91	9.75	6.40
$n_3p_1k_1$	15.55	13.78	9.50	6.77
$n_3p_1k_2$	15.50	13.51	9.46	7.09
$n_3p_1k_3$	15.04	13.70	9.26	7.20
$n_3p_2k_1$	15.19	13.64	9.26	7.10
$n_3p_2k_2$	15.15	13.56	9.39	7.06
$n_3p_2k_3$	15.50	13.55	9.73	6.82
$n_3p_3k_1$	15.29	13.57	9.41	7.05
$n_3p_3k_2$	14.86	13.79	9.19	7.03
$n_3p_3k_3$	15.09	13.24	9.70	7.07
$F_{26,27}$	1.59	0.61	0.75	1.19
SE_m	0.747	0.294	0.201	0.252
CD(0.05)	–	–	–	–

Table 66. Retention of potassium in the soil column at different depths

Treatment	Potassium (%)			
	0-15 cm	15-30 cm	30-45 cm	45-60 cm
$n_1p_1k_1$	29.66	25.05	14.03	10.43
$n_1p_1k_2$	29.70	25.09	14.57	10.65
$n_1p_1k_3$	30.24	25.11	14.81	10.08
$n_1p_2k_1$	29.88	25.13	14.66	10.31
$n_1p_2k_2$	29.72	24.76	15.04	10.21
$n_1p_2k_3$	29.70	25.52	14.35	10.14
$n_1p_3k_1$	29.72	25.00	14.40	10.71
$n_1p_3k_2$	30.23	25.36	14.38	10.16
$n_1p_3k_3$	29.57	24.99	14.61	10.41
$n_2p_1k_1$	30.07	25.19	14.35	10.47
$n_2p_1k_2$	30.07	25.38	14.51	10.12
$n_2p_1k_3$	29.90	25.34	14.62	10.15
$n_2p_2k_1$	29.52	25.30	14.51	10.20
$n_2p_2k_2$	30.19	25.24	14.61	10.15
$n_2p_2k_3$	30.11	24.89	15.00	10.16
$n_2p_3k_1$	30.08	25.12	14.79	10.10
$n_2p_3k_2$	29.79	24.93	14.86	10.22
$n_2p_3k_3$	29.49	24.35	15.27	10.39
$n_3p_1k_1$	29.71	25.17	14.67	10.17
$n_3p_1k_2$	30.04	25.30	14.55	10.16
$n_3p_1k_3$	30.11	24.80	15.05	10.15
$n_3p_2k_1$	30.10	25.32	14.63	10.06
$n_3p_2k_2$	30.21	24.67	15.24	10.10
$n_3p_2k_3$	30.01	25.19	14.76	10.06
$n_3p_3k_1$	30.05	25.08	14.86	10.07
$n_3p_3k_2$	30.09	24.67	14.85	10.49
$n_3p_3k_3$	30.24	25.03	14.85	10.12
$F_{26,27}$	0.38	0.42	0.53	1.28
SE_m	0.384	0.404	0.389	0.158
CD(0.05)	–	–	–	–

treatment combinations. The retention ranged from 29.49 to 30.24 per cent at 0-15 cm, 24.35 to 25.52 per cent at 15-30 cm, 14.03 to 15.27 per cent at 30-45 cm and 10.06 to 10.71 per cent at 45-60 cm.

DISCUSSION

5. DISCUSSION

Field experiments were conducted during 1998-99 and 1999-00 to find the nutrient requirement of banana cv. Njalipoovan for higher yield and better quality. The results generated from the field experiments were statistically analysed and are discussed in this chapter.

5.1 Growth attributes

The plant height and girth recorded at different stages of growth will form a key index to assess the vigour of banana. Application of nitrogen at the highest level of 300 g plant^{-1} significantly increased the height of the plant, girth of the pseudostem, total number of leaves and number of functional leaves at all the stages of growth in both the years (Tables 3a, 4a, 5a and 6a). Nitrogen is the chief promoter of growth and constituent of proteins and protoplasm. It is the element responsible for generating a good vegetative frame which is an essential prerequisite for higher yield in banana (Shanmugavelu *et al.*, 1992; Shanmugham and Velayudham, 1972). It is a proven fact that an adequate supply of nitrogen promotes vegetative growth especially leaf production and keeps leaves functional for a longer time (Russel, 1973 and Tisdale *et al.*, 1995). Stimulation of vegetative growth at higher rates of applied nitrogen has been reported earlier in banana by Hazarika and Mohan (1991), Prabhuram (1992), Sheela (1995), Singh and Suryanarayana (1999) and Prakashmany (2002).

Phosphorus at 200 g $plant^{-1}$ increased the plant height and the pseudostem girth at all the stages indicating the role of phosphorus in improving the vegetative growth. Though the P requirement of banana is much less compared to N and K (Bhan, 1976 and Natesh, 1987), its role in cell division and growth might be the reason for the present result.

In the case of potassium, the height and girth of pseudostem was maximum at 600 g $plant^{-1}$ at most of the stages. The pseudostem of banana is actually a concentric bundle of leaf sheaths emerging directly from the corm. K nutrition helps to the normal phyllotaxy of the plant at 160^{o}. The leaves develop one just above the other with more distance between the petioles leading to increased height of pseudostem. Potassium has important role in increasing the cambial and meristematic activity of growing apex. All these have contributed to the increased height and girth of the pseudostem at higher levels of K. Similar results were reported by Khoreiby and Salem (1991), George (1994) and Ramkumar *et al.* (1998).

Potassium at 400 g $plant^{-1}$ increased the total number of leaves and they were retained upto harvest in both the years. Nitrogen being the element most needed for the growth of foliage, its uptake at higher levels of K might have contributed to increased leaf number. The increased vigour and meristematic activity of the plant due to increased NK ratio in the plant tissue might be another reason for maximum leaf production at 400 g plant^{-1}. Application of K_2O at 600 g plant^{-1} did not bring any significant increase in leaf number. It appears that the antagonistic effect of excess potassium in soil could have affected the uptake of other nutrients like Mg and resulted reduction in canopy (Russell, 1973). Similar growth response in banana cv. Nendran was reported by Dumas (1980) and Prakashmany (2002).

Application of nitrogen at 300 g plant^{-1} markedly reduced the total duration of the crop in both the years (Table 7a). Applied N exerted its effect on total crop duration mainly by influencing the days to shooting. There was a reduction of 22-29 days in the total crop duration when N level was increased from 100 to 300 g plant^{-1}. Nitrogen reduced phyllochron and increased the leaf area in a short span of time thereby helping the plant to attain early physiological maturity. Thus shooting occurs early which inturn reduced the total duration. The effect of N on crop duration was noted as early in 1940 by Croucher and Mitchell. Later it was confirmed by many workers (Kohli *et al.*, 1984; Nair, 1988; Thankaselvabai, 1989; and Geetha, 1998).

Potassium at 400 g plant^{-1} reduced the duration of the crop. This might be due to the enhanced vigour of the plant which inturn improved the vegetative growth. More vigorous plants took comparatively lesser time to shooting (Venkatesan *et al.*, 1965). Higher levels of potassium might have contributed much to advance flowering and harvesting. This view was corroborated by Jambulingam *et al.* (1975) who observed earlier flowering and maturation with potassium application above 360 g plant^{-1}. Similar results were reported by Peters (1997) in banana cv. Nendran.

5.2 Physiological parameters

5.2.1 Leaf area index

Increasing rates of nitrogen application significantly increased LAI at most of the growth stages during the period of experimentation. Maximum values were recorded at 300 g N plant^{-1} (1.77 in 98-99 and 1.61 in 99-00 respectively) (Table 9a). As the level of N supply increases, the extra protein produced allows the leaves to grow larger and the amount of leaf area available for photosynthesis is roughly proportional to the amount of N supplied (Russell, 1973). Larger leaf size coupled with more number of functional leaves retained per plant at higher N levels as indicated in Table 6a could have resulted in higher LAI in this study. The beneficial effect of N application on LAI has been reported by Singh *et al.* (1990), Peters (1997) and Geetha (1998).

Phosphorus at 300 g plant^{-1} remarkably increased the LAI in the initial stages in both the years. However towards harvest, there was no significant effect of P application on LAI. Phosphorus present in the meristematic regions helps in increasing the leaf number. Phosphorus seems to increase the leaf area with out affecting the power of the leaves to translocate carbohydrates (Russell, 1973). Previous studies by

Shanmugavelu *et al.* (1992) also indicated that P fertilization favoured general vegetative growth of banana.

Potassium at higher rates significantly influenced the LAI during the initial and active vegetative growth phases (Table 9a) in both the years. More number of functional leaves (Table 6a) and greater leaf size might have contributed to the higher LAI at higher levels of K supply. The lack of significance for the treatment effects at the harvest stage might be due to the drastic reduction in leaf production by the plants following bunch emergence. The trend is in accordance with the finding of Watson (1947) that potassium increased the size of the leaves in the early part of growing season, though this effect disappeared by harvest. This report further justifies the requirement of the highest level of K, 600 g $plant^{-1}$ in this study to maintain higher LAI at peak growth stage in both the years. George (1994) also reported that K application resulted in a greater leaf area in banana cv. Nendran.

5.2.2 Dry matter accumulation and partitioning

Growth an irreversible gain in dry matter, is the sum total of the vital metabolic processes of cell division and enlargement. The amount of dry matter produced by a plant depends upon its photosynthetic efficiency (Arnon, 1975). The effectiveness of photosynthesis to a great extent is the function of leaf number. In the present study mineral nutrition with N, P and K at higher rates resulted in a significant increase in total dry matter production (Table 11a), (Fig. 3a and 3b). Application of nitrogen at the highest level, 300 g plant^{-1} resulted in significant higher dry matter accumulation in leaf, pseudostem, rhizome and bunch and eventually the whole plant in both the years (Tables 12a, 13a, 14a and 15a) (Figs. 4a and 4b). Nitrogen is an important constituent of proteins and polyribose complex which are the building blocks of plant tissues. Plants receiving higher levels of nitrogen will have high rate of photosynthesis, protein and carbohydrate synthesis. This has favoured higher dry matter accumulation in both the vegetative structure and bunch which has ultimately resulted in higher biomass production. The present results are in agreement with the findings of Prabhuram (1992) and Prakashmany (2002).

The influence of phosphorus in promoting leaf, pseudostem, rhizome and bunch dry matter was significant upto 300 g plant^{-1} in both the years (Tables 12a, 13a, 14a and 15a), (Figs. 5a and 5b). But significantly higher rhizome dry matter was obtained with 200 g P plant^{-1} in the initial stages. In the case of bunch dry matter the level p_2 (200 g plant^{-1}) and p_3 (300 g plant^{-1}) had similar effect. However, the total dry matter appreciably increased by increasing the level of phosphorus from 100 to 300 g plant^{-1}. Phosphorus is a constituent of ATP and co-enzymes NAD and NADP. The essential processes such as photosynthesis, nitrogen metabolism and carbohydrate metabolism are dependent on the action of these co-enzymes. Higher levels of phosphorus would have accelerated all the above processes which inturn resulted in higher dry

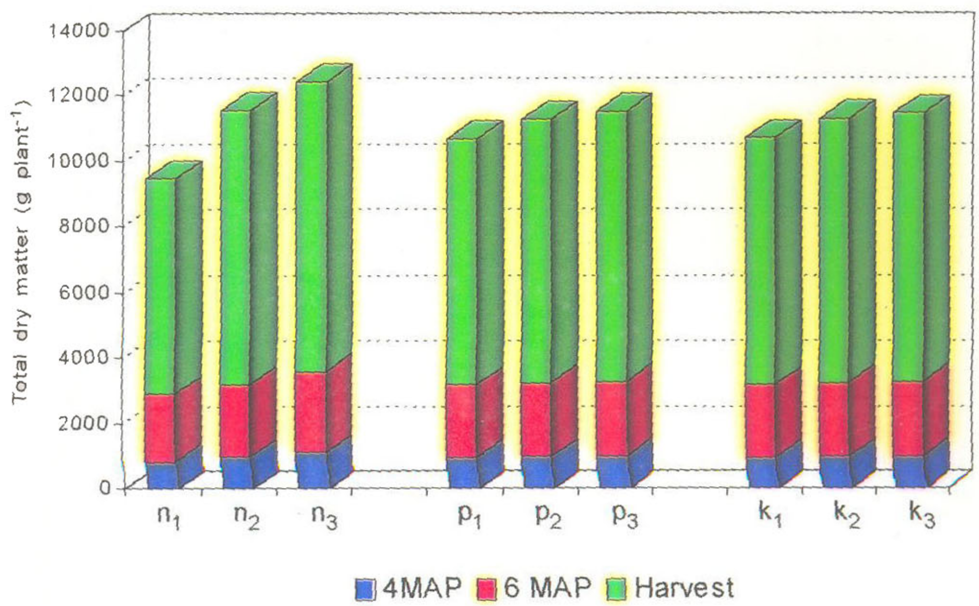

Fig. 3a. Effect of nitrogen, phosphorus and potassium on total dry matter production (98-99)

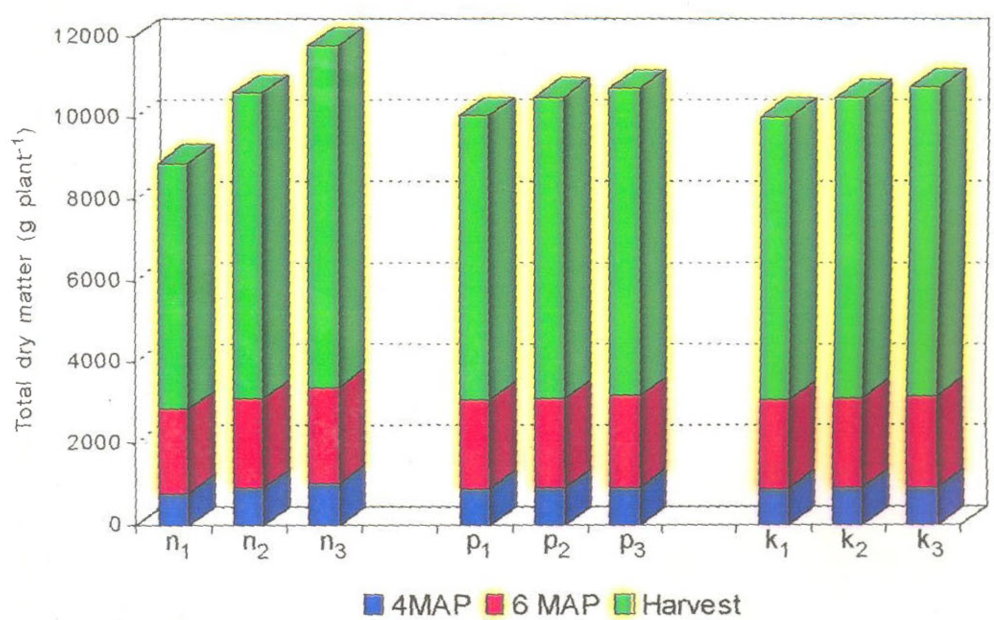

Fig. 3b. Effect of nitrogen, phosphorus and potassium on total dry matter production (99-00)

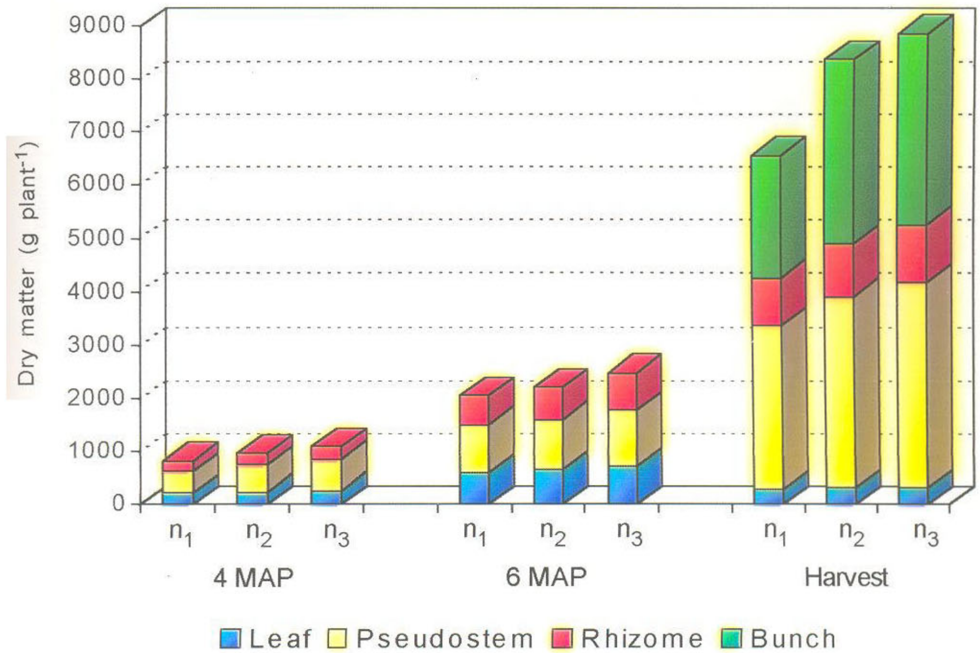

Fig. 4a. Dry matter distribution as influenced by nitrogen (98-99)

