STANDARDISATION OF PLANT PART AS AN INDEX OF POTASSIUM STATUS IN BANANA, *MUSA* (AAB GROUP) NENDRAN

BY

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THESIS
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1994

Dedicated

to

my

beloved parents

DECLARATION

I hereby declare that this thesis entitled "Standardisation of plant part as an index of potassium status in banana, *Musa* (AAB group) Nendran" 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 of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Standardisation of plant part as an index of potassium status in banana, *Musa* (AAB group) Nendran" is a record of research work done independently by **Smt. Sumam George** 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.

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LIST OF ABBREVIATIONS USED IN THIS THESIS

m	–	Metre
g	–	Gram
l	–	Litre
t	–	Tonnes
@	–	At the rate of
^{o}C	–	Degree celsius
%	–	Per cent
N	–	Normal
M	–	Molar
cm	–	Centi metre
mm	–	Milli metre
nm	–	Nano metre
kg	–	Kilogram
cal	–	Calories
cv.	–	Cultivar
$plant^{-1}$	–	Per plant
ha^{-1}	–	Per hectare
MSL	–	Mean sea level
LAI	–	Leaf area index
MAP	–	Months after planting
DAP	–	Days after planting
FYM	–	Farm yard manure
CSS	–	Corrected sum of squares
TCSS	–	Total corrected sum of squares
N	–	Nitrogen
P	–	Phosphorus
P_2O_5	–	Phosphorus pentoxide

K	–	Potassium
K_2O	–	Potash
Ca	–	Calcium
Mg	–	Magnesium
Fe	–	Iron
Mn	–	Manganese
Zn	–	Zinc
Cu	–	Copper
HF	–	Hydro fluoric acid
HCl	–	Hydro chloric acid
$HClO_4$	–	Perchloric acid
HNO_3	–	Nitric acid
NaOH	–	Sodium hydroxide
NH_4OAc	–	Ammonium acetate
DTPA	–	Diethylene tri amine penta acetic acid
dS	–	Deci siemens
c mol	–	Centi mole
K_0	–	No K
K_1	–	75 g K_2O $plant^{-1}$
K_2	–	150 g K_2O $plant^{-1}$
K_3	–	225 g K_2O $plant^{-1}$
K_4	–	300 g K_2O $plant^{-1}$
K_5	–	450 g K_2O $plant^{-1}$
K_6	–	600 g K_2O $plant^{-1}$
S_1	–	Early vegetative stage
S_2	–	Late vegetative stage
S_3	–	Shooting stage
S_4	–	Post shooting stage
S_5	–	Bunch maturation stage
S_6	–	Harvest stage

INTRODUCTION

1. INTRODUCTION

Banana, the oldest among the fruits to be cultivated by man is a major fruit crop of India which stands second only to Brazil in world banana production. It is cultivated in an area of 65070 ha in Kerala, the second largest banana producing state next to Maharashtra (FIB, 1994). Being a crop that thrives equally well as an irrigated crop on the uplands and as a rainfed crop in the low lands it is the choice of both the large and medium farmer. It is an essential component of the homestead of the marginal farmer too.

Banana plays a versatile role in the every day life of an Indian as almost every part of the plant has got utility in some way or other. The fruit, a rich source of starch, minerals and vitamins with a high calorific value (1 cal g^{-1}) serves as staple food for the adults and weaning food for the infants. It can be used for dessert as well as culinary purposes Different parts of the plant like the male bud, the tender internal stalk and the developing corm are used as vegetable. The full grown entire plant is used for festive decorations on auspicious occasions. The leaf laminae are widely used as substitute for dinner plates. The dried leaves are used for basket and hat making on a small scale. The pseudostem is used for pulp making in paper industry. The dried leaf sheath which yields excellent fibre is used in many cottage industries and also in textile industry. The pseudostem ash is said to be a sure remedy for snake poison.

Among the different cultivars of banana, Musa (AAB) group Nendran, popularly known as nana nendran' is the most popular commercial variety in Kerala occupying on area of 22602 ha which is 35 per cent of the total area under banana. The relative firmness of the pulp makes it ideal for the preparation of 'chips', a delicious favourite of the young and the old alike which is an added tribute over the other uses.

Potassium has been recognised as the key element in banana nutrition, the effect of this nutrient being manifested equally on the quantitative and qualitative aspects of the crop. The nutrient is required in far greater quantity by the crop than any other nutrient. The K requirement of banana is also much more than that by any other crop. Potassium is the costliest nutrient since the country's entire requirement is met from external sources. The applied K is also liable to wastage through leaching and run off due to its high solubility. The major clay type of the soils of Kerala being Kaolinitic with low cation exchange capacity the fixing capacity of the soils for this nutrient is low. Climatic factors like heavy rainfall which is irrationally distributed add to the gravity of the problem. In a scenario like this, it becomes highly imperative to take steps for the reappraisal of the present fertilizer schedule not only in the state, but also at the national level for need based application of K fertilizer to ensure minimum wastage and maximum efficiency.

In this context the present study was undertaken with the following objectives.

1. Selection of the index plant part in banana cv. Nendran for foliar diagnosis for K at different growth stages of the crop.

2. Fixing of the critical K levels in the index part and in soil for maximum response to fertilizer application and yield.

3. Study of the growth characters, yield and yield attributes, quality characters of the fruit and uptake of various nutrients by the crop under different levels of K nutrition.

4. Estimation of the quantities of nutrients that could be recycled back to soil by a crop of this variety.

It is hoped that findings of the present study will help in further elucidation of the role of K in the nutrition of banana cv. Nendran and in the planning of a judicious and scientific manurial schedule for K taking into consideration both the yield and quality of the crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana renowned to be nature's most K demanding crop, has been an interesting topic of study to plant scientists on a global scale for the last few decades. The crop has vast adaptability to thrive on a variety of soil and climatic conditions as extensively as between latitudes 33^0N and 33^0 S. Potassium has been recognised as the key element in banana nutrition, the beneficial effects of this nutrient being manifested equally on the quantity as well as quality of the produce. This nutrient is required in greater quantity by the crop than any other nutrient and plant requirement of the same is unapparelled by that of any other crop. The luxuriant growth character of the crop combined with its heavy feeding habits prompted great many scientists to undertake investigations in this field. Hence the results of research on banana are vast and scattered. Only those having a pertinent bearing on the subject of the present study are reviewed here.

Furcroy and Vauquelin (1807) are the the pioneers who recognised the pivotal role played by K in banana nutrition as evidenced by their documentation that the banana plant sap contained high concentration of K.

2.1 Potassium nutrition and growth characters in banana

The requirement of K in very large quantities by the banana plant was reported by Fawcett (1921), Norris and Ayyar (1942), De cuncha and Fraga (1963) and Twyford (1965) based on the results of manurial experiments conducted by them. The effect of the nutrient is manifested on the luxuriant vegetative growth habits of this crop, the largest among the herbaceous plants.

2.1.1 Height and girth of the plant

Chu (1959) reported that K fertilizing greatly increased the pseudostem growth in banana in a soil of Taiwan.

Ho (1971) observed significant positive correlation coefficients between leaf K concentration at different growth stages and relative percentage value of circumference and height of the pseudostem in banana, cv. Fairyman under three levels of K application. He opined that application of K in the early stage gave the largest height and circumference, both of which were significantly correlated with final fruit yield.

Teaotia *et al.* (1970) conducted simple, partial and multiple correlation studies on some quantitative characters in banana and found that bunch yield was strongly correlated with pseudostem circumference and its contribution to yield was large in all the three years of study.

Increased pseudostem height and girth by higher rates of K application in banana, cv. Robusta was reported by Turner and Bull (1970).

Potassium applicatin producing taller banana plants was reported by Lahav (1972a). He observed from a study of banana suckers grown in sand culture receiving six levels of K ranging from 0 to 292 ppm that pseudostem height and circumference were smaller in plants receiving low K levels.

Jambulingam *et al.* (1975) found soil application of increased K levels producing increased height and girth of pseudostem in banana, cv. Robusta.

The pseudostem circumference was highly correlated with the midrib concentration of K as reported by Caldas *et al.* (1978).

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

The experiment conducted by Sheela (1982) on K nutrition in rainfed banana, cv. Palayankodan showed that the different K levels tried ranging from 0 to 600 g K $plant^{-1}$ did not influence the girth of the pseudostem at any stage of plant growth. The height of the pseudostem at late vegetative phase and shooting were influenced significantly, the levels of 500 g and 400 g respectively producing the maximum heights.

Fabregar (1986) recorded girth of pseudostem increasing with increasing rates of K application upto 800 kg ha^{-1} $year^{-1}$ in banana, cv. Umalag.

Mustaffa (1987) concluded from a study on the effect of increasing doses of K fertilizer on cv.Robusta banana that increased K level of 400 g $plant^{-1}$ significantly increased the height and circumference of the pseudostem.

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

Results of investigation by Hedge and Srinivas (1991) pointed out significant statistical relationship between increased K levels and girth of pseudostem.

The height and basal circumference of the pseudostem in banana cv Dwarf Cavendish were found to respond positively to the highest level of K application (Khoreiby and Salem, 1991).

2.1.2 Number of leaves and leaf area

In sand culture experiments, Murray (1960) studied the effect of K on the growth and leaf analysis of banana and observed that leaf area was only half in K deficient plants after four months of growth compared to control.

Brezesowsky and Biesen (1962) obtained more leaves from an experimental plot receiving the highest level of K than the lowest, the N and P rates remaining the same.

Ho (1969) found that the application of K at the early stage gave the largest number of leaves in banana cv. Fairyman.

Lahav (1972a) noted that in K deficient banana plants, the leaves were smaller and their longevity shorter, thus diminishing the total foliage area.

Ramaswamy *et al.* (1977) based on their work in banana cv. Dwarf Cavendish reported that increased rate of K application upto a level of 450 g $plant^{-1}$ produced significant increase in leaf area.

Twenty per cent reduction in total leaf area in banana cv. Williams under K deficiency was reported by Turner and Barkus (1980).

Sheela (1982) found that different levels of K application did not influence the total number of functional leaves and leaf area index in banana, cv. Palayankodan. However, a tendency for high leaf number and increased leaf area with higher levels of K was noticed.

As reported by Mustaffa (1987), the application of the highest level of K of 400 g $plant^{-1}$ produced the largest number of leaves and leaf area.

Baruah and Mohan (1991) studied the effect of K on LAI, phyllochron and number of leaves in Cavendish banana and observed that K application resulted in significant variation in the LAI and phyllochron, the highest K dose producing the lowest phyllochron and the largest number of leaves. On the basis of another work, the same authors (1992) attributed the reduced leaf size of Cavendish banana in Assam to the lack of K.

Khoreiby and Salem (1991) conducted investigations on the effect of K on vegetative growth and nutritional status of banana cv. Dwarf Cavendish and found that the highest level of K application produced the most vigorous leaves resulting in greater surface area. The leaves also contained balanced and adequate concentration of macro and micro nutrients.

2.2 Potassium nutrition and yield in banana

In documentations by Norris and Ayyar (1942), Garcia *et al.* (1980), and Shanmughavelu *et al.* (1992), K is placed as the topmost wrung of the nutrient ladder in deciding the fruit yield in banana.

Significant positive correlation between K application, yield and yield attributing bunch characters like number of hands and fruits $bunch^{-1}$, size of fruit and bunch weight have been reported by many workers.

2.2.1. Number of hands and fruits $bunch^{-1}$

Bhangoo *et al.* (1962) found that a fertilizer schedule of 350 N, 160 P and 180 K increased the number of hands and marketable fingers $bunch^{-1}$ compared to N alone.

Jagirdar and Ansari (1966) studied the effect of N, P and K on the growth and production of Cavendish banana and found that the highest yield in terms of number of fingers per unit area was obtained from plants that received K alone.

Ho (1969) reported that application of K in the early stage increased the number of hands and fingers $bunch^{-1}$ in banana, cv. Fairyman in South Taiwan.

Increase in the number of hands bunch^{-1} and fingers hand^{-1} as a result of K application to banana was observed by Uexkull (1970) in South Taiwan.

Lahav (1977) observed that a low K content decreased the number of hands in banana cv. Williams resulting in decreased bunch size. The hands were also deformed.

Ramaswamy *et al.* (1977) found that increasing the level of soil application of K to banana cv. Dwarf Cavendish upto 450 g plant^{-1} significantly increased the number of hands and fruits bunch^{-1}, the characters which were significantly correlated with yield also.

According to Caldas *et al.* (1978) the bunch characteristic, number of hands bunch^{-1} had a very high positive correlation with K content in the midrib.

Study conducted by Sheela (1982) in banana, cv. Palayankodan with different levels of K application showed that the highest level of K application viz. 600 g plant^{-1} produced the highest number of hands and fingers bunch^{-1} with statistical significance.

An experiment conducted by Cordero (1985) in Costa Rica showed that K application increased the number of hands and fingers bunch^{-1} each by 18 per cent over control

Study by Obiefuna (1984) on the effect of K application during the floral initiation stage in plantains showed that K application at the 19th - 20th leaf stage (four to five months after planting) significantly increased the number of marketable fingers by 33.7 per cent.

In banana cv. Umalag Fabregar (1986) found that the number of hands bunch^{-1} increased with increasing rates of K application upto 800 kg ha^{-1} year^{-1}.

Tandon and Sekhon (1988) reported increase in the number of hands and fingers bunch^{-1} in Robusta banana due to K application.

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.

In a study conducted in Bangladesh Hedge and Srinivas (1991) observed improvement in yield in banana associated with increased hands and fingers bunch^{-1} upto a K level of 300 g plant^{-1}.

Baruah and Mohan (1992) found that the response of banana cv. Dwarf Cavendish in Assam to K application was in terms of increase in the weight of the second hand which proved to be a significant yield attributing character.

2.2.2 Length, girth, weight and volume of fruit

Uexkull (1970) found that under South Taiwan conditions, K application increased yield in banana by increasing the size of the finger, the most economic range of fertilizer application being 300 to 600 g K plant^{-1} year^{-1}.

Ramaswamy (1971) obtained significant increase in size of fruit at harvest in banana cv. Dwarf Cavendish by increasing the rate of K application.

Based on a sand culture study, Lahav (1972a) reported that a low K content in banana affected the fruit fingers in their length and circumference.

Studies conducted by Venkatarayappa *et al.* (1973) revealed that application of K at the post shooting stage of Cavendish banana significantly increased the volume and weight of fruits in both Giant Cavendish and Dwarf Cavendish banana. The length/girth ratios of fruits were more in K treated plants than in control plots.

Sheela (1982) concluded based on the experiment in banana cv. Palayankodan with different levels of K that K application significantly increased the girth and weight of the finger.

An increase of finger weight by 44.2 per cent over control in plantains by the application of 300 g K plant^{-1} at floral initiation stage was reported by Obiefuna (1984).

Potassium increasing finger size in Robusta banana was observed by Tandon and Sekhon (1988).

Hedge and Srinivas (1991) noticed improvement in yield in banana when the rate of K application was raised to 300 g plant^{-1}. Increased finger weight was one of the factors which contributed to this.

In Assam soil in banana cv. Dwarf Cavendish, Baruah and Mohan (1992) obtained response to K application in terms of increase in the length and circumference of the fingers.

2.2.3. Weight of bunch

General improvement of yield in banana with increasing levels of K application has been documented by Chu (1959), Ho (1969), Ramaswamy *et al.* (1977) and Tandon and Sekhon (1988).

Taking into consideration the reduction in bunch weight under low K supply, Twyford (1965) recommended a high K containing mixture for banana, 12N:4P:30K.

Jagirdar and Ansari (1966) in a fertilizer experiment in Cavendish banana got the heaviest bunches from plants that received K alone.

Turner and Bull (1970) demonstrated a reduction in bunch yield associated with a reduction in overall vegetative growth under K deficiency.

Uexkull (1970) attributed K to be the determinant factor in deciding the yield in banana in terms of bunch weight.

Ho (1971) recommended the application of 1000 kg k_2O ha^{-1} for high yields in banana, cv. Fairyman in a soil of South Taiwan.

The bunch weight in banana cv. Nendran was found to be influenced significantly by K application upto 228 g $plant^{-1}$ level beyond which it decreased as reported by Pillai *et al.* (1977).

Caldas *et al.* (1978) found that weight of bunch was highly and positively correlated to the K content in the midrib in banana.

In banana cv. Palayankodan Sheela (1982) observed positive significant effect for K on bunch weight, the highest being from the treatment having the highest level of K.

Obiefuna (1984) observed increase in bunch weight by 73.9 per cent over control by applying 300 g K $plant^{-1}$ at the 20th leaf stage.

Cordero (1985) obtained 20 per cent increase in bunch weight over control when 750 kg K ha^{-1} was applied.

On a Matina sandy clay loam soil in banana cv. Umalag Fabregar (1986) found that the bunch weight increased with increasing rates of K application upto 800 kg ha^{-1} $year^{-1}$.

In the Carribean Coast of Costa Rica, Garita and Jaramillo (1986) found that enhanced K levels increased bunch size and bunch weight in banana cv. Giant Cavendish.

Bellie (1987) studied the effect of split application of fertilizers on banana cv. Nendran and concluded that the highest bunch yield was from the treatment which received a fertilizer dose of 150:90:300 g NPK $plant^{-1}$.

Mustaffa (1987) obtained the highest yield of 45.4 t ha^{-1} which was 35 per cent higher than the control at 300 g K $plant^{-1}$.

Sharma and Yadav (1987) conducted investigations on the effect of different methods and times of manuring on the growth and yield of banana which showed that the heaviest bunch (18.42 kg) was obtained when 110 g K $plant^{-1}$ was dibbled near young banana suckers.

Obiefuna and Onyete (1988) recommended an annual application of 500 g K $plant^{-1}$ for the heaviest bunch weight, the demand for K being double that of N.

Nair *et al.*, (1990) observed that eventhough bunch weight of banana cv. Nendran grown in rice fallows showed linear increase with higher levels of K application, the different levels did not significantly influence the other bunch characters like length of bunch, weight of hand, weight and girth of fruit etc.

Baruah and Mohan (1992) found that the bunch weight increased with increase in the level of K application in banana cv. Dwarf Cavendish in Assam soil.

Chong *et al.* (1992) showed that 900-1200 kg K_2O ha^{-1} increased banana yield by 11.6 tonnes ha^{-1} over control. Each kg of K_2O produced 10 to 12 kg of fruit.

2.3 Potassium nutrition and quality characters in banana

The dominance of K in the nutrition of banana is manifested by its profound influence on improving the crop quality over and above enhanced yields.

2.3.1. Total soluble solids

Report by Jambulingam *et al.* (1975) provide evidence for the pronounced effect of K on soluble solids in banana.

Ramaswamy *et al.* (1977) studied the effect of application of different levels of K on quality parameters in banana cv. Dwarf Cavendish and found that higher K applications increased the total soluble solids.

Vadivel and Shanmughavelu (1978) observed that in banana cv. Robusta K application increased the total soluble solids content of the fruit.

Based on the study conducted in banana cv. Palayankodan Sheela (1982) postulated that increasing K application significantly influenced the total solids in the pulp, the highest K level of 600 g plant^{-1} producing the highest value of 29.82 per cent.

In banana cv. Jahaji Baruah and Mohan (1986) observed increased content of total solids as a result of increasing the levels of K application.

Content of total soluble solids in banana cv. Umalag was positively correlated with K fertilization (Fabregar, 1986)

Mustaffa (1987) reported that K application improved the quality of banana cv. Robusta by increasing the brix or total solids.

Ram and Prasad (1989) noted that total solids increased significantly with increased levels of K in banana cv. Campiergang local.

Investigation by Hedge and Srinivas (1991) revealed that increasing the level of K fertilization significantly increased the total solids in banana.

2.3.2. Acidity

In banana cv. Giant Cavendish and Dwarf Cavendish, Venkatarayappa *et al.* (1973) observed lowered acidity as a result of K application in Tirupathi soil.

Jambulingam *et al.* (1975) documented the pronounced effect of K on reducing titrable acidity in banana cv. Robusta.

Ramaswamy et al. (1977) reported acidity in banana cv. Dwarf Cavendish ranging from 2.9 to 4.2 per cent, the acidity showing reduction with increase in level of K.

Vadivel and Shanmughavelu (1978) observed acidity in banana cv. Robusta decreasing with increased level of K application.

Sheela (1982) observed acidity in the range of 0.427 to 0.502 per cent in banana cv. Palayankodan under graded levels of K, the control plot showing the highest value.

In banana cv. Jahaji Baruah and Mohan (1986) observed titrable acidity which ranged from 0.18 to 0.44 per cent decreasing with increasing levels of K application.

As reported by Chathopadhyay and Bose (1986) acidity of the fruit in banana cv. Dwarf Cavendish showed reduction with increase in K levels.

Although not significant, high rates of K reduced acidity in the ripe fruits of banana cv. Umalag as reported by Fabregar (1986).

Mustaffa (1987) attributed the improvement in the quality of banana cv. Robusta under high level of K application due to the reduction in acidity.

According to Ram and Prasad (1989) different K levels did not influence total titrable acidity.

Contrary to above observations Prevel (1989) found that high K fruits were higher in acidity.

2.3.3. Total, reducing and non-reducing sugars

Ramaswamy *et al.* (1977) obtained the highest content of reducing sugars of magnitude 13.2 per cent from plot that received the highest level of K of 550 g plant^{-1}. Non-reducing sugar content also showed tendency to increase with K level in banana cv. Dwarf Cavendish.

Effect of increasing the rates of K on quality parameter in banana cv. Robusta was studied by Vadivel and Shanmughavelu (1978). The results indicated that K application increased the contents of total and reducing sugars.

Sheela (1982) found the total and reducing sugar contents being significantly influenced by K treatment in banana cv. Palayankodan while for non reducing sugars, there was no effect. However higher values for these characters were associated with higher K levels.

Baruah and Mohan (1986) observed significant response in banana cv. Jahaji to K in the form of increased content of total, reducing and non reducing sugars.

Although not significant high rates of K application to banana cv. Umalag reduced the sugar contents, as reported by Fabregar (1986).

Ram and Prasad (1989) found the highest total sugar content in banana cv. Campiergang local for the lowest level of K which was 300 g $plant^{-1}$

Samra and Qadar (1990) demonstrated that soil and foliar application of K resulted in increased total and reducing sugars.

2.3.4 Sugar-acid ratio

Uexkull (1970) observed K improving the sugar acid ratio in banana under South Taiwan conditions. Similar effect of K in banana was reported by Zehler *et al.* (1981) also.

Enhanced sugar-acid ratio with increased level of K application to banana cv. Robusta was observed by Vadivel and Shanmughavelu (1978).

The significant effect of K on sugar acid ratio in banana cv. Palayankodan was noted by Sheela (1982). The values ranged between 29.54 and 40.00, the lowest for the control and the highest for the second highest level of K which was 500 g $plant^{-1}$.

In an exhaustive work to study the effect of K on quality aspects in banana cv. Jahaji, Baruah and Mohan (1986) found that the maximum sugar acid ratio of 134 was at the highest level of K.

According to Uexkull and Bosshart (1987) sugar-acid ratio, an important quality character in banana, was improved by K application.

2.3.5 Vitamin C

Mustaffa (1987) studied the role of K in improving the quality of banana cv Robusta and found that increase in the ascorbic acid content of the fruit was associated with increased K levels.

Prevel (1989) found that high K fruits were higher in Vitamin C.

The ascorbic acid content in banana increased as a result of soil and foliar application of K (Samra and Qadar, 1990)

2.3.6 Pulp peel ratio

Sheela (1982) reported the pulp peel ratio in banana cv. Palayankodan to be in the range of 2.95 to 3.50 under different K levels the lowest being recorded at the control level.

Prevel (1989) noted that high K containing banana fruits exhibited high pulp-peel ratios.

Contrary to other reports, Hedge and Srinivas (1991) postulated that increasing the level of K application decreased the pulp peel ratio in banana.

2.3.7 Shelf life

General improvement in the storage life of banana by K was reported by Chu (1959).

Ho (1968) observed K improving the fruit condition in banana evidenced even after storage for 20 days.

Uexkull (1970) attributed the effect of K on improving the storage life of banana to the increase in the thickness and firmness of the rind.

Zehler *et al.* (1981) observed K improving the storage properties of banana fruit.

In banana cv. Umalag, Fabregar (1986) did not find any significant effect for K on the shelf life of the ripe fruit.

In a report, Uexkull and Bosshart (1987) stated that K improved the shelf life of the banana fruit by increasing the firmness of the pulp.

2.4 Potassium nutrition and dry matter production in banana

Turner and Barkus (1980) studied the effect of K on dry matter production in banana cv. Williams. They found that K deficiency resulted in a reduction of 79 per cent in the total dry matter content of fruits while the roots were unaffected.

Sheela (1982) observed that increasing the levels of K increased the total dry matter content in banana, cv. Palayankodan The highest level of K application viz. 600 g plant^{-1} produced the highest dry matter content at the late vegetative stage.

Investigations on the dry matter production and uptake of macro nutrients by banana cv. Prata by Gomes *et al.* (1991) showed that uptake of all nutrients except that of K by the petiole was correlated with dry matter production.

Hedge and Srinivas (1991) found that increasing K levels upto 300 g $plant^{-1}$ increased the total dry matter production and its distribution into the pseudostem and fruit in banana. But further increase had no effect. Leaf dry matter remained unaffected by different K levels.

2.5 Potassium concentration and its uptake in banana as affected by K nutrition

Ho (1969) studied the K content in the third leaf of banana, cv. Fairyman grown on a S.Taiwan soil as affected by different levels of K application ranging from 0 to 600 g $plant^{-1}$. The K content increased with increase in the rate of application, the highest rates recording the highest K values during all the seasons the study was conducted.

Randhawa *et al.* (1973) pointed out that increasing the level of K application to banana significantly increased the K content of the leaf tissue, the highest K content resulting from the application of the highest K level.

Garcia *et al.* (1980) studied the distribution of N, P, K, Ca and Mg in banana leaves under different levels of K application in red soils of Cuba. They observed that high fertilization of K increased the K levels in the leaves.

Sheela (1982) reported that varying levels of K had significant influence on the K content of all plant parts in banana cv. Palayankodan. The K content increased with increasing level of K. Between control and the highest level of 600g K $plant^{-1}$, there was a difference of 77% in the K content of fruits.

Garita and Jaramillo (1986) noted that leaf K levels in banana cv. Gaint Cavendish increased as the rate of K application increased in the Carribean soils of Costa Rica.