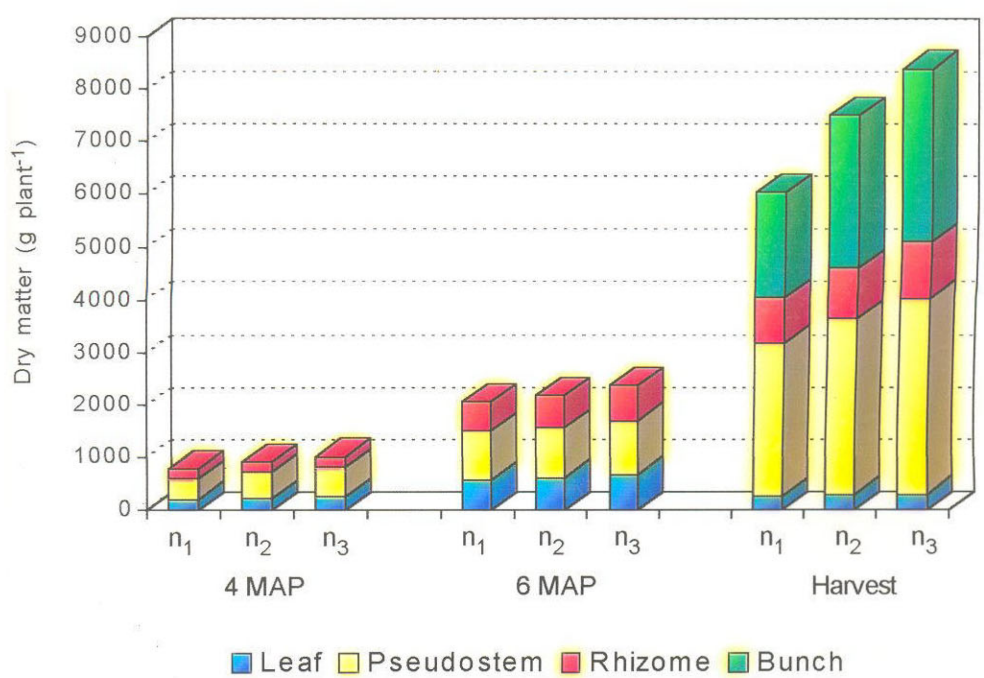

Fig. 4b. Dry matter distribution as influenced by nitrogen (99-00)

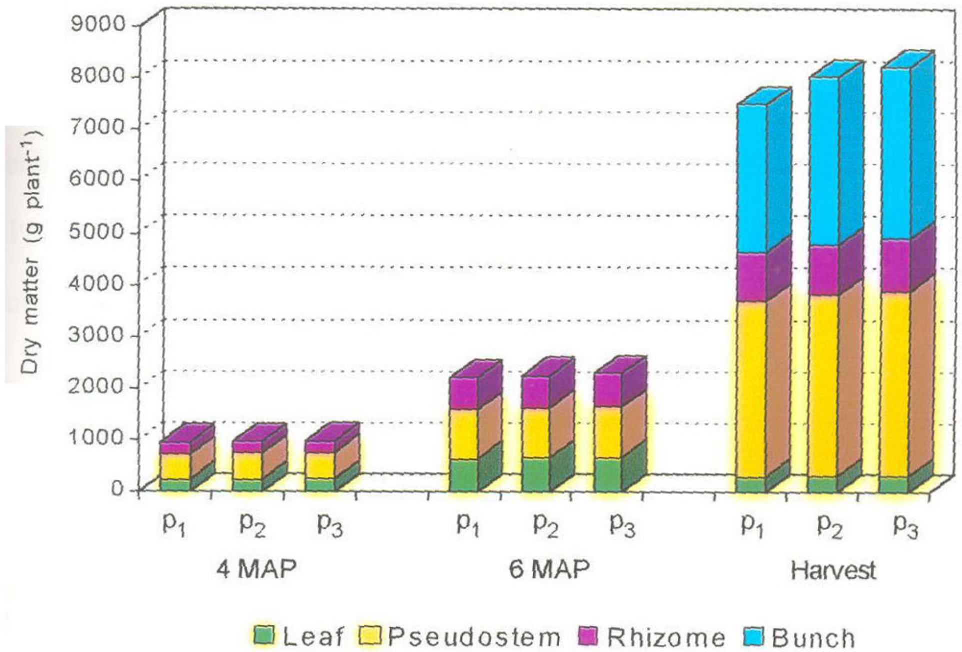

Fig. 5a. Dry matter distribution as influenced by phosphorus (98-99)

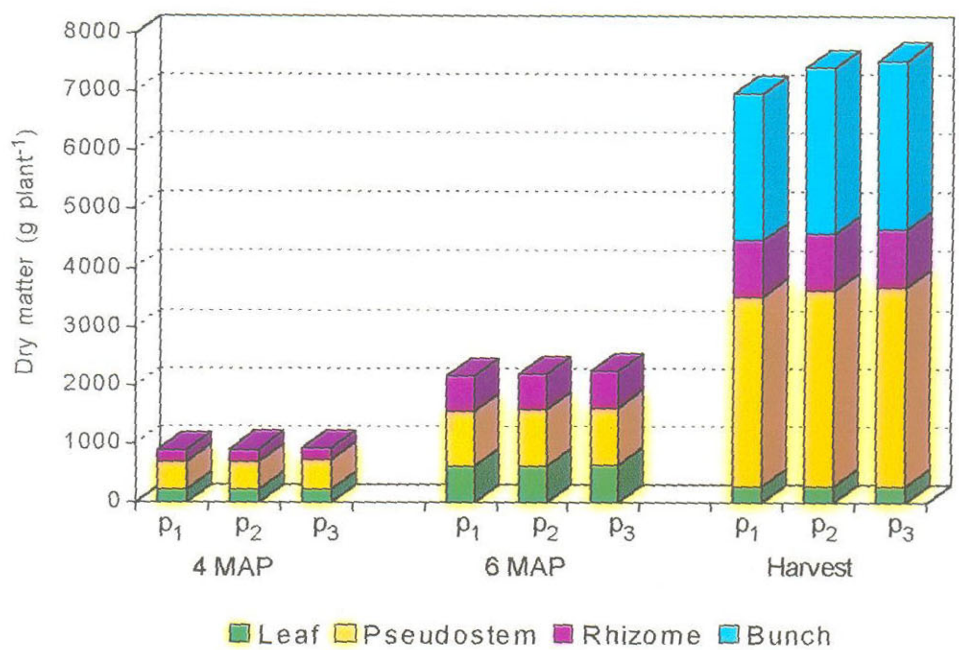

Fig. 5b. Dry matter distribution as influenced by phosphorus (99-00)

matter production. The increase in dry matter production is the outcome of higher rate of growth and better accumulation of photosynthates owing to enhanced nutrient uptake (Dave *et al.,* 1990). The favourable effect of P fertilization on total dry matter production in banana has been reported by Dave *et al.* (1990) and Shehana (1997).

Higher levels of potassium resulted in higher leaf, pseudostem, rhizome and bunch dry matter production. But at 6 MAP in 99-00, the influence of K was significant upto 400 g plant^{-1} only in the case of leaf, pseudostem and rhizome dry matter production (Tables 12a, 13a and 14a) (Figs. 6a and 6b). Potassium is an essential co-factor for many of the enzymes catalysing many metabolic pathways in plants of which protein and carbohydrate synthesis are most important. It functions in the formation of an effective polyribose complex that preceeds the active incorporation of amino acids into proteins (Lubin and Ennis, 1964). It may be recalled in this context that K exerted significant influence in enhancing leaf area and leaf area duration resulting in higher photosynthetic rates. It is well known that potassium has key role in photosythesis and translocation of assimilates in sink (Tisdale *et al.*, 1995). Potassium also reduced the loss of water by transpiration so that more organic matter can be produced per unit quantity of water consumed by a crop well supplied with K (Beringer, 1978). It may be noted that the favourable effect of higher rates of potassium on growth and yield resulted in higher plant dry weight in both the years (Table 11a) (Figs. 3a and 3b). The present results are in conformity with those previously reported in banana cv. Nendran (George, 1994 and Sindhu, 1997).

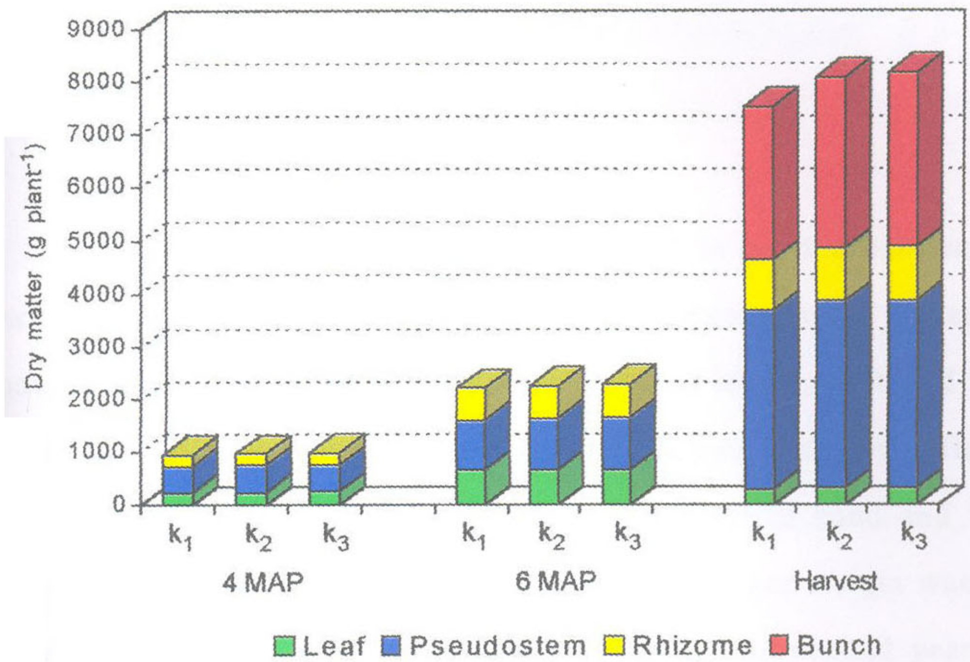

Fig. 6a. Dry matter distribution as influenced by potassium (98-99)

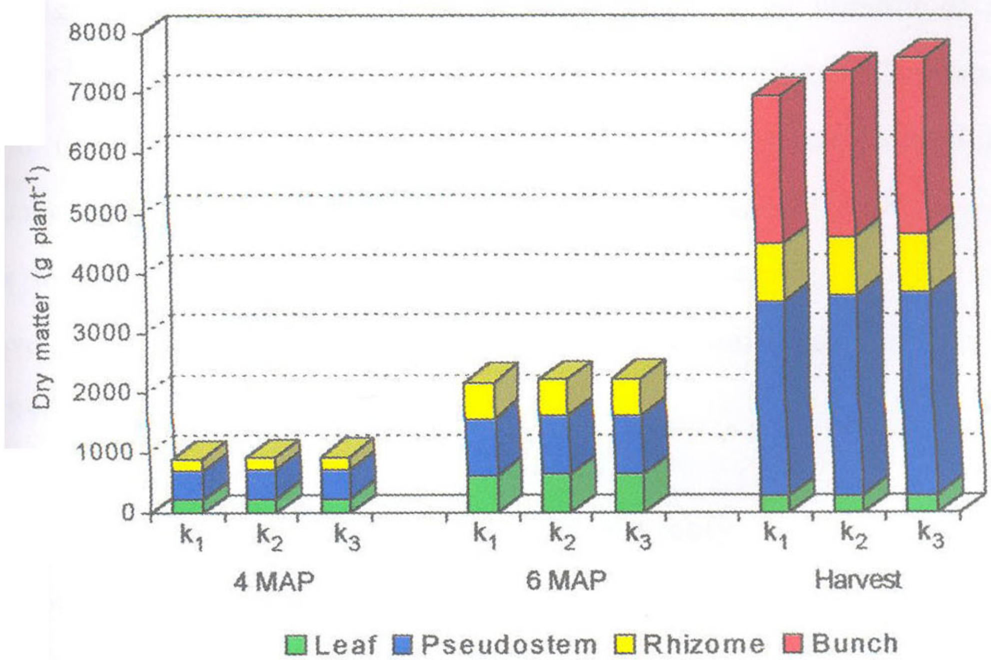

Fig. 6b. Dry matter distribution as influenced by potassium (99-00)

5.3 Yield components and yield

5.3.1 Yield components

The attributes that determine the yield in banana are length of bunch, number of hands bunch^{-1}, number of fingers bunch^{-1}, weight of hand and individual finger characteristics such as length, girth and weight (Stover and Simmonds, 1987). Applied nitrogen markedly influenced the yield attributing characters, particularly weight of hand and weight of finger (Tables 16a and 18a). The increase in finger weight was 60.69 per cent in the first year and 89.73 per cent in the second year when nitrogen was increased from 100 to 300 g plant^{-1}. This trait could be seen to have, actually contributed to the final bunch weight. The influence of N on length and girth of fruit was also conspicuous. Mathew (1980) observed that applied N increased the girth and weight of fingers and it exerted no significant effect on the number of hands bunch^{-1} and number of fingers bunch^{-1}. On the other hand, Chattopadyay *et al.* (1980) observed increase in fruit weight, length and circumference, number of hands bunch^{-1} and number of fingers bunch^{-1} with increase in the level of N applied to banana cv. Giant Governor. Similar results have been reported by Sheela (1995) and Aravindakshan and Pushkaran (1996).

Application of phosphorus appreciably influenced the yield attributes both in 98-99 and 99-00. During both the years, phosphorus influenced only upto 200 g plant^{-1} in increasing the weight of hand, girth of finger and weight of finger. The impact of phosphorus application at

200 and 300 g plant^{-1} was similar in number of hands bunch^{-1} and number of fingers bunch^{-1} in 99-00 (Tables 16a and 18a). Adequate supply of phosphorus with N and K had favoured the root proliferation and penetration covering very large soil root volume resulting in high uptake of the nutrient. These factors might have contributed to the favourable condition in the soil for growth and development of the plant and thereby exerting positive effects on the yield attributing factors. Favourable effect of phosphorus in combination with N and K on yield attributes had been reported earlier by Nambisan *et al.* (1980) and Natesh (1987).

Potassium nutrition significantly influenced the yield attributing characters. Appreciable increase in weight of hand, girth of finger and weight of finger was obtained by the application of 400 g K plant^{-1} in both the seasons. The weight of hand significantly increased with increasing levels of K in 99-00 (Tables 16a). The effect of potassium in improving the yield attributes in banana was confirmed by many workers (Sheela, 1982; Mustaffa, 1987 and Baruah and Mohan, 1992). Improved vegetative characters particularly more number of leaves produced at the higher level might have resulted in the production of more photosynthates. The effect of increased photosynthetic efficiency was expressed in the higher length and number of fingers bunch^{-1} at higher levels of K. All these factors might have contributed to the beneficial effect of potassium in improving the yield attributes.

Perceptible reduction in the case of number of hands bunch^{-1}, number of fingers bunch^{-1}, weight of hand, length of finger, girth of finger and weight of finger was observed with N, P and K application at 100, 100, 200 g plant^{-1}. The crop growth is directly related to the availability of nutrients in the soil. The inadequate supply and low availability of plant nutrients affect physiological processes like cell division, cell enlargement and finally photosynthesis. Increased uptake of nutrients might have improved the photosynthetic efficiency and would have increased the carbondioxide assimilation efficiency with concomitant increase in growth and dry matter production thereby increasing the yield attributes. The above findings are in accordance with the reports by Krishnan and Shanmughavelu (1983) and Kurien *et al.* (1985).

5.3.2 Bunch weight

Influence of nitrogen on weight of bunch was remarkable during both the years. Nitrogen application at 300 g plant^{-1} enhanced the bunch weight considerably (Table 17a) (Fig. 7). Results to date indicate positive yield response of banana to nitrogen application (Chatopadhyay *et al.*, 1980; Mathew, 1980; Kohli *et al.*, 1984; Singh and Kashyap, 1992; Sheela, 1985 and Geetha, 1998). Highest values of yield attributes obtained by the application of nitrogen at 300 g plant^{-1} ultimately contributed to the highest yield. Increased availability and uptake of nutrients at higher levels of N might have led to the better expression of growth characters and yield attributes which ultimately resulted in higher yield. According to Russell (1973), with an increase in N supply the extra protein produced permits the plants to have more surface area available for photosynthesis, resulting in better nitrogen use efficiency and enhanced growth.