Irizarry *et al.* (1988) found during a fertilizer trial in banana cv. Grand Nain in Puerto Rico that K concentration steadily increased in the plant under increasing levels of K application.

Ray *et al.* (1988) observed that increased doses of applied K were reflected in increased contents in the banana leaves.

According to Vadivel and Shanmughavelu (1988) in spite of different levels and methods of K application, its concentration in the banana leaf remained a constant within a range of 4.0 to 5.0 per cent.

2.6. Potassium nutrition and uptake of other nutrients in banana

In K deficient plants raised by Murray (1960) on sand culture, increased levels of P and Ca in the leaves were observed.

Increasing K supply to banana according to Prevel and Montagut (1966) had a large depressing effect on Mg concentration in leaves and pseudostem, but very little effect in fruit and roots.

Ho (1969) observed that the increment of K fertilizers depressed the leaf concentration of Ca, Mg and N, but there was no such effect for P in banana, cv. Fairyman.

Induced deficiencies of K, Ca and Mg in banana plants were studied by Lacoueuilhe and Prevel (1971). A low cation sum (K + Ca + Mg) in the first leaf proved to be an indication of K deficiency. A clear K-Mg antagonism was also established.

Caldas *et al.* (1973) in their study observed that K content was negatively correlated with Ca and Mg at both floral differentiation and floral emergence stages. The findings confirmed that Mg per cent in the cation sum (K + Ca + Mg) remained more or less a constant while K was progressively replaced by Ca as the plant developed.

Study by Lahav (1974) on the influence of K on the content of macro elements in banana sucker confirmed that ionic antagonism K:Mg was stronger than K:Ca. An increase in K concentration was followed by a decrease in N.

Chathopadhyay and Mallik (1977) found K and Ca uptake in banana increasing with high K fertilization.

Garcia *et al.* (1978) noted negative correlation between K-Mg, K-Ca and Ca-yield and positive correlations between Ca-Mg and K-yield in bananas grown on a red soil of Cuba. In another experiment, Garcia *et al.* (1980) observed negative correlations in banana leaves between K and Ca, K and Mg and between each of the ratios K/N, K/Ca and K/Mg and response to K fertilizer.

On reviewing twenty four years of research in banana nutrition, Prevel (1978) observed that the absorption rates of exchangeable cations by the banana plant were determined by the relative proportions among K, Ca and Mg.

Bondad *et al.* (1983) compared the leaf nutrient composition of Musa as affected by K application and saw that the leaf P, Ca and Mg increased markedly and N and K decreased in plots that received potash application when compared to control.

Turner (1983) observed that an increase in K reduced the proportion of all nutrients except K in the roots and increased the proportion in the fruit.

Turner and Barkus (1983) studied the uptake and distribution of mineral nutrients in banana in response to the supply of K, Mg, Mn and observed that increasing K supply increased the uptake of most elements except Mg whose uptake was unaffected. Cu uptake was reduced.

In another investigation Turner and Barkus (1985) conducted long term studies on the absorption rates and competition between ions in banana which revealed that increased K increased the plant uptake of K and P and decreased that of N, Ca, Mg and Ca. The lamina K/Ca + Mg ratio did not show a useful relationship with yield.

Garita and Jaramillo (1986) studied the response of banana cv. Giant Cavendish to increased rates of K in Caribbean soils and found that as the rate of K_2O application increased, leaf K level and leaf K/Mg ratio increased and leaf K/N ratio decreased.

Vadivel and Shanmughavelu (1988) found that a rise in K concentration in the banana leaf was followed by a drop in Ca and Mg contents.

2.7. Nutrient uptake/removal in banana

Baillon *et al*. (1933) recorded NPK uptake by a single plant of banana cv. Cavendish in Canary islands to be of the order 165 g N, 35 g P and 772 g K respectively.

Based on a three year study on bananas in Antilles, Montagut and Prevel (1966) concluded that amount of nutrients removed were 60 kg N, 125 kg P_2O_5 and 100 kg K against a production of 30 t ha^{-1}.

Joseph (1971) worked out the nutrient requirement of a crop producing 6.5 t $acre^{-1}$ of fruit as 34lb N, 7 lb P, 225 lb K, 27 lb Ca and 44 lb Mg $acre^{-1}$.

Veerannah *et al*. (1976) studied the nutrient uptake by banana cv. Robusta and found that the requirement of K was higher (932.67 kg ha^{-1}) before flowering. After flowering, the requirement was less, only 137.00 kg ha^{-1}.

In Williams hybrid banana grown on a coastal plain of Israel, Lahav (1977) found that K fertilization increased K uptake by 5.5 per cent in the blade and 22.5 per cent in the petiole.

A crop of Maricongo plantains in Puerto Rico consisting of 2988 plants ha^{-1} removed 70 kg N, 9 kg P, 242 kg K, 2 kg Ca and 11 kg Mg as reported by Samuel *et al.* (1978).

For a crop of Cavendish banana producing an yield of 32 to 48 ton ha^{-1}, the range of values in Kg ha^{-1} for nutrient uptake were 180 for K, 95 to 140 for Ca and 34 to 40 for Mg (Marchal and Mallesard, 1979).

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

The uptake of major nutrients by a rainfed crop of banana cv. Palayankodan under different levels of N application was studied by Valsamma Mathew (1980). Potassium uptake which increased with the stages of growth upto shooting did not show a corresponding increase with the levels of N applied.

Goswami and Khera (1981) worked out the ratios of P and K uptake by different crops relative to N. They reported that for a banana population of 2965 plants ha^{-1}, the ratios were 100 N : 44 P: 311 K while the nutrient removals were 448 for N, 197 for P and 1395 for K, all expressed in kg ha^{-1}.

Godefroy (1982) reported that a banana crop yielding 40 to 60 tonnes of bunches ha^{-1} removed 80-120 kg N, 240-360 kg K_2O, 20-30 kg P_2O_5 and 10 - 15 kg each of Ca and Mg.

Nutrient uptake by intensely managed high yielding Grand Nain plantains grown on an ultisol in Puerto Rico at different growth stages was studied by Irizarry *et al.* (1982). The study showed that on an average, the uptake of different nutrients which increased upto harvest were of the order 249 for N, 21 for P, 585 for K, 60 for Mg and 147 for Ca, expressed in kg ha^{-1}.

Mengel and Kirkby (1982) reported the nutrient removal by a banana crop yielding 45 tonne of fruits ha^{-1} to be to the tune of 78 kg ha^{-1} N, 22 kg ha^{-1} P and 224 kg ha^{-1} K.

Jaramillo and Garita (1982) reported that a ton of banana fruit contained 1.25 to 2.00 kg N, 0.50 kg P_2O_5, 6.00 kg K_2O, 0.23 kg Ca and 0.33 kg Mg.

Kemmler and Hobt (1987) reported nutrient removal in the order of 250 kg ha^{-1} N, 60 kg ha^{-1} P_2O_5, 1000 kg ha^{-1} K_2O and 140 kg ha^{-1} Mg by a banana crop producing an yield of 40 t ha^{-1}.

Shanmughavelu *et al* (1987) worked out values for the nutrient uptake by a crop of banana cv. Poovan which produced an yield of 35 t ha^{-1}. The values were 408, 35, 1285, 35 and 35 kg ha^{-1} for N,.P, K, Ca and Mg respectively.

Describing banana as the world's most K demanding crop, Uexkull and Bosshart (1987) pointed out that to produce an yield of 50 t ha^{-1}, banana required about 1960 kg of K_2O ha^{-1}.

The NPK uptake rates and their ratios for Midstem, Dundilei and Dwarf banana were worked out by Chong *et al.* (1992). The magnitude of nutrient uptake in kg ha^{-1} by a banana population of 3000 plants was of the order N - 448, P_2O_5 - 448, K_2O - 1680 and Mg - 175.

The values reported by Anil (1994) for nutrient removal by banana cv. Nendran in Vellayani red loam soil were 197 to 349 kg N, 60 to 86 kg P_2O_5 and 433 to 706 kg K_2O on per ha basis.

2.8 Nutrient recycling in banana

Banana, the largest of the herbaceous plants is a heavy feeder of nutrients. The comparatively long life span of the crop and its efficiency for tapping nutrients even from subsoil result in that a tremendous quantity of nutrients get locked up in the vast biomass. The bunch accounts for less than 50% of the total biomass, on dry weight basis. Even after the removal of the bunch, the left over plant parts can be a potential source of nutrients to the growing sucker or another crop if incorporated into the soil through the phenomenon of nutrient recycling.

Baillon *et al.* (1933) studied the nutrient uptake by banana cv. Cavendish in Teneriffe soil. The fruits, accounted for only 16.9 per cent of total dry matter. In a plant producing a total dry weight of 18295 g, 173 g N, 40 g P 813 g K, 196 g Ca and 112 g Mg were contained by parts other than the fruit.

Twyford and Walmsley (1968) reported that in a healthy Robusta plant grown on a brown sandy loam in Windward islands, the bunch removed only 3.2 per cent of total Mn uptake, 3.8 per cent of Fe uptake, 23 per cent of Zn uptake and 24.7 per cent of Cu uptake. The values reported for the uptake by the whole plant were 283 for Mn, 1069 for Fe, 192 for Zn and 73 for Cu expressed as mg plant^{-1}

Turner (1972) proposed that in banana cv. Williams, the pseudostem which had 39 per cent of the total dry weight could contribute more than 40% of the requirement of the ratoon crop of all the elements except Zn and Mg if left entirely in the field after bunch harvest.

In a crop of Maricongo plantains in Puerto Rico, Samuel *et al.* (1978) found that after the removal of the bunch which constituted only 32.6 per cent of the total dry matter 262 kg N, 13 kg P, 1471 kg K, 208 kg Ca and 45 kg Mg were left behind in the pseudostem and leaves in a ha of field.

Godefroy (1982) opined that about 150 to 200 t ha^{-1} year^{-1} of fresh material could be added to the soil of banana plantations by the way of recycling of the trash which consisted of leaves and pseudostem left after the harvest of the bunch.

Irizzarry *et al.* (1988) reported that the bunch harvest in Grand Nain banana grown on a red acid clay soil of Puerto Rico resulted in the removal of 52% of the total dry matter. Left behind in 13,209 kg ha^{-1} of dry plant residues were 153 kg N,10 kg P, 448 kg K, 139 kg Ca and 38 kg Mg.

Gomes *et al.* (1991) proposed that a large part of the nutrients in banana cv. Prata which showed a ratio of 20:12:10:9:1 among K, N, Mg, Ca and P content could be returned to the soil after harvest.

2.9 Foliar diagnosis as a tool for soil fertility evaluation in banana

Plant analysis, a sensitive and practical technique in soil fertility evaluation has assumed the status of the most reliable source for providing information on the status of mineral nutrients in a soil since they are estimated at the actual site of their productive function. The impracticability of analysing the whole plant led scientists to choose or index specific plant parts, the analysis of which will give equal information as whole plant analysis. Attempts at the standardisation of plant part to be sampled were made by several scientists and the outcome was that for almost all crops, the leaf often described as the chemical laboratory of the plant' proved to be the best.

Banana was one of the earliest crops chosen by scientists to be studied under the approach of foliar diagnosis' owing to its lexuriant growth and heavy feeding habits. Because of the interdependence of tissue nutrient concentration on factors like the specific anatomic organ to be sampled, its ontogeny, stage of growth of the plant, variety, season etc., efforts for the standardisation of foliar analysis in banana by scientists showed slow progress. This was made all the more complicated by the interplay of growth and nutritional patterns in banana which were more complex than in any other crop.

2.9.1. Spatial variability of nutrient content in banana leaf

The banana leaf is assymetrical, the differences between the different areas arising from the process of leaf development. Variations in nutrient contents are considerable, both transversely and longitudinally.

The impracticability of taking the whole banana leaf as the sample owing to its size prompted Dumas (1960) to map spatial variability in its mineral content. Variations in nutrient content even within each half of the blade were considerable both transversely and longitudinally.

Twyford and Coulter (1964) found nutrient concentration to vary considerably within the leaf tissue of the banana. K, P, Fe and Ca were more concentrated near the base while N, Mg and Mn were concentrated near the tip.

Lahav (1972 b) showed that a five cm longitudinal displacement of the leaf area sampled could give a difference in K content equivalent to that from an application of K fertilizer. In another investigation, (Lahav 1972 c) studied the factors influencing the K content of the third leaf of banana sucker. The K content was found to vary considerably along the length of the blade. He opined that petiole analysis provided more information than the blade for cations.

Langenegger and Du Plėssis (1977) observed that for foliar analysis in banana cv. Dwarf Cavendish, the conductive tissues were useful indicators of the K status of the plant They also opined that it was easier to define and locate a petiole sample than a midrib sample.

Prevel (1977) found that the relative change in K concentration in the banana leaf from the base to the tip was 85 per cent. Variations were also noticed across the lamina from midrib to margin. According to him conductive tissues were useful indicators of cations.

The chemical composition of plantain leaves in relation to their ranks and section was studied by Samuel and Beale (1977) K content was found to decrease in the blade, but to increase in the midrib from leaf number two to five. Regarding the section of the sample K content decreased from the base to the tip of the leaf in both the blade and the midrib.

2.9.2. Indexing of plant part and stage of sampling in banana

Hewitt (1955) suggested the third leaf in banana counted from the top of the plant to be the best indicator of the nutritional status of the plant in respect of K. The best time for sampling, according to him was the time when the inflorescence emerged.

Hewitt and Osborne (1962) and Warner and Fox (1977) reported the third leaf to be the index part in banana cv. Lacatan and Giant Cavendish respectively.

According to Ho (1969) one third section of the lamina of the third leaf, on either side of the midrib in the mid part of the leaf, five cm in width was the best part for sampling for foliar analysis in banana cv. Fairyman.

Uexkull (1970) found the third fully unfurled leaf (central portion of the leaf lamina without midrib) to be the index part in banana.

Langenegger and Du Plessis (1977) opined that for foliar analysis in banana cv. Dwarf Cavendish, the two most promising tissues were a section of the mid two third of midrib and the corresponding lamina from leaf three sampled after flowering at a stage when two hermaphrodite hands became visible.

Messing (1978) suggested the choice of complete strips of tissue from the centre of the lamina of the third youngest leaf for diagnostic sampling for K in banana.

Ramirez *et al.* (1978) found that the first leaf of banana cv. Dwarf Cavendish in Aragua contained higher levels of K than the third and hence proved to be a better indicator of the nutrient.

Boland (1980) reported the second leaf to be the best indicator of the K status of the banana plant in a soil of Jamaica.

Ndubizu (1984) suggested the sixth leaf in plantain to be the best organ for K analysis.

Langenegger and Smith (1986) observed that in banana cv. Dwarf Cavendish, the lamina K after flowering showed a close relationship while the midrib K showed a quadratic relationship with yield which coincided more with actual response.

Sreedevi et al. (1989) suggested flag leaf to be the index part as it made a prominent contribution to photosynthesis.

In a red soil of Banglore under banana Bhargava *et al.* (1992) found the third fully opened leaf to be the best part for sampling.

2.9.3 Critical K level in banana for maximum production

A level of 3.3 per cent K in banana cv. Lacatan and 3.8 per cent in banana cv. Robusta were reported to be critical by Hewitt and Osborne (1962) and Twyford and Coulter (1964) respectively.

Ho (1969) found that a tissue concentration of 4.75 per cent K in the dry matter of the third leaf of six month old plants of banana cv. Fairyman to be critical.

Uexkull (1970) reported a critical range of 4.5 to 5.0 per cent K in the third leaf for the highest yield in banana.

In banana cv. Robusta, critical K levels of 3.11 per cent, 2.9 per cent, 4.5 per cent and 4.39 per cent were reported by Turner (1972), Twy ford and Walmsley (1974), Vadivel (1976) and Jambulingam *et al.* (1975) respectively.

Ashok kumar (1977) reported a range of 3.6 to 5.0 per cent K to be critical in banana cv. Robusta.

In banana cv. Giant Cavendish in Hawaiian soil, Warner and Fox (1977) found a K content of 3.2 per cent as the critical level.

Boland (1980) reported a critical K level of 3.8 to 4.0 per cent in the second leaf for maximum production in banana.

Critical K ranges of 3.97 to 4.19 per cent and 3.8 to 4.0 per cent were reported by Krishnan and Shanmughavelu (1980) and Nambisan *et al.* (1980) respectively in banana cv. Robusta.

Falcon and Fox (1985) reported a critical level of 3.2 per cent K in banana cv. Giant Cavendish while

Langenegger and Smith (1986) reported a level of 3.5 to 4.0 per cent K in banana cv. Dwarf Cavendish.

Ray *et al*. (1988) suggested a K level of 3.8 per cent as a good indicator of satisfactory productivity in banana.

For maximum production of banana in a red soil of Banglore, Bhargava *et al*. (1992) recommended a K level of 4.2 per cent in the index leaf.

2.10 Critical K level in soil for economic response

Croucher and Mitchell (1940) observed from a fertilizer investigation with banana cv. Gros Michel that soils with K content lower than 300 ppm responded to the application of K fertilizer.

Walmsley *et al*. (1971) postulated that because of the shallow root system of banana which has a high demand for K. response to fertilizer could be expected if exchangeable soil K was less than 0.4 me 100 g^{-1}.

Falcon and Fox (1985) reported a soil critical level of 2.26 me K 100 g^{-1} for maximum production in banana cv. Giant Cavendish.

Langenegger and Smith (1986) found that in banana cv. Dwarf Cavendish, production decreased beyond a soil critical level of 200 mg K kg^{-1}.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A field experiment in banana, _Musa_ (AAB group) Nendran was conducted in the sandy clay loam soil of Vellayani with seven graded levels of K. The main objectives were the selection of the best part in this variety of banana as an index of K status of the plant and the determination of the critical K concentration in that part at different growth stages of the crop for maximum response to fertilizer application and yield. The study also envisaged the fixing up of critical K levels in soil at different growth stages of the crop below which response to applied potassic fertilizers could be expected. The effect of K on the growth characters of the crop, dry matter production, concentration and uptake of various nutrients, yield and yield attributes, quality characters of the fruit, soil content of some important nutrients and the quantities of various nutrients that could be recycled back to soil upon harvest of the crop also have been investigated in this study programme.

In this chapter are presented the details regarding the field experiment conducted, observations recorded, analytical methods used and statistical procedures followed for achieving the objectives of the study.

3.1 Experimental site

The field experiment was laid out in the B block of Palappoor area of the instructional farm attached to College of Agriculture, Vellayani. Geographically the area is situated 8^{o} 5' North latitude, 77^{o} 1' East longitude and at an altitude of 29 m above MSL.

3.2 Soil

Soil of the experimental field comes under the taxonomic class 'Loamy Kaolinitic Isohyperthermic Aeric Tropic Fluvaquents'. Soil samples (0 to 30 cm) were collected before application of the treatments and were subjected to laboratory analysis for their important physico-chemical properties. The samples were air dried under shade, powdered with a wooden mallet and sieved through a 2 mm sieve. The methods employed for the important determinations made are outlined below.

Estimated character	Method adopted	Reference
Soil reaction	Direct reading using Perkin-Elmer Metrion V pH meter (Model 80)in 1:2.5 soil water suspension	Jackson(1973)
Electrical conductivity	Direct reading using Elico Soil Bridge Type CM. 84 in 1:2.5 soil water suspension	Jackson(1973)
Cation exchange capacity	NH_4 saturation by 1 N NH_4 OAc (pH 7.0)	Jackson (1973)
Mechanical analysis	Bouyoucous Hydrometer method	Piper(1967)
Organic Carbon	Chromic acid wet digestion	Jackson (1973)
Available N	Alkaline permanganate method	Subbiah and Asija (1956)
Available P	Bray extraction and photo electric colorimetry making use of chlorostannous reduced molybdo phosphoric blue colour in HCl system	Jackson(1973)
Total K	$HF/HClO_4$ digestion and flame photometry	Pratt(1965)
Exchangeable K	1 N NH_4OAc(pH 7.0) extraction and flame photometry	Stanford and English (1949)
Exchangeable Ca,Mg	1 N NH_4OAc (pH 7.0) extraction and atomic absorption spectro photometry	Jackson (1973)
Available micronutrients (Fe, Mn, Cu, Zn)	DTPA extraction and atomic absorption spectro photometry	Lindsay and Norvell (1978)
Fixed K	(1 M HNO_3 extractable K - 1 N NH_4OAc extractable K)	Wood and Deturk (1941)

3.3 Season

The cropping period was from August '91 to May '92, the season most suitable for irrigated Nendran banana.

3.4 Weather parameters

The major weather parameters during the season were monitored. The maximum temperature, minimum temperature, relative humidity and total rainfall during the period ranged from 29.4 to 33.0^{o} C (mean 31.0^{o} C), 20.4 to 25.4^{o} C (mean 23.1^{o} C), 72.0 to 81.6 per cent (mean 76.9 per cent) and 0 to 247.1 mm (mean 78.2 mm) respectively. The graphical presentation of the data is given in figure 1.

3.5. Lay out details of the experiment

Lay out plan of the experiment is presented in Figure 2. The details of the experimental techniques followed are described below.

Design : Randomised Block Design

Replications : 3

Spacing : 2 m^2

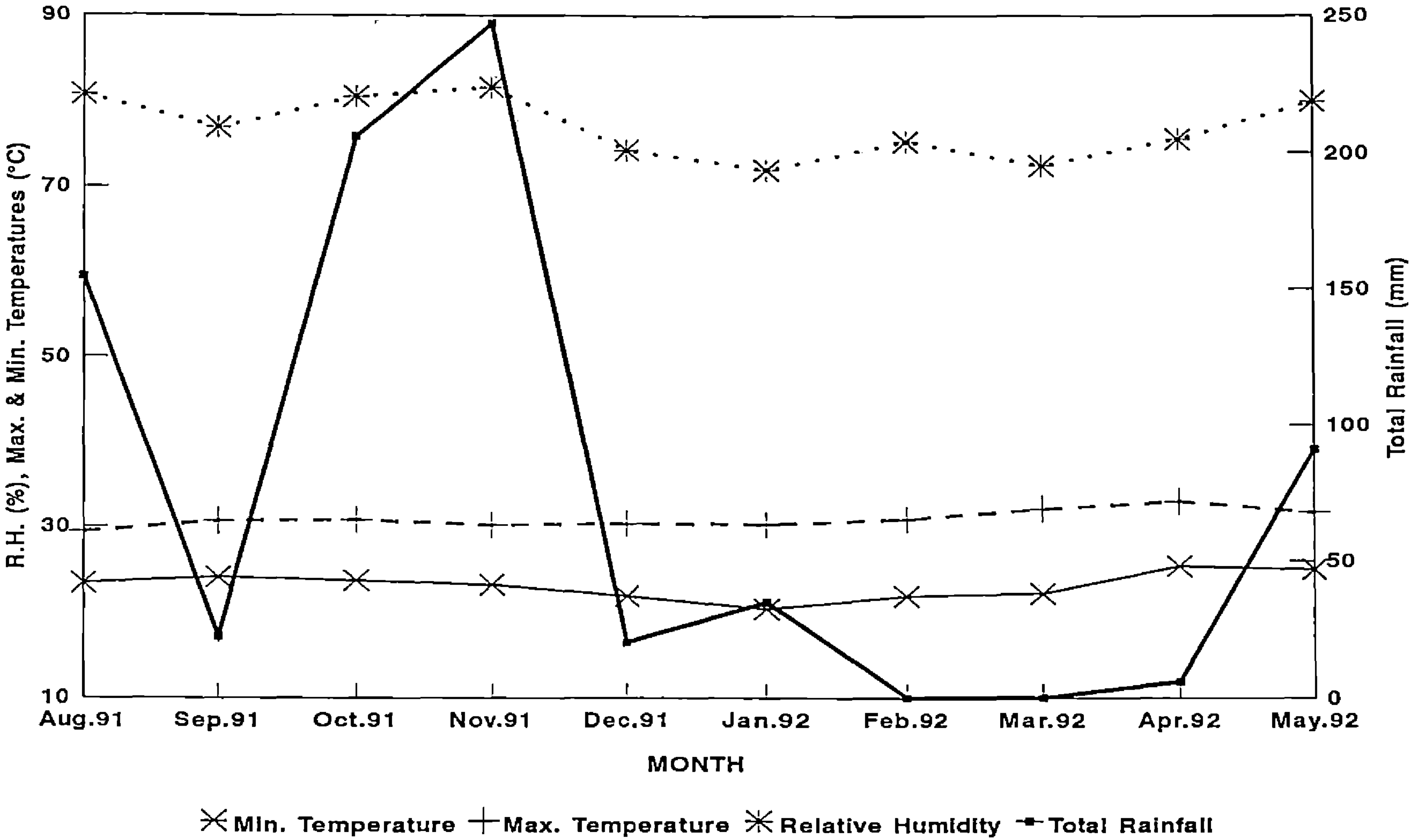

Fig. 1. Main meteorological parameters during the cropping period (August, 1991 to May, 1992)

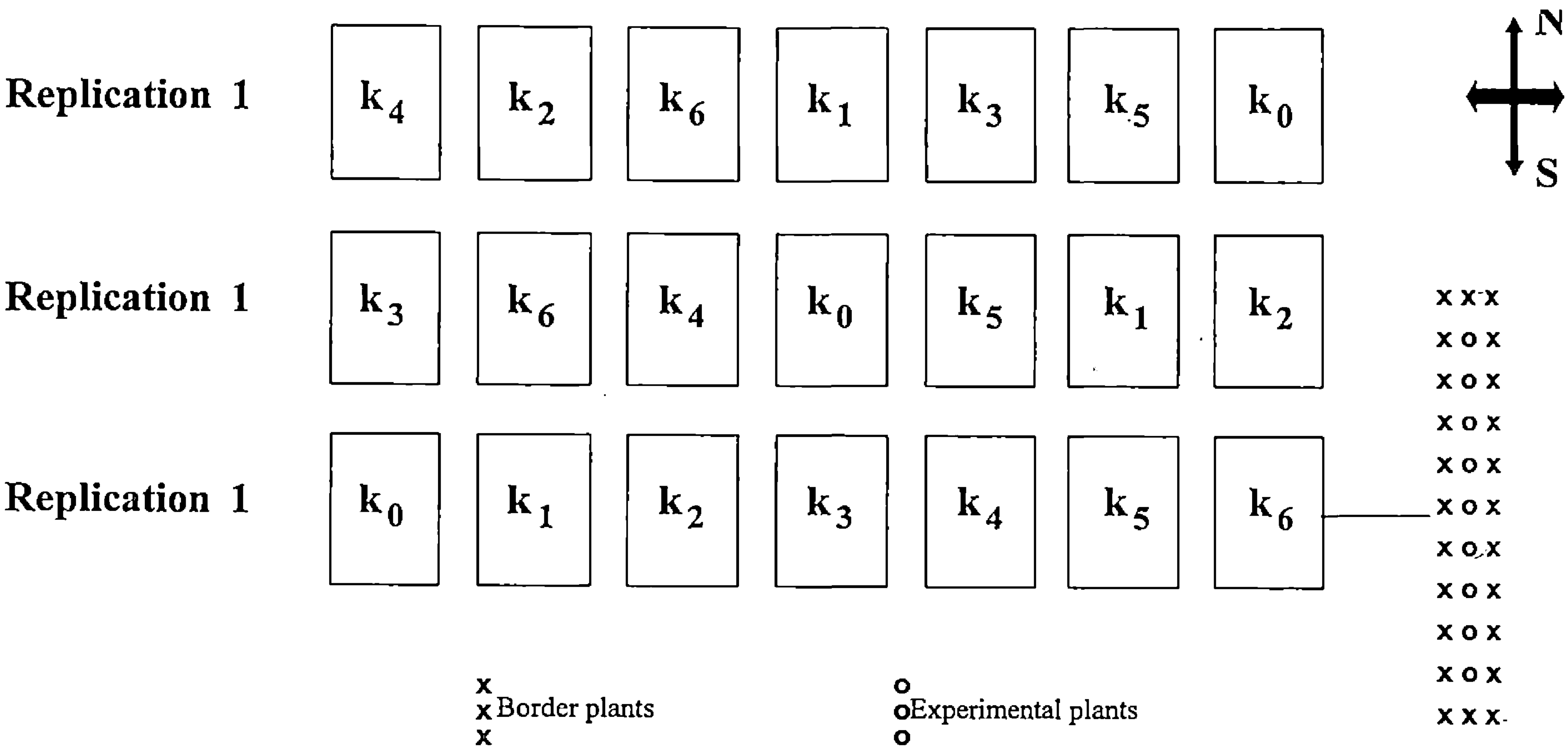

Fig. 2. Lay out of the experimental site

Variety : *Musa* (AAB group) Nendran

Plot size : 20 m x 4 m

Treatments : 7 levels of K where K represents the package of practices recommendations of Kerala Agricultural University for K for irrigated Nendran banana (300 g K_2O plant^{-1} in five equal splits). (KAU, 1989)

Notation	Level of K	Quantity of K
k_0	Control	No K
k_1	0.25 K	75 g K_2O plant^{-1}
k_2	0.50 K	150g K_2O plant^{-1}
k_3	0.75 K	225g K_2O plant^{-1}
k_4	1.00 K	300g K_2O plant^{-1}
k_5	1.50 K	450g K_2O plant^{-1}
k_6	2.00 K	600g K_2O plant^{-1}

Fertilizer application

Urea (46 per cent N), Mussoorie rock phosphate (22 per cent P_2O_5) and Muriate of potash (60 per cent K_2O) were used as the sources of N, P and K respectively besides farm yard manure applied basally @ 10Kg plant^{-1}. The levels of N and P were kept constant for all treatments. One hundred and ninety g N plant^{-1} was applied in 6 equal splits first as basal and the rest one, two, four, five and six months after planting. One hundred and fifteen g P_2O_5 plant^{-1} was applied in two splits, first as basal and the second one month after planting. Potassium was applied as per the technical programme in five equal splits first as basal, and the rest one, two, four and five months after planting.

Planting material

Three month old disease free robust suckers of uniform weight were selected for planting to ensure maximum homogenity in their physiological maturity. The rhizomes were dipped in cowdung slurry treated with 0.2 per cent BHC, and ash, dried in the sun for 4 days and stored for 15 days in shade before planting.

Plant protection measures

Phorate (10% G) was applied uniformly to all plants @ 25 g plant^{-1} 20 DAP in the soil and 12.5 g each 75 and 165 DAP in the leaf axils as a prophylactic measure against the bunchy top insect vector, Pentalonia nigronervosa. A spray of 0.3 per cent phosphamidon was given to all plants at the third and fourth month for controlling the leaf caterpillar, Spodoptera sp.

Maintenance of the crop

Hand weeding was resorted to as and when required. Mulching was provided at the basin till the suckers established well. Irrigation was done at weekly intervals at the rate of 40 l plant^{-1} during the summer months. Suckers were prevented from emerging by smothering them on the very first day of emergence.

Nine plants were maintained in each plot. Six were intended for destructive sampling at six major growth stages of the crop. Three plants were kept for harvest.

Stages of sampling

Six stages during the growth period of the crop were identified for recording the observations and sampling.

S1. Two months after planting - Early vegetative stage

S2. Four months after planting - Late vegetative stage

S3. Six months after planting - Shooting stage

S4. Seven months after planting - Post shooting stage

S5. Eight months after planting - Bunch maturation stage

S6. Nine months after planting - Harvest stage

3.6. Growth characters

The following growth characters of the crop were recorded as detailed below.

3.6.1. Height of the plant (cm)

Height of the plant was measured from the base of the stem at the soil level to the axil of the youngest unopened leaf at two, four, six, seven, eight and nine months after planting.

3.6.2. Girth of the pseudostem (cm)

Girth of the pseudostem at the soil level and at 20 cm and one meter heights above the soil level were measured using a flexible measuring tape at two, four, six, seven, eight and nine months after planting. Girth of the pseudostem at one meter height could not be recorded in any of the plants at two months after planting as the plants had not grown to the required length.

3.6.3. Number of leaves plant^{-1}

The total number of leaves including both green and senescent ones was recorded at two, four, six, seven, eight and nine months after planting.

3.6.4. Number of functional leaves plant^{-1}

Number of green leaves capable of photosynthesis were recorded at two, four, six, seven, eight and nine months after planting.

3.6.5. Total leaf area (m^2)

The leaf area of each functional leaf was calculated adopting the formula put forward by Murray (1960).

Leaf area = 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 the 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 two, four, six, seven, eight and nine months after planting.

3.6.6. Leaf area index

Leaf area index (LAI) was computed from the values of the total leaf area of a plant and the geographical area occupied by it using the formula,

$$\text{LAI} = \frac{\text{total leaf area of a plant}}{\text{geographical area occupied by it}}$$

3.7. Bunch characters

The following characters of the bunch were recorded immediately after harvest of the fully matured bunch. The disappearance followed by the rounding of the fruit angles was taken as the indication of maturity (Stover and Simmonds, 1987).

3.7.1. Length of bunch (cm)

Length of the bunch was measured from the point of attachment of the first hand to that of the last hand.

3.7.2. Number of hands bunch^{-1}

The number of hands in a bunch for each treatment was counted.

3.7.3. Number of fingers bunch^{-1}

The total number of fingers in a bunch was recorded.

3.7.4. Distance between hands in a bunch (cm)

The distances between adjacent hands in a bunch were recorded and the mean value calculated for a bunch.

3.7.5. Weight of hand (kg)

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

3.7.6. Weight of bunch (kg)

The weights of the bunches were recorded including the peduncle.

3.8. Finger characters

The following characters of the finger were recorded on the middle finger in the top row of the second hand designated by Gottriech *et al.* (1964) as the index finger.

3.8.1. Length of finger (cm)

The length of the finger was measured from the tip of the finger to the point of attachment to the peduncle.

3.8.2. Girth of finger (cm)

The girth of the finger was measured at the midportion of the finger.

3.8.3. Weight of finger (g)

The weight of the index finger was determined after detaching it from the peduncle.

3.9. Quality characters

The index finger selected for recording the observations was used for the chemical analysis to assess the quality characters of the fruit. Samples taken from the top, middle and bottom portions were macerated in a blender and made upto a known volume. Aliquots taken from this were used for the analysis of the following characters as detailed below.

Estimated character	Method adopted	Reference
3.9.1. Total solids	Direct reading using hand refractometer	Ranganna (1977)
3.9.2. Acidity	Titration against 0.1N NaOH	Ranganna (1977)
3.9.3. Reducing sugars	Copper reduction method using Fehling's solution	Chopra and Kanwar (1976)
3.9.4. Total sugars	Copper reduction using Fehling's solution after HCl digestion	Chopra and Kanwar (1976)
3.9.5. Vitamin C	Redox Titration using 2, 6 dichloro phenol indophenol in acid medium	Ranganna (1977)

3.9.6. Non reducing sugars

Non reducing sugar content was computed using the values for total and reducing sugars adopting the formula,

Non reducing sugars = (Total sugars-Reducing sugars) x 0.95

3.9.7. Sugar - acid ratio

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

3.9.8. Pulp - peel ratio

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

3.9.9. Shelf life

The number of days taken from harvest of the fruit to the development of black spots on the peel was recorded to determine the shelf life of the fruit at room temperature.

3.10. Dry matter content

At each sampling stage, one plant from each treatment of a replication was uprooted. The entire plant was separated into lamina, petiole, midrib, pseudostem and rhizome and the fresh weight of each was recorded. At the harvest stage, the fruit and the root were included in the sampling. Determination of the dry matter content of each anatomical part was done according to the method suggested by Piper (1967). Five hundred g of each fresh sample was washed, sundried, oven dried at 70° to 80°C to constant weight and the moisture content calculated. Using the values for percentage moisture and wet weight of each part, total dry matter production was calculated.

3.11. Plant chemical analysis

The different anatomical parts, lamina, petiole, midrib, pseudostem, rhizome, fruit and root were separately analysed for their nutrient contents. Each part of the uprooted plant was chopped, bulked, homogenised and a representative sample drawn from each lot The samples cleaned, oven dried to constant weight at 80°C and ground in a Wiley mill were then analysed for the different nutrients. The methods adopted for the chemical analysis are given below.

Potassium, Ca and Mg estimations were done in samples at all the six stages of crop growth while N, P, Fe, Mn, Zn and Cu estimations were done in samples at the harvest stage only.

Estimated character	Method adopted	Reference
N	Microkjeldahl digestion in sulfuric acid and distillation	Jackson (1973)
P	Nitric-Perchloric sulfuric acid digestion (10:4:1) and colorimetry (Vanado molybdate yellow colour in sulfuric acid medium)	Jackson (1973)
K	Nitric-Perchloric-Sulfuric acid digestion (10:4:1) and flame photometry	Piper (1967)
Ca, Mg	Nitric-Perchloric-Sulfuric acid digestion (10:4:1) and atomic absorption spectro photometry	Piper (1967)
Fe, Mn, Cu, Zn	Nitric-Perchloric-Sulfuric acid digestion (10:4:1) and atomic absorption spectro photometry	Lindsay and Norvell (1978)

3.12. Nutrient uptake

Uptake of each nutrient by each plant part at every growth stage of the crop was computed from the values of the dry matter content and the per cent nutrient content of each part. The total nutrient uptake was calculated by summing up the uptake by the different parts.

3.13. Nutrient recycled

The amount of each nutrient recycled was calculated by subtracting the nutrient uptake by the bunch from the total nutrient uptake by the plant at harvest.

3.14. Soil analysis

Soil samples were collected at all the six growth stages of the crop on the day previous to the application of fertilizers From four points around the plant within a lateral distance of 0-30cm, sub samples were collected from a depth of 0-30cm (Mohan and Madhava Rao, 1985). The composite sample drawn from this was air dried, powdered, sieved through 2mm sieve and analysed for the following constituents as detailed below.

Estimated character		Method adopted	Reference
Exchangeable	K	1 N NH_4 OAc (P^H 7.0) extraction and flame photometry	Stanford and English (1949)
Exchangeable	Ca	1 N NH_4 OAc (P^H 7.0) extraction and atomic absorption spectrophotometry	Jackson (1973)
Exchangeable	Mg	1 N NH_4 OAc (P^H 7.0) extraction and atomic absorption spectrophotometry	Jackson (1973)

3.15. Indexing of plant part

For indexing the best plant part or 'reflect' in banana for K, the third leaf upto the 6th month (Hewitt, 1955) and the flag leaf there after (Sreedevi *et al.*, 1989) were sampled and separated into petiole, midrib and lamina portion shown below (Prevel *et al.*, 1986).

Illustration of the same is given in figure : 3

Petiole - distal half portion

Midrib - Five cm long piece of midrib exactly half way along the leaf.

Lamina - Five cm wide strip across the leaf on either side of the midrib sample.

The samples were dried, powderd and analysed for K content as mentioned earlier. The data were analysed using appropriate statistical tools for achieving the objective.

3.16. Statistical analysis

The data generated out of the field experiment and the subsequent chemical analysis were scrutinised statistically to aid in the interpretation of results.

Statistical techniques like analysis of variance applicable for Randomised block design and regression analysis were employed to bring out the effect of K on the various growth, yield and quality characters of the crop. Simple correlations were worked out between yield and some important crop characters to study the nature of their

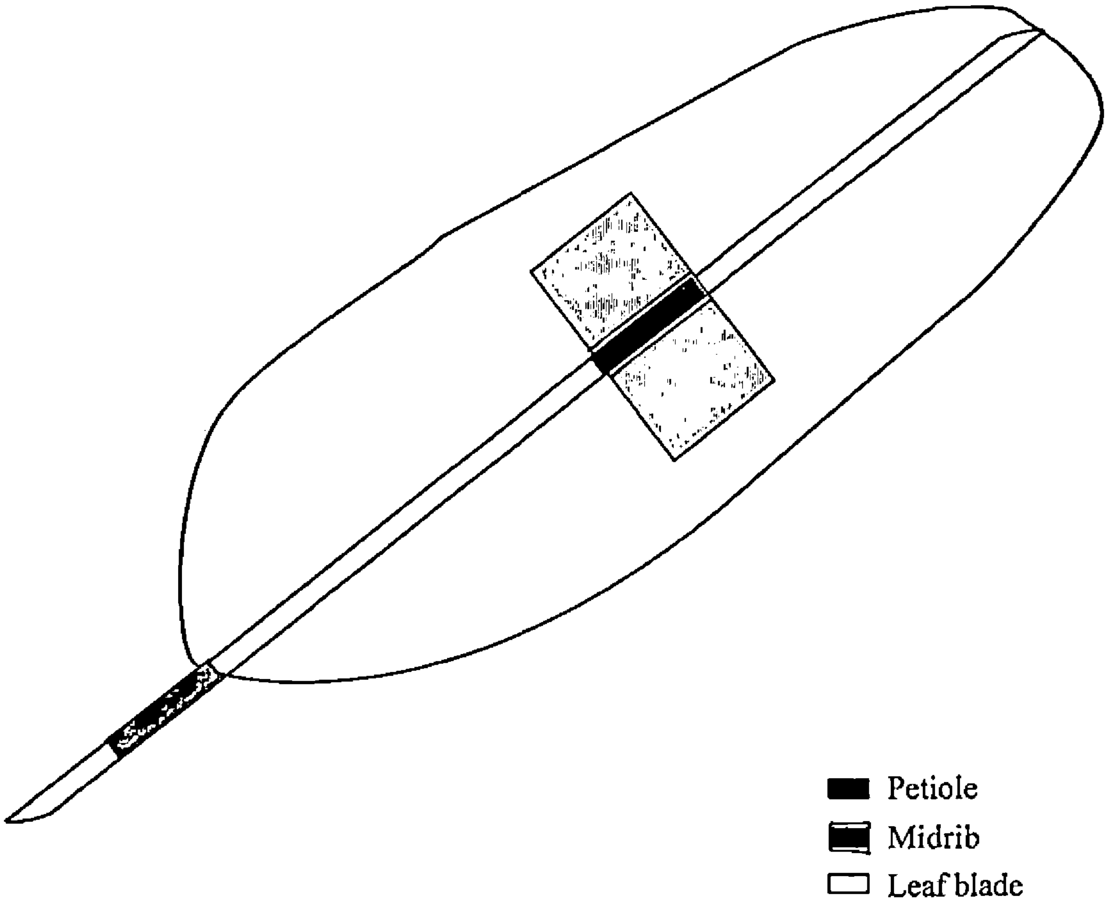

Fig. 3. Selection of sections of Leaf No. 3 for indexing for K status in banana cv. Nendran

relationship (Snedecor and Cochran, 1967). Path coefficient analysis was adopted to high light the direct and indirect effects of important yield attributing bunch characters on yield (Singh and Choudhary, 1985).

3.16.1. Indexing of plant part in banana cv. Nendran for K status

Regression analysis was carried out relating the K content in the petiole, lamina and midrib of the third leaf/flag leaf at each stage to bunch yield. The part which showed the highest yield predictability through R^2 value was selected as the index part at that stage (Rathore and Manohar, 1990).

3.16.2. Critical K level in plant part for maximum response to fertilizer application and yield

On the basis of the above regression analysis, quadratic regression models were worked out at each growth stage of the crop. They were of the type $y = a + bx + cx^2$ where y = bunch yield and x = petiole K concentration. The expected bunch yields thus worked out were plotted against petiole K concentration and graphs were constructed at each growth stage of the crop. The petiole K concentration corresponding to maximum yield was located on the graph and designated as critical level of maximum yield. The critical level for economic yield was determined on the basis of the definition for the same put forward by Tisdale *et al.* (1985) and Rathore and Manohar (1990). Accordingly petiole K concentration corresponding to yield 10 per cent less than the maximum was located on the graph and designated as critical level for economic yield. Verification of economic yield in terms of response to input application was done on the basis of the definition for the same postulated by Prevot and Ollagnier (1957). For this response in terms of increase in yield per unit increase in K concentration was worked out at a definite interval. Critical level for economic yield was taken as the level at which response was maximum.

3.16.3. Critical K level in soil for maximum response to fertilizer application and economic yield

The critical K level for maximum response to fertilizer application and economic yield was determined both graphically and statistically.

3.16.3.1. Graphical method

The scatter diagram technique developed by Cate and Nelson (1965) was adopted to determine the critical K concentration graphically.

Yield values expressed as per cent of the maximum (Y-axis) were plotted against soil test values for K (X-axis) at different growth stages of the crop. The points were then distributed into four quadrants by using plastic overlay so that maximum points lay in the two positive opposite quadrants. Parallel lines were drawn each to X and Y axises. The intersecting point of the line drawn parallel to Y-axis on X-axis was taken as the critical soil level of K.

3.16.3.2. Statistical method

The method suggested by Cate an Nelson (1971) of partitioning soil test yield variable into two classes was followed for determining critical K level statistically. The technique involved the following calibration steps.

1. The soil test values denoted as X were ordered into an array on the basis of their rankings.

2. Against each was placed its corresponding per cent yield denoted as Y. The (X:Y) pairs were maintained in this order through out the analysis.

3. A critical level of X denoted as X' was postulated in such a way that there were at least two values of $X < X'$

4. The successive X' value was selected by increasing the first X' value such that one more X was included in the group $X < X'$.

5. Series of X' values were postulated until the group in which $X > X'$ contained only two X values. Each X' value divided the set of Y values into two populations, population 1 and population 2.

6. The corrected sums of squares of the deviations from the mean of the two populations that arose at each postulation of X' value were then calculated and denoted as CSS1 and CSS2 respectively.

7. The sum of CSS1 and CSS2 for each X' level was calculated.

8. The corrected sum of squares of deviations from the mean of the whole population was calculated and denoted as TCSS.

9. The difference TCSS - (CSS1 + CSS2) for each X' level was computed and expressed as a proportion of TCSS denoted as R^2 for each level of X'.

$$\text{ie} \quad R^2 = \frac{\text{TCSS} - (\text{CSS1} + \text{CSS2})}{\text{TCSS}}$$

10. Series of R^2 values were obtained in this way and the X' value corresponding to the highest R^2 value was fixed as the critical level.

RESULTS

4. RESULTS

A field experiment in Musa (AAB group) Nendran with seven levels of K was conducted in the sandy clay loam soil of Vellayani during August, 1991 to May, 1992. Identification of the index plant part and fixing up of critical K level in the index part and in soil for maximum response to fertilizer application and yield in this variety of banana were the main objectives envisaged in this study. Effects of K on growth characters of the crop, dry matter production, uptake of various nutrients, bunch yield and yield attributes and quality characters of fruits were also studied in detail. The levels of K tried were k_0 (control), k_1 (75 g K_2O plant^{-1}), k_2 (150 g K_2O plant^{-1}), k_3 (225 g K_2O plant^{-1}), k_4 (300 g K_2O plant^{-1}), k_5 (450 g K_2O plant^{-1}) and k_6 (600 g K_2O plant^{-1}). The stages fixed for recording observations, sampling and analysis were early vegetative stage (two months after planting), late vegetative stage (four months after planting), shooting stage (six months after planting), post shooting stage (seven months after planting), bunch maturation stage (eight months after planting), and harvest stage (nine months after planting).

4.1 Soil

The important physical and chemical properties of the soil at the beginning of the experiment are presented in Table 1.

The soil of the experimental site belonged to sandy clay loam textural class. On fertility basis, it was high in organic carbon, medium in available nitrogen and phosphorus, high in available potash and sufficient in micronutrients. The soil reaction was acidic and electrical conductivity of the soil solution within safe limits.

4.2 Climate

The atmospheric temperature during the cropping period was condusive for the growth of irrigated Nendran banana, the maximum and minimum temperatures not showing much fluctuation between the extreme values. The relative humidity was also more or less steady through out the cropping period. But the monthly distribution of rainfall was erratic. Of the total 649.80 mm of rainfall received by

Table 1. Important physico chemical characteristics of the soil before the experiment

Estimated character	Content in soil
Mechanical composition	
Coarse sand	51.50 %
Fine sand	11.75 %
Silt	6.00 %
Clay	28.00 %
Textural class	Sandy clay loam
Soil reaction	4.45
Electrical conductivity	0.05 dSm^{-1}
Cation exchange capacity	9.70 cmol (p^{+}) kg^{-1}
Organic carbon	0.83 %
Available N	490.00 kg ha^{-1}
Available P_2O_5	22.80 kg ha^{-1}
Exchangeable K_2O	288.00 kg ha^{-1}
Exchangeable Ca	125.00 kg ha^{-1}
Exchangeable Mg	27.93 kg ha^{-1}
Available Fe	50.00 kg ha^{-1}
Available Mn	21.68 kg ha^{-1}
Available Zn	1.40 kg ha^{-1}
Available Cu	2.72 kg ha^{-1}
Total K	676.00 kg ha^{-1}
Fixed K	325.00 kg ha^{-1}

the crop, 83 per cent was before the shooting stage. At the post shooting stage, no rain was received, but irrigation compensated for this.

4.3 Growth characters of banana cv. Nendran as influenced by different levels of K application

The mean data on the growth characters under different levels of K application are presented in Tables 2 to 5.

4.3.i Height of plant

Table 2 furnishes the mean data on the height of plant as influenced by different levels of K application.

Height of plants, in general showed an increasing trend with increase in the level of K application upto k_4 level. Inspite of the initial high K status of the soil, the control plants recorded the minimum height at all stages. Significant variation in the height was observed only at the post shooting and bunch maturation stages under the effect of treatments. At the post shooting stage, K_6 recorded the maximum value of 314.00 cm. This was on par with all

Table 2. Effect of K levels on height of plant and girth of pseudostem at ground level (mean table)

Treatment	Height of plant (cm)						Girth of pseudostem at base (cm)					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
k_0	79.00	147.33	150.33	182.00	249.00	270.00	25.33	43.83	36.33	43.33	41.33	45.67
k_1	92.33	185.67	183.33	182.00	278.00	291.33	29.00	54.33	53.67	52.33	49.67	48.67
k_2	91.00	211.33	216.33	274.33	279.33	306.33	31.00	58.33	58.67	49.33	52.33	57.33
k_3	79.33	200.00	205.00	276.67	304.00	314.33	25.33	54.67	61.67	54.67	55.00	54.00
k_4	92.67	210.00	215.67	299.00	325.33	299.33	32.67	65.33	62.33	63.33	61.33	58.00
k_5	84.33	162.33	167.33	270.33	301.00	307.33	26.67	55.67	63.00	63.33	59.67	58.33
k_6	102.33	160.00	166.67	314.00	321.67	319.67	29.67	50.67	58.00	69.00	65.33	63.33
CD (0.05)	NS	NS	NS	53.17**	40.59*	NS	NS	NS	11.24**	7.23**	5.96**	6.27**

k_0 - Control
k_1 - 75 g K_2O plant^{-1}
k_2 - 150 g K_2O plant^{-1}
k_3 - 225 g K_2O plant^{-1}
k_4 - 300 g K_2O plant^{-1}
k_5 - 450 g K_2O plant^{-1}
k_6 - 600 g K_2O plant^{-1}

S_1 - Early vegetative stage
S_2 - Late vegetative stage
S_3 - Shooting stage
S_4 - Post shooting stage
S_5 - Bunch maturation stage
S_6 - Harvest stage

* Significant at 5% level
** Significant at 1% level

treatments except control and k_1. At bunch maturation stage k_4 registered the highest value of 325.33 cm. This was on par with k_6, k_5 and k_3.