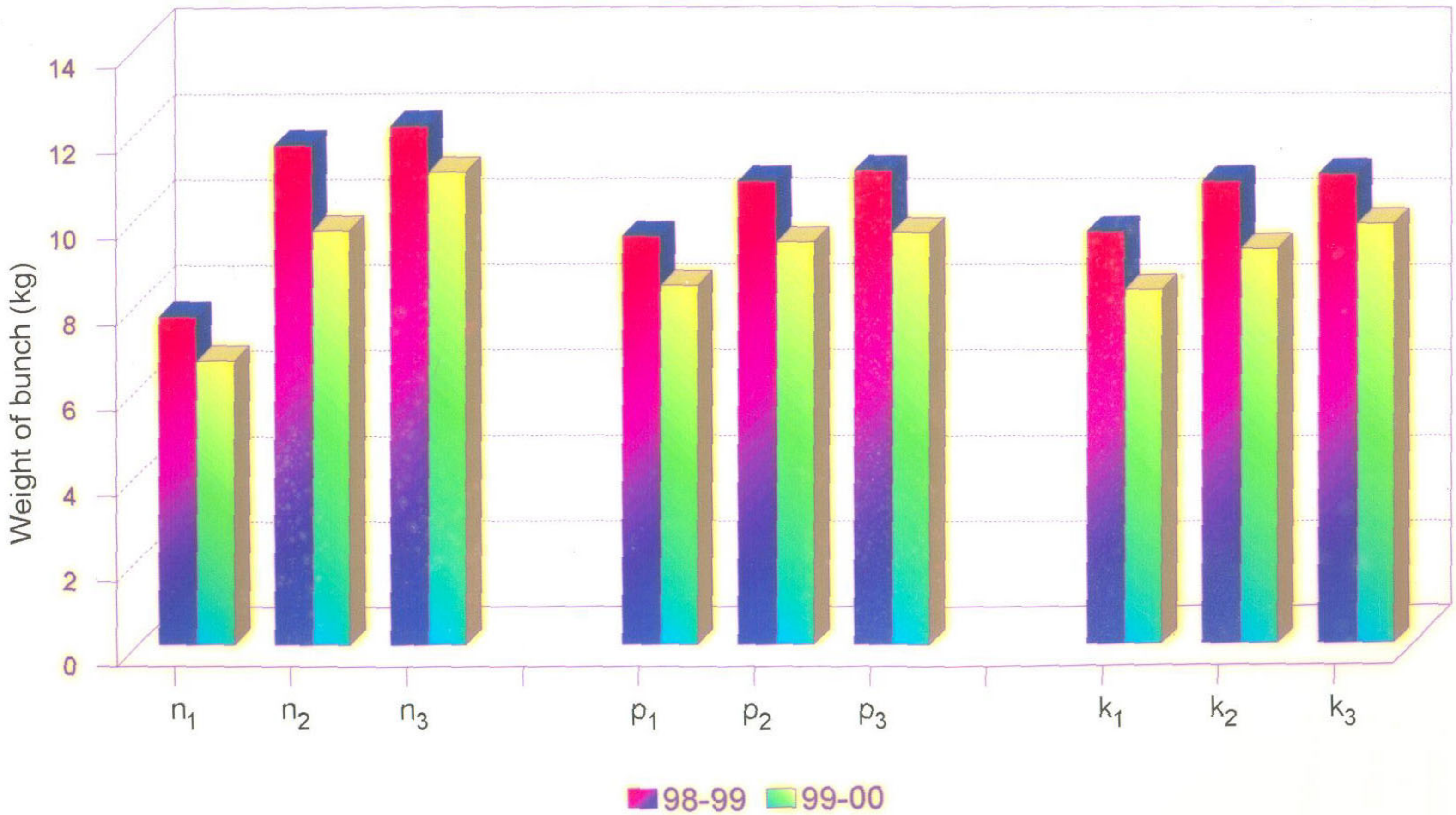

Fig. 7. Effect of nitrogen, phosphorus and potassium on weight of bunch

The impact of phosphorus at 200 g plant^{-1} in increasing the bunch weight in both the years indicated the significant role of phosphorus in improving the bunch weight (Table 17a) (Fig. 7). Positive effect of phosphorus in improving the growth as well as yield attributes were noticed only upto 200 g plant^{-1}. Among the growth characters girth of pseudostem and number of functional leaves have contributed to increased bunch yield. In the present study, these characters were high at higher levels of phosphorus. This was corroborated by the reports of several workers. The girth of pseudostem at shooting was a determinant of yield as reported by Krishnan and Shanmugavelu (1983) and Rosamma and Namboothiri (1990). Among the yield attributes, number and weight of fingers which were high at higher levels of phosphorus might have contributed to increased yield. Positive influence of phosphorus in increasing the bunch weight was reported earlier (Natesh, 1987).

Application of potassium remarkably increased the weight of bunch in both the years. During the first plant crop, significant response was obtained at 400 g plant^{-1} (10.82 kg plant^{-1}). The yield increase due to applied K was not conspicuous above 400 g plant^{-1} (Table 17a) (Fig. 7). These results are in agreement with the findings of Sheela (1995) and Peters (1997). Potassium exerted positive influence on number of functional leaves and LAI (Tables 6a and 9a) which led to more photosynthetic activity and more assimilate production. Dry matter production is also high at higher levels of K. Enhanced uptake of nitrogen, phosphorus and potassium at higher levels of potassium application could have resulted in vigorous growth and development. The possibility of the rhizome and pseudostem acting as storage organs of excess K in banana and as a circulation pump for distribution of the same to the bunch at bunch maturation and harvest stage has been reported by Huang *et al.* (1992). Combined effects of all these factors might have favoured bunch yield. Beneficial effect of K on yield had been reported earlier (Sheela, 1982; Kumar and Shanmughavelu, 1988; Nair *et al.*, 1990; Sindhu 1997; Lopez and Espinosa, 1998; Saad and Atawia, 1999 and Vijaya Raghavan and Ayyam Perumal, 2000).

All the interactions were significant in both the years. The yields obtained with N + P at interactions 300 g N + 300 g P_2O_5, 300 g N + 200 g P_2O_5, 200 g N + 300 g P_2O_5 and 200 g N + 200 g P_2O_5 were comparable. The combination of N and P_2O_5 at 300 g each plant^{-1} recorded an increase in yield by 3.4 per cent and 13.9 per cent over N and P_2O_5 applied at 200 g each plant^{-1} during the first and second year respectively (Table 17b).

In the case of N x K interaction, the yields under the interactions of 300 g N + 600 g K_2O, 300 g N + 400 g K_2O, 200 g N + 600 g K_2O and 200 g N + 400 g K_2O were statistically on par. Similarly in the P x K interaction, the combinations, 300 g P_2O_5 + 600 g K_2O, 300 g P_2O_5 + 400 g K_2O, 200 g P_2O_5 + 600 g K_2O and 200 g P_2O_5 + 400 g K_2O had similar effects in increasing the bunch weight. The combination of P and K applied at lower levels recorded the lowest bunch weight.

A significant N x P x K interaction was present in both the years. Application of N, P_2O_5 and K_2O at 300:300:600 g plant^{-1}, 300:300:400 g plant^{-1}; 300:200:600 g plant^{-1}, 300:200:400 g plant^{-1}, 200:300:600 g plant^{-1}, 200:300:400 g plant^{-1}, 200:200:600 g plant^{-1} and 200:200:400 plant^{-1} produced almost the same yield (Tables 17c). Application of N, P_2O_5 and K_2O at 300:300:600 g plant^{-1} showed an yield increase to the tune of 3.5 per cent and 3.70 per cent over the treatment combination of N, P_2O_5 and K_2O at 200:200:400 g plant^{-1} during the first and second year respectively. The trends observed in the effects of independent or two way interactions of factors explained earlier was reflected in the N x P x K interaction also.

The response of crops to fertilizer application depends upon the status of available plant nutrients in the soil and a low rating means that crops on such soil should respond very readily to nutrient application (Bains and Bahardwaj, 1976). Bray (1948) and Mc Cants and Black (1957) also had the same view with respect to crop response to fertilizers. In the present study the soil nutrient status was low which explains the better response to applied fertilizers. It was also observed that mineral nutrition with NPK at higher levels increased the availability of nitrogen, phosphorus, potassium and micronutrients. This again indicated the favourable growth condition prevailed in the soil which inturn might have increased the uptake of nutrients resulting in the maximum growth and yield.

Response of banana to high fertilizer application is well known. The nutrient requirement of the crop during early growth phase could not be met from soil alone but warrants an external application through fertilizers. Being a heavy feeder of nutrients, banana shows response to graded levels of nutrients which would become non-linear at higher levels.

The increased rate of crop growth coupled with high values of yield attributes might have contributed for enhanced bunch yield in the case of application of N, P_2O_5, K_2O at 300:300:600 g plant^{-1}. However, it was statistically on par with the treatment combination of N, P_2O_5, K_2O at 200:200:400 g plant^{-1}. The magnitude of variation in bunch yield was only marginal. Hence the above results clearly suggest that in banana to meet the nutritional requirement of major nutrients, application of N, P_2O_5, K_2O at 200:200:400 g plant^{-1} is quite sufficient for the sandy soils of *Onattukara*. There would be no need to further increase the levels of N, P_2O_5, K_2O beyond 200:200:400 g plant^{-1} as the results had shown almost same yields at higher levels of N, P_2O_5, K_2O.

5.4 Quality attributes of fruit

Application of nitrogen and potassium at varying levels influenced the quality of fruits. The quality of fruits was best expressed in terms of high TSS, total sugar, reducing sugar, sugar-acid ratio, pulp-peel ratio and low acidity with increasing levels of nitrogen and potassium (Tables 19a, 20a and 21a) (Figs. 8a, 8b, 9a and 9b). Increase in sugar content observed might be due to respirational demand, adequate supply of nutrients, synthesis of invertase and starch splitting enzymes (Barnell, 1940). According to Nitsos and Evans (1969) inadequate supply of N and K resulted in the decreased activity of enzyme sucrose synthetase and increased activity of hydrolytic enzymes such as amylose and saccharase. This led to accumulation of soluble carbohydrates especially monosaccharides. But adequate supply of N and K ensured optimal

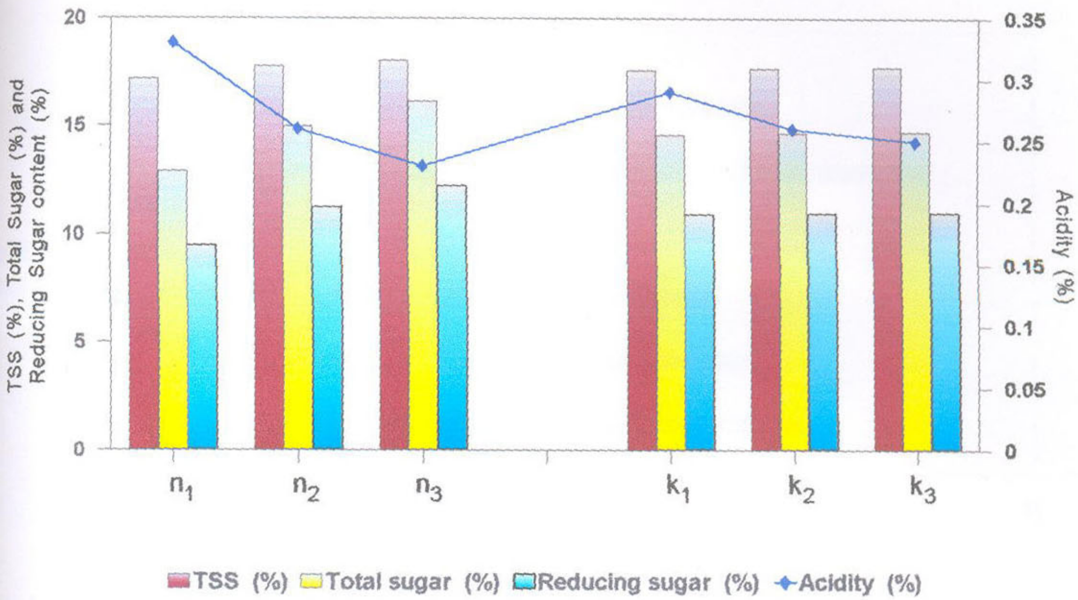

Fig. 8a. Effect of nitrogen and potassium on TSS, total and reducing sugar content and acidity of fruits (98-99)

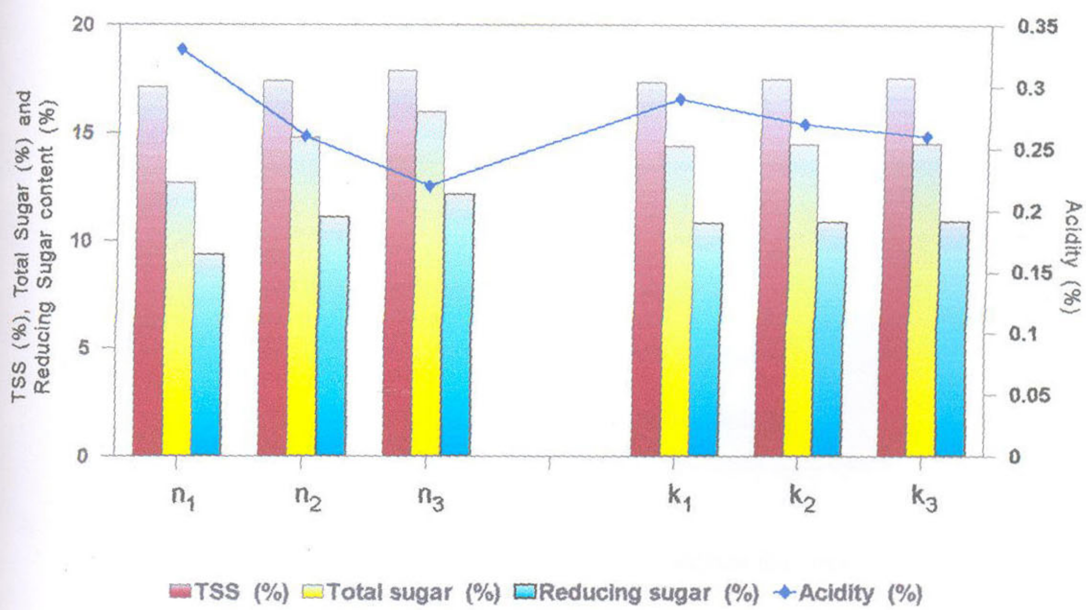

Fig. 8b. Effect of nitrogen and potassium on TSS, total and reducing sugar content and acidity of fruits (99-00)

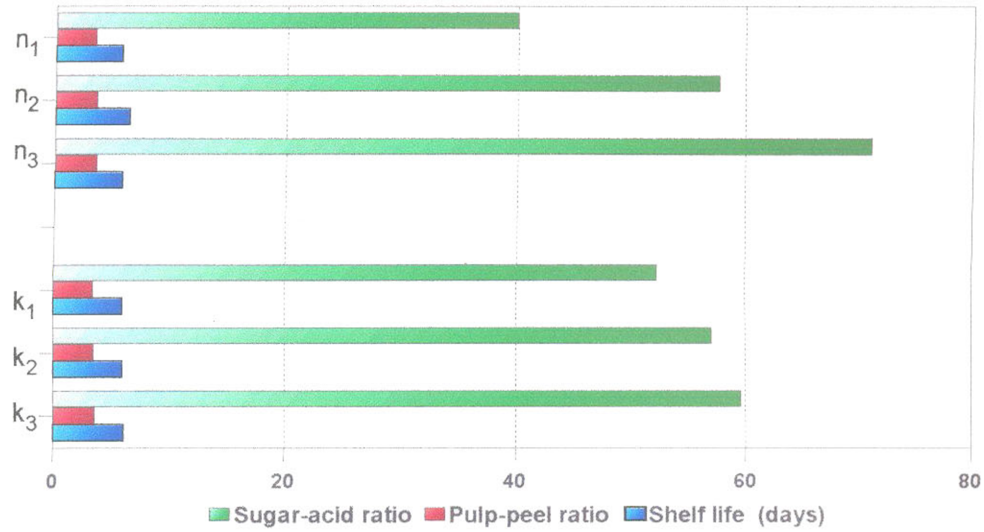

Fig. 9a. Effect of nitrogen and potassium on sugar-acid ratio, pulp-peel ratio and shelf life of fruits (98-99)

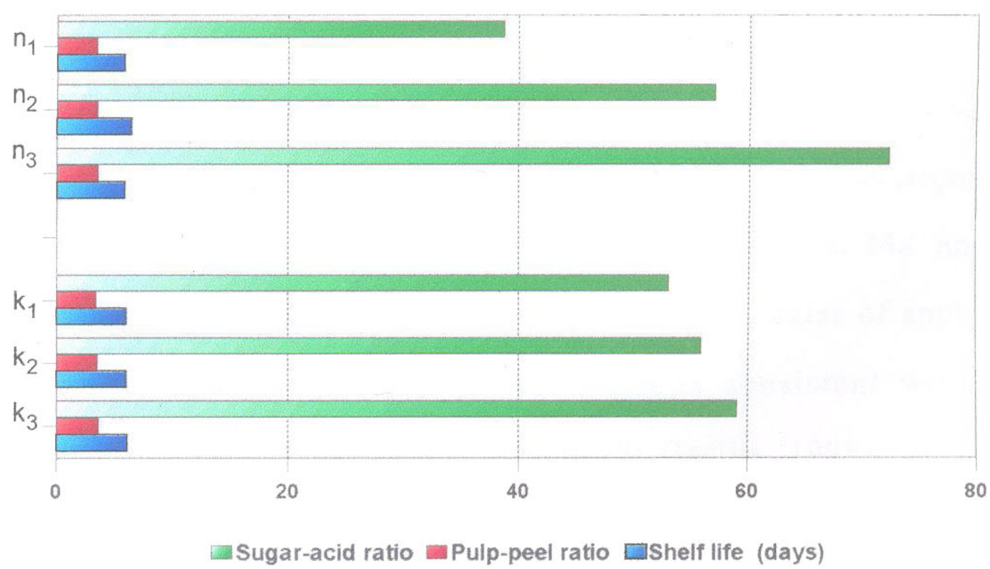

Fig. 9b. Effect of nitrogen and potassium on sugar-acid ratio, pulp-peel ratio and shelf life of fruits (99-00)

functioning of sucrose synthetase and suppression of hydrolytic enzymes leading to build up of greater quantity of sugars in the proplastids. Similar results have been reported by Ramaswamy *et al.* (1977), Vadivel and Shanmugavelu (1978), Terra *et al.* (1983) and Prevel (1989) and Hassan and Chattopadhyay (2000).

The increase in pulp-peel ratio with higher levels of N and K was mainly due to the increase in pulp weight due to the enhanced activity of enzymes involved in starch and protein synthesis. The results are in conformity with the reports by Sheela (1982); Lahav and Turner (1983) and Prevel (1989).

5.5 Uptake of nutrients

5.5.1 Major nutrients

5.5.1.1 Nitrogen

The effect of applied nitrogen on total uptake of nitrogen in different plant parts and thereby in the whole plant was significant throughout the period of experimentation (Tables 22a, 23a, 24a and 49a) (Fig. 10). Increase in the uptake of N due to higher rates of application of N is a proven fact. The present result is consistent with those previously reported in banana (Peters, 1997; Geetha, 1998).

Similarly uptake of nitrogen was favoured by the application of phosphorus and potassium. Increased N uptake due to increase in K fertilization has also been reported by Hegde and Srinivas (1991). Better

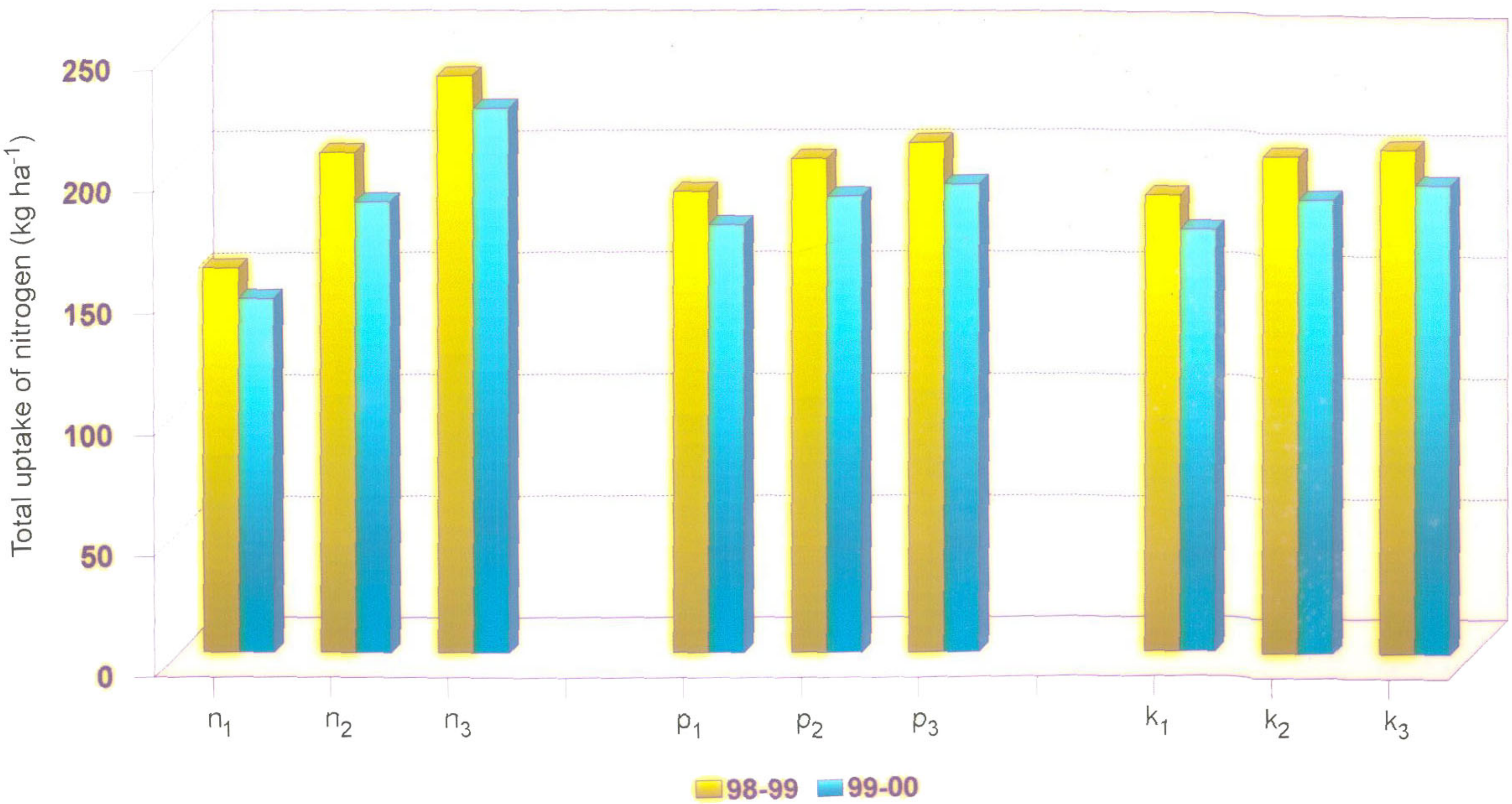

Fig. 10. Effect of nitrogen, phosphorus and potassium on total uptake of nitrogen

N uptake is commonly associated with adequate P and K fertilization. Uptake of nitrogen occurs at the expense of energy from ATP which requires phosphorus and potassium for synthesis (Tisdale *et al.*, 1995). The increased turgidity of the cells under adequate supply of K consequent to regulation of transpiration also might have increased the uptake of N.

5.5.1.2 Phosphorus

Application of nitrogen, phosphorus and potassium appreciably increased the uptake of phosphorus in leaf, pseudostem, rhizome and bunch which ultimately led to the increased total uptake (Tables 25a, 26a, 27a and 49a) (Fig. 11). Application of nitrogen at higher rate increases the protein biosynthesis leading to the formation of new tissues. The high energy phosphorus compounds, ADP and ATP are involved in the biosynthesis of proteins. Hence for the operation of the pathway, phosphorus is utilized in greater amounts at higher rates of N (Tisdale *et al.*, 1995).

In the present study, higher rates of phosphorus and potassium also favoured P uptake. Potassium promotes N uptake and protein synthesis, a high energy dependent pathway that requires sufficient amount of P. Increased uptake of P by potassium application has been reported by Bondad *et al.* (1983), Turner and Barkus (1985) and George (1994). Lahav (1977) also found synergism between phosphorus and potassium in banana cv. Williams especially in the petiole and leaf blade.

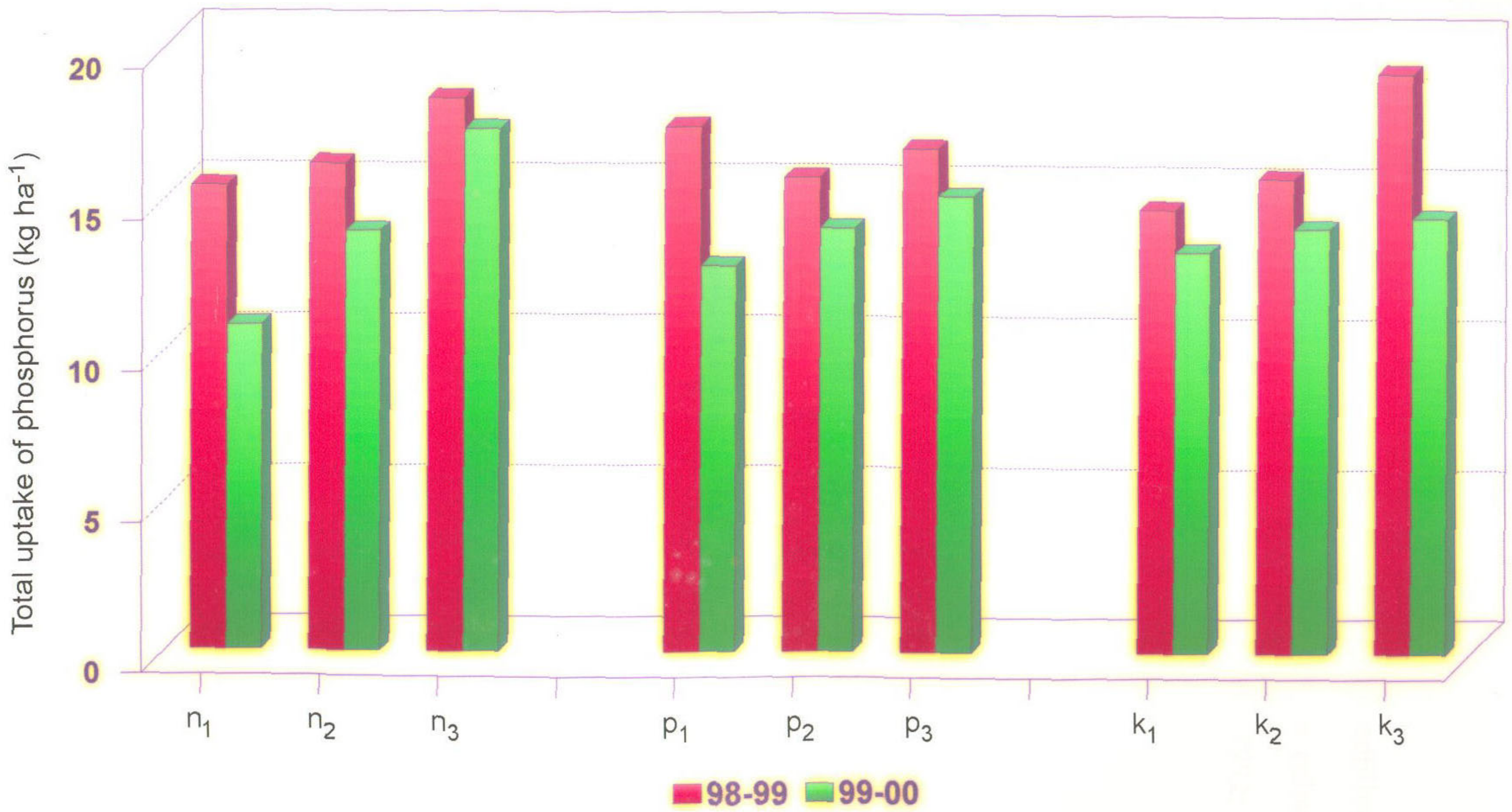

Fig. 11. Effect of nitrogen, phosphorus and potassium on total uptake of phosphorus

5.5.1.3 Potassium

The uptake of potassium was increased by the application of nitrogen, phosphorus and potassium. Higher rate of N in enhancing K uptake has been established earlier (Shanmugavelu *et al.*, 1992; George, 1994; Sindhu, 1997).

The indispensable involvement of K in the synthesis of ATP needed for photosynthesis as well for N uptake has been reported earlier (Tisdale *et al.*, 1995).

The general trend that can be observed on the basis of this study is that the total uptake of K increased with increase in the levels of K supplied, the maximum values being recorded at the highest level of K (Tables 28a, 29a, 30a and 49a) (Fig. 12). Similar observations were made by Irizarry *et al.* (1988), Vadivel and Shanmugavelu (1988), Sheela and Aravindakshan (1990), Hegde and Srinivas (1991) and George (1994). Increased nutrient concentrations built up in the tissue following K application account for the increased uptake of K at higher levels of application.

5.5.2 Secondary nutrients

Different levels of nitrogen, phosphorus and potassium appreciably influenced Ca and Mg uptake. Applied N and P increased the uptake of calcium and magnesium in leaf, pseudostem, rhizome and

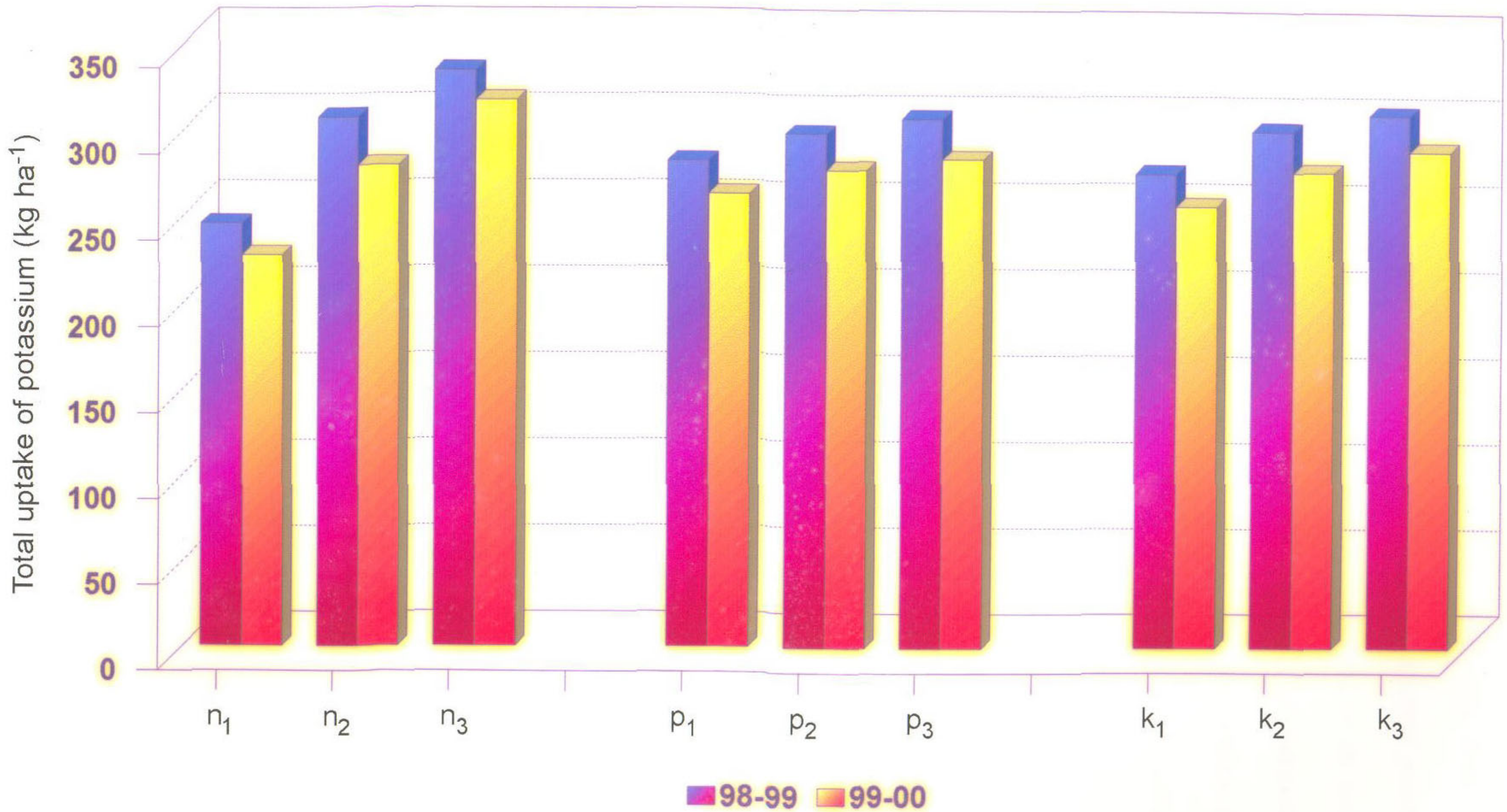

Fig. 12. Effect of nitrogen, phosphorus and potassium on total uptake of potassium

bunch and eventually in the whole plant (Tables 31a, 32a, 33a, 34a, 35a, 36a and 50a) (Figs. 13 and 14). The increased dry matter produced on account of higher levels of N and P application resulted in an increase in the uptake of these two nutrients. But in the case of potassium, the uptake of calcium increased when the level of K was increased from 200 to 400 g $plant^{-1}$ beyond which there was a reduction. As explained by Mengel and Kirkby (1982), cation species are attracted by the negative electro potential of the cell which is being continuously regenerated by H^+ extrusion. Potassium can traverse the plasma membrane more easily and have greater chance of saturating the continuously generated negative potential. Cations which enter the cell rapidly depress the uptake of others. K^+ is absorbed at a faster rate which inturn acts as competitors. Tandon and Sekhon (1988) attributed another reason for decreased Ca uptake at higher levels of K supply. Potassium is the largest non-hydrated cation among the nutrient cations required by the plant. The number of oxygen ions surrounding K in mineral structure is 8-12 as against 6-8 for Ca. So the strength of each K-0 bond is relatively weak. Hence K^+ is preferred over Ca in cation exchange reaction. The results obtained in the present study is in conformity with the findings of George (1994).

The uptake of Mg was significantly influenced by N and P application. But potassium responded only upto 400 g $plant^{-1}$. Turner and Barkus (1985) reported that eventhough increasing K supply increased the uptake of most elements, the uptake of Mg was unaffected.