4.3.2 Girth of pseudostem at different heights

The results are presented in Table 2 and 3. The different K treatments caused significant variation in the girth of the pseudostem at the base (ground level) only at the later stages of growth viz. shooting, post shooting, bunch maturation and harvest stages (Table 2). At all the stages, the lowest values were recorded by the control treatment. At the shooting stage, k_5 recorded the maximum girth at base (63.00 cm) which was on par with all treatments except control. At the post shooting, bunch maturation and harvest stages, the highest K level, k_6 recorded the maximum girths of 69.00 cm, 65.33 cm and 63.33 cm respectively at the ground level. At the post shooting stage and bunch maturation stages, k_6 was on par with k_4 and k_5

Girth of the pseudostem at 20 cm height was influenced significantly by the treatments at shooting, post shooting and bunch maturation stages (Table-3). Control plots

Table 3. Effect of K levels on girth of pseudostem at 20 cm and 1m height (mean table)

Treatment	Girth of pseudostem at 20 cm height (cm)						Girth of pseudostem at 1 m height (cm)					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
k_0	21.00	38.33	33.00	41.33	40.00	42.00	N	29.33	34.00	31.00	29.33	35.33
k_1	25.00	46.33	50.00	48.33	46.67	45.33	O	33.00	43.00	38.67	35.00	36.33
k_2	26.33	50.33	34.67	48.00	48.67	41.67		37.33	34.00	41.67	37.67	38.33
k_3	22.00	47.33	57.00	51.67	51.67	51.67	D	32.67	45.00	44.00	39.33	41.33
k_4	26.33	51.33	56.00	57.00	55.33	55.67	A	40.00	45.67	45.33	40.67	42.67
k_5	21.67	45.00	56.67	57.00	53.00	54.33	T	28.67	45.33	44.67	39.67	39.00
k_6	25.33	40.00	53.00	62.33	58.00	55.67	A	26.33	41.67	46.00	42.67	46.33
CD(0.05)	NS	NS	16.09*	5.02**	5.57**	NS		NS	NS	5.19**	4.29**	NS

k_0 – Control
k_1 – 75 g K_2O $plant^{-1}$
k_2 – 150 g K_2O $plant^{-1}$
k_3 – 225 g K_2O $plant^{-1}$
k_4 – 300 g K_2O $plant^{-1}$
k_5 – 450 g K_2O $plant^{-1}$
k_6 – 600 g K_2O $plant^{-1}$

S_1 – Early vegetative stage
S_2 – Late vegetative stage
S_3 – Shooting stage
S_4 – Post shooting stage
S_5 – Bunch maturation stage
S_6 – Harvest stage

* Significant at 5% level
** Significant at 1% level

recorded the minimum values at all stages. At the shooting stage, the highest value of 57.00 cm recorded by k_3 was on par with all except control and k_2. At post shooting and bunch maturation stages, k_6 resulted in the highest values for girth at 20 cm height, the values being 62.33 cm and 58.00 cm respectively. At the post shooting stage, k_6 was significantly higher than all other treatments. At bunch maturation stage, k_6 was on par with k_5 and k_4.

Significant variation in the girth of the pseudostem at 1 m height was observed at post shooting and bunch maturation stages as a result of different levels of K application (Table-3). At early vegetative stage this observation could not be recorded as the plants had not attained the required height. At both post shooting and bunch maturation stages, k_6 recorded the maximum values, 46.00 cm and 42.67 cm respectively. At post shooting stage k_6 was on par with all treatments except k_0 and k_1. At the bunch maturation stage k_6 was on par with k_3, k_4 and k_5.

4.3.3 Total number of leaves and number of functional leaves

The mean data are presented in table 4. Total number of leaves and number of functional leaves showed an

Table 4. Effect of K levels on number of total and functional leaves (mean table)

Treatment	Total number of leaves						Number of functional leaves					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
k_0	11.00	14.67	12.67	12.67	8.33	10.33	8.67	8.00	6.67	8.00	6.00	5.00
k_1	11.67	14.67	12.00	15.33	8.00	10.00	9.00	8.67	9.00	6.00	5.00	3.00
k_2	12.00	16.00	11.67	17.00	9.00	11.00	10.00	9.00	7.00	5.67	5.00	3.67
k_3	12.00	16.67	14.33	13.00	8.33	10.33	9.67	9.00	10.00	6.33	4.33	2.00
k_4	11.67	15.33	14.00	15.00	8.67	10.67	9.67	9.33	7.67	6.67	6.00	2.67
k_5	10.33	13.67	13.67	15.00	10.97	12.67	8.67	8.33	7.33	8.00	7.50	3.00
k_6	11.33	15.33	14.00	15.67	12.67	14.67	9.00	8.33	8.00	10.33	8.33	4.00
CD(0.05)	NS	NS	NS	2.56*	1.71*	NS	NS	NS	NS	2.00**	0.83**	NS

k_0 - Control
k_1 - 75 g K_2O $plant^{-1}$
k_2 - 150 g K_2O $plant^{-1}$
k_3 - 225 g K_2O $plant^{-1}$
k_4 - 300 g K_2O $plant^{-1}$
k_5 - 450 g K_2O $plant^{-1}$
k_6 - 600 g K_2O $plant^{-1}$

S_1 - Early vegetative stage
S_2 - Late vegetative stage
S_3 - Shooting stage
S_4 - Post shooting stage
S_5 - Bunch maturation stage
S_6 - Harvest stage

* Significant at 5% level
** Significant at 1% level

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increasing trend with increase in K applied at all growth stages of banana cv. Nendran. Significant variations in these characters were observed only at the post shooting and bunch maturation stages.

At the post shooting stage the maximum total number of leaves (17.00) was recorded by K_2 which was on par with that obtained at higher levels. At bunch maturation stage the maximum number of leaves (12.67) was observed in k_6 plot which was on par with k_5.

At the post shooting stage k_6 recorded the maximum number of functional leaves (10.33). This was significantly higher than all other treatments. At bunch maturation stage also, k_6 recorded the maximum value of 8.33 which was on par with k_5. The minimum value of 5.00 was recorded by both k_1 and k_2 which were on par with the control.

4.3.4 Leaf area and leaf area index

Table 5 presents the mean data on the leaf area and leaf area index under different levels of K.

Table 5. Effect of K levels on leaf area and leaf area index (mean table)

Treatment	Leaf area (m^2)						Leaf area index					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
k_0	1.44	4.47	3.60	4.76	3.40	2.65	0.36	1.12	0.90	1.19	0.85	0.67
k_1	1.54	5.33	6.06	5.33	3.51	1.55	0.38	1.33	1.52	1.33	0.88	0.38
k_2	1.55	6.58	5.72	5.52	4.30	2.90	0.39	1.64	1.43	1.38	1.08	0.73
k_3	1.09	5.97	7.24	5.85	3.24	2.55	0.28	1.49	1.81	1.46	0.81	0.64
k_4	1.45	6.83	5.92	6.80	5.64	2.12	0.36	1.71	1.48	1.70	1.41	0.53
k_5	1.04	4.68	5.81	7.60	4.84	2.66	0.26	1.17	1.45	1.90	1.21	0.67
k_6	1.38	4.54	4.99	8.90	7.96	3.66	0.35	1.14	1.25	2.22	1.99	0.92
CD(0.05)	NS	NS	NS	2.15*	1.52*	NS	NS	NS	NS	0.47**	0.38**	NS

k_0 – Control
k_1 – 75 g K_2O $plant^{-1}$
k_2 – 150 g K_2O $plant^{-1}$
k_3 – 225 g K_2O $plant^{-1}$
k_4 – 300 g K_2O $plant^{-1}$
k_5 – 450 g K_2O $plant^{-1}$
k_6 – 600 g K_2O $plant^{-1}$

S_1 – Early vegetative stage
S_2 – Late vegetative stage
S_3 – Shooting stage
S_4 – Post shooting stage
S_5 – Bunch maturation stage
S_6 – Harvest stage

* Significant at 5% level
** Significant at 1% level

Significant variations were observed only at the post shooting and bunch maturation stages for both leaf area and leaf area index.

At the post shooting stage k_6 recorded the maximum leaf area of 8.90 m^2 which was on par with k_5 and k_4. Control recorded the minimum leaf area (4.76 m^2). At bunch maturation stage also k_6 registered the highest leaf area of 7.96 m^2 which was significantly higher than all other treatments. The minimum value of 3.24 m^2 was recorded by k_3 which was on par with k_2, k_1 and control.

Leaf area index also followed the same trend as that of leaf area among the treatments showing significant variation at post shooting and bunch maturation stages. At both stages, k_6 recorded the maximum leaf area index, 2.22 and 1.99 respectively. At post shooting stage, k_6 was on par with k_5. The minimum value of 1.19 was recorded by the control. At bunch maturation stage, k_6 was significantly higher than all other treatments. The lowest value of 0.81 registered by k_3 was on par with k_2, k_1 and control.

4.4 Dry matter production in banana cv. Nendran as influenced by different levels of K application

The mean data on dry matter production at different growth stages of banana cv. Nendran under the influence of different levels of K application are presented in Tables 6 7 and 8.

At the early vegetative stage there was a general tendency for decrease in dry matter production beyond k_2 level. Among the different parts midrib alone showed significant variation under varying levels of K (Table 6). The maximum production of 565.00 kg ha^{-1} was by k_2 which was on par with all treatments except control which recorded the minimum production of 152.50 kg ha^{-1}.

At late vegetative stage, dry matter production showed a tendency for decrease beyond k_4 level. No part was significantly affected by different K levels (Table 6).

At the shooting stage, dry matter production by midrib, rhizome and total dry matter production showed significant variation between the treatments (Table 7). Treatment k_4 produced the maximum dry weight in the midrib

Table 6. Effect of K levels on dry matter production in different plant parts at early and late vegetative stages (mean table)

Treatment	Dry matter production (kg ha^{-1}) Early vegetative stage						Late vegetative stage					
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total
k_0	618.33	64.18	152.50	1328.33	325.00	2488.34	1930.83	210.00	405.83	5521.68	716.68	8785.02
k_1	649.18	82.50	414.15	1530.00	268.33	2944.16	2836.68	480.00	1006.68	9813.33	791.68	14928.37
k_2	769.18	78.33	565.00	1588.33	281.68	3282.52	2785.00	375.00	799.18	10634.18	1166.68	15760.04
k_3	695.00	60.00	336.68	1209.18	190.83	2491.69	2494.18	315.00	596.68	8806.68	1050.00	13262.54
k_4	691.68	81.68	435.00	1421.68	241.68	2871.72	2562.50	352.50	619.18	11855.00	1562.50	16951.68
k_5	366.68	34.18	295.83	665.00	162.50	1524.19	1982.50	292.50	607.50	8125.83	641.68	11650.01
k_6	669.18	67.50	347.00	781.68	238.33	2103.69	1708.33	285.00	485.00	6690.00	700.00	9868.33
CD (0.05)	NS	NS	337.08*	NS	NS	NS	NS	NS	NS	NS	NS	NS

k_0 - Control

k_1 - 75 g K_2O $plant^{-1}$

k_2 - 150 g K_2O $plant^{-1}$

k_3 - 225 g K_2O $plant^{-1}$

k_4 - 300 g K_2O $plant^{-1}$

k_5 - 450 g K_2O $plant^{-1}$

k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level

** Significant at 1% level

Table 7. Effect of K levels on dry matter production in different plant parts at shooting and post shooting stages (mean table)

Treatment	Dry matter production (kg ha^{-1})											
	Shooting stage						Post shooting stage					
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total
k_0	2357.50	300.00	450.00	9916.68	633.33	13657.51	2460.00	315.00	722.50	8250.00	858.33	12605.83
k_1	4100.00	660.00	945.00	15708.33	933.33	22346.66	2425.83	435.00	1135.83	13479.18	1375.00	18850.84
k_2	4134.18	345.00	1282.50	18687.50	1441.68	26890.86	2460.00	405.00	927.50	15666.68	1741.68	21200.86
k_3	3826.68	510.00	1282.50	18541.68	1933.33	26094.19	2801.68	495.00	1027.50	16562.50	1625.00	22511.68
k_4	4920.00	705.00	1327.50	19375.00	2108.33	28435.83	2767.50	555.00	1845.00	18083.33	2383.33	25634.16
k_5	4270.83	885.00	1192.50	18375.00	1741.68	26465.01	4031.68	630.00	1776.68	20208.33	2058.33	28705.02
k_6	3895.00	465.00	855.00	16208.33	2000.00	23423.33	3690.00	720.00	1877.50	19770.83	1850.00	27908.33
CD (0.05)	NS	NS	529.03*	NS	503.43**	7447.30*	1113.43*	NS	587.53**	5729.13**	788.50*	6426.86**

k_0 - Control

k_1 - 75 g K_2O plant^{-1}

k_2 - 150 g K_2O plant^{-1}

k_3 - 225 g K_2O plant^{-1}

k_4 - 300 g K_2O plant^{-1}

k_5 - 450 g K_2O plant^{-1}

k_6 - 600 g K_2O plant^{-1}

* Significant at 5% level

** Significant at 1% level

(1327.50 kg ha^{1}) which was on par with all treatments except control which recorded the minimum value of 450.00 kg ha^{-1}. Rhizome dry matter production was maximum (2108.33 kg ha^{-1}) at k_4 level. This was on par with k_3, k_5 and k_6. The minimum production of 633.33 kg ha^{-1} was in the control plot. In the case of total dry matter production, the maximum production of 28435.83 kg ha^{-1} recorded by k_4 was on par with all treatments except control, which recorded the minimum production of 13657.51 kg ha^{-1}.

At the post shooting stage the dry matter contents in all plant parts except petiole varied significantly under the influence of treatments (Table 7). All parts showed a general tendency for increased dry matter production with increase in K application. In the leaf blade the dry matter production was the highest (4031.68 kg ha^{-1}) at k_5 level which was on par with k_6. Control was on par with k_1 which recorded the minimum value of 2425.83 kg ha^{-1}. In the midrib the maximum value of 1877.50 kg ha^{-1} recorded by k_6 was on par with k_4 and k_5. The minimum value of 722.50 kg ha^{-1} was recorded by the control. The maximum dry matter content in the pseudostem (20208.33 kg ha^{-1}) was at k_5 level and this was on par with all treatments except k_1 and control which recorded the minimum production of 8250.00 kg ha^{-1}. In the rhizome k_4 registered the highest dry matter content of 2383.33 kg ha^{-1} which was on par with all treatments except k_1 and control which recorded the minimum value of 858.33 kg ha^{-1}. The total dry matter production was maximum (28705.02 kg ha^{-1}) at k_5 level which was on par with k_3, k_4 and k_6. The minimum (12605.83 kg ha^{-1}) was at the control level.

At the bunch maturation stage the dry matter production in the pseudostem and total dry matter production were significant. In the pseudostem the maximum dry matter content of 18958.33 kg ha^{-1} was registered by k_6 which was on par with k_3, k_4 and k_5 (Table 8). The total dry matter production was maximum (25969.19 kg ha^{-1}) at k_6 level which was on par with k_3, k_4 and k_5. The minimum (12061.68 kg ha^{-1}) was in the control plot.

At harvest stage of the crop the dry matter production in the leaf blade, pseudostem, rhizome, bunch and total dry matter production varied significantly as a result of treatment application (Table 8). In the leaf blade, pseudostem and rhizome k_6 recorded the maximum values of 1810.83 kg ha^{-1}, 17812.50 kg ha^{-1} and 2866.67 kg ha^{-1}

Table 8. Effect of K levels on dry matter production in different plant parts at bunch maturation and harvest stages (mean table)

Treatment	Dry matter production (kg ha^{-1}) Bunch maturation stage						Harvest stage							
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Root	Bunch	Total
k_0	1879.18	270.00	450.00	8854.18	608.33	12061.69	854.17	150.00	427.50	10729.17	916.67	133.33	3875.00	17085.84
k_1	1298.33	300.00	517.50	13125.00	1058.33	16299.16	341.67	150.00	225.00	11625.00	1550.00	166.67	5250.00	19308.34
k_2	1298.33	165.00	562.50	13500.00	1425.00	16950.83	1230.00	165.00	315.00	15937.50	2166.67	200.00	6835.00	26849.17
k_3	1810.83	330.00	562.50	14958.33	1475.00	19136.66	1264.17	112.50	169.17	16375.00	2000.00	316.67	7850.00	28087.51
k_4	3450.83	675.00	1057.50	18020.83	1350.00	24554.16	1503.33	120.00	202.50	15312.50	2416.67	241.67	6500.00	26296.67
k_5	2562.50	570.00	810.00	15104.18	1400.00	20446.68	1332.50	165.00	382.50	16395.83	2708.33	275.00	6600.00	27859.16
k_6	3621.88	795.00	1102.50	18958.33	1491.68	25969.19	1810.83	195.00	495.00	17812.50	2866.67	300.00	6625.00	30105.00
CD (0.05)	NS	NS	NS	4102.48**	NS	6876.95*	723.09*	NS	NS	4667.81*	838.87**	NS	1013.98**	5434.14**

k_0 - Control
k_1 - 75 g K_2O $plant^{-1}$
k_2 - 150 g K_2O $plant^{-1}$
k_3 - 225 g K_2O $plant^{-1}$
k_4 - 300 g K_2O $plant^{-1}$
k_5 - 450 g K_2O $plant^{-1}$
k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level
** Significant at 1% level

respectively. In the leaf blade k_6 was on par with all treatments except k_1 and control. In the pseudostem k_6 was on par with all treatments except k_1 and control which recorded the minimum value of 10729.17 kg ha^{-1} In the rhizome k_6 was on par with k_2, k_4 and k_5. The minimum production of 916.67 kg ha^{-1} was at the control level. The dry matter content in the bunch was maximum (7850.00 kg ha^{-1}) at k_3 level which was significantly higher than all other treatments. The minimum value of 3875.00 kg ha^{-1} was in the control plot. The total dry matter production was maximum (30105.00 kg ha^{-1}) at k_6 level which was on par with treatments other than k_1 and control.

4.5 Concentration of K in different parts of banana cv. Nendran at various growth stages as influenced by different levels of K application

Tables 9, 10 and 11 present the mean data on the concentration of K in banana cv. Nendran at various growth stages under different levels of K application.

In all plant parts and at all stages of crop growth, K concentration tended to show an increase with increase in the level of K application. In most cases, the maximum values were recorded by the highest level of K application and the lowest by the control.

At the early vegetative stage, only the petiole and midrib showed variation due to treatments (Table 9). In the petiole, k_4 resulted in the highest concentration of 2.56 per cent. This treatment was on par with values of all other treatments except control which resulted in the least K content of 0.75 per cent. In the midrib k_6 recorded the maximum value of 1.15 per cent which was on par with k_5 and k_4. The minimum value, 0.20 per cent was recorded by the control.

At the late vegetative stage the K contents of the leaf blade, petiole and midrib were significantly influenced by different K levels (Table 9). In the leaf blade, k_6 registered the highest K content of 0.82 per cent which was on par with the value at k_3 level. Control recorded the lowest value of 0.26 per cent. In the case of petiole, k_4 produced the maximum K content of 1.35 per cent which was significantly higher than all other treatments. The minimum content of 0.43 per cent was recorded by both the control and

Table 9. Effect of K levels on K concentration in different plant parts at early and late vegetative stages (mean table)

Treatment	Concentration of K (% on oven dry basis)									
	Early vegetative stage					Late vegetative stage				
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome
k_0	0.95	0.75	0.20	1.72	1.40	0.26	0.43	0.29	0.72	0.57
k_1	1.68	1.71	0.86	1.51	1.01	0.60	0.43	1.05	0.61	0.55
k_2	1.72	2.35	0.93	1.67	1.23	0.62	1.02	1.09	1.04	0.41
k_3	1.94	2.08	1.02	1.89	1.69	0.70	0.92	1.25	1.01	0.55
k_4	1.69	2.56	1.05	1.64	1.84	0.54	1.35	1.11	1.51	0.36
k_5	1.51	2.29	1.07	1.28	1.35	0.61	1.09	1.12	0.96	0.51
k_6	1.40	2.11	1.15	1.42	1.50	0.82	1.00	1.17	1.26	0.64
CD (0.05)	NS	0.89*	0.12*	NS	NS	0.19**	0.20**	0.25**	NS	NS

k_0 – Control
k_1 – 75 g K_2O $plant^{-1}$
k_2 – 150 g K_2O $plant^{-1}$
k_3 – 225 g K_2O $plant^{-1}$
k_4 – 300 g K_2O $plant^{-1}$
k_5 – 450 g K_2O $plant^{-1}$
k_6 – 600 g K_2O $plant^{-1}$

* Significant at 5% level
** Significant at 1% level

k_1. In the midrib the highest K content of 1.25 per cent was recorded by k_3 which was on par with all treatments except control which recorded the lowest K content of 0.29 per cent.

At the shooting stage petiole and pseudostem showed significant variation in the K contents as a result of K application (Table 10). The maximum value of 1.50 per cent in the petiole was registered by k_5 level which was on par with all treatments except control and k_1 which recorded the minimum values. In the pseudostem, k_4 recorded the maximum value of 2.69 per cent which was on par with k_6. Control and k_1 recorded the minimum values.

At the post shooting stage, K contents in the leaf blade and petiole differed significantly under different K levels (Table 10). The highest K content in the leaf blade was recorded by k_5 (1.40 per cent). This was on par with k_6, k_4 and k_3. Control treatment resulted in the lowest K content of 0.33 per cent. In petiole, the highest value of 5.10 per cent resulted from k_5 level which was on par with k_6. The lowest value of 0.60 per cent was recorded in the control plot.

Table 10. Effect of K levels on K concentration in different plant parts at shooting and post shooting stages (mean table)

Treatment	Concentration of K(% on oven dry basis)									
	Shooting stage					Post shooting stage				
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome
k_0	0.67	0.64	0.79	0.88	0.89	0.33	0.60	1.53	2.31	1.27
k_1	0.55	0.60	0.85	0.63	0.55	0.70	1.20	1.40	4.13	2.80
k_2	0.51	1.45	0.69	1.39	1.01	0.73	2.17	1.70	3.47	2.20
k_3	0.67	1.06	0.57	1.34	0.95	0.93	2.37	2.37	2.80	3.07
k_4	0.79	1.25	0.44	2.69	1.19	1.10	3.40	2.23	2.50	2.93
k_5	0.89	1.50	0.43	2.04	0.60	1.40	5.10	1.73	3.40	2.00
k_6	1.20	1.38	0.81	2.53	1.41	1.30	4.60	1.73	2.33	2.07
CD (0.05)	NS	0.46**	NS	0.48*	NS	0.52**	0.80**	NS	NS	NS

k_0 - Control
k_1 - 75 g K_2O plant^{-1}
k_2 - 150 g K_2O plant^{-1}
k_3 - 225 g K_2O plant^{-1}
k_4 - 300 g K_2O plant^{-1}
k_5 - 450 g K_2O plant^{-1}
k_6 - 600 g K_2O plant^{-1}

* Significant at 5% level
** Significant at 1% level

At the bunch maturation stage all plant parts showed significant variation in their K contents as a result of different levels of K application (Table 11). In the leaf blade k_3 produced the maximum K content of 1.93 per cent which was on par with k_2 and k_1 levels. The minimum content of 0.47 per cent was in the control plot. The petiole K content registered the highest value of 4.00 per cent at k_6 level. This was higher than all other treatments. The lowest value of 1.33 per cent was recorded by the control as well as k_2 level. In the midrib k_5 recorded the highest values of 2.93 per cent whieh was on par with k_6. The lowest value of 0.93 per cent was registered by k_1 which was on par with control. In the pseudostem the highest concentration of 3.53 per cent was registered by k_6 with which were on par k_5 and k_3. The lowest value of 0.93 per cent was recorded in the control plot. In the rhizome the highest value of 4.97 per cent recorded by k_3 was on par with k_4 and k_6.

At harvest stage all plant parts except leaf blade and root showed highly significant variations in their K contents as a result of K treatments (Table 11). In the petiole the highest K level, k_6 produced the highest K content of 2.60 per cent. This was significantly higher than

Table 11. Effect of K levels on K concentration in different plant parts at bunch maturation and harvest stages (mean table)

Treatment	Concentration of K (% on oven dry basis)											
	Bunch muturation stage					Harvest stage						
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Root	Bunch
k_0	0.47	1.33	1.07	0.93	0.60	0.77	0.43	1.33	1.20	1.53	1.57	0.94
k_1	1.33	1.47	0.93	1.20	1.63	1.07	1.07	2.00	0.93	1.77	1.40	1.16
k_2	1.47	1.33	1.47	1.73	2.20	0.93	0.67	1.00	2.40	2.70	1.10	1.40
k_3	1.93	1.73	1.47	2.00	4.97	1.53	1.60	2.00	3.27	5.33	1.13	1.99
k_4	0.93	2.13	1.07	1.47	4.47	0.60	1.87	1.60	3.10	1.60	1.00	2.23
k_5	0.97	1.80	2.93	3.07	2.13	1.07	1.73	2.00	2.30	2.20	0.60	2.31
k_6	0.60	4.00	2.13	3.53	3.87	0.67	2.60	3.80	0.93	2.60	2.00	2.54
CD (0.05)	0.67**	0.78**	1.05**	1.66**	1.70**	NS	0.66**	0.56**	0.97**	1.08**	NS	0.41**

k_0 - Control

k_1 - 75 g K_2O $plant^{-1}$

k_2 - 150 g K_2O $plant^{-1}$

k_3 - 225 g K_2O $plant^{-1}$

k_4 - 300 g K_2O $plant^{-1}$

k_5 - 450 g K_2O $plant^{-1}$

k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level

** Significant at 1% level

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all other treatments. The lowest content of 0.43 per cent was obtained at the control level. In the midrib also, k_6 resulted in the maximum K content of 3.80 per cent which was higher than the rest of the treatments. In the pseudostem k_3 recorded the highest K content (3.27 per cent) which was on par with k_5, k_4 and k_2. The rhizome K content showed the highest value of 5.33 per cent at k_3 level. This was higher than the rest of the treatments. The lowest value of 1.53 per cent was recorded by the control. In the fruit, the highest K level, k_6 registered the highest K content of 2.54 per cent. This was on par with k_5 and k_4. Control resulted in the lowest value, 0.94 per cent.

4.6 Uptake of K, Ca and Mg at different growth stages of banana cv. Nendran as influenced by different levels of K application

4.6.1 Uptake of K

The mean data on the uptake of K under different levels of K application at different growth stages are presented in Tables 12, 13 and 14.

At the early vegetative stage total potassium uptake showed a general tendency to increase with increasing K supply upto k_4 level and then showed a decrease at still higher levels (Table 12). Among the plant parts the midrib alone showed significant variation in K uptake under different levels of K supply. In the midrib k_2 resulted in the maximum K uptake (5.24 kg ha^{-1}) which was on par with all treatments except control which recorded the minimum uptake of 0.32 kg ha^{-1}.

At the late vegetative stage, the uptake of K by the petiole alone was significantly influenced by different K treatments (Table 12). The maximum value of K uptake by the petiole (4.82 kg) was at k_4 which was on par with k_2 and k_5. The minimum value of 0.93 kg ha^{-1} was in the control plot.