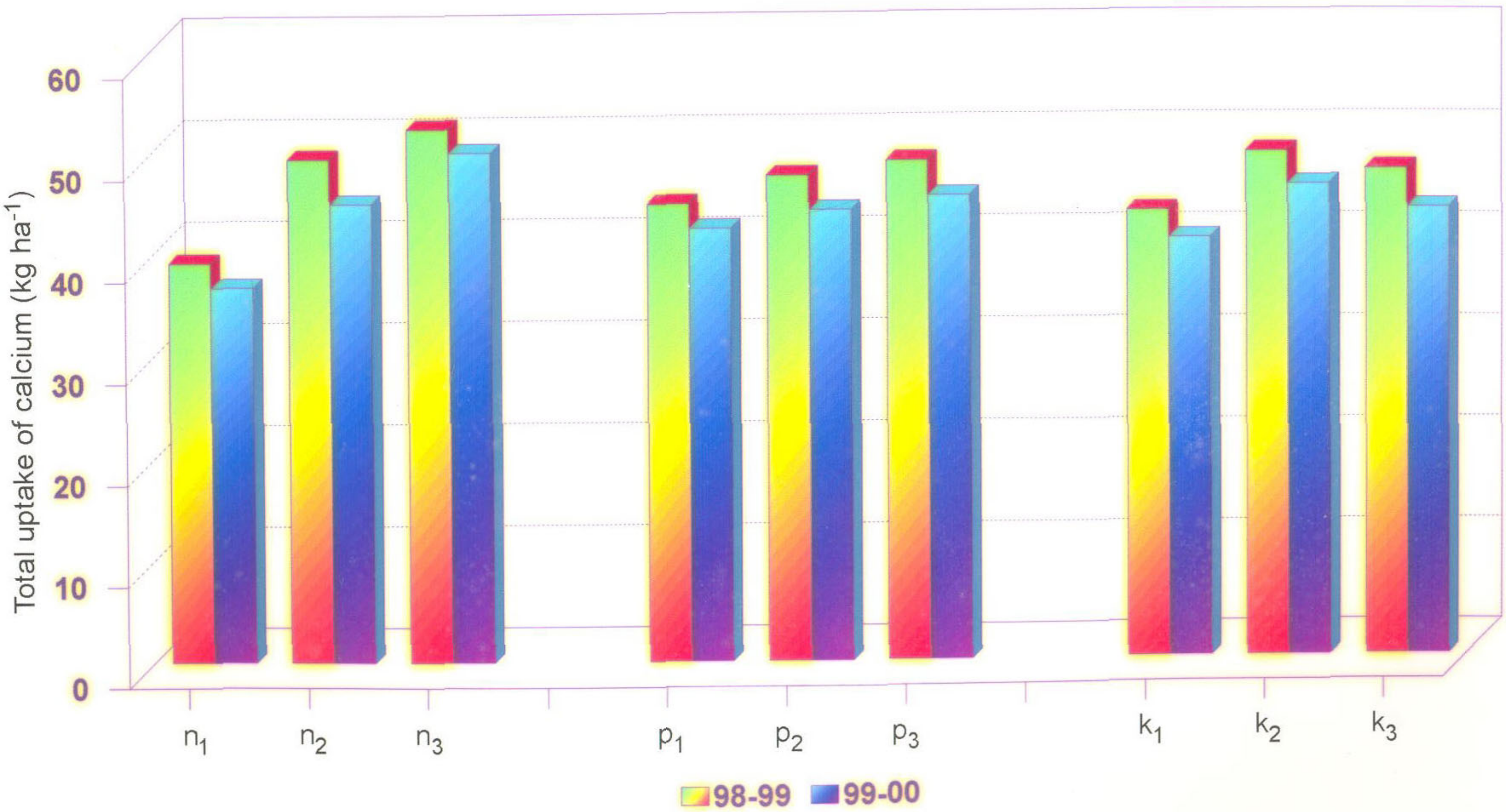

Fig. 13. Effect of nitrogen, phosphorus and potassium on total uptake of calcium

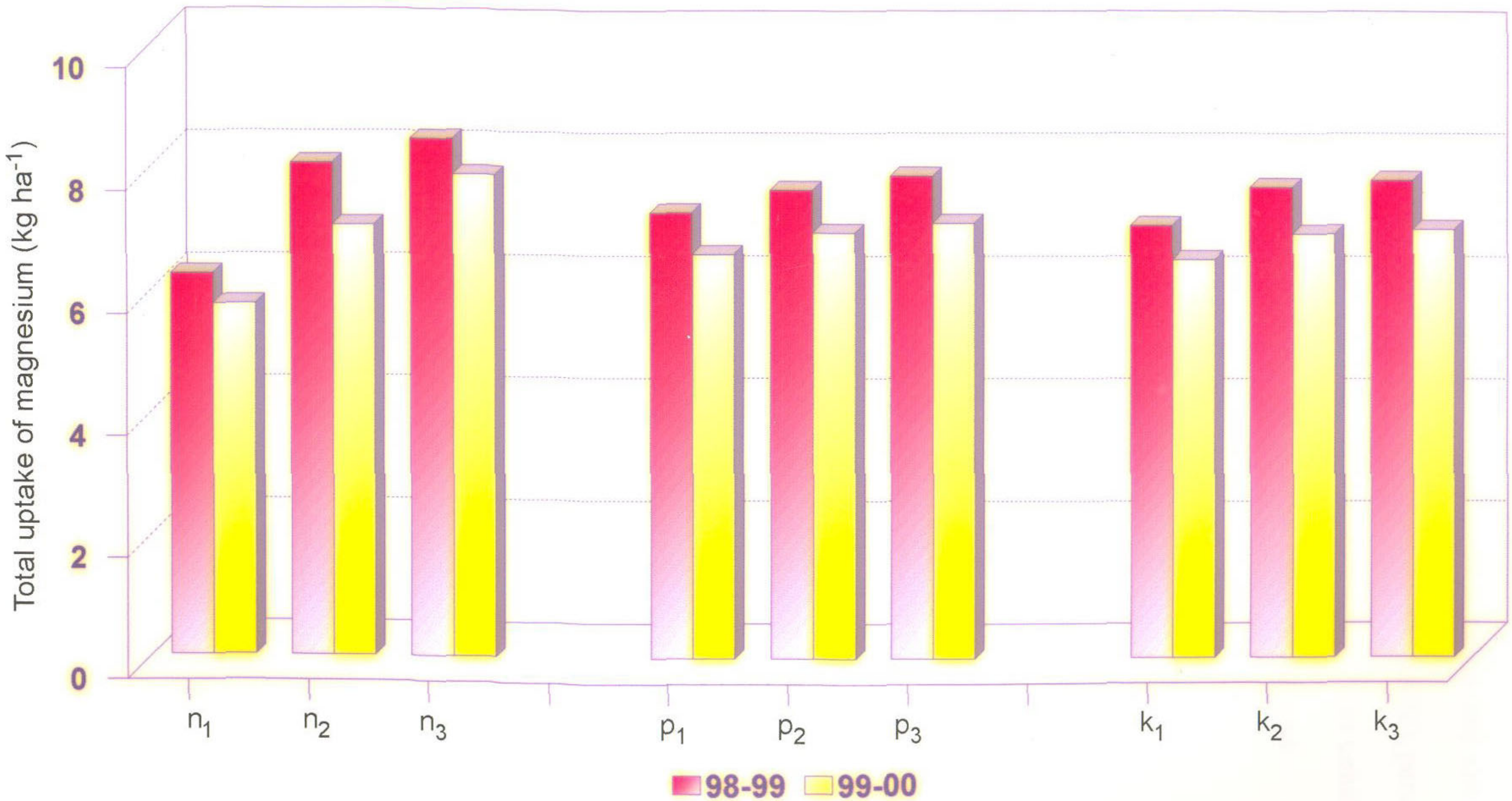

Fig. 14. Effect of nitrogen, phosphorus and potassium on total uptake of magnesium

Singh *et al.* (1991) observed that varied K application did not affect the Mg content of leaves. According to Caldas *et al.* (1973) percentage of Mg in the cation sum K + Ca + Mg remained more or less constant while K was progressively replaced by Ca as the plant developed.

5.5.3 Micro-nutrients

The uptake of micro nutrients such as iron, manganese, zinc and copper in leaf, pseudostem, rhizome and bunch was favoured by the application of higher levels of N, P and K which resulted in the release of major nutrients when it undergoes mineralization. This would have increased the availability of major and micro nutrients and provided a better environment for high root development favouring increased absorption, dry matter production and better uptake of plant nutrients.

5.6 Nutrient status of soil

5.6.1 Organic carbon

The different levels of nitrogen, phosphorus and potassium did not influence the organic carbon content of the soil in both the years. But there was a slight increase in organic carbon in the post harvest soil in both the years (Table 52a). The organic matter in the residue contributed by the current crop upon decomposition might have increased the organic carbon content of the soil.

5.6.2 Available nitrogen

Nitrogen supplementation at higher rates enhanced the nitrogen content of the soil at all stages (Table 53a) (Fig. 15). Improving soil N status through increased application of inorganic fertilizers was reported by Srikul and Turner (1995). Individual effect of phosphorus was not significant in increasing the available nitrogen content of the soil. Potassium at higher rates also increased the available nitrogen status of the soil. Maintenance of higher available N status due to higher N and K replenishments is almost a rule. According to Minhar and Bora (1982), an increase in the rate of applied nitrogen along with P and K was associated with an increase in the build up of total and available nitrogen. Increase in rate of inorganic nitrogen added may also enhance the nitrate nitrogen content of the soil possibly due to conversion of applied mineral nitrogen through nitrification process (Krishnan, 1986 and Yadav and Singh, 1991). Enhancement in available N status with higher NPK fertilization was noticed by Peters (1997).

5.6.3 Available phosphorus

Application of nitrogen, phosphorus and potassium resulted in an appreciable increase in the P content of the soil (Table 54a) (Fig. 16). There was a build up in the P content after the harvest of the crop. The higher status of phosphorus revealed comparatively lesser uptake of applied phosphorus. Another possible reason that can be attributed is the release of fixed phosphorus in presence of applied N and K. Maintenance of higher available P content at higher levels of K is well

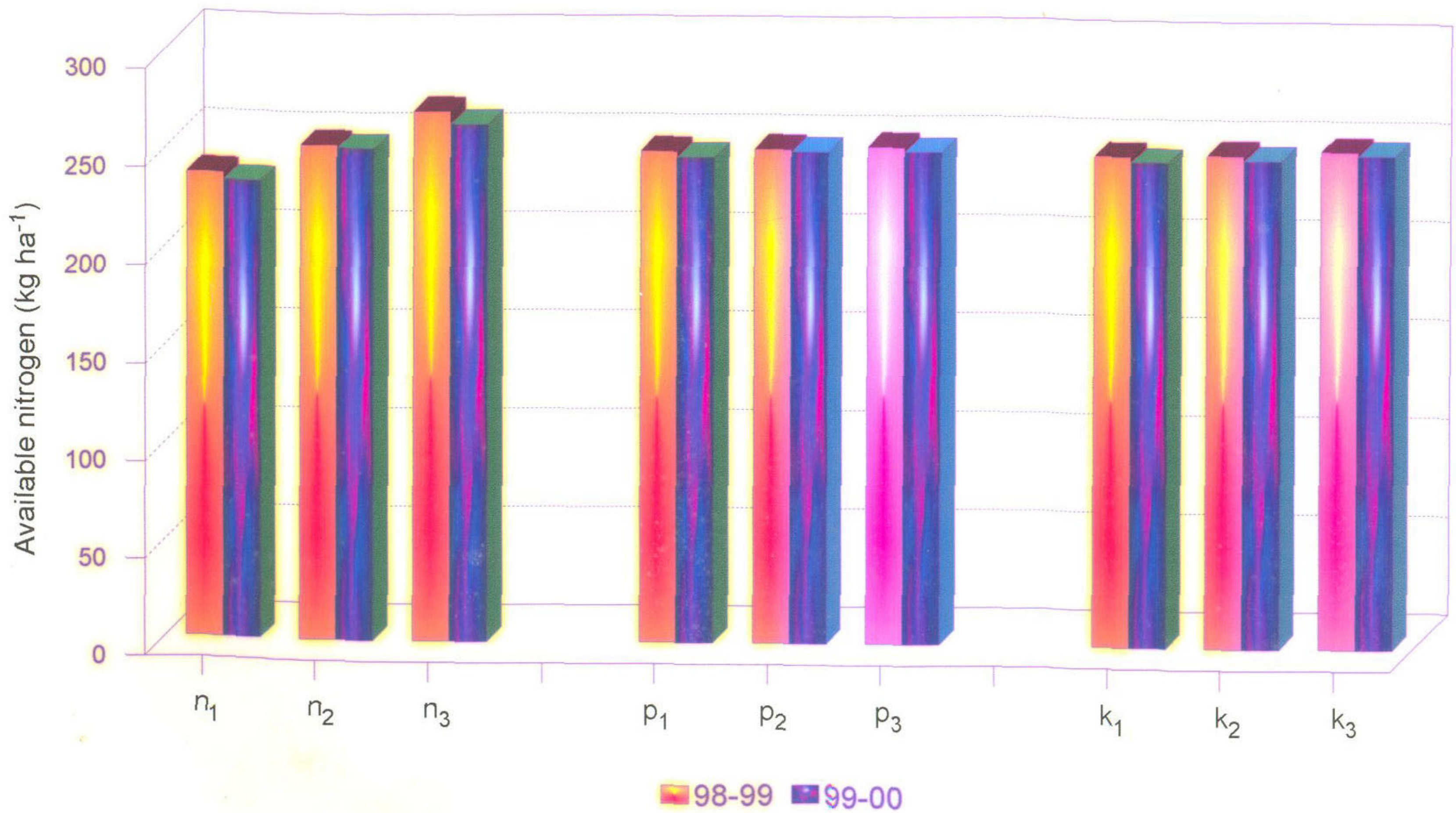

Fig. 15. Influence of nitrogen, phosphorus and potassium on available nitrogen content of the soil at the termination of experiment

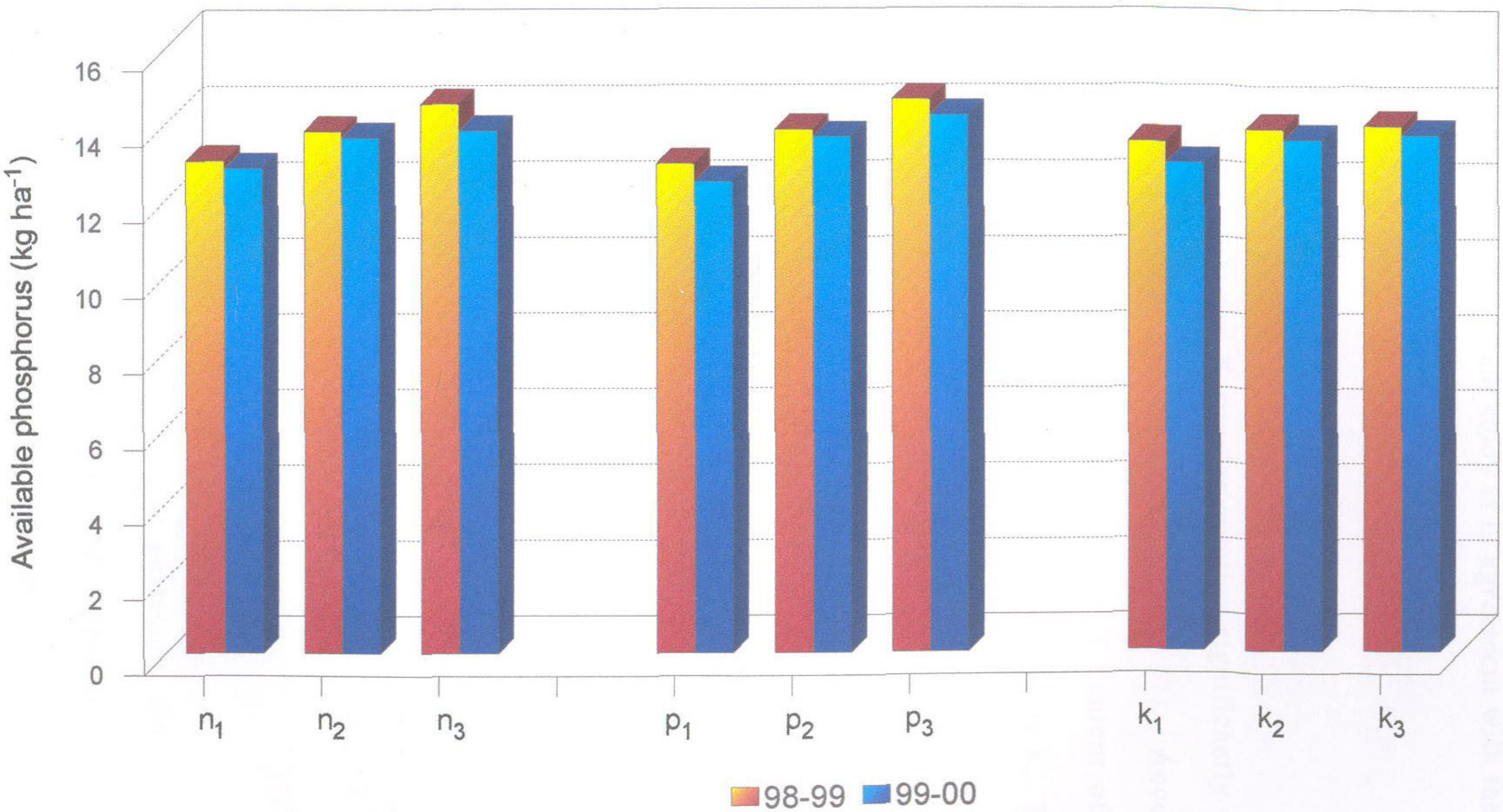

Fig. 16. Influence of nitrogen, phosphorus and potassium on available phosphorus content of the soil at the termination of experiment

known. The results of the present study is in agreement with the findings of Sheeja (1990).

5.6.4 Available potassium

Higher rates of N and K supplementation significantly enhanced available K content of the soil (Table 55a) (Fig. 17). According to Prabhakar (1996), the marginal increase in the K content of the soil indicates better synergestic effect between N and available K. The result corroborates with that of George (1994) and Sindhu (1997).

5.6.5 Secondary nutrients

There was no significant variation in the content of calcium and magnesium in the soil even after the experiment (Tables 56 and 57). One of the possible reasons that can be attributed is the release of plant nutrients due to the biodegradation of crop residues added to soil. It has to be emphasized that roots accumulate considerable amount of plant nutrients and when it is turned back into the soil results in the release of appreciable amount of plant nutrients.

5.6.6 Micronutrients

Applied nitrogen, phosphorus and potassium did not bring any marked variation in the manganese, zinc and copper content of the soil. Iron did not follow any definite pattern by the application of higher levels of nitrogen (Tables 58a, 59, 60, 61). Corraboratory results were reported

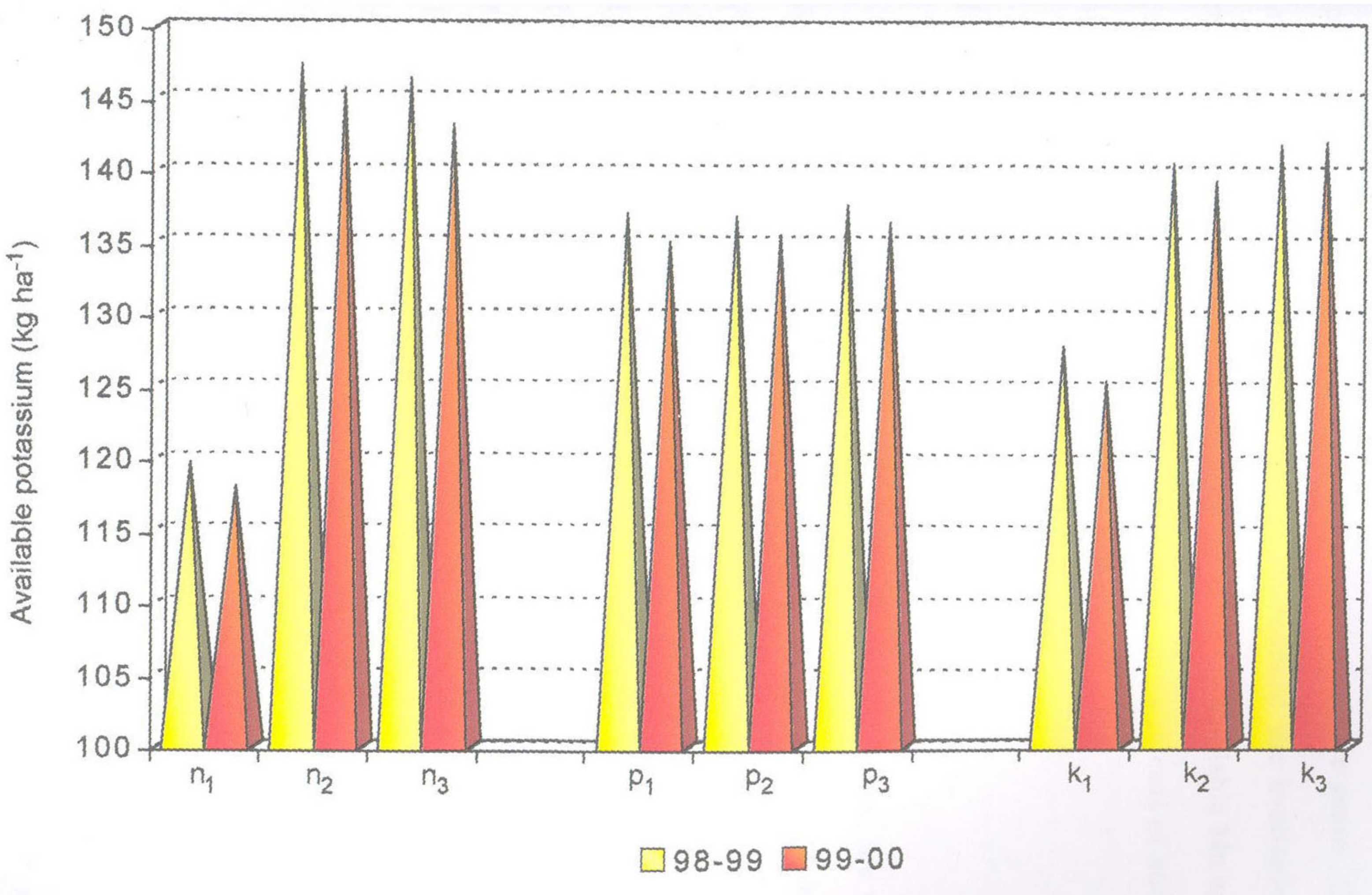

Fig. 17. Influence of nitrogen, phosphorus and potassium on available potassium content of the soil at the termination of experiment

by Sharma *et al.* (1999). Phosphorus supply did not significantly influence the available iron content of the soil in both the years. On the other hand, increasing levels of potassium reduced the available iron content. However, there was a slight increase in the available Mn and Zn content of soil after harvest. This might be due to the release of nutrients by the addition of crop residues.

5.7 Economic analysis

The economics of the treatments clearly indicate that the use of fertilizer nutrients is essential in the commercial production of banana. Among the major nutrients studied, application of nitrogen at 300 g $plant^{-1}$ had given rupees 1.81 and 1.66 per rupee invested on cultivation in the first year and second year respectively (Table 62a). It was clearly followed by nitrogen application of 200 g $plant^{-1}$ registering rupees 1.75 and 1.53 per rupee invested in the first and second plant crop respectively. In the case of phosphorus nutrition, P_2O_5 applied at 300 g $plant^{-1}$ had shown 1.64 and 1.46 per rupee invested on cultivation. It was statistically on par with P_2O_5 applied at 200 g $plant^{-1}$. Mineral nutrition with potassium also had recorded similar trend to that of N and P application. The apparent responses in the individual effects were also closely reflected in the two way interactions viz., N x P, N x K and P x K (Table 62b).

Considering the three way interaction of N with P and K, application of nitrogen, phosphorus and potassium at 200:200:400 g $plant^{-1}$

had given the highest values 1.96 and 1.84 per rupee invested in cultivation during 98-99 and 99-00 respectively (Table 62c). The treatment combination of NPK at lower levels recorded lowest economic returns.

The substantial increase made in bunch weight due to treatment effects might have resulted in maximum returns thereby enhancing BCR. In the present study it was evident that application of N along with P_2O_5 and K_2O at 200:200:400 g plant^{-1} had produced significant effects on growth and yield attributes besides improving the fertility status of soil. In this context it has to be emphasized that supplementation of plant nutrients in adequate quantities through chemical fertilizers is very essential for the growth and development of banana. Use of chemical fertilizers in required quantities has been found to be highly beneficial.

5.8 Soil column studies

5.8.1 Leaching of nutrients

Application of different levels of nitrogen, phosphorus and potassium did not bring any significant variation in the leaching loss of nutrients (Table 63). The loss of nutrients due to leaching depends upon the physical properties of the soil rather than the levels of nutrients applied. The soil used for the present study has low organic matter content and available nitrogen status. According to Russell (1973), if the mineral nitrogen status of the soil is low, crop and leaching losses appear to be the dominant sources of loss. In the present investigation, the loss of nitrogen by leaching was in range of 23.17 to 23.98 per cent of the applied N. Mahapatra *et al.* (1980) reported a higher loss (43 per cent of N applied as urea) from a field under 11 week old paddy at Central Rice Research Institute, Cuttack.

5.8.2 Nutrient retention

The retention of nutrients at different depth in the soil column was not influenced by the different levels of N, P and K applied (Tables 64, 65 and 66). But the retention of the above nutrients was high in the top 0-15 cm followed by 15-30 cm depth. The lowest was associated with 30-45 cm and 45-60 cm depth. The soil at the depth of 0-15 cm and 15-30 cm is having greater amount of organic matter and mineral nutrients. The clay content also is high. The top layer represents the Ap horizon of the soil profile. The activity of microbial population is more and the soil is in a dynamic stage. The above conditions might have favoured the better retention of nutrients in the soil at a depth of 0-15 and 15-30 cm when compared to 30-45 cm and 45-50 cm.

SUMMARY

6. SUMMARY

A research programme entitled nutrient management for banana, *Musa* (AB group) Njalipoovan in *Onattukara* soils was undertaken at Onattukara Regional Agricultural Research Station, Kayamkulam for a period of two years during the cropping seasons of 1998-1999 and 1999-2000 to find out the nutritional requirement of banana cv. Njalipoovan. The experiment was laid out in confounded 3^3 factorial, confounding NPK in replication I and NP^2K in replication II. The treatments consisted of three levels each of nitrogen (100, 200 and 300 g plant^{-1}), phosphorus (100, 200 and 300 g plant^{-1}) and potassium (200, 400 and 600 g plant^{-1}) with one absolute control in each block and the experiment was replicated twice. In addition to this, a column study to find the loss and retention of nutrients was also undertaken separately. The salient findings emanated from the research are briefed below.

The growth attributes like plant height, pseudostem girth, total number of leaves and number of functional leaves increased significantly with increasing levels of N recording maximum values at 300 g N plant^{-1}. Phosphorus increased the above growth attributes upto 200 g plant^{-1}. Potassium fertilisation at 600 g plant^{-1} retained more number of functional leaves particularly during the vegetative growth stage. However

towards harvest at 400 g K_2O plant^{-1} more number of functional leaves were retained. Combination of nitrogen with phosphorus and potassium at 300:300 g plant^{-1} and 300:400 g plant^{-1} respectively had recorded the highest values for all the above growth attributes like height and girth of plant, at all the stages of growth.

Increasing doses of nitrogen reduced the number of days from planting to shooting and thereby the total duration of the crop. Potassium nutrition at 400 g plant^{-1} was found to be beneficial in reducing the total duration of the crop.

Higher rates of nitrogen, phosphorus and potassium perceptibly increased the leaf area and LAI particularly in the active vegetative stage of the crop. However towards harvest, nitrogen application at higher rates tended to enhance the LAI but applied phosphorus and potassium did not have any influence. The interaction effects N x P, N x K and P x K also influenced the leaf area and LAI.

The leaf emergence rate was found to be highest with nitrogen application at 300 g plant^{-1}. Applied P did not have any effect on leaf emergence rate whereas it was high at 400 g K_2O plant^{-1}.

Higher dry matter accumulation in leaves, pseudostem, rhizome and bunch and thereby as the whole plant was obtained at 300 g N plant^{-1}. Phosphorus application increased the leaf and pseudostem dry matter production of the crop. Bunch dry matter was higher at 300 g P_2O_5 plant^{-1}

in 98-99 and at 200 g P_2O_5 plant^{-1} in 99-00. Potassium fertilization at 600 g plant^{-1} increased the leaf, rhizome and bunch dry matter production and resulted in higher whole plant biomass.

Increasing doses of nitrogen significantly increased the length of the bunch and number of hands bunch^{-1} in both the years. Application of phosphorus at 300 g plant^{-1} increased the number of hands and number of fingers bunch^{-1} during 98-99. During the subsequent year, the number of hands and number of fingers bunch^{-1} at 200 g P_2O_5 plant^{-1} and 300 g P_2O_5 plant^{-1} were on par. Potassium fertilization at 400 g plant^{-1} increased the length of bunch, number of hands and number of fingers bunch^{-1} in 99-00.

The individual finger characteristics like length, girth and weight of finger significantly increased at 300 g N plant^{-1}. Enhanced levels of phosphorus and potassium also promoted all these attributes. The combination of N with P_2O_5, N with K_2O and P_2O_5 with K_2O at higher levels also had shown increased values for finger characteristics.

The bunch weight remarkably increased at 300 g N plant^{-1}. Bunch weight was significantly higher at 300 g P_2O_5 and 600 g K_2O plant^{-1}. Considering the three way interaction, the bunch yield obtained by the application of N, P_2O_5, K_2O at 300:300:600 g plant^{-1} was statistically on par with that at 200:200:400 g plant^{-1} in both the years.

Higher TSS, total sugar, reducing sugar, sugar acid ratio and pulp-peel ratio were recorded at 300 g N plant^{-1}. The acidity was lower at high rate of nitrogen application. However, the non-reducing sugars remained unchanged at different levels of N. Shelf life of the fruits was longer at 200 g N $plant^{-1}$. Higher levels of potassium also promoted, TSS, total sugars, reducing sugars, sugar acid ratio, pulp-peel ratio and shelf life while P application did not influence any of these quality attributes.

The uptake of N, P and K by the different plant parts like leaf, pseudostem, rhizome and bunch increased with the higher levels of N, P_2O_5 and K_2O. Application of N, P_2O_5, K_2O each at 300, 300 and 600 g $plant^{-1}$ recorded higher uptake of N, P and K by leaf, pseudostem, rhizome and bunch. It was comparable with the main effects of N, P_2O_5 and K_2O each applied at 200, 200 and 400 g $plant^{-1}$.

The uptake of calcium and magnesium in different plant parts such as leaf, pseudostem and rhizome increased with increasing levels of N and P_2O_5 with the highest values at 300 g each $plant^{-1}$. Potassium at 400 g $plant^{-1}$ increased the calcium and magnesium uptake by different plant parts. Potassium supply at 600 g $plant^{-1}$ reduced the calcium uptake while the Mg uptake was not affected.

Higher levels of nitrogen, phosphorus and potassium increased the uptake of micronutrients such as iron, manganese, zinc and copper by the leaf, pseudostem and rhizome.

Different levels of nitrogen, phosphorus and potassium did not cause appreciable variation in the organic carbon content of the soil.

Higher rates of N increased the available N, P and K contents of the soil after harvest. P application increased the available N and P content. Potassium application at 600 g plant^{-1} led to an appreciable build up of K in soil. However, there was no significant variation in the calcium and magnesium content of the soil due to these treatments.

Different levels of nitrogen, phosphorus and potassium did not have any influence on the available iron, manganese, zinc and copper contents of the soil.

Economic analysis of various treatments showed that application of nitrogen, phosphorus and potassium at 200:200:400 g plant^{-1} recorded economically profitable higher yield besides higher net income and benefit cost ratio of 1.96. This treatment was statistically on par with the application of 300:300:600 g N, P_2O_5 and K_2O plant^{-1} with a benefit cost ratio 1.93.

Studies on soil column indicated that the loss of nutrients through leaching remained unchanged with different treatments. The nitrogen loss was estimated in the range of 23.17 to 23.98 per cent, phosphorus from 1.66 to 1.81 per cent and potassium from 15.95 to 16.53 per cent of applied nutrients.

The retention of nutrients at different depths was not influenced by any of the treatment effects. The retention of N, P and K was found to be highest at 0-15 cm followed by 15-30 cm.

Overall, results summarized here showed that the banana (cv. Njalipoovan) crop can be profitably cultivated in the homesteads of Kerala. The current research brings out the need of application of N, P_2O_5, K_2O at 200:200:400 g plant^{-1} for obtaining maximum yield with high quality.

Future line of research

- Since the nutritional requirement of banana cv. Njalipoovan in *Onattukara* soil is standardised, further studies with different sources of the nutrients have to be undertaken.

- Future research should focus on developing an effective Integrated Plant Nutrition System (IPNS) using organic and inorganic sources of nutrients, biofertilizers and growth regulators.

- Further research is required to explore the residual effect of applied nutrients in the first and second ratoon crops.

- Scope of fertigation may be investigated with a view to improve the efficiency of fertilizer application thus reducing the cost of cultivation.

REFERENCES

REFERENCES

Agrawal, S., Pandey, S.D. and Tiwari, B.I. 1997. Studies on the effect of high status of nitrogen and potassium on qualitative characters of *in vitro* banana fruit cv. Robusta *Orissa. J. Hort.* 25 : 67-72

Agrawal, S., Patel, R.K., Pandey, S.D. and Agrawal, S. 1998. Influence of higher levels of nitrogen and potassium on growth and yield potential of *in vitro* banana cv. Robusta. *Mysore J. agric. Sci.* 32 : 275-280

Ali, M.M., Rahman, G.K.M.M., Ali, M.I. and Habibullah. 1991. Fertilization increases banana yields. *Better crops int.* 7 : 19

Anil, B.K. 1994. Standardisation of spacing for tissue culture banana cv. Nendran (AAB group). M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 168

Anjorin, H.O. and Obigbesan, G.O. 1983. Influence of nitrogen fertilization on early growth and development of plantain (*Musa paradisiaca*). *Fruits* 38 : 300-302

Anjorin, H.O. and Obigbesan, G.O. 1987. Influence of nitrogen fertilizer on the flowering and yield of plantain. *International Co-operation for effective plantain and banana research, Proceedings of the third meeting,* May 27-31, 1985. Abidjan, Ivory Coast, pp. 115-117

A.O.A.C. 1977. *Official and Tentative Methods of Analysis.* Association of Official and Analytical Chemists. Washington, Eleventh edition, pp. 53-126Aravindakshan, M. and Pushkaran, K. 1996. *Banana compendium,* Kerala Agricultural University, Thrissur, p. 160

Aravindakshan, M. and Pushkaran, V. 1996. Banana nutrition. *J. Trop. Agric.* 36 : 142-144

Arnon, I. 1975. Physiological principles of dry land crop production. *Physiological aspects of dry land farming* (ed. Gupta, V.S). Oxford and IBH Publishing Co., New Delhi, pp. 3-145

Bains, S.S. and Bahardwaj, B.L. 1976. Fertilizer management of efficient crop production. *Soil Fertility - Theory and Practice* (ed. Kanwar, J.S.). Indian Council of Agricultural Research, New Delhi, p. 503

Barnell, H.R. 1940. Studies on tropical fruits VIII. *Ann. Bot. London.* 4 : 39-71

Baruah, P.J. and Mohan, N.K. 1985. Effect of potassium on vegetative growth of banana (*Musa* AAA, Cavendish subgroup). *Banana Newsl.* 8 : 23-24

Baruah, P.J. and Mohan, N.K. 1986. Effect of K on fruit sugar, acidity, TSS and sugar : acid ratio of 'Jahaji' banana (*Musa* AAA, Cavendish subgroup). *Banana Newsl.* 9 : 14-15

Baruah, P.J. and Mohan, N.K. 1992. Effect of K on yield and yield attributing characters of Dwarf Cavendish banana (*Musa* AAA group, Cavendish sub group) in Assam. *Banana Newsl.* 15 : 24-25

Bellie, T. 1987. Effect of increased doses of phosphorus and split application of fertilizers in Nendran banana (AAB M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, p.