Uptake of K by petiole and pseudostem and total uptake varied significantly under the treatments at the shooting stage (Table 13). In the petiole the maximum uptake of 6.36 Kg ha^{-1} was recorded by k_6 which was on par with all other treatments except control which recorded the minimum uptake of 1.82 kg ha^{-1}. The pseudostem registered the highest K uptake of 519.72 kg ha^{-1} at k_4 level which was

Table 12. Effect of K levels on uptake of K in different plant parts at early and late vegetative stages (mean table)

Treatment	Uptake of K (kg ha^{-1})											
	Early vegetative stage						Late vegetative stage					
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total
k_0	5.17	0.47	0.32	23.14	4.74	33.84	5.09	0.93	1.22	40.75	4.10	52.09
k_1	10.97	1.47	3.44	28.76	2.27	46.91	17.35	2.06	10.86	56.19	4.33	90.79
k_2	13.39	1.83	5.24	28.33	3.51	52.30	17.13	3.82	7.26	112.38	5.20	145.79
k_3	14.22	1.34	3.47	20.27	2.80	42.17	17.46	2.83	7.45	87.59	5.68	121.01
k_4	11.47	2.15	4.55	22.63	4.42	45.22	13.90	4.82	6.83	184.00	5.37	214.92
k_5	5.65	0.78	3.06	8.69	2.18	20.36	12.03	3.23	6.93	80.07	2.45	104.71
k_6	9.92	1.37	3.99	11.05	3.38	29.71	14.81	2.81	6.30	66.02	5.12	95.06
CD (0.05)	NS	NS	2.69**	NS	NS	NS	NS	1.63**	NS	NS	NS	NS

k_0 - Control
k_1 - 75 g K_2O $plant^{-1}$
k_2 - 150 g K_2O $plant^{-1}$
k_3 - 225 g K_2O $plant^{-1}$
k_4 - 300 g K_2O $plant^{-1}$
k_5 - 450 g K_2O $plant^{-1}$
k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level
** Significant at 1% level

significantly higher than the rest of the treatments. k_1 registered the lowest value of 99.74 kg ha^{-1} which was on par with control. The total uptake was maximum (594.47 kg ha^{-1}) at the k_4 level which was significantly higher than all other treatments. The total uptake was minimum (126.39 kg ha^{-1}) at the control level.

At the post shooting stage leaf blade, petiole, midrib and the whole plant uptake showed significant variation (Table 13). The uptake by the leaf blade showed the maximum value of 56.58 kg ha^{-1} at k_5 level. This was on par with k_6 and k_4. The minimum value of 8.10 kg ha^{-1} was recorded by the control. The uptake by the petiole was maximum at k_6 level (33.12 kg ha^{-1}) which was on par with k_4 and k_5. The lowest petiole K uptake of 1.83 kg ha^{-1} was in the control plot. In the midrib the maximum uptake of 41.51 kg ha^{-1} was registered by k_4 which stood on par with k_5 and k_6. The minimum uptake of 11.29 kg ha^{-1} was registered by the control. The total K uptake was maximum 843.65 kg ha^{-1} at k_5 level which was on par with all other treatments except control which recorded the lowest value of 226.41 kg ha^{-1}.

At the bunch maturation stage all plant parts except leaf blade varied significantly in K uptake under

Table 13. Effect of K levels on uptake of K in different plant parts at shooting and post shooting stages (mean table)

Treatment	Uptake of K (kg ha^{-1})											
	Shooting stage						Post shooting stage					
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total
k_0	15.58	1.82	3.39	99.91	5.69	126.39	8.10	1.83	11.29	194.29	10.90	226.41
k_1	23.96	3.87	8.30	99.74	5.00	140.87	17.15	5.22	18.64	555.17	41.30	637.48
k_2	21.15	5.00	9.50	259.71	16.06	311.42	18.04	8.49	15.65	532.92	38.22	613.32
k_3	23.42	5.38	7.33	247.47	18.21	301.81	26.51	11.73	22.93	471.08	51.00	583.25
k_4	38.87	5.09	5.82	519.72	24.97	594.47	32.87	19.68	41.51	433.44	70.53	598.03
k_5	38.22	5.10	4.92	374.95	10.40	433.59	56.58	32.22	30.82	684.33	39.70	843.65
k_6	51.67	6.36	6.50	390.89	28.22	483.64	48.69	33.12	32.70	463.42	39.78	617.71
CD (0.05)	NS	3.12**	NS	90.13**	NS	112.88**	26.38**	15.68**	16.00*	NS	NS	309.90*

k_0 - Control

k_1 - 75 g K_2O $plant^{-1}$

k_2 - 150 g K_2O $plant^{-1}$

k_3 - 225 g K_2O $plant^{-1}$

k_4 - 300 g K_2O $plant^{-1}$

k_5 - 450 g K_2O $plant^{-1}$

k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level

** Significant at 1% level

different levels of K supply (Table 14). The total uptake was also significantly affected. The petiole K uptake was maximum (31.80 kg ha^{-1}) at k_6 level which was on par with k_4. The minimum value, 2.16 kg ha^{-1} was at k_2 level which was on par k_1 and control. In the midrib uptake of 23.22 kg ha^{-1} which was maximum was at k_5 level was on par with k_6 and k_4. The minimum uptake of 4.32 kg ha^{-1} was in the control plot. In the pseudostem K uptake was maximum (661.13 kg ha^{-1}) at k_6 level. With this was on par, k_5. The minimum value of 80.42 kg ha^{-1} was at the control level. In the rhizome k_3 recorded the highest K uptake (69.02 kg ha^{-1}) which was on par with k_4 and k_6. Control yielded the lowest value, 3.83 kg ha^{-1}. The total K uptake was maximum (789.90 kg ha^{-1}) at k_6 level which was on par with k_5. The minimum total K uptake of 101.47 kg ha^{-1} was by the control.

At harvest all parts except leaf blade showed significant variation in K uptake as a result of varied K supply (Table 14). The total K uptake was also significantly affected. In the petiole k_6 registered the highest K uptake of 5.10 kg ha^{-1} which was significantly higher than all other treatments. Control registered the lowest value, 0.63 kg ha^{-1}. Midrib showed the maximum K uptake of 18.45 kg ha^{-1} at

Table 14. Effect of K levels on uptake of K in different plant parts at bunch maturation and harvest stages (mean table)

Treatment	Uptake of K (kg ha^{-1}) Bunch maturation stage						Harvest stage							
	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Total	Leaf blade	Petiole	Midrib	Pseudostem	Rhizome	Root	Bunch	Total
k_0	8.88	4.02	4.32	80.42	3.83	101.47	6.58	0.63	5.04	136.67	14.42	2.07	36.64	202.05
k_1	17.15	4.26	5.04	159.17	17.77	203.39	2.87	1.68	4.68	103.83	24.98	2.35	60.90	201.29
k_2	22.96	2.16	7.65	226.42	31.20	290.39	11.48	1.20	3.20	366.00	58.88	2.18	96.30	539.24
k_3	33.69	5.64	7.29	311.75	69.02	427.39	17.90	1.86	3.39	512.75	106.17	3.67	155.94	801.68
k_4	32.25	14.40	11.70	265.42	61.00	384.77	9.02	2.16	2.88	470.00	37.00	2.30	145.59	668.95
k_5	24.26	9.00	23.22	474.17	32.63	563.28	15.58	2.64	7.56	379.19	59.83	1.62	152.19	618.61
k_6	19.48	31.80	20.79	661.13	56.70	789.90	12.44	5.10	18.45	165.58	76.73	6.00	170.19	454.49
CD (0.05)	NS	19.09**	11.89**	287.11**	26.17**	287.98**	NS	2.11*	8.79**	125.24**	29.46**	2.43*	44.12**	174.07**

k_0 - Control
k_1 - 75 g K_2O plant$^{-1$}
k_2 - 150 g K_2O plant^{-1}
k_3 - 225 g K_2O plant^{-1}
k_4 - 300 g K_2O plant^{-1}
k_5 - 450 g K_2O plant^{-1}
k_6 - 600 g K_2O plant^{-1}

* Significant at 5% level
** Significant at 1% level

k_6 level, which was significantly higher than all other treatments which were on par with k_4 which recorded the minimum value of 2.88 kg ha^{-1}. In the pseudostem the maximum uptake of 512.75 kg ha^{-1} was recorded by k_3 treatment. This stood on par with k_4. The lowest value of 103.83 kg ha^{-1} was recorded by k_1 which was on par with control. The rhizome also recorded the maximum K uptake of 106.17 kg ha^{-1} at the k_3 level. This was on par with k_6. Control plot registered the minimum uptake of 14.42 kg ha^{-1}. In the root k_6 treatment resulted in the maximum uptake of 6.00 kg ha^{-1} which was on par with k_3. In the bunch, the highest K uptake of 170.19 kg ha^{-1} was registered by k_6 which stood on par with k_3, k_4 and k_5. The lowest K uptake of 36.64 kg ha^{-1} was recorded in the control plot. The total uptake of K at harvest which varied significantly was the highest at k_3 level (801.68 kg ha^{-1}) which was on par with k_4. The lowest (201.29 kg ha^{-1}) was at k_1 level which was on par with the control.

4.6.2 Uptake of Ca

The mean data on the total uptake of Ca at different growth stages under different levels of K application are presented in Table 15.

Table 15. Effect of K levels on total uptake of Ca and Mg at different growth stages (mean table)

Treatment	Uptake of Ca (kg ha^{-1})						Uptake of Mg (kg ha^{-1})					
	S_1	S_2	S_3	S_4	S_5	S_6	S_1	S_2	S_3	S_4	S_5	S_6
k_0	34.48	109.55	236.45	129.82	106.76	112.85	7.03	12.85	32.27	12.02	5.86	21.50
k_1	25.81	85.24	106.60	76.99	73.38	89.65	5.93	13.63	32.02	16.83	9.27	15.87
k_2	32.20	85.30	129.97	89.96	39.66	110.07	7.21	14.90	30.63	16.45	9.87	25.67
k_3	16.00	73.95	134.55	97.25	73.89	121.31	3.80	13.52	26.35	16.73	12.02	20.53
k_4	18.46	55.56	86.71	108.51	105.53	91.14	5.63	17.82	44.87	32.55	12.06	26.38
k_5	14.96	76.39	118.70	110.17	83.73	76.93	2.60	9.05	33.07	33.07	14.85	21.93
k_6	18.16	71.61	136.52	49.59	33.07	106.32	4.23	9.28	39.34	20.59	15.84	19.84
CD(0.05)	11.76*	NS	54.78**	NS	NS	NS	NS	5.50*	2.19*	NS	NS	NS

k_0 – Control
k_1 – 75 g K_2O plant^{-1}
k_2 – 150 g K_2O plant^{-1}
k_3 – 225 g K_2O plant^{-1}
k_4 – 300 g K_2O plant^{-1}
k_5 – 450 g K_2O plant^{-1}
k_6 – 600 g K_2O plant^{-1}

S_1 – Early vegetative stage
S_2 – Late vegetative stage
S_3 – Shooting stage
S_4 – Post shooting stage
S_5 – Bunch maturation stage
S_6 – Harvest stage

* Significant at 5% level
** Significant at 1% level

At all the growth stages of banana cv. Nendran total Ca uptake showed a decreasing trend with increase in K supply. The maximum values at all stages were recorded by the control. At early vegetative and shooting stages the treatment effects differed significantly.

At the early vegetative stage control recorded the maximum Ca uptake of 34.38 kg ha^{-1}. This was on par with k_1 and k_2. The minimum value of 14.96 kg ha^{-1} recorded by k_5 was on par with k_3, k_4 and k_6.

At the shooting stage also total Ca uptake varied significantly due to the different levels of K applied. The maximum uptake of 236.45 kg ha^{-1} was registered by the control which was significantly higher than all other treatments. The minimum uptake of 86.71 kg ha^{-1} was recorded by k_4 which was on par with the rest of the treatments.

4.6.3 Uptake of Mg

Table 15 presents the mean data on the total uptake of Mg at different growth stages as affected by varying levels of K application.

Eventhough total Mg uptake did not follow any uniform trend under varying levels of K supply a decrease was noticed after k_4 level at all stages except at bunch maturation stage. At that stage Mg uptake increased steadly with increased K supply.

Significant variation in total Mg uptake was observed only at the late vegetative and shooting stages. At both these stages, k_4 recorded the maximum uptake values of 17.82 and 44.87 kg ha^{-1} respectively. At late vegetative stage k_4 was on par with control, k_1, k_2 and k_3. The minimum uptake of 9.05 kg ha^{-1} registered by k_5 was on par with k_6. At shooting stage k_4 was on par with k_5 and k_6. The minimum value of 26.35 kg ha^{-1} was recorded by k_3 which was on par with control, k_1 and k_2.

4.7 Uptake of N and P at harvest in banana cv. Nendran as influenced by different levels of K application

The mean values of total uptake of N and P by banana cv. Nendran at harvest under diffenential K supply are presented in Table 16.

Table 16. Effect of K levels on total uptake of N and P at harvest stage (mean table)

Treatment	Uptake of N (kg ha^{-1})	Uptake of P (kg ha^{-1})
k_0	112.95	44.04
k_1	221.18	46.17
k_2	232.87	45.11
k_3	218.66	49.71
k_4	237.60	72.27
k_5	258.23	96.72
k_6	279.78	77.53
C.D. (0.05)	78.57**	19.19**

k_0 - Control

k_1 - 75g k_2O $plant^{-1}$

k_2 - 150g k_2O $plant^{-1}$

k_3 - 225g k_2O $plant^{-1}$

k_4 - 300g k_2O $plant^{-1}$

k_5 - 450g k_2O $plant^{-1}$

k_6 - 600g k_2O $plant^{-1}$

* Significant at 5% level
** Significant at 1% level

4.7.1 Uptake of N

The total uptake of N by banana cv. Nendran showed a general tendency of increase with increase in the level of K application. The maximum was at k_6 level (279.78 kg ha^{-1}) which was on par with all treatments except control which recorded the minimum uptake value of 112.95 kg ha^{-1}

4.7.2 Uptake of P

An increasing trend with increase in the level of K applied was observed in the case of total uptake of P by banana cv. Nendran at harvest. It was maximum (96.72 kg ha^{-1}) at k_5 level which was on par with k_6. The minimum uptake of 44.04 kg ha^{-1} was recorded by the control level which was on par with k_1, k_2 and k_3.

4.8 Uptake of micronutrients at harvest in banana cv. Nendran as influenced by different levels of K application

The mean data on the total uptake of micronutrients at harvest under varying levels of K supply are presented in Table 17.

Table 17. Effect of K levels on total uptake of micronutrients at harvest stage (mean table)

Table	Total uptake (kg ha^{-1})			
	Iron	Manganese	Zinc	Copper
k_0	2.87	0.83	0.21	0.19
k_1	3.61	0.95	0.24	0.27
k_2	4.99	1.08	0.20	0.28
k_3	7.99	1.33	0.43	0.45
k_4	6.12	1.02	0.19	0.35
k_5	5.08	1.15	0.22	0.39
k_6	5.31	1.12	0.23	0.43
CD(0.05)	1.51*	NS	0.12*	NS

k_0 - Control

k_1 - 75 g K_2O $plant^{-1}$

k_2 - 150 g K_2O $plant^{-1}$

k_3 - 225 g K_2O $plant^{-1}$

k_4 - 300 g K_2O $plant^{-1}$

k_5 - 450 g K_2O $plant^{-1}$

k_6 - 600 g K_2O $plant^{-1}$

* Significant at 5% level

** Significant at 1% level

4.8.1 Uptake of Fe

Significant variation was observed in the total uptake of Fe at harvest under differential K supply (Table 17). The highest Fe uptake of 7.99 kg ha^{-1} recorded by k_3 was sognificantly higher than all other treatments. The lowest uptake of 2.87 kg ha^{-1} was recorded by the control.

4.8.2 Uptake of Mn

Total Mn uptake at harvest did not show significant variation among the different treatments (Table 17). However the maximum uptake value of 1.33 kg ha^{-1} was recorded by k_3 and the minimum value of 0.83 kg ha^{-1} by the control.

4.8.3 Uptake of Zn

Significant variation was caused by the differential application of K in the total Zn uptake at harvest (Table 17). The highest uptake of Zn (0.43 kg ha^{-1}) by k_3 was significantly higher than other treatments which were all on par.

4.8.4 Uptake of Cu

There was no significant variation in Cu uptake at different levels of K application (Table 17) k_3 registered the highest Cu uptake of 0.45 kg ha^{-1} while control level registered the lowest value of 0.19 kg ha^{-1}.

4.9 Yield and yield attributes in banana cv. Nendran as influenced by different levels of K application

The mean data on the yield and yield attributes under different levels of K application are presented in Table 18.

All the important yield characters studied showed positive trend towards k_3 level of K application (225 g K_2O $plant^{-1}$). This level recorded the maximum values for the characters, number of hands $bunch^{-1}$, number of fingers $bunch^{-1}$, weight of hand, length of finger, girth of finger, weight of finger and bunch yield.

The different levels of K application caused significant variation in the number of hands $bunch^{-1}$, number of fingers $bunch^{-1}$, w[illegible] of hand and weight of bunch. The maximum number of hands $bunch^{-1}$ (5.67) was recorded by k_3.

Table 18. Effect of K levels on yield characters and bunch yield(mean table)

Treatment	Length of bunch (cm)	Number of hands bunch^{-1}	Number of fingers bunch^{-1}	Distance between hands in a bunch (cm)	Weight of hand (kg)	Length of finger (cm)	Girth of finger (cm)	Weight of finger (g)	Weight of bunch (kg)
k_0	51.00	4.67	32.67	5.64	0.92	21.53	12.12	153.50	5.17
k_1	59.33	4.00	28.67	6.61	1.46	23.83	12.97	212.98	7.00
k_2	56.67	5.00	36.00	5.81	1.85	24.47	14.12	232.07	9.13
k_3	56.33	5.67	40.67	5.83	1.87	25.70	14.63	247.35	10.47
k_4	65.33	5.00	39.67	5.92	1.42	23.83	13.97	214.36	8.67
k_5	55.67	4.68	38.67	5.53	1.56	24.70	14.08	222.53	8.80
k_6	63.00	5.01	39.33	5.48	1.70	23.10	13.35	184.96	8.83
CD(0.05)	NS	0.61**	3.51**	NS	0.46*	NS	NS	NS	1.32**

k_0 - Control
k_1 - 75 g K_2O plant^{-1}
k_2 - 150 g K_2O plant^{-1}
k_3 - 225 g K_2O plant^{-1}
k_4 - 300 g K_2O plant^{-1}
k_5 - 450 g K_2O plant^{-1}
k_6 - 600 g K_2O plant^{-1}

* Significant at 5% level
** Significant at 1% level

This was significantly higher than all other treatments. The minimum value of 4.00 was recorded by k_1 level.

The number of fingers bunch^{-1} was maximum (40.67) at the k_3 level which was on a par with all other higher levels of K.

The maximum value for weight of hand (1.87 kg) was recorded by k_3 and the minimum value (0.92 kg) by the control.

The bunch weight showed increasing trend with increase in the quantity of K applied upto k_3 level and then decreased gradually. The maximum bunch weight of 10.47 kg was recorded by k_3 which was significantly higher than all other treatments. The lowest bunch weight of 5.17 kg was recorded in the control plot.

4.10 Quality parameters of the fruit of banana cv. Nendran as influenced by different levels of K application

Table 19 presents the mean data on the quality characters under different levels of K application.

Table 19. Effect of K levels on quality characters of fruit(mean table)

Treatment	Total soluble solids (%)	Acidity (%)	Reducing sugars (%)	Total sugars (%)	Non-reducing sugars (%)	Sugar-acid ratio	Protein (%)	Vitamin C mg $100g^{-1}$	Pulp/ peel ratio	Shelf-life (number) of days
k_0	17.90	0.132	5.32	16.62	10.74	40.30	6.43	1.07	3.09	3.00
k_1	19.33	0.111	6.14	18.49	11.73	55.32	6.93	1.07	3.17	3.67
k_2	18.13	0.090	4.55	20.47	15.12	49.91	7.18	1.14	3.18	4.00
k_3	19.30	0.085	3.96	22.19	17.32	46.59	8.34	1.18	3.22	5.67
k_4	18.57	0.098	4.48	22.10	16.74	45.71	8.15	1.42	3.26	5.67
k_5	20.10	0.094	4.27	22.16	17.00	45.99	8.08	1.19	3.23	6.00
k_6	20.63	0.083	4.56	24.28	18.73	54.94	8.17	1.47	3.28	6.33
CD(0.05)	NS	NS	1.27*	1.17*	0.98**	NS*	NS	NS	0.08**	0.82*

k_0 – Control
k_1 – 75 g K_2O $plant^{-1}$
k_2 – 150 g K_2O $plant^{-1}$
k_3 – 225 g K_2O $plant^{-1}$
k_4 – 300 g K_2O $plant^{-1}$
k_5 – 450 g K_2O $plant^{-1}$
k_6 – 600 g K_2O $plant^{-1}$

* Significant at 5% level
** Significant at 1% level

Among the quality characters studied, the contents of total sugars, reducing sugars, non reducing sugars, pulp peel ratio and shelf life were influenced significantly by different levels of K application.

The total sugar content of fruit increased with increasing K supply. It was maximum (24.28 per cent) at k_6 level which was significantly higher than all other treatments. The minimum content (16.62 per cent) was recorded in the control plot.

Reducing sugars were maximum (6.14 per cent) at k_1 level which was on par with the control. The minimum (3.96 per cent) was recorded by k_3 which was on par with k_2 and all other higher levels.

The highest value for the content of non reducing sugars (18.73 per cent) was recorded by k_6 which was significantly higher than all other treatments. The minimum (10.74 per cent) was recorded by the control.

The pulp peel ratio showed a steady increasing trend with increase in K application. The maximum ratio of 3.28 was scored by k_6 which was on par with k_3, k_4 and k_5. The minimum value of 3.09 was recorded by fruits of the control plot.

The maximum shelf life of 6.33 days was recorded by k_6 which stood on par with k_3, k_4 and k_5. The minimum shelf life of 3.00 days was recorded by the fruits of the control treatment.

4.11 Soil exchangeable K, Ca and Mg at different growth stages of banana cv. Nendran as influenced by different levels of K application

The mean data on the soil content of exchangeable K, Ca and Mg at different growth stages are presented in Table 20.

4.11.1 Exchangeable K

Exchangeable K content of the soil varied significantly under different levels of K supply at all the major growth stages of the crop. With increase in the level of K supply exchangeable K content of soil increased. With advancing growth stages of the crop also K content of the soil increased.

Table 20. Effect of K levels on exchangeable K, Ca and Mg contents of the soil (mean table)

Exchangeable k_2o (kg ha^{-1})

Treatment	S_1	S_2	S_3	S_4	S_5	S_6
k_0	242.67	234.00	214.00	197.33	174.00	150.00
k_1	246.00	246.00	229.33	185.33	155.33	135.67
k_2	291.67	279.67	274.67	240.00	281.33	239.00
k_3	318.33	306.33	376.00	403.33	383.67	350.00
k_4	328.33	338.00	376.00	412.33	458.33	468.67
k_5	354.00	384.00	372.67	419.33	443.00	414.33
k_6	363.00	370.33	358.00	419.33	434.33	410.33
CD(0.05)	34.14**	36.60**	34.34**	23.57**	45.43**	26.61**

Exchangeable ca (kg ha^{-1})

Treatment	S_1	S_2	S_3	S_4	S_5	S_6
k_0	111.67	113.33	130.00	116.67	151.67	135.00
k_1	120.67	113.33	108.33	140.00	121.67	100.00
k_2	125.00	115.00	106.67	108.33	110.00	81.67
k_3	106.67	108.33	120.00	105.00	85.00	90.00
k_4	95.00	83.33	103.33	81.67	93.33	90.00
k_5	86.67	98.33	81.67	73.00	76.67	80.00
k_6	86.67	65.00	76.67	76.67	103.33	83.33
CD(0.05)	16.34**	15.55**	26.70**	18.18**	17.16**	16.74**

Exchangeable Mg (kg ha^{-1})

Treatment	S_1	S_2	S_3	S_4	S_5	S_6
k_0	29.67	30.67	28.00	29.00	28.67	30.00
k_1	30.00	30.33	22.67	28.33	27.00	29.00
k_2	26.00	24.67	24.67	27.00	26.00	27.00
k_3	30.67	28.00	23.00	28.00	28.33	24.00
k_4	28.00	29.33	28.00	27.33	25.67	27.00
k_5	28.00	25.00	26.33	20.33	26.67	23.33
k_6	22.00	26.00	21.33	18.67	20.33	15.67
CD(0.05)	NS	NS	NS	5.17**	NS	3.81**

k_0 - Content
k_1 - 75 g K_2O $plant^{-1}$
k_2 - 150 g K_2O $plant^{-1}$
k_3 - 225 g K_2O $plant^{-1}$
k_4 - 300 g K_2O $plant^{-1}$
k_5 - 450 g K_2O $plant^{-1}$
k_6 - 600 g K_2O $plant^{-1}$

S_1 - Early vegetative stage
S_2 - Late vegetative stage
S_3 - Shooting stage
S_4 - Post shooting stage
S_5 - Bunch maturation stage
S_6 - Harvest stage

* Significant at 5% level ** Significant at 1% level

At early vegetative stage k_6 recorded the maximum K content of 363.00 kg K_2O ha^{-1} which was on par with k_5. The minimum content of 242.67 kg K_2O ha^{-1} was recorded by the control plot. At late vegetative stage k_5 registered the highest K content of 384.00 kg ha^{-1} which stood on par with k_6. Control registered the lowest K content of 234.00 kg ha^{-1}. At the shooting stage of banana the highest K content of 376.00 kg K_2O ha^{-1} was recorded by both k_3 and k_4 which were on par with k_5 and k_6. The lowest content of 214.00 kg K_2O ha^{-1} was in the control plot. At the post shooting stage both k_5 and k_6 recorded equal values (419.33 kg K_2O ha^{-1}) which was the highest K content. These were on par with k_3 and k_4. The lowest content of 185.33 kg K_2O ha^{-1} was recorded by k_1 which was on par with the control. At bunch maturation stage k_4 recorded the maximum K content of 458.33 kg K_2O ha^{-} which was on par with k_5 and k_6. The minimum value of 155.33 kg K_2O ha^{-1} was at the k_1 level which was on par with the control. At the harvest stage of the crop the treatment k_4 resulted in the maximum K content of 468.67 kg K_2O ha^{-1}. This was significantly higher than all other treatments. k_1 registered the minimum content of 135.67 kg K_2O ha^{-1} which was on par with the control.

4.11.2 Exchangeable Ca

The different levels of K application caused significant variation in the exchangeable Ca content of the soil at all the major growth stages of the crop. At all these stages exchangeable Ca content showed a decrease with increase in the rate of K applied, the lower levels recording the maximum values.