Beringer, H. 1978. The role of K in yield formation. *Potash Rev.* 12 : 16

Bhan, K.C. 1976. Banana - a fruit of masses. *Indian Hort.* 11 : 16-20

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

Bondad, A.A., Anunciado, I.S. and Tabora, P.C. 1983. Effect of K on growth, nutrient composition and fibre yield of *Musa* for pulp production. *Potash Rev.* 3 : 27

Bouyoucos, C.J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agron. J.* 54 : 464-465

Bray, R.H. 1948. *Diagnostic techniques for soils and crops.* (ed. Kittchen, H.B.) American Potash Institute, p.86

*Bravo, J.J., Garcia, V., Diaz, A. and Alvarez, C. 1980. Soil plant relationship in banana plantations on the island of La Palma. *Anales de Edafotogia Y Agrobiologia.* 39 : 913-922

*Caldas, F.E., Garcia, V. and Garcia, P.V. 1973. Study on banana nutrition in the Canary islands. 11 Interactions between cations. *Fruits.* 28(5): 351-355

Chattopadhyay, P.K. and Bose, T.K. 1986. Effect of NPK nutrition on growth, yield and quality of Dwarf Cavendish banana (*Musa cavendishii* Lamb.). *Indian Agricst.* 30 : 213-222

Chattopadhyay, P.K., Holder, N.C., Maiti, S.C. and Bose, T.K. 1980. Effect of nitrogen nutrition on growth, yield and quality of Giant Governor. *National Seminar on Banana Production Technology.* Tamil Nadu Agricultural University, Coimbatore, pp. 109-112

Chong, Z.X., Yan, L.X., Peng, Z.Q. and Peizhi, X. 1992. Nitrogen, phosphorus and potassium nutrition characteristics and balanced fertilization for banana. *Better Crops int.* 12 : 18-19

Croucher, H.M. and Mitchell, W.K. 1940. Fertilizer investigation with the Gros Michel banana. *Dep. Sci. agric. bull.* Jamica 19 : 30

Cordero, H.M. 1985. Potash response of banana. *Int. Fertil. Correspondent* 26 : 6-7

Dagade, V.G. 1986. Effects of graded levels of nitrogen, phosphorus and potassium fertilization on growth, yield and nutrient status of basrai banana. *Indian J. Agric. Chem.* 19 : 1-7

Dave, S.K., Katrodia, J.S. and Patel, M.L. 1990. Nutrition and growth of banana cv. Basrai in deep black soils of South Gujarat. *Fertil. News.* 35 : 19-26

Dawood, D.H., Salih, A.A. and Ali, A.A. 1999. Response of Dwarf Cavendish banana to nitrogen fertilization on heavy clay soils. *Sudan J. Agric. Res.* 2 : 89-91

Dumas, J. 1980. Production technology of banana in territories of Africa. *Fruits* 15 : 277-290

FIB. 2002. *Farm Guide.* Farm Information Bureau, Government of Kerala

*Garita, C.R. and Jaramillo, C.R. 1984. Response of cultivar Giant Cavendish (*Musa* AAA) to increasing rates of potassium soils on the Caribbean coast of Costa Rica. *Informe - Mensual - UPEB.* 8 : 50-55

Geetha, K. 1998. Integrated plant nutrition system (IPNS) for maximising yield in banana, *Musa* (AAB group) 'Nendran'. Ph.D thesis, Kerala Agricultural University, Thrissur, p. 149

Geetha, K. and Nair, R.R. 2000. Integrated plant nutrition system (IPNS) for banana. *Ann. agric. Res.* 21 : 499-503

George, S. 1994. Standardisation of plant part as an index of potassium status in banana, *Musa* (AAB group) Nendran. Ph.D thesis, Kerala Agricultural University, Thrissur, p. 185

Godefroy, J. 1982. Inorganic fertilization in the commercial culture of banana. Soil diagnosis applied to the programming of manuring. *Fruits.* 37 : 225-227

Goswami, N.N. and Khera, M.S. 1981. Role of K in increasing crop production in India. *Potash Rev.* 5 : 16

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

Gubbuk, H., Paydas, S. and Kaska, N. 1991. Effect of different application rates of nitrogen and farm yard manure on the nutrient concentrations in the leaves of cvs. Cavendish and Basrai. *J. Pl. Nutr.* 20: 33-39

*Gubbuk, H., Paydas, S. and Kaska, N. 1993. Effect of different nitrogen and farm yard manure levels on the stem and finger growth and the duration of fruit development of 'Cavendish' and 'Basrai' banana clones. *Doga, Turk - Tarim - Ve - Ormancilik - Dergesi* 17 : 236-253

Gupta, R.P. and Dakshinamoorthi, C. 1980. *Procedures for physical analysis of soil and collection of Agrometeorological data.* Indian Agricultural Research Institute, New Delhi, p. 116

Hassan, M.A. and Chattopadhyay, P.K. 2000. Influence of potassium on growth, yield and quality characters of Cavendish banana. *Banana : Improvement Production and Utilization* (eds. Singh, H.P. and Chadha, K.L.). Proceedings of the Conference on Challenges for Banana Production and Utilization in 21st Century, 1996. Association for the Improvement in Production and Utilization of Banana, National Research Centre on Banana, Trichy, pp. 325-330

Hassan, M.A., Das, B.C., Bhattacharya, S., Suresh, C.P. and Bhattacharya, S. 1999a. Potash fertilization for maximum yield and quality of Cavendish banana (*Musa* AAA). *Environment and Ecol.* 17 : 543-545

Hassan, M.A., Suresh, C.P., Bhattacharya, S., Chattopadhyay, P.K. and Bhattacharya, S. 1999b. Uptake pattern of nutrients in Cavendish banana (*Musa* AAA). *Environment and Ecol.* 17 : 560-562

Hazarika, D.N. and Mohan, N.K. 1990. Effect of levels of nitrogen and time of application on fruit quality of 'Jahaji' banana. *Banana Newsl.* 13 : 26-29

Hazarika, D.N. and Mohan, N.K. 1991. Effect of nitrogen on growth and yield of banana cv. Jahaji (*Musa* AAA group, Cavendish sub group). *Hort. J.* 4 : 5-10

Hegde, D.M. 1988. Growth and yield analysis of Robusta banana in relation to soil water potential and nitrogen fertilization. *Sci. Hort.* 37 : 145-155

Hegde, 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

*Hernandez, T., Robaina, P. and Garcia, T. 1981. Effect of different rates of nitrogen on banana (*Musa sapientum*) var. Giant Cavendish (victoria). *Ciencia - Y - Tecnica - en - la Agricultura, - Suclos - Y - Agroquimica* 4 : 33-43

Holder, G.D. and Gumbs, F.A. 1983. Effects of nitrogen and irrigation on the growth and yield of banana. *Trop. Agric.* 60 : 179-183

Huang, W.Z., Liang, X.Y. and Lun, X.J. 1992. Diagnosis of K deficiency in bananas using the method of different values. *Commun. Soil Sci. Pl. Analysis.* 23(1&2) : 75-84

Irizarry, H., Abruna, F., Garcia, R.J. and Diaz, N. 1982. Nutrient uptake by intensively managed plantains as related to stage of growth at two locations. *J. agric. Univ. Puerto Rico.* 66 : 331-345

Irizarry, H., Rivera, E. and Rodriguez, J. 1988. Nutrient uptake and dry matter composition in the plant crop and first ratoon of the Grand Naine banana grown on an ultisol. *J. agric. Univ. Puerto Rico.* 72 : 337-351

Jackson, M.L. 1973. *Soil Chemical Analysis*. Second edition. Prentice Hall of India Private Ltd., New Delhi, p. 498

Jambulingam, A.R., Ramaswamy, N. and Muthukrishnan, C.R. 1975. Studies on the effect of potassium on Robusta banana. *Potash Rev.* 27 : 4-6

KAU. 1993. Annual Report. Kerala Agricultural University, Directorate of Research, Vellanikkara, Thrissur, p. 287

KAU. 1996. Kerala Agricultural University. *Package of Practices : Recommendations Crops 1996.* Directorate of Extension, Mannuthy, Thrissur, pp. 179-185

Khandare, V.S., Kadam, B.A., Wakle, P.K. and Badgire, B.B. 1998. Effects of fertilizer doses on yield of banana ratoon crop cv. Ardhapuri. *J. Maharastra agric. Univ.* 23 : 314-315

Khoreiby, A.M.K. and Salem, A.T. 1991. Effect of potassium on the vegetative growth and the nutritional status of Dwarf Cavendish banana. *Bull. Faculty agric. Univ.* 42 : 247-258

Kohli, R.R., Iyengar, B.R.V. and Reddy, Y.T.N. 1984. Growth, dry matter production and yield in 'Robusta' banana as influenced by different levels of N. *Indian J. Hort.* 41 : 194-198

*Kohli, R.R., Reddy, Y.T.N. and Iyengar, B.R.V. 1985. Effect of nitrogen on biomass distribution in Robusta banana. *Gartenbace Wissen Se Shaft.* 50(3) : 117-120

Kotur, S.C. and Mustaffa, M.M. 1984. Effect of spacing and nitrogen on the leaf nutrient status of Robusta banana. *South Indian Hort.* 32 : 324-326

Krishnan, B.M. and Shanmugavelu, K.G. 1983. Correlation studies in banana cv. Robusta. *South Indian Hort.* 31 : 110-111

Krishnan, P.K. 1986. Integrated use of organic wastes and fertilizer nitrogen. M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, p.

Kumar, A.A.K. and Shanmugavelu, K.G. 1988. Effect of foliar spray of urea and Azotobacter applied to soil on banana cv. Robusta. *Banana Newsl.* 11 : 11

Kumar, R., Rajan, S. and Kumar, R. 1998. Effect of potassium on growth, yield and quality of ratoon crop of banana cv. Dwarf Cavendish. *J. Potss. Res.* 14 : 115-118

Kurien, T.M., Prabhakaran, P.V. and Varkey, P.A. 1985. Path coefficient analysis in Nendran variety of banana. *South Indian Hort.* 33 : 386-390

Lahav, E. 1977. Effect of manure and fertilizer treatment on cv. Williams hybrid banana and its mineral content. *Trop. Agric.* 54 : 113-116

Lahav, E. and Turner, D.W. 1983. Banana Nutrition. *Plant Bulletin* No.: 7. International Potash Institute Burne, Switzerland. p. 62

Lahav, E. and Zamet, D. 1982. Nitrogen : Potassium fertilizer ratios in bananas. *Alon Hanotea* 36 : 247-250

Lekshmi, R. 2000. Substitution of K by Na in banana *Musa* (AAB group) var. 'Nendran'. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 87

Lin, M.L. and Fox, R.L. 1992. The comparative agronomic effectiveness of rock phosphate and superphosphate for banana. *Fertil. Res.* 31 : 131-135

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. *J. Soil Sci. Soc. Am.* 42 : 421-428

Lopez, A. and Espinosa, J. 1998. Banana response to potassium. *Better crops int.* 12 : 3-5

Lubin, M. and Ennis, H.L. 1964. On the role of intracellular K in protein synthesis. *Biochim. Biophys. Acta.* 80 : 614-631

Mahapatra, I.C., Prasad, R. and Shinde, J.E. 1980. *FAI Seminar on Fertilizers in India in the Eighties Part II*, New Delhi, p. 143-147

Mathew, V. 1980. Nitrogen nutrition in banana cv. Palayankodan. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 96

Mc Cants, C.B. and Black, C.A. 1957. A biological slope - ratio method for evaluating nutrient availability in soils. *Soil Sci. Soc. Ann. Proc.* 21 : 296-301

Mengel, Konrad and Kirkby, E.A. 1982. *Principles of Plant Nutrition*. International Potash Institute, Switzerland, p. 453

Minhar, R.S. and Bora, N.C. 1982. Distribution of organic carbon and forms of nitrogen in a topographic sequence of soils. *J. Indian Soc. Soil Sci.* 30 : 135-139

Mohan, N.K. and Rao, M.V.N. 1985. Determination of active root zone in banana using radio active P. *South Indian Hort.* 33 : 217-220

Murray, D.B. 1960. The effect of deficiencies of the major nutrients on growth and leaf analysis of banana. *Trop. Agric.* 37 : 97-106

Mustaffa, M.M. 1983. Effect of spacing and nitrogen on growth, yield and quality of hill banana. *South Indian Hort.* 31 : 270-273

Mustaffa, M.M. 1987. Growth and yield of Robusta banana in relation to potassium nutrition. *J. Potss. Res.* 3 : 129-132

Mustaffa, M.M. 1988. Studies on growth, yield and quality of hill banana as a result of potassic fertilizer use. *J. Potss. Res.* 4 : 75-79

Nair, G.V. 1988. Nutritional requirement of Nendran banana under rice fields. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 91

Nair, G.V., Nair, S.R. and Sulekha, G.R. 1990. Effect of N, K and their application on the yield and yield components of Nendran banana grown in rice fields. *South Indian Hort.* 38 : 58-62

Nambisan, K.M.P., Krishnan, B.M., Selvarajan, M. and Rajasekharan, L.R. 1980. Manuring of bananas. *National seminar on Banana Production Technology.* Tamil Nadu Agricultural University, Coimbatore, pp. 134-141

Nanjan, K., Nambisan, K.M.P., Krishnan, B.M., Thatham, V., Paulas, Ramaswamy, N. and Khader, A.O.B.M. 1980. The nitrogen fertilization of banana under Periyar river command area in Tamil Nadu. *National Seminar on Banana Production Technology.* Tamil Nadu Agricultural University, Coimbatore, pp. 113-117

Natesh, B. 1987. Effect of split application of fertilizers in banana cv. Nendran. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 98

Nitsos, R.E. and Evans, H.J. 1969. Effect of univalent cations on the activity of particulate starch synthetase. *Pl. Physiol.* 44 : 1260-1266

Obiefuna, J.C. 1984. Effect of potassium application during the floral initiation stage of plantains (*Musa* AAB). *Fertil. Res.* 5 : 315-319

Obiefuna, J.C. and Onyete, P.O. 1987. The effect of nitrogen and potassium imbalance on the growth and yield of plantains. *Hort. Abstr.* 57 : 10005

Osborne, R.E. and Hewitt, C.W. 1963. The effect of frequency of application of N, P and K fertilizers on Lacatan bananas in Jamaica. *Trop. Agric.* 40(1) : 1-8

*Oubahou, A.A. and Dafiri, M. 1987. Banana N and K nutrition. *J. appl. Hort.* 57 : 630-632

Pandit, S.N., Singh, C., Raj, R.N., Jha, K.K. and Jain, B.P. 1992. Fertilizer scheduling for dwarf banana in Bihar. *J. Res.* 4 : 25-29

Panse, V.G. and Sukhatme, P.V. 1967. *Statistical Method for Agricultural Workers.* Second edition. Indian Council of Agricultural Research, New Delhi, p. 381

Parida, G.N., Ray, D.P., Nath, N. and Dora, D.K. 1994. Effect of graded levels of NPK on the growth of Robusta banana. *Indian Agricst.* 38 : 43-50

Pawar, V.P., Kathmale, D.K. and Deshmukh, Z.V. and More, T.A. 1997. Effects of fertilizer doses and their application on production of Basrai banana. *J. Maharashtra agric. Univ.* 22 : 166-168

Peters, D. 1997. Maximisation of productivity by rescheduling the nutrient application in banana (*Musa* AB group Nendran). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p.

Pillai, O.A.A. and Khader, A.J.B.M. 1980. Studies on fertilizer requirement of Robusta banana. *National Seminar on Banana Production Technology.* Tamil Nadu Agricultural University, Coimbatore, pp. 118-121

Piper, C.S. 1967. *Soil and Plant Analysis*. Asia Publishing House, Bombay, p. 368

Prabhakar, K.S. 1996. Studies on standardisation of optimum dose and time of nitrogen application in Rasthali banana. M.Sc. (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 86

Prabhuram, R. 1992. Effect of organic manure and urea on the growth and development of banana cv. Rasthali and changes in the soil eco system. M.Sc. (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 105

Prakashmany, N. 2002. Yield maximization in banana cv. Nendran through systematic approach of fertilizer use in the red loam soils of Vellayani. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 110.

Prevel, P.M. 1989. Physiological processes related to handling and storage quality of crops. *Methods of K research in plants* IPI, Berne, Switzerland, p. 236

Rajeevan, P.K. 1985. Intraclonal variations and nutritional studies in banana cv. Palayankodan. Ph.D. thesis, Kerala Agricultural University, Thrissur, p. 195

Ram, R.A. and Prasad, J. 1988. Effect of nitrogen, phosphorus and potassium on fruit quality of banana cv. Campierganj Local (*Musa* ABB). *South Indian Hort.* 36 : 290-292

Ram, R.A. and Prasad, J. 1989. Studies on nutritional requirement of banana cv. Campierganj Local (*Musa* ABB). *Narendra Deva J. agric. Res.* 4 : 196-200

Ramaswamy, N. 1971. Studies on the effect of nitrogen on growth and development of Robusta (*Musa Cavendishii* L.). M.Sc. (Ag.) dissertation. Annamalai University, Annamalainagar, p. 79

Ramaswamy, N. 1976. Studies on the effect of different levels of phosphoric acid on the yield and quality of Robusta banana. *Annamalai Univ. agric. Res. Annual* 6 : 30-37

Ramaswamy, N., Sunderarajan, S. and Khader, M. 1977. Effect of application of different levels of potassium on the yield of Dwarf Cavendish banana. *Madras agric. J.* 64 : 363-368

Ramkumar, R., Rajan, S. and Kumar, R. 1998. Effect of potassium on growth, yield and quality of ratoon crop of banana cv. Dwarf cavendish. *J. Potass. Res.* 14 : 115-118

Ranganna, S. 1997. *Manual of Analysis of Fruits and Vegetable Products*. Tata Mc. Graw Hill Publishing Company Ltd., New Delhi, p. 94

Ray, D.P., Parida, G.N. and Chatterjee, B.K. 1988. Nutrient concentration in leaf tissue with different nutritional levels in Robusta banana. *Indian Agricst.* 32 : 249-256

Ray, P.K. and Yadav, J.P. 1994. Response of Basrai banana in different doses and timing of nitrogen application in calcareous soil of North Bihar. *Hort. J.* 7 : 89-96

Rosamma, C.A. and Namboothiri, K.M.N. 1990. Genetic analysis of yield in banana. *Agric. Res. J. Kerala* 28(1&2) : 1-8

Russell, E.W. 1973. *Soil Conditions and Plant Growth.* Tenth edition. Longman Group Ltd., London, p. 849

Saad, M.M. and Atawia, A.A.R. 1999. Effect of potash application on growth, yield and fruit quality of 'Grand Naine' banana in sandy soil under drip irrigation system. *Alexandria J. agric. Res.* 44 : 171-180

Samra, J.S. and Quadar, A. 1990. Nutrient interaction affecting fruit quality. *Proceedings of Group discussion on Potassium and its influence on quality of fruits and vegetable crops.* Indian Agricultural Research Centre, New Delhi, pp. 32-36

Sanker, B.K. and Rao, M.V.N. 1993. Nutritional investigations in Nendran banana fruit and dry matter yield. *Madras agric. J.* 80 : 17-18

Shaikh, M.R., Rana, M.A., Rizvi, S.I.A. and Jagirdar, S.A.P. 1985. Effect of various NPK doses on the growth and production of Basrai banana. *Pakistan J. agric. Res.* 6 : 183-186

Shankar, K.B. 1980. Nutritional investigation in Nendran banana (French plantain AAB). M.Sc. (Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 86

Shanmugam, K.S. and Velayudam, K.S. 1972. Better manure your bananas. *Agric. digest.* 3(12) : 17-22

Shanmugavelu, K.G., Aravindakshan, K. and Sathiamoorthy, S. 1992. *Banana Taxonomy, Breeding and Production Technology.* Metropolitan Book Co., Pvt. Ltd., New Delhi, p. 459

Sharma, K.R., Srivastava, P.C., Ghosh, D. and Gangwar, M.S. 1999. Effect of boron and farm yard manure application on growth, yield and boron nutrition to sunflower. *J. Pl. Nutr.* 22 : 633-640

Sharma, S.B. 1984. Effect of soil and foliar application of urea on the growth and yield of banana. *Punjab Hort. J.* 24 : 33-35

Sharma, S.B. and Yadav, J.P. 1987. Effect of different methods and times of manuring on growth and yield of banana. *Fertil. News.* 32 : 33-35

Shawky, I., Bondok, A., Ei-Shazly, S. and EI-Gazzar, A. 1993. Effect of different levels of nitrogen on vegetative growth and mineral content of Hindy banana plants grown in sandy culture. *Ann. agric. Sci.* 28 : 699-710

Shehana, R.S. 1997. Increasing phosphorus efficiency in banana cv. Nendran. Ph.D. thesis, Kerala Agricultural University, Thrissur, p. 168

Sheeja, V.G. 1990. Comparative efficiency of different phosphatic fertilizers in rainfed Nendran banana. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 66

Sheela, V.L. 1982. Potassium nutrition in rainfed banana *Musa* (AAB group) Palayankodan. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, p. 109

Sheela, V.L. 1995. Growth pattern, flowering and yield potential of tissue cultured plants of banana (*Musa* (AAB group) 'Nendran') and standardisation of fertilizer schedule. Ph.D. thesis, Kerala Agricultural University, Thrissur, p. 241

Sheela, V.L. and Aravindakshan, M. 1990. Production of dry matter and uptake of nutrients in rainfed banana *Musa* (AAB group) Palayankodan as influenced by different levels of K. *South Indian Hort.* 38(5) : 240-244

Shelke, B.D. and Nahate, P.A. 2000. Response of fertilizer treatments on growth and yield of banana cv. Dwarf Cavendish. *Banana - Improvement, Production and Utilization* (eds. Singh, H.P. and Chadha, K.L.). Proceedings of the Conference on Challenges for Banana Production and Utilization in 21st Century, September 24-25, 1996. Association for the Improvement in Production and Utilization of Banana (AIPUB), Trichy, pp. 322-324

Sindhu, J. 1997. Prediction of potassium fertilizer requirement of banana, *Musa* (AAB group) 'Nendran'. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 181

Singh, D., Brar, M.S. and Brar, A.S. 1991. Response to K application and its critical level for American Cotton. *J. Indian Soc. Soil Sci.* 39 : 494-499

Singh, D.B. and Suryanarayana, M.A. 1999. Response of Cavendish banana to different nitrogen levels and their split applications. *J. appl. Hort.* 1 : 122-124

Singh, H.P., Yadav, I.S. and Singh, K.D. 1990. Response of a plant crop of Dwarf Cavendish banana (Musa AAA, Cavendish) to nitrogen and potassium growing in a sandy loam soil in the sub tropics. *J. Potss. Res.* 6(2) : 60-69

Singh, J. and Kashyap, R. 1992. Effect of spacing and levels of nitrogen on growth and yield of banana cv. Robusta. *Ad. Pl. Sci.* 5 : 203-207

Srikul, S. and Turner, D.W. 1995. High nitrogen supply and soil water deficits change the rate of fruit growth of banana cv. Williams and promote tendency to ripen. *Sci. Hort.* 62(3) : 165-174

Stover, R.H. and Simmonds, N.W. 1987. *Bananas*. Third edition. Longman Scientific and Technical, England, p. 468

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

Sunu, S. 2001. Substitution of muriate of potash by common salt in banana *Musa* (AAA group, Cavendish subgroup) Robusta. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 98

Sweidon, A.M., Fayek, M.A., Ibrahim, F.A. and El-Khoreiby, A.K. 1981. Morphological and histological studies on banana plants under the effect of nitrogen, gibberellic acid and ethrel. *Ann. agric. Sci.* 15 : 163-176

Tandon, H.L.S. and Sekhon, G.S. 1988. *Potassium Research and Agricultural Production in India.* Fertilizer Development and Consultation Organisation, New Delhi, p. 144

Tangaselvabai, T. 1989. Effect of split application of increased dose of nitrogen and *Azospirillum* in Rasthali (AAB) banana (*Musa* spp.) M.Sc. (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore, p. 85

Terra, N.N., Garcia, E. and Lajolo, F.M. 1983. Starch sugar transformation during banana ripening. The behaviour of UDP glucose pyrophosphorylase, sucrose synthetase and invertase. *J. Food Sci.* 48 : 1097-1100

Tirkey, T., Pandey, S.D. and Sharma, G.L. 1998. Effect of nitrogen levels and time of application of NPK on yield and quality of *in vitro* raised banana cv. Dwarf Cavendish. *South Indian Hort.* 46 : 65-67

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. 1995. *Soil Fertility and Fertilizers*, Fifth edition, Prentice Hall of India Private Ltd., New Delhi, p. 638

*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. Hort.* 12 : 27-45

Turner, D.W. and Barkus, B. 1982. Yield, chemical composition and maturity of 'Williams' banana fruit in relation to supply of K, Mg and Mn in sand culture. *Sci. Hort.* 14 : 28-31

Turner, D.W. and Barkus, B. 1985. Long term nutrient application rates and competition between ions in banana in relation to supply of K, Mg and Mn. *Fertil. Res.* 4(2) : 127-134

Upadhyay, N.P. 1988. Effect of N, P and K fertilizers on growth yield and quality of banana (*Musa cavendishii* L.) variety Harichal. *Prog. Hort.* 20 : 257-362

Vadivel, E. and Shanmugavelu, K.G. 1978. Effect of increasing rates of potash on the quality of banana cv. Robusta. *Potash Rev.* 24(8): 4

Vadivel, E. and Shanmugavelu, K.G. 1988. Effect of different levels and methods of application of K on the leaf concentration of nutrient in banana cv. Robusta. *Banana Newsl.* 11 : 16-18

Valmayor, R.V. 1994. Nematodes and weevil borer conference rationale. *Banana Nemodes and Weevil Borers in Asia and Pacific* (eds. Valmayor, R.V., Siloyoi, B., Jamaluddin, S.H., Espino, R.R.C. and Pasana, O.C.). INIBAP - ASPNET, Los Bonas, Philippines, pp. 298-302

Varkey, P.A. and Pushkaran, K. 1992. *Banana cultivation.* Kerala Agricultural University, Thrissur, p. 54

Venkatesam, C., Venkatareddy, K. and Rangacharlu, V.S. 1965. Studies on the effect of nitrogen, phosphoric and potash fertilization on the growth and yield of banana. *Indian J. Hort.* 22(2) : 175-184

Vijayaraghavan, H. and Ayyamperumal, A. 2000. Foliar nutrition of N and K for banana cv. Poovan. *Banana : Improvement, Production and Utilization* (eds. Singh, H.P. and Chadha, K.L.). Proceedings of the Conference on Challenges for Banana Production and Utilization in 21st Century, 1996. Association for the Improvement in Production and Utilization of Banana, National Research Centre on Banana, Trichy, pp. 292-296

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. N.S.* 11 : 41-76

Yadav, I.S. and Singh, K.D.N. 1991. Transformation of applied nitrogen in relation to its availability to sugar cane in a calcareous soil. *J. Indian Soc. Soil Sci.* 39 : 292-297

Zehler, E., Kreipe, H. and Gething, P.N. 1981. Potassium sulphate and potassium chloride : their influence on the yield and quality of cultivated crops. *IPI Res. Topics.* 9 : 72-73

* Originals not seen

APPENDICES

APPENDIX - I

Weather parameters during the cropping periods and the previous five years (monthly average)

Month	Temperature (°C)						Relative humidity (%)			Total rainfall (mm)			Number of rainy days			Evaporation (mm)		
	Maximum			Minimum														
	98-99	99-00	Five year mean	98-99	99-00	Five year mean	98-99	99-00	Five year mean	98-99	99-00	Five year mean	98-99	99-00	Five year mean	98-99	99-00	Five year mean
April	35.5	32.2	33.6	25.1	23.7	23.1	91	94	90.8	73	362.5	137.5	7	12	9	5.1	3.9	4.3
May	33.7	30.5	32.9	25.2	23.7	23.4	95	95	91.2	263.7	398.3	194.2	11	22	9	3.6	3.1	3.7
June	31.6	30.9	30.9	23.8	23.5	22.6	95	94	95	415.6	374.8	472	23	13	18.4	2.8	3.2	2.9
July	30.7	29.8	30.1	23.5	23.2	21.8	96	96	95.2	247.9	441.2	559	21	24	24.6	2.7	3	2.3
August	30.7	30.8	30.2	23.9	23.4	22.3	96	96	95.4	385.1	107.2	236.4	15	9	15.2	3.1	3.5	2.9
September	30.4	31.5	30.9	23.6	23.3	23.4	96	95	93.6	401.9	51.6	226.7	22	7	12.2	3	3.7	3.4
October	30.5	30.2	31.4	23.3	23.2	23.2	95	95	94.4	411	489.9	425.1	15	20	16.8	2.9	2.8	3.4
November	31.3	32.2	31.7	23.2	22.8	22.9	95	94	94	153.8	51.7	199	5	4	9.2	2.7	2.7	2.9
December	32	32.9	32.7	22.2	21.1	21.1	94	91	92	59.6	12.4	54.8	8	1	3.2	2.7	3.1	3.4
January	32.8	33.2	33.5	20.3	20.6	20.8	93	93	91	3.4	15.4	16.8	1	2	0.8	3.6	3.3	4.2
February	34.4	31.7	33.4	22	22.7	22.2	93	95	91.2	4.4	294.2	16	0	7	0.8	4.2	3.5	4.6
March	33.6	32.7	34.2	23.9	23.7	23.4	95	92	91.6	55.3	55.5	33.9	2	3	1.4	4.4	4	5.1
April	32.2	32.9	33.9	23.7	24.9	24.2	94	93	91	362.5	186.7	139.5	12	7	9.2	3.9	3.9	4.3
May	30.5	32.6	33.2	23.7	24.1	24.6	95	93	91.8	398.3	196.1	196.7	22	12	9	3.1	4	3.7

APPENDIX - II

Average input costs and market price of produce

Items	Cost
INPUTS	
a. Labour	
1. Man labourer	Rs. 150 day^{-1}
2. Women labourer	Rs. 150 day^{-1}
b. Cost of suckers	Rs. 7.00 $sucker^{-1}$
c. Cost of manures and fertilizers	
1. Farm yard manure	Rs. 400 t^{-1}
2. Urea	Rs. 4.10 kg^{-1}
3. Mussoorie rock phosphate	Rs. 2.50 kg^{-1}
4. Muriate of potash	Rs. 3.80 kg^{-1}
d. Cost of other items	
1. Poles for proping	Rs. 17 $pole^{-1}$
OUTPUT	
Market price of fruit	Rs. 10.00 kg^{-1}

ABSTRACT

Banana cv. Njalipoovan is a popular variety cultivated in homesteads of Kerala. The nutritional requirement of the cultivar has not yet been worked out. Field experiments were conducted at Onattukara Regional Agricultural Research Station, Kayamkulam in Alappuzha district during 1998-99 and 1999-00 to formulate an effective nutrient management schedule for the cultivar in *Onattukara* soil. In addition to this a soil column study was undertaken separately to assess the leaching losses of nutrients in the soil and retention of applied nutrients at different depths.

Three levels each of nitrogen at 100, 200 and 300 g plant^{-1}, phosphorus at 100, 200 and 300 g plant^{-1} and potassium at 200, 400 and 600 g plant^{-1} apart from $n_0p_0k_0$ (control) in each block were tested in confounded 3^3 factorial, confounding NPK in replication I and NP^2K in replication II.

Application of nitrogen at 300 g plant^{-1} increased the growth attributes like height of the plant, girth of the pseudostem, total number of leaves and number of functional leaves. Nitrogen supply at higher rates reduced the total duration of the crop, increased the LAI and leaf emergence rate, dry matter accumulation in leaves, pseudostem, rhizome

and bunch. Yield attributes and bunch yield increased significantly upto 300 g N plant^{-1}. The quality of the fruit was favoured by the application of higher rates of nitrogen. N supplementation at higher rates was beneficial for the uptake of N, P, K, Ca and Mg and micronutrients such as Mn, Zn and Cu. It also enhanced the available N, P, K, Ca and Mg in soil.

Supply of phosphorus at 200 g plant^{-1} increased the above growth attributes at most of the stages. LAI in the early stages of growth was favoured by P supply at high rate. Phosphorus application at 300 g plant^{-1} favoured dry matter accumulation in leaves, pseudostem, rhizome and bunch. Yield attributes and yield were high by applying phosphorus at 200 g plant^{-1}. Fruit quality was not affected by the application of P. Higher rate of P_2O_5 enhanced the uptake of N, P, K, Ca, Mg and micronutrients. P nutrition increased the available N and P content of the soil.

Potassium nutrition at higher rates promoted all the above growth characters, leaf area, LAI and dry matter accumulation in different plant parts. Potassium applied at 400 g plant^{-1} favoured the yield attributes and yield of crop. Application of K_2O at 600 g plant^{-1} yielded better quality fruits with appreciable total sugars, reducing sugars, sugar-acid ratio, pulp-peel ratio and shelf life. Higher rates of K_2O enhanced the uptake of N, P, K and micronutrients like iron, manganese, zinc and copper. Potassium supply at 400 g plant^{-1} was beneficial in increasing the calcium and magnesium uptake by different plant parts. Application of K_2O at higher rates resulted in appreciable build up of N, P and K in the soil.

The combination of N, P_2O_5 and K_2O applied at 300:300:600 g $plant^{-1}$ had appreciably increased the growth characters, yield attributes, and nutrient uptake. It was comparable to that of N, P_2O_5 and K_2O at 200:200:400 g $plant^{-1}$. The bunch yield obtained by the application of N, P_2O_5 and K_2O at 300:300:600 g $plant^{-1}$ was also comparable with that of 200:200:400 g $plant^{-1}$. However, mineral nutrition of N, P_2O_5 and K_2O at 200:200:400 g $plant^{-1}$ had given the maximum benefit-cost ratio of 1.96. Therefore it can be concluded from the study that application of N, P_2O_5 and K_2O at 200:200:400 g $plant^{-1}$ is beneficial for getting higher yield and maximum economic returns.