At both early and late vegetative stages k_2 recorded the maximum exchangeable Ca contents of 125.00 kg ha^{-1} and 115.00 kg ha^{-1} respectively. At the former stage k_2 was on par with the control and k_1 and minimum value of 86.67 kg ha^{-1} was recorded by both k_5 and k_6. At the latter stage k_2 was on par with control, k_1 and k_3 levels. At this stage the minimum value of 65.00 kg ha^{-1} was at k_6 level. At the shooting stage control recorded the highest exchangeable Ca content of 130.00 kg ha^{-1} which was on par with k_1, k_2 k_3 and k_4. The minimum content of 76.67 kg ha^{-1} was for k_6 level. At the post shooting state k_1 recorded the highest exchangeable Ca content of 140.00 kg ha^{-1}. This was significantly higher than all other treatments. The lowest content of 73.00 kg ha^{-1} was at k_5 which was on par with k_4

and k_6. At the bunch maturation stage control plot showed the maximum exchangeable Ca content of 151.67 kg ha^{-1} which was significantly higher than all other treatments. The minimum value was recorded by k_5. At the harvest stage of the crop also, control plot registered the highest exchangeable Ca content of 135.00 kg ha^{-1} which was significantly higher than the rest of the treatments.

4.11.3 Exchangeable Mg

In general exchangeable Mg content showed a decrease with increase in the level of K supply, the lower values being recorded at higher levels of K application.

The different levels of K application significantly influenced the exchangeable Mg content of the soil only at the post shooting and harvest stage of the crop.

At the post shooting stage control registered the maximum exchangeable Mg content of 29.00 kg ha^{-1} which was on par with all other treatments except k_5 and k_6. The minimum value of 18.67 kg ha^{-1} was registered by k_6 which was on par with k_5. At the harvest stage also control recorded the highest Mg content of 30.00 kg ha^{-1} which was on par with k_1, k_2 and k_4. The lowest content of 15.67 kg ha^{-1} was at k_6 level.

4.12. Correlation studies

Table 21 furnishes the coefficients of correlation between bunch yield and some important growth, yield, quality and soil characters in banana cv. Nendran. Several growth characters showed positive and highly significant relationship with yield. The plant height at the harvest stage of the crop showed the maximum relationship with yield (r = 0.691**). Girth of the plant at the base of the pseudostem measured at the late vegetative, shooting, bunch maturation and harvest stages showed positive and significant association with yield. Among these, the value measured at the shooting stage recorded the highest coefficient of correlation (r = 0.778**). Girth of the pseudostem at 1m height showed highly significant relationship with yield at the bunch maturation stage (r = 0.736**). Total leaf area and leaf area index at shooting stage showed significant correlation with yield (r = 0.605** and 0.700** respectively).

Table 21. Coefficients of correlation between some important crop characters

Correlation between		Coefficient of correlation
X	Y	
Plant height at shooting	Yield	0.454*
Plant height at bunch maturation	Yield	0.500*
Plant height at harvest	Yield	0.691**
Girth at base at late vegetative	Yield	0.435*
Girth at base at shooting	Yield	0.778**
Girth at base at bunch maturation	Yield	0.646**
Girth at base at harvest	Yield	0.692**
Girth at 1m height at post shooting	Yield	0.640**
Girth at 1M height at bunch maturation	Yield	0.736**
Girth at 1M height at harvest	Yield	0.596**
Total leaf area at shooting	Yield	0.605**
Leaf area index at shooting	Yield	0.700**
Total dry matter at shooting	Yield	0.685**
Total dry matter at post shooting	Yield	0.550**
Total dry matter at bunch maturation	Yield	0.453**
Total dry matter at harvest	Yield	0.810**
Total K uptake at late vegetative	Yield	0.460*
Total K uptake at shooting	Yield	0.538**
Total K uptake at bunch maturation	Yield	0.547**
Total K uptake at harvest	Yield	0.861**
Fingers $bunch^{-1}$	K uptake at shooting	0.475*
Weight of hand	K uptake at post shooting	0.540*
Weight of hand	K uptake at bunch maturation	0.577**
Length of fruit	K uptake at late vegetative	0.463*
Weight of fruit	K uptake at late vegetative	0.532*
Total sugars	K uptake at shooting	-0.791**
Flesh peel ratio	K uptake at shooting	0.723**
Soil K at early vegetative	Yield	0.576**
Soil K at late vegetative	Yield	0.544*
Soil K at shooting	Yield	0.703**
Soil K at post shooting	Yield	0.638**
Soil K at bunch maturation	Yield	0.640**
Soil K at harvest	Yield	0.616**

* Significant at 5% level ** Significant at 1% level

Total dry matter content of the plant from the shooting stage upto harvest showed significant relationship with yield. At the harvest stage of the crop the maximum association was observed (r = 0.810**) followed by the shooting stage (r = 0.685**).

Total K uptake at late vegetative, shooting, bunch maturation and harvest stages showed highly significant relationship with yield. The maximum association was recorded at the harvest stage (0.861**). The important bunch characters, number of fingers bunch^{-1} and weight of hand showed significant relationship with total K uptake by the plant at the shooting and post shooting stages (r = 0.475* and 0.540* respectively). Weight of hand was also positively related to total K uptake at the bunch maturation stage (0.577**). The fruit characters, length and weight of individual fruit were associated with total K uptake at the late vegetative stage (r = 0.463* and 0.532* respectively).

The important quality characters, flesh peel ratio and total sugar content showed maximum relationship with total K uptake at shooting stage (r = 0.723** and 0.791** respectively). The exchangeable K content of the soil at all the stages of crop growth showed positive and significant relationship with yield. The maximum association was manifested by the exchangeable K content at the shooting stage of the crop (r = 0.703**).

DISCUSSION

5. DISCUSSION

A field experiment was conducted in the sandy clay loam soil of the Instructional Farm attached to College of Agriculture, Vellayani giving seven graded levels of K to select the index part of Musa (AAB) Nendran for fixing the crical K concentration for maximum response to applied K and yield. Attempt was also made to fix the soil critical level of exchangeable K at different growth stages of the crop for economic yield. Effects of K on growth characters, yield and yield parameters, quality of fruit and uptake of other nutrients were also evaluated. Quantities of plant nutrients recycled by growing a crop of this variety which is one of the heaviest feeders of soil nutrients were also assessed. The salient results generated in the course of investigation are briefly discussed below.

5.1 Growth characters in banana cv. Nendran as influenced by K nutrition

5.1.1 Height of plant

There was no significant difference in height of plants under varied levels of K application upto the shooting stage (Table 2). However control plants recorded the minimum values at all the stages of growth. At post shooting and bunch maturation stages treatment effects were significant. The highest K level, K6 (600 g K_2O plant^{-1}) recorded the maximum values of 314.00 cm and 321.67 cm respectively.

The height of the banana plant is measured from the base of the pseudostem to the axil of the youngest leaf. The pseudostem in banana is actually a concentric bundle of leaf sheaths emerging directly from the corm. Under reduced K levels the normal phyllotaxis of the plant is affected. Instead of 160^{o} in healthy plants, K deficient plants show a phyllotaxis of 180^{o}. The leaves develop one just above the other with only small distance between the petioles leading to reduced pseuaostem height. K starvation resulting in such an effect in banana has been reported by Freiberg and stewart (1960) and Lahav (1972a).

Height of banana plant has a direct relationship with the number of leaves produced by it according to Summerville (1944) since the petiole elongates sufficiently to permit full opening of the lamina. This view was supported by Kothavade *et al.* (1985) also. In the present study the number of leaves produced was more at the post shooting and bunch maturation stages by plants receiving higher levels of K (Table 4). The above influence might have contributed to the increase in plant height at higher levels of K.

Cooil (1948) attributed the retardation of plant height in K deficient plants to the low cambial and meristematic activity of the growing apex resulting in the shortening of internodal length and rosetting of the leaves. Decrease in the height of banana plants caused by the emergence of leaves at very close spacing in K deficient plants was reported by Venema (1958) and Ziv (1970).

Positive effect of K application on height of banana plant has been documented by Chu (1959), Ho (1971), Turner and Bull (1970), Jambulingam *et al.* (1975), Sheela (1982), Krishnan and Shanmughavelu (1983), Mustaffa (1987), Oubahou and Dafiri (1987) and Khoreiby and Salem (1992).

Several reasons can be attributed to the lack of significance for K treatments at the early growth stages of the crop. The soil of the experimental site with its initial high content of K might have been adequate to meet the K requirement of plants even at low level of K supply in the initial growth stages so that deficiency became manifested only at the later stages. The plants received the full dose of K only by the shooting stage. The lack of competition between the plants for sunlight seems to be another reason. At the early stages, light was not a limiting factor as the plant canopy did not occupy the complete ground space. This holds good for the harvest stage of the present study also when no statistical significance for the treatment effects was observed. The active growing phase of the plants being over with most leaves in the senescent stage, a proportionate growth of the pseudostem with increase in the level of K supplied might not have taken place.

5.1.2 Girth of the pseudostem

The girth of the pseudostem measured at the base showed significant variation as a result of the treatments at later stages of growth from shooting (Table 2). The girth at 20 cm height showed significant variation at shooting, post shooting and bunch maturation stages while the girth at 1 m height varied significantly at post shooting and bunch maturation stages (Table 3). At all these stages, girth showed a positive trend with increase in K supplied. The maximum values were recorded by K6 (600 g K_2O $plant^{-1}$) at most of the stages.

As the pseudostem of banana is made up of tightly packed leaf sheaths, the number of leaves produced has a direct bearing on the girth of the pseudostem. The number of functional leaves produced was more in plants receiving higher levels of K (Table 4) which may be a reason for girth of pseudostem registering higher values at increased K levels.

Enhanced girth of pseudostem in banana as a result of application of increasing levels of K has been reported by several workers like Ho (1971), Turner and Bull (1970), Lahav (1972a), Jambulingam *et al.* (1975), Caldas *et al.* (1978), Bravo *et al.* (1980), Fabregar (1986), Mustaffa (1987). Oubahou and Dafiri (1987), Hedge and Srinivas (1991) and Khoreiby and Salem (1991).

The correlation between pseudostem height and circumference has been well documented by Croucher and

Mitchell (1940) and Lahav (1972a). The accelerated growth of pseudostem at the shooting, post shooting and bunch maturation stages especially under stress conditions of sunlight due to the closing in of the canopy poses as a reason for enhanced girth of pseudostem at these stages. The satisfactory rate of photosynthesis and meristematic activity under adequate supply of K can also be quoted as possible reasons.

Senescence of leaves leading to shrinkage of tissues of leaf sheath as well as lesser production of leaves after bunch maturation stage (Table 4) might have reduced the girth of pseudostem at 20 cm and 1 m height at harvest stage of the crop. Treatment differences were not significant at this stage though the same trend as observed at the post shooting and bunch maturation stages was there.

5.1.3 Leaf production

There was no significant variation in the total number of leaves or number of functional leaves produced by banana cv. Nendran under different levels of K except at the post shooting and bunch maturation stages (Table 4). At both the stages, K6 (600 g K_2O plant^{-1}) registered the maximum number of leaves, 15.67 and 12.67 respectively. These were significantly higher than all other treatments. Minimum numbers of leaves were produced by the control or low K treatments at all stages of growth.

The results of the present study are in agreement with the reports of Murray (1960), Brezesowsky and Biesen (1962), Ho (1969), Lahav (1972a), Sheela (1982), Mustaffa (1987) and Baruah and Mohan (1991). Nitrogen being the element most needed for the growth of foliage its uptake at higher levels of K supply (Table 16) might have contributed to increased leaf number. The increased vigour and meristematic activity of the plant brought about as a result of increased N K ratio in the plant tissue might be another reason.

5.1.4 Leaf area and leaf area index

The leaf area in banana cv. Nendran under different levels of K supply varied significantly only at the post shooting and bunch maturation stages (Table 5). Graphical presentation of the data is given in Figure 4. At both

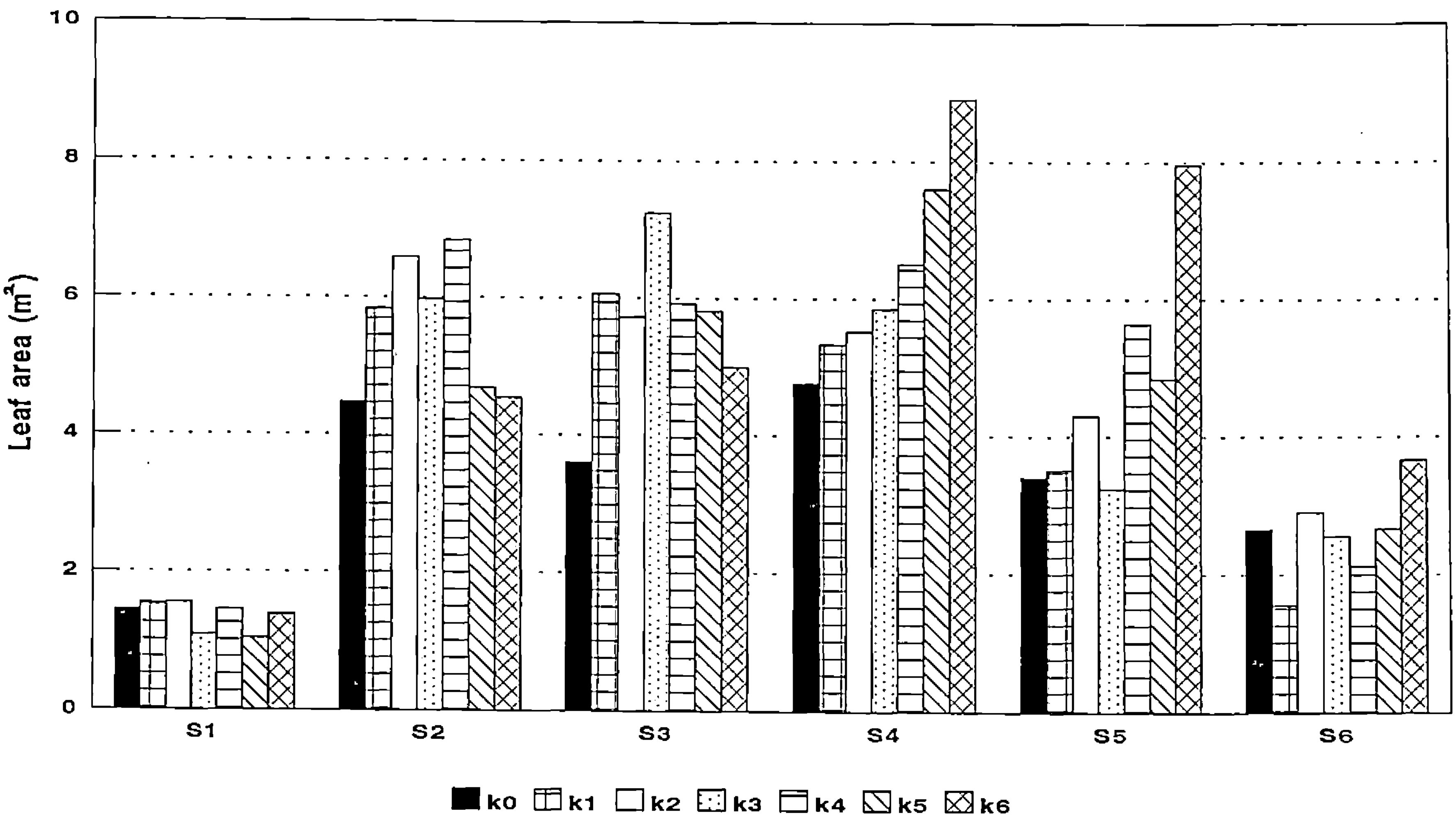


Fig. 4. Effect of k levels on leaf area in banana cv. Nendran at different growth stages

stages, K6 (600 g K_2O plant^{-1}) recorded the maximum values of 8.90m^2 and 7.96 m^2 respectively. The findings are in confirmity with the report by Baruah and Mohan (1991) who found the highest K dose producing the largest number of leaves and leaf area.

Drastic reduction in leaf area in K deficient plants compared to healthy plants has been reported by Murray (1960), Ramaswamy *et al.* (1977) and Turner and Barkus (1980). Lahav (1972a) opined that K deficiency reduced the size of leaves and shortened their longevity leading to diminished leaf area in banana cv. Robusta.

Potassium starvation causes a considerable increase in the mortality rate of older leaves. Normally necrosis starts along wind tears in the blade. But K deficient leaves exhibit normal senescence symptoms at a much accelerated rate. As only the functional leaves were considered for determining the leaf area, their lower number along with decreased leaf size might have contributed to decreased leaf area at lower levels of K supply.

At the early growth stages of the crop, different K treatments could not influence leaf area significantly. The last split of fertilizer application coincided with the shooting stage of the crop and only by the post shooting stage, the crop received the full dose of K. Hence the effects of the different treatments became manifested from this stage onwards only. Sheela (1982) and Geetha Nair (1988) also could not obtain any significant effect for the K treatments on leaf area in banana cv. Palayankodan and Nendran respectively upto the shooting stage.

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.

Leaf area index, being a computed derrivative of leaf area followed the same trend as that of leaf area at all the growth stages (Table 5).

5.2 Dry matter production in banana cv. Nendran as influenced by K nutrition

The results of the study on the effect of different levels of K on dry matter production in banana cv. Nendran presented in Tables 6, 7 and 8 indicate that dry matter production by the different plant parts did not confirm to any consistent pattern during the early growth stages of the crop.

The total dry matter production showed significant variation only at the shooting, post shooting, bunch maturation and harvest stages. At all the four stages, dry matter production was maximum at higher levels of K application while control recorded the minimum values. These findings are in agreement with the reports by Twyford and Walmsley (1974), Turner and Barkus (1980) Sheela (1982), Gomes *et al.* (1991) and Hedge and Srinivas (1991). As evident from the data of the present study the pseudostem, leaf blade and rhizome contributed most to total dry matter. The height and girth of the pseudostem and number of leaves were higher at higher levels of K supply which might have contributed to increased total dry matter production.

Potassium is an essential cofactor for many of the enzyme catalysed steps in metabolic pathways in plants, the most important among them being in protein and carbohydrate synthesis. It functions in the formation of an effective polyribose complex that precedes the active incorporation of amino acids into proteins (Lubin and Ennis, 1964). In carbohydrate synthesis, K accelerates the starch synthetase activity by protecting the enzyme from thermal inactivation. (Akatsuka and Nelson, 1966). Another beneficial effect of K is in the reduction of water losses 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). The increase in cellular volume by mitosis and expansion requires a net increase in the salt content of the plant so that turgor of the cells can be maintained. This is ensured by an adequate supply of K (Russel and Shorrocks (1959). It is also involved in the photosynthetic ATP synthesis and NADPH production. Adequate K nutrition also extends the duration of photosynthesis and of assimilate storage in the sink. In the present study in plants receiving higher levels of K, the accelerated rate of photosynthesis, protein and carbohydrate synthesis might have contributed to the higher dry matter production compared to lower K levels.

Loomis and Williams (1963) observed that with increase in leaf area index, there was a corresponding increase in light absorption and dry matter production. This is in agreement with the finding in the present study also as increased leaf area index was found associated with higher levels of K supply.

The distribution pattern of dry matter into the various plant parts showed that at all stages of crop growth, pseudostem was the largest repository of dry matter followed by leaf blade, rhizome, midrib and petiole in the decreasing order except at the harvest stage when the bunch constituted the second largest sink next to pseudostem.

A close examination of the data on the dry matter production by different plant parts at harvest stage (Table 8) points out that in spite of the differences in the total dry matter production by the different treatments, K3 (225 g K_2O plant^{-1}) was the most efficient in diverting the maximum dry matter towards the bunch (28 per cent).

5.3 Potassium concentration in different parts of banana cv Nendran as influenced by K nutrition

A critical scrutiny of the data on K concentration in different plant parts under varying levels of K supply presented in Tables 9,10 and 11 shows that increased levels of application were reflected in the tissue concentration at all growth stages of the crop. The highest level of K resulted in the maximum concentration in most cases and control in the minimum values.

At the early vegetative stage the different K levels resulted in significant variation in the K content of the petiole and midrib while at the late vegetative stage, the petiole, midrib and leaf blade showed significant variation. At the shooting stage, the petiole and pseudostem were the organs significantly influenced. At post shooting stage leaf blade and petiole were significantly affected. At the bunch maturation stage all parts showed significant variation in their K contents while at the harvest stage all parts except leaf blade and root showed significant variation. The noteworthy feature in this context is that petiole was the only organ which showed significant variation in K concentration under varied levels of K application at all stages of crop growth proving itself to be the most sensitive organ to changes in supply of K. At all growth stages and in all plant parts the highest level of K application produced the highest K concentration or was on par with the treatment recording the highest K concentration.

The general trend observed in the present study of increasing tissue K concentration with increased rates of K application agrees with the reports by Ho (1969), Garcia *et al*. (1978), Sheela (1982), Garita and Jaramillo (1986), Irizarry *et al*. (1988), Vadivel and Shanmughavelu (1988), Ray *et al*. (1988) and Baruah and Mohan (1991). Kubenbuch (1990) suggested two possibilities for increase in tissue K concentration subsequent to K fertilization. According to him diffusion is the main process supplying K to the root. Potassium fertilization increases K availability because of a steep concentration gradient thus created which results in a high K flux around the roots. Spatial access for K is also increased due to higher mobility in the soil especially under adequate soil moisture conditions.

A comparative study of the tissue concentration in the various organs at different growth stages shows that at the early vegetative stage petiole proved to be the largest respository of K. At the late vegetative, shooting and post shooting stages pseudostem was the richest source while at the bunch maturation and harvest stages rhizome proved to be the richest source.

Figure 5 depicts the concentration of K in the different parts of banana cv. Nendran at shooting stage under different levels of K supply. It is clear from the figure that upto k_3 level of supply K concentration in the pseudostem is comparatively less, but at higher levels it is more concentrated in the pseudostem. This confirms with the report by Huang *et al.* (1992) who found pseudostem acting as storage organ of excess of K in several banana cultivars.

5.4 Uptake of major nutrients in banana cv. Nendran as influenced by K nutrition

5.4.1 Nitrogen

The experiment results indicated that increasing levels of K application increased total N uptake in banana cv. Nendran at harvest (Table 16). The maximum was recorded by k_6 level (600 g K_2O plant $^{-1}$) and this was on par with all other treatments except control. Findings similar to this were reported by Lahav (1977) and Hedge and Srinivas (1991). According to them increasing K fertilization significantly increased the uptake of N which was mainly the consequence of increased dry matter production. The increased turgidity of

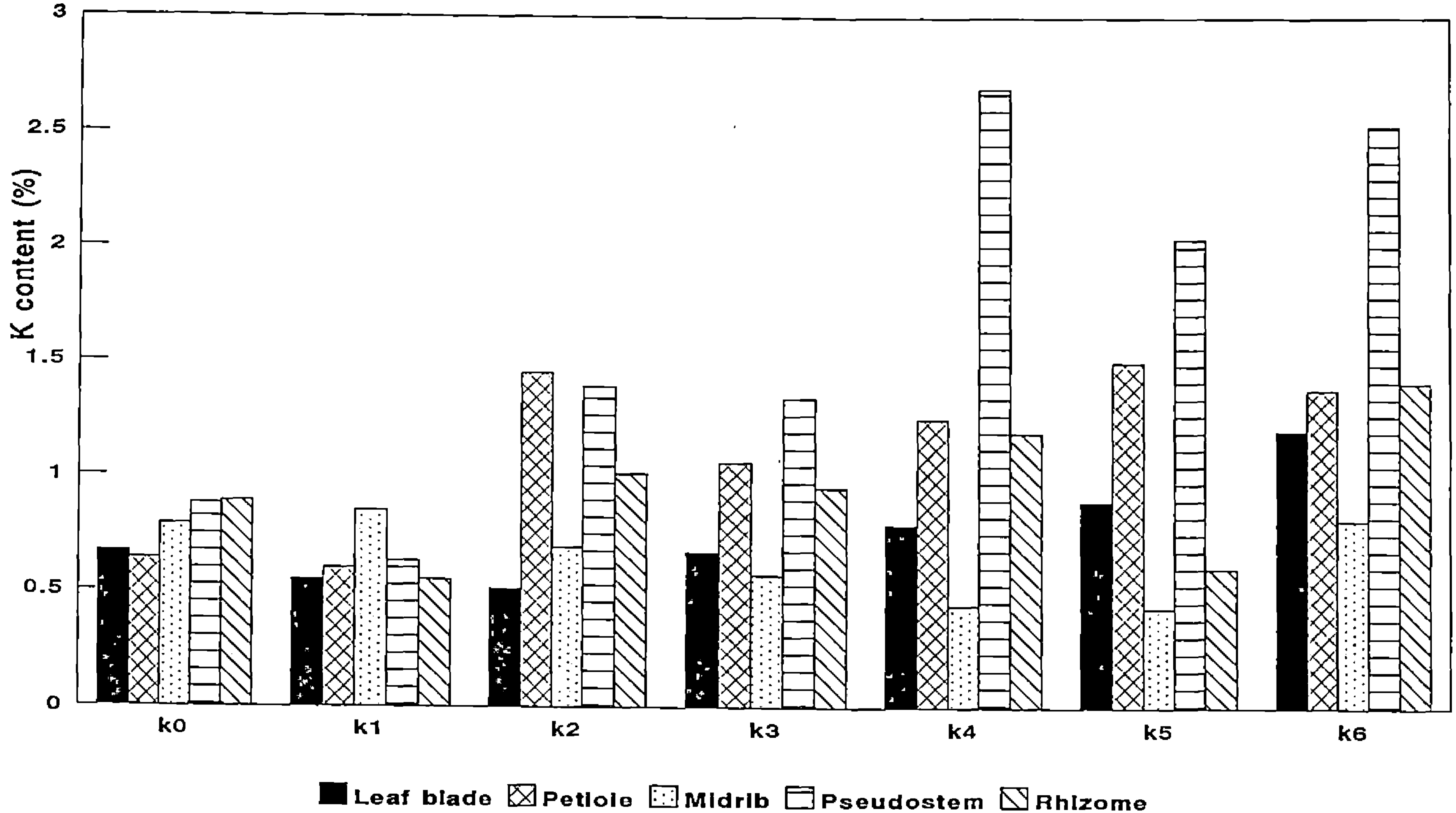


Fig. 5. Effect of k levels on k content of different parts in banana cv. Nendran at shooting stage

the cells under as adequate supply of K consequent to regulation of transpiration also might have increased the uptake of N. Figure 6 depicts the relationship between K nutrition and total uptake of N and P by banana cv. Nendran at harvest.

5.4.2 Phosphorous

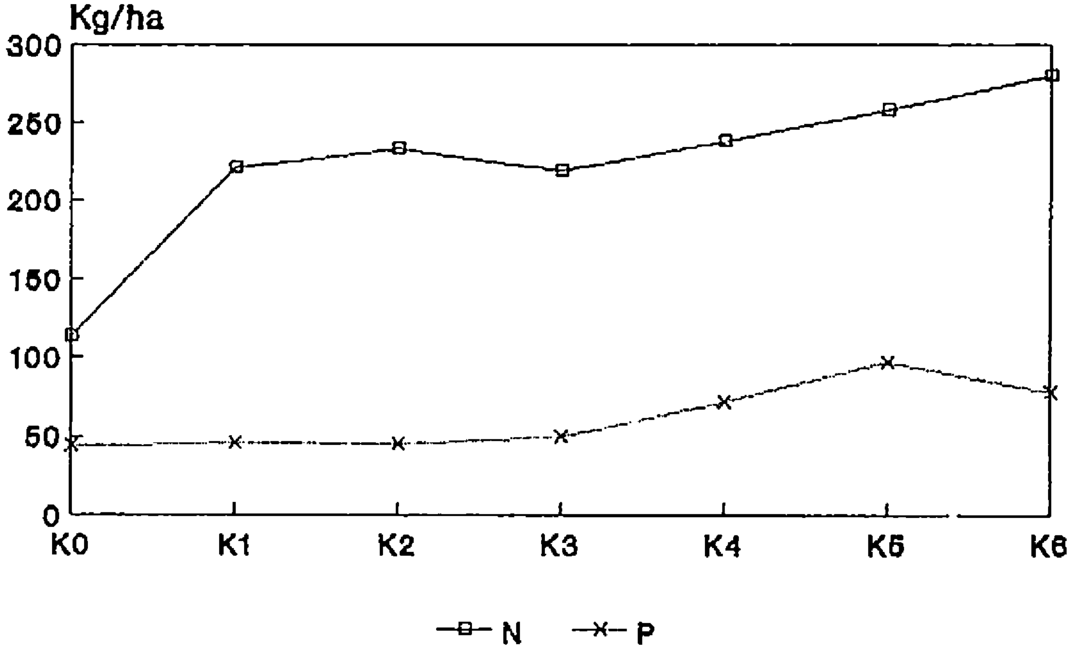
Application of K significantly increased the total uptake of P by banana cv. Nendran at harvest (Table 16). The higher levels of K recorded maximum values while the lower and control levels resulted in minimum values. Bondad *et al.* (1983) and Turner and Barkus (1985) on the basis of long term studies in banana on absorption rates and competition between ions arrived at similar conclusions. They reported that K application resulted in increased uptake of P. Lahav (1977) also found synergism between K and P uptake in banana cv. Williams especially in the petiole and blade.

5.4.3 Potassium

The general trend that can be observed on the basis of this study is that the total uptake of K increased with

Fig :6

Effect of K levels on uptake of N and P in banana cv. Nendran at harvest stage



increase in the level of K supplied, the maximum values mostly being recorded at the highest level of K supplied viz. 600 g K_2O plant^{-1}. Similar observations were made by Randhawa *et al.* (1973), Chathopadhyay and Mallik (1977), Garcia *et al.* (1978), Garita and Jaramillo (1986), Irizarry *et al.* (1988), Vadivel and Shanmughavelu (1988), Sheela and Aravindakshan (1990) and Hedge and Srinivas (1991). The enhanced dry matter production as well as the increased nutrient concentration built up in the tissue following K application account for the increased uptake rates at higher levels of K application.

At all stages of crop growth, the pseudostem proved to be the major plant part responsible for the maximum K uptake as evident from Figures 7 and 8. An inspection of the data on the distribution of K uptake in various parts at the harvest stage of the crop reveals that on an average pseudostem accounted for 59 per cent of the total K uptake followed by bunch (24 per cent), rhizome (11 per cent), leaf blade (2 per cent) and petiole, midrib and root together less than 4 per cent.

Fig: 7 Effect of K levels on uptake of K by different parts of banana cv. Nendran at shooting stage

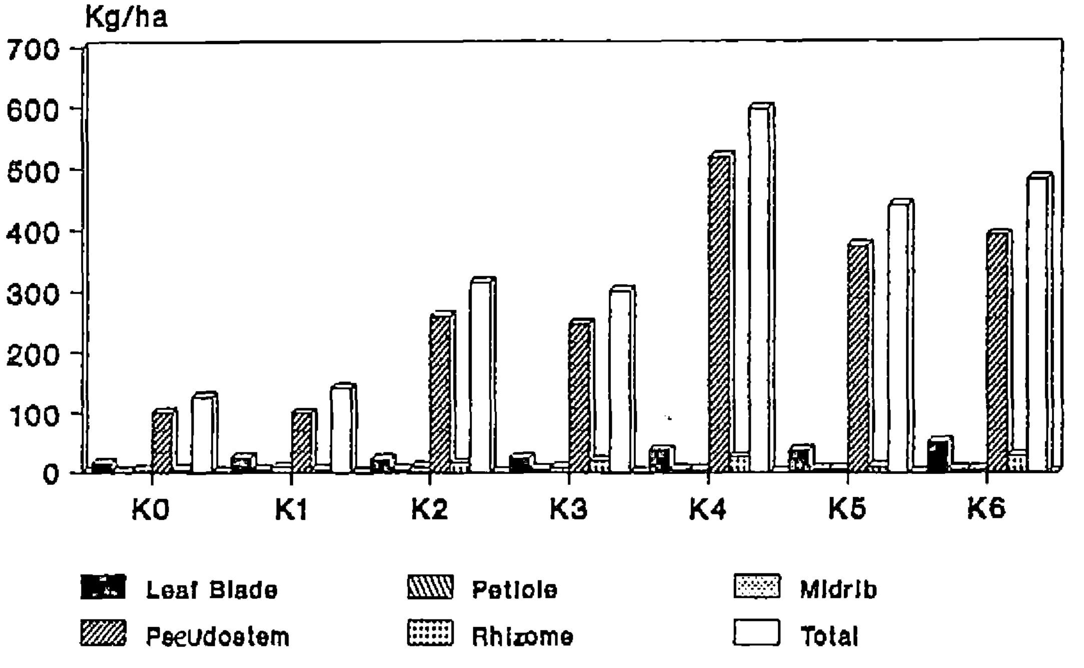
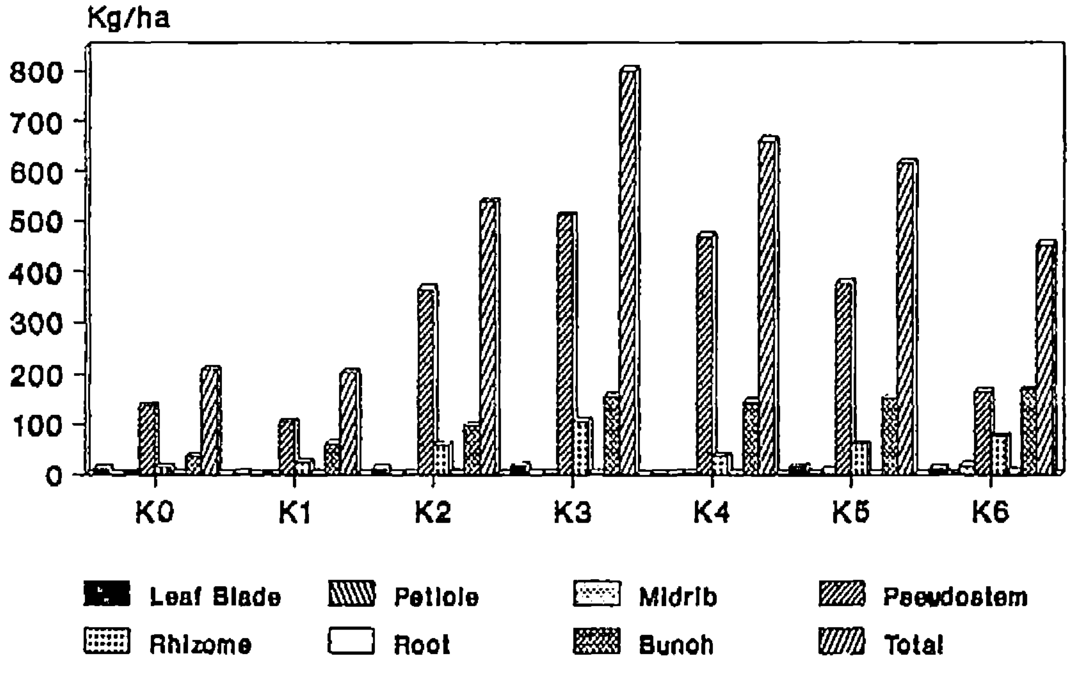


Fig: 8 Effect of K levels on uptake of K by different parts of banana cv. Nendran at harvest stage



5.5 Uptake of secondary nutrients in banana cv. Nendran as influenced by K nutrition

5.5.1 Calcium

At all the major growth steages of the crop, the maximum Ca uptake was observed at the control level. At higher levels of K supply Ca uptake decreased in general (Table 15). The effect of K on Ca uptake was more conspicous in the early growth stages. At later stages the increased dry matter production in general might have masked the relative small difference in Ca concentration between the different treatments

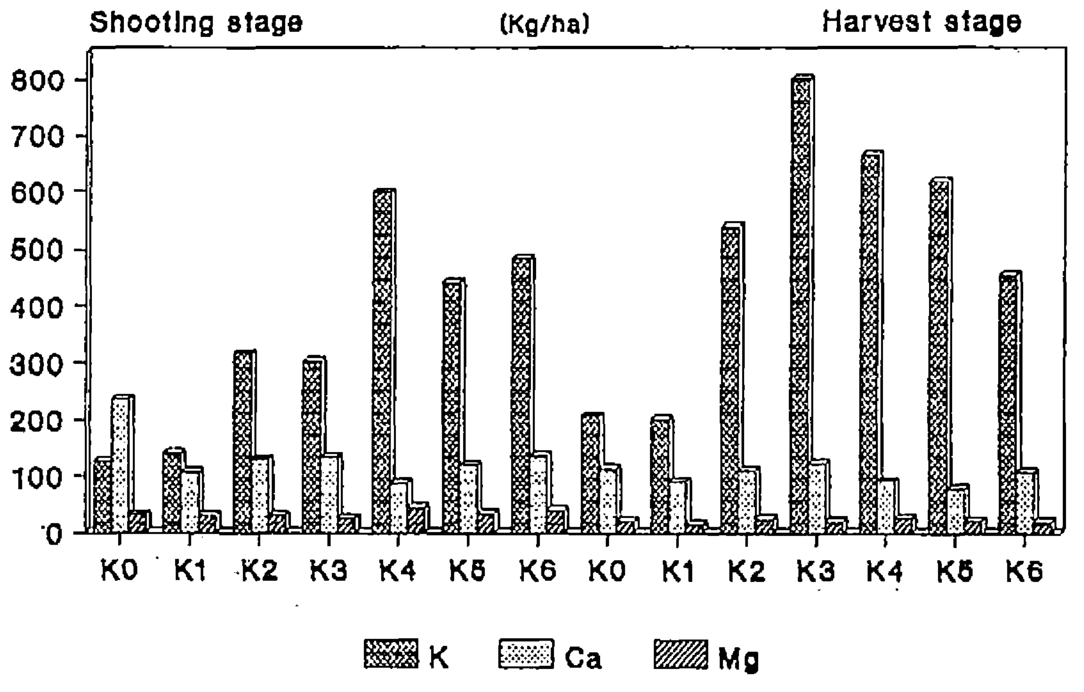
Results in confirmity with the above findings have been reported by Murray (1960), Caldas *et al.* (1973), Lahav (1977), Garcia *et al.* (1978), Turner (1983), Turner and Barkus (1983) and Vadivel and Shanmughavelu (1988) based on similar work conducted in other cultivars of banana. According to Prevel (1978) the absorption rates of exchangeable cations by the banana plant are determined by the relative proportion among K, Ca and Mg, these being the interacting ions. Mengel and Kirkby (1982) gave an explanation for decrease in absorption of Ca at higher levels of K supply. According to these scientists cation species are attracted by the negative electro potential of the cell which is being continuously regenerated by H^+ extrusion. Cation species which can traverse the plasma membrane more easily like K^+ have a greater chance of saturating the continuously generated negative potential than those cation species for which plasma membrane acts as a barrier. Cations which enter the cell rapidly depress the uptake of others. Most of the plants absorb K^+ at a faster rate and these act as competitors. Tandon and Sekhon (1988) attributed decreased Ca uptake at higher levels of K supply to another reason. According to that K has a polarizability equal to 0.088 nm which is higher than that of Ca (0.053 nm). Potassium is also the largest non hydrated cation among the nutrient cations required by plants. The number of oxygen ions surrounding K in mineral structure is 8 or 12 as against 6-8 for Ca. So the strength of each K-O bond is relatively weak. Hence K^+ is preferred over Ca in cation exchange reactions.

5.5.2 Magnesium

The uptake behaviour of Mg by banana cv. Nendran under different levels of K supply followed an inconsistent pattern at all the stages of crop growth. Significant variation in total Mg uptake was observed only at the late vegetative and shooting stage of the crop (Table 15). At both stages maximum Mg uptake was recorded at the k_4 level (300 g K_2O plant^{-1}). Montagut and Prevel (1966) also reported such irregular uptake pattern of Mg by banana grown in Antilles based on a three year study. They attributed this to the dependence on several soil properties. Turner and Barkus (1985) reported their finding that even though increasing K supply increased the uptake of most elements the uptake of Mg was unaffected. In American cotton, Singh *et al.* (1991) observed that varied K application did not affect the Mg content of the leaves. According to Caldas *et al.* (1973) percentage Mg in the cation sum K + Ca + Mg remained more or less a constant while K was progressively replaced by Ca as the plant developed.

Figure 9 illustrates the relative uptake of K, Ca and Mg under different levels of K supply at the shooting and harvest stages in banana cv. Nendran.

Fig: 9 Effect of K levels on relative uptake of K, Ca and Mg in banana cv. Nendran at shooting and harvest stages



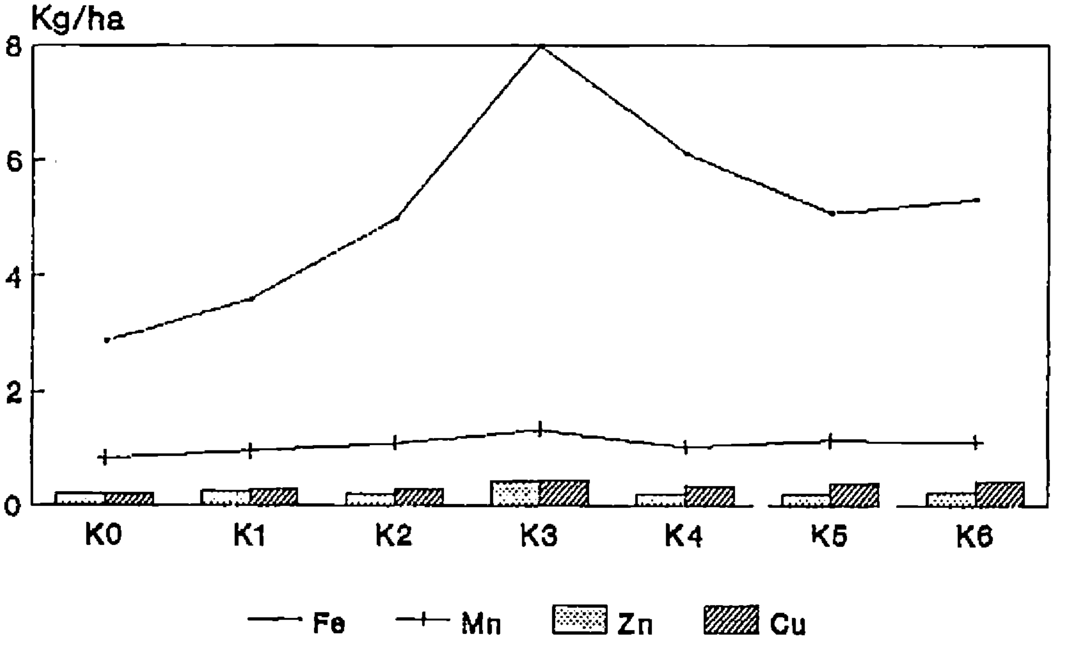
5.6 Uptake of micronutrients in banana cv. Nendran as influenced by K nutrition

The study indicated that addition of K caused significant variation in the total uptake of Fe and Zn where as the influence on Mn and Cu uptake were not pronounced (Table 17 and Figure 10).

The treatment K3 (225 g K_2O plant^{-1}) recorded the maximum values for both Fe and Zn uptake which were significantly higher than all other treatments. In both the cases the uptake increased upto k3 level and then gradually decreased. The high values for Fe and Zn uptake at K3 level could be accounted for by the relatively higher concentration of these nutrients in the bunch and pseudostem at this level coupled with higher dry matter contents also. (Table 8) According to Walmsley and Twyford (1976) the bunch was the largest repository of Fe and Zn followed by pseudostem.

The application of different levels of K did not have much influence on uptake of Mn and Cu by the crop even though a general tendency for increase with increase in levels of K was noticed for both nutrients upto k3 level.

Fig: 10 Effect of K levels on uptake of Fe,Mn,Zn and Cu in banana cv.Nendran at harvest stage



5.7 Recycling of nutrients in soil under banana cv. Nendran

In our normal practice when a bunch of banana is harvested the pseudostem supporting the bunch with leaves is removed either entirely or partially in the harvesting operation. Along with this is lost the reserve of all nutrients which can be a potential source to the next crop. For banana this loss is tremendous owing to the large biomass of the plant and its heavy feeding habits.

The balance sheet of nutrients (kg ha^{-1}) in the soil of the present study after harvest of the bunch is presented below (Table 22). Treatment k4 has been taken as the example for illustration being the package of practices recommendation of Kerala Agricultural University for irrigated banana cv. Nendran (KAU, 1989). The nutrient recommendation at this level in the form of chemical fertilizers work out to 475 kg N, 287.5 kg P_2O_5 and 750 kg K_2O besides 125 kg N, 62.5 kg P and 125 kg K in the form of FYM for a ha of crop. At this level the total dry matter production was 26297 kg ha^{-1} of which the bunch constituted only 6500 kg ha^{-1}. This mean that only 25 per cent of total dry matter need be removed by way of harvest of the produce while the rest can be incorporated back in to soil.

Table 22. Balance sheet of nutrients (Kg ha^{-1}) in soil under banana cv. Nendran

	N	P	K	Ca	Mg
Initial Soil Value	490	23.0	288	125	28
Added through fertilizer	475	287.5	750	--	--
Added through manure	125	62.5	125	--	--
Total uptake by crop	238	72.0	669	91	26
Uptake by bunch	65	28.0	146	22	18
Final soil value	428	21.0	469	90	27
Quantity that can be added if bunch alone is removed	173	44.0	523	69	8
% increase in the final nutrient status over initial value	123	283.0	344	127	125

A careful scrutiny of the data shows that chances for negative values in the final soil status exist for all nutrients except K if the entire crop is removed. Even for N and P depletion will occur in spite of addition throuh manures and fertilizers. On the other hand if the crop residues after harvest of the bunch alone is returned back to soil, positive values will be shown in the final soil status by all the nutrients. For K a three fold increase in final status over initial status can be observed as a result of nutrient recycling.

The phenomenon of nutrient cycling has special significance for banana which is one of the heaviest feeders of soil nutrients and which is the largest of the harbaceous plants. Lahav (1973) reported the chance of the mother plant meeting 40 per cent of the nutrient requirement of the ratoon plant through this phenomenon. Reports highlighting the scope of nutrient cycling in banana have been put forward by Baillon *et al.* (1933), Twyford and Walmsley (1974), Turner (1972), Godefroy (1982), Samuel *et al.* (1978), Irizarry *et al.* (1988) and Gomes *et al.* (1991).

5.8 Yield and yield characters in banana cv. Nendran as influenced by K nutrition

A critical scrutiny of the data on bunch yield and yield characters presented in Table 18 reveals that all the important yield attributing characters of the crop showed a positive trend towards the treatment K3 (225 g K_2O plant^{-1}).

In banana the characters numbers of hands bunch^{-1}, number of fingers bunch^{-1}, weight of hand and length, girth and weight of finger are considered determinants of yield (Stover and Simmonds, 1987). Correlation analysis conducted during the present investigation also indicated positive relationship between these factors and yield. The different K treatments tried in the present study caused significant variation for the characters, number of hands bunch^{-1}, number of fingers bunch^{-1} and weight of hand. The level K3 registered the maximum values for these characters. Even though not significant the highest values for the other characters viz. length, girth and weight of finger were also recorded by K3.

The favourable disposition of all these factors at K3 level was reflected on the bunch yield also; The bunch yield of 10.47 kg recorded by this treatment was significantly higher than that by all other treatments. Increased bunch yield through the direct contribution of number of hands and fingers bunch^{-1} was reported by Teaotia *et al.* (1970), Sreerangaswami et al. (1980), Vijayaraghava Kumar (1981), Krishnan and Shanmughavelu (1983) and Kurien *et al.* (1985) based on genetic analysis of yield characters.

The effects of different K levels on the size of the whole bunch and representative hand and finger are depicted in plates 1,2,3 and 4.

Among the morphological characters the girth of the pseudostem at shooting stage was reported to be a determinant of yield by Krishnan and Shanmughavelu (1983) and Rosamma and Namboothiri (1990). The treatment K3 registered the maximum girth of pseudostem at 20 cm height at shooting stage. This might have also contributed to the high yield recorded by K3.

Other characters which showed positive and significant correlation with yield in this study and for

Plate Nos. 1 & 2. Effect of K levels on size of bunch in banana cv. Nendran

Plate No. 3. Effect of K levels on size of second hand in banana cv. Nendran

Plate No. 4. Effect of K levels on size of index finger in banana cv. Nendran

which treatment K3 recorded maximum values were leaf area and leaf area index at shooting, K content and uptake in the rhizome at bunch maturation and harvest stages, K content and uptake in the pseudostem at harvest and total Fe and Mn uptake at harvest. Positive and significant correlation between bunch yield and total leaf area at shooting stage in banana cv. Robusta as a consequence of enhanceed photosyn thesis was reported by Krishnan and Shanmughavelu (1983). The possibility of the rhizome and pseudostem acting as storage organs of excess K in banana and as circulation pumps for distribution of the same to the bunch at bunch maturation and harvest stages has been reported by Huang *et al.* (1992). All these factors might have contributed to the higher bunch yield at K3 level.

The decrease in yield attributes and yield above K3 level may be explained on the basis of critical soil level, the determination of which formed a part of this study. The critical soil levels at all the growth stages were found to be around or slightly less than the initial test value of the soil which itself was high. So to maintain the soil fertility at these levels, application of fertilizer at the K3 level (225 g K_2O plant^{-1}) itself was sufficient. The higher levels of K application seem to have induced only vegetative growth and nutrient uptake without resulting in effective diversion of the same to the economic part. Yet another reason for decreased yields above K3 level might be due to the nutrient imbalances caused by excessive K uptake.

5.8.1. Path coefficient analysis of yield parameters in banana cv. Nendran

The yield parameters considered to be the most important in banana were selected for studying their direct and indirect effects on yield. They included number of hands $bunch^{-1}$, number of fingers $bunch^{-1}$, weight of hand, length of fruit, girth of fruit, weight of fruit and length of bunch. All of them except the length of bunch showed significant positive relationship with yield. Path coefficient analysis technique was employed to study the cause and effect relationship of these factors with yield.

The results presented in Table 23 and illustrated in Figure 11 indicated that among the yield parameters, number of fingers $bunch^{-1}$ had the maximum direct effect (0.5809) on yield followed by girth of fruit (0.4514) and

Table 23 Direct and indirect effects of yield parameters on yield in banana cv. Nendran

Parameters	Direct effect	Indirect +	Indirect −	Total correlation	Maximum indirect effect +	Maximum indirect effect −
(X_1) Number of hands $bunch^{-1}$	0.0800	0.6968	0.0720	0.705**	0.4091(X2)	0.0624(X4)
(X_2) Number of fingers $bunch^{-1}$	0.5809	0.1380	0.0585	0.660**	0.0564(X1)	0.0439(X4)
(X_3) Weight of hand	0.3486	0.4794	0.0912	0.737**	0.3023(X5)	0.0802(X4)
(X_4) Length of fruit	−0.1394	0.8835	0.0052	0.739**	0.3894(X5)	0.0052(X7)
(X_5) Girth of fruit	0.4514	0.3770	0.1248	0.704**	0.2335(X3)	0.1202(X4)
(X_6) Weight of fruit	0.0844	0.7297	0.1224	0.692**	0.4378(X5)	0.1194(X4)
(X_7) Length of bunch	0.0204	0.3411	0.0354	0.326	0.1486(X2)	0.0354(X4)

Residue = 0.20 ** Significant at 1% level

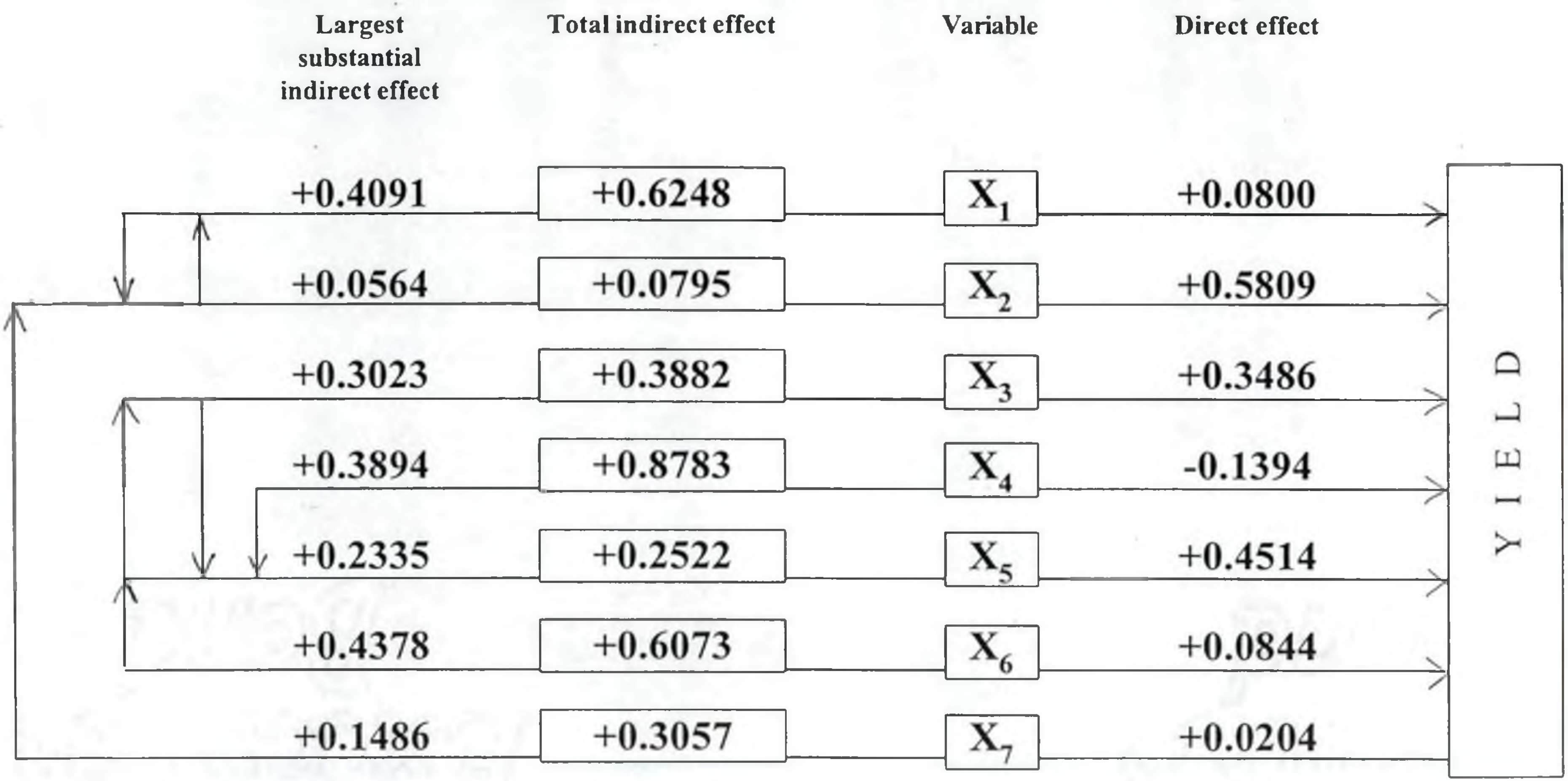


Fig. 11. Path analysis of yield attributes in banana cv. Nendran

weight of hand (0.3486). The influence of the parameter number of hands $bunch^{-1}$ on yield was indirectly through the character number of fingers $bunch^{-1}$ (0.4091). Similarly length and weight of fruit did not have substantial direct effect on yield, but had indirect effect through the character girth of fruit (0.3894 and 0.4378 respectively). The results are in confirmity with the reports by Teaotia *et al.* (1970), Sreerangaswami (1980), Krishnan and Shanmughavelu (1983) and Kurien *et al.* (1985).

5.9 Quality characters in banana cv. Nendran as influenced by K nutrition

The results presented in Table 19 highlight the role of K in banana nutrition in improving the quality of the produce. Total, reducing and non reducing sugars, pulp-peel ratio and shelf life, the characters which decide the quality of banana fruit were favourably and significantly influenced by K nutrition. The other quality characters namely total soluble solids, acidity, sugar-acid ratio, protein and Vitamin C contents showed definite improvement with increase in K levels, though statisticaly not significant.

The total sugars were maximum at the highest level of K application and minimum at the control. Reducing sugars, on the other hand, showed a reverse trend (Figure 12). Nitsos and Evans (1969) proved that deficiency of K resulted in decreased activity of the enzyme sucrose synthetase and increased activity of hydrolytic enzymes such as amylase and saccharase. This led to accumulation of soluble carbohydrates especially monosaccharides. On the other hand an adequate K supply ensured optimal functioning of sucrose synthetase and suppression of hydrolytic enzymes, the net result of which was the built up of greater quantity of sugars in the proplastids. Perrenoud (1977), Beringer (1978), Terra *et al*. (1983) and Prevel (1989) also cited similar evidences. The non reducing sugar content being a computed derrivative of the total and reducing sugar contents followed the same trend as that of total sugars, showing increasing trend with increasing K levels. Agreeing reports have been put forward by Ramaswamy *et al*. (1977) and Vadivel and Shanmughavelu (1978).

The pulp peel ratio showed maximum value at the highest level of K application, (Fig. 13). The minimum value

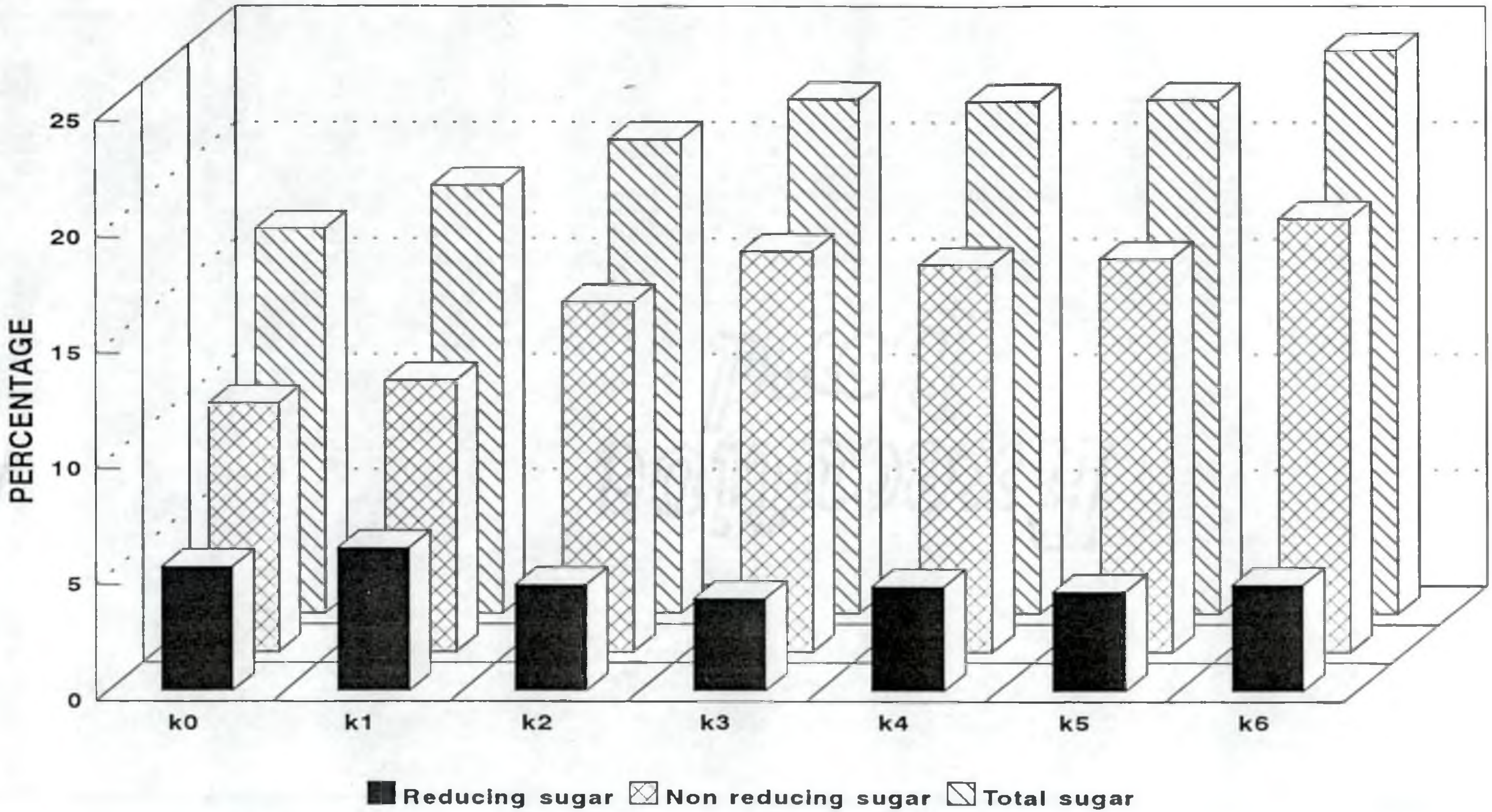
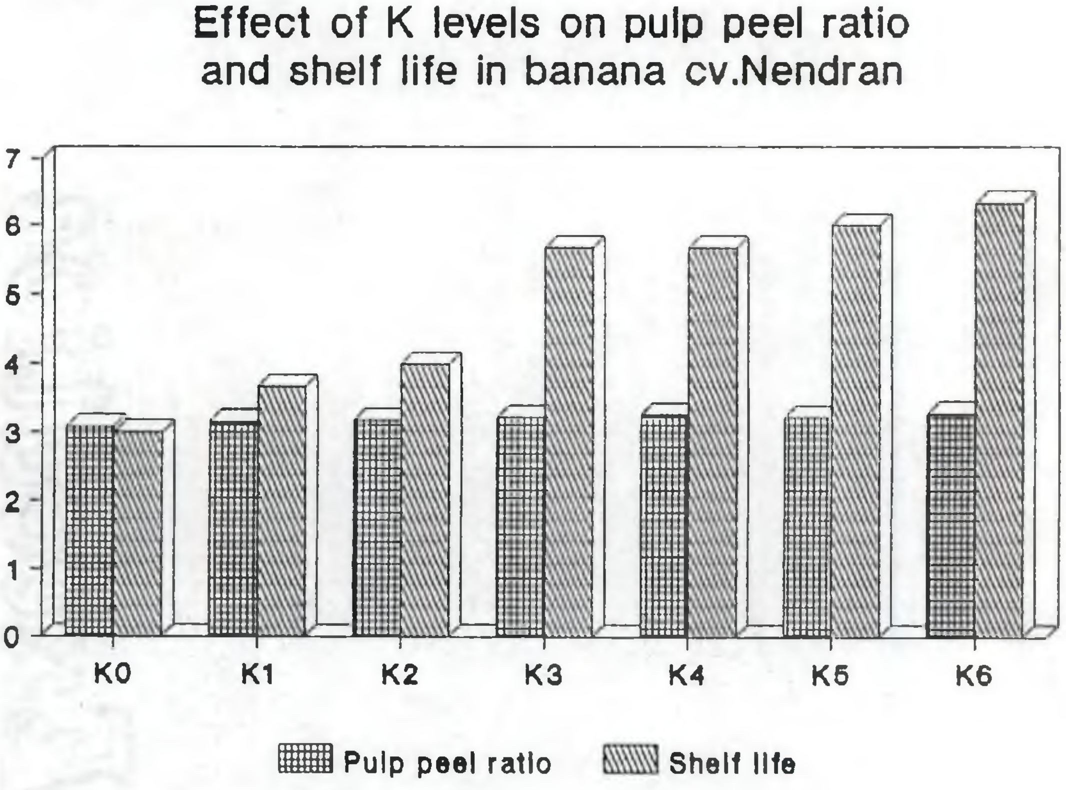


Fig. 12. Effect of k levels on reducing sugar, non reducing sugar, and total sugar in banana cv. Nendran

Fig:13


Effect of K levels on pulp peel ratio
and shelf life in banana cv.Nendran
7
6
5
4
3
2
1
0
K0
K1
K2
K3
K4
K5
K6
Pulp peel ratio
Shelf life

was in the fruits of the control plot. The increase in pulp-peel ratio with higher K levels was mainly due to the increase in pulp weight which was the consequence of satisfactory activity of the enzymes involved in starch and protein synthesis under an adequate supply of K. Sheela (1982) and Prevel (1989) reported similar results.

The shelf life of the fruit at room temperature was the highest at the highest K level and the lowest for the fruits from the control plot. The appearance of brown spots on the peel was taken as an index of detioration of fruit quality. Prevel (1989) observed an enhanced production of ascorbic acid under the influence of K which was responsible for the slowing down of oxidation processes responsible for enzymatic browning on the peel of the banana fruit. Mulder (1956) and Almazan (1991) reported increased respiration under conditions of K deficiency to produce ATP to compensate for low production of the same as a result of poor photo phosphorylation. This increased respiration led to cell wall degradation as a consequence of pectin solubilization under enhanced activity of the enzymes polygalacturonase and pectin esterase. The findings of the present study are in agreement with the findings of Uexkull (1970) and Uexkull and Bosshart (1986) who attributed the improvement in storage life to the increased firmness of the pulp and rind brought about by K nutrition.

5.10 Soil status of exchangeable K, Ca and Mg at different growth stages of banana cv. Nendran as influenced by K application

Application of potassic fertilizers caused significant variation in the exchangeable K and Ca contents of the soil at all the major growth stages of the crop (Table 20). The treatments significantly affected the exchangeable Mg content only at the post shooting and harvest stages.

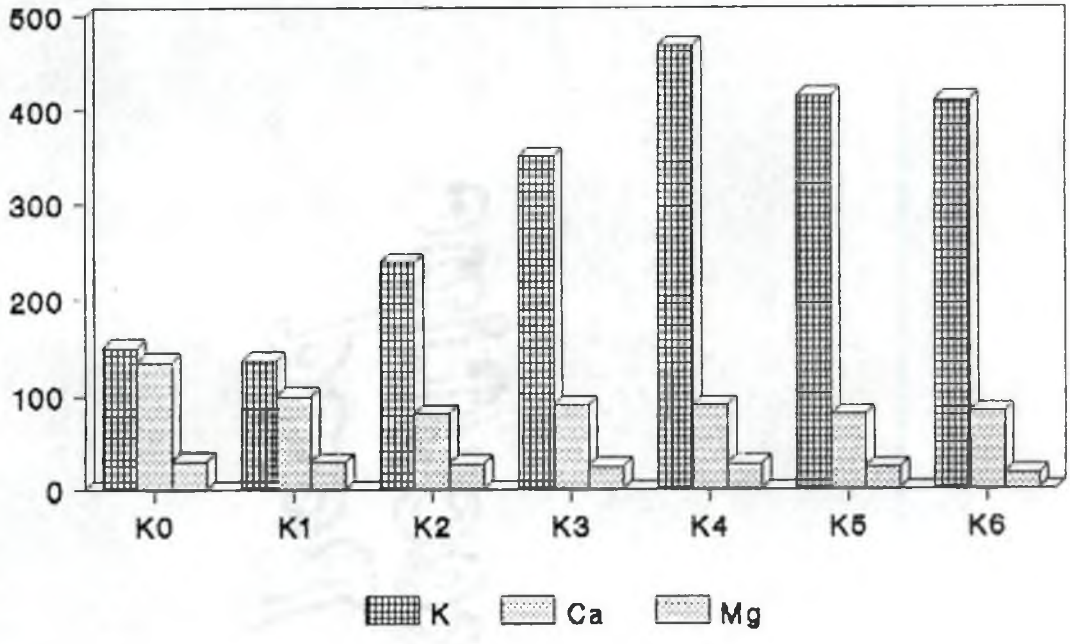
The higher levels of K application resulted in the highest contents of soil exchangeable K at all the stages. In most cases the highest level, K6 (600 g K_2O plant^{-1}) registered the maximum values while the control recorded the minimum values. Above K4 level of application (300 g K_2O plant^{-1}) the exchangeable K contents did not vary significantly among the treatments. Out of 649.80 mm of total rainfall received by the crop 83 per cent was during the period upto the shooting stage during which time fertilizer application was also practiced. The major clay type of the soil being kaolinitic as evidenced by low cation exchange capacity, the excess fertilizer might have been lost through leaching.

The exchangeable Ca status of the soil, on the other hand showed a decreasing tendency with increase in applied K levels, the maximum values being recorded by the control or by the lower levels of K application.

The exchangeable Mg status of the soil also showed the same trend as that by Ca even though the effects were not significant except at the post shooting and harvest stages. At these stages the control level recorded the maximum values.

The behaviour of these three elements can be considered together as these are interacting elements and ionic equilibrium relationship exists between them. Beckett (1964) suggested the equilibrium activity ratio AR ^{k}e, ak/ a Ca+Mg as a satisfactory estimate of the availability of K. Addition of potassic fertilizers can increase this ratio (Tisdale *et al*., 1985) which simultaneously reflects on increased ionic concentration of K in the solution in

Fig: 14 Effect of K levels on soil content of exchangeable K,Ca and Mg under banana cv.Nendran at harvest stage



equilibrium with the soil and decreased that of Ca and Mg. These types of antagonistic associations between K and Ca and between K and Mg in banana as the result of monovalent divalent interaction have been reported by Fabregar (1986) and Prevel (1989).

The less pronounced effect of k-Mg antagonism in the present study might be due to the lower concentration of exchangeable Mg in the soil compared to exchangeable Ca (Table 1). Exchangeable Mg constituted only 21 per cent of exchangeable Ca content.

5.11 Indexing of plant part in banana cv. Nendran for K status

Lundegardh (1935) defined index plant part as that part of a plant which gives the highest predictability on yield. This is on the assumption that there is an emperical relationship between the nutrient content of a properly selected plant part and the final performance of the plant. Usually the leaf is selected for foliar analysis being the focal point of all the biochemical functions of the plant. In banana the third leaf has been reported to be the index leaf (Hewitt, 1955; Lahav, 1972c; Boland, 1980 and Prevel *et al.* 1986). It has the advantage of having fully matured, but not entered the phase of senescence.

Even within each half of the blade considerable spatial variability in mineral content exists both transversely and longitudinally. Lahav (1972 b) showed that a five cm. longitudinal displacement of the leaf area sampled could give a difference in K content equivalent to that from the application of K fertilizer. Prevel *et al.* (1986) found that the relative change in the K concentration in the banana leaf from the base to the tip was 85 per cent. The large size of the leaf also makes whole leaf sampling impractical. Usually the inner half of the leaf is selected as the margins may be scorched by salinity or wind.

In the present study the midrib, lamina and petiole portions of the third leaf upto shooting and of the flag leaf there after were selected as described below.

Petiole:- Distal half portion.

Midrib:- Five cm. piece of midrib exactly half way along the leaf.

Lamina:- Five cm wide strip across the leaf on either side of the midrib sample.

The flag leaf was selected as it is reported to contribute maximum to yield (Chapman, 1975 and Sreedevi *et al.*,1989). The samples were analysed for their K contents which were related to bunch yield using quadratic regression models of the type, $y = a + bx + cx^2$ where y is the yield and x, the K (%) in the plant part. The values for coefficient of correlation obtained at each growth stage of the crop are given below.

	Value for R^2					
Leaf part.	S1	S2	S3	S4	S5	S6
Midrib	0.163	0.627	0.348	0.059	0.120	0.038
Lamina	0.037	0.626	0.047	0.411	0.023	0.305
Petiole	0.363	0.777	0.622	0.606	0.690	0.631

The petiole recorded the highest R^2 values at all the stages of crop growth showing maximum relationship with yield and it was selected as the best index for foliar sampling for K in banana cv. Nendran. Prevel *et al.* (1986) and Langenegger and Du Plessis (1977) also observed that conductive tissues of banana, both petiole and midrib were useful indicators of the cations and suggested the choice of the petiole as it was easier to define and locate a petiole sample than any other leaf part. Ulrich (1945) also found petiole to be the index part in Ladino clover for K status.

Among the different growth stages of the crop the late vegetative stage was selected as the optimum stage for sampling in banana cv. Nendran as the K content of the petiole at that stage was found to hold the maximum association with yield, evident from the highest R^2 value (R^2 = 0.777). Warner and Fox (1977) and Turner (1980) also reported the late vegetative stage before shooting to be physiologically the best time for sampling in banana cv.Williams and Giant Cavendish respectively.

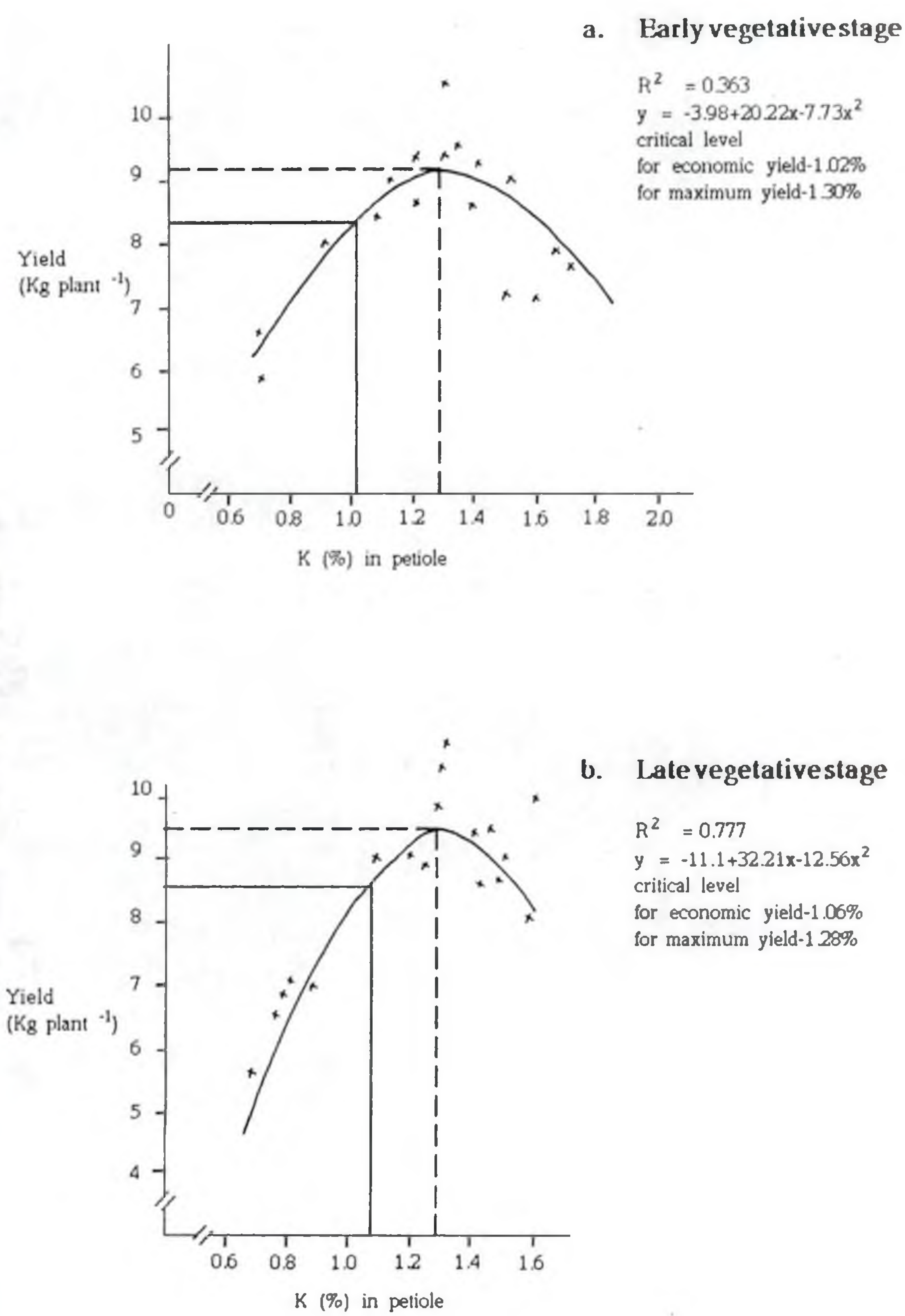
5.12. Critical K level in the petiole for maximum response to fertilizer application and yield

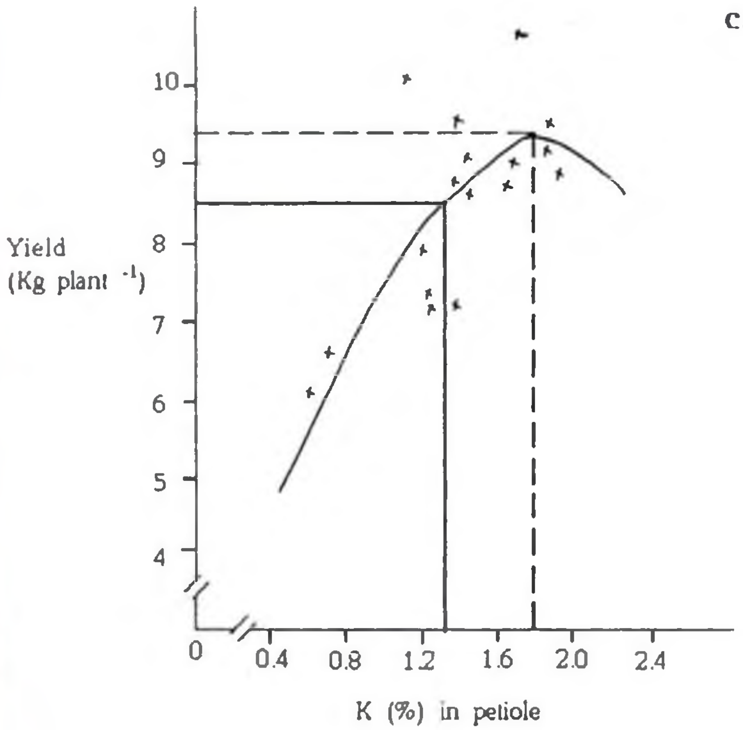
On the basis of the quadratic regression models mentioned above and presented below of the type $y = a + bx + cx^2$ where y = bunch yield and x = K (%) in the petiole, expected bunch yield values were worked out.

Stage of crop growth	Regression model
S1	$Y = -3.98 + 20.22 X - 7.73 x^2$
S2	$Y = -11.10 + 31.21 X - 12.56 x^2$
S3	$Y = -02.26 + 10.50x - 2.89 x^2$
S4	$Y = 0.06 + 7.44 x - 1.53 x^2$
S5	$Y = 0.75 + 6.92 x - 1.38 x^2$
S6	$Y = 2.19 + 5.89 x - 1.19 x^2$

Graphs were plotted at each growth stage relating bunch yield values and petiole K contents (Figures 15a to f). The maximum yields that could be obtained were worked out on the basis of the above regression models. The petiole K concentrations corresponding to these were located on the graph and designated as critical level for maximum yield.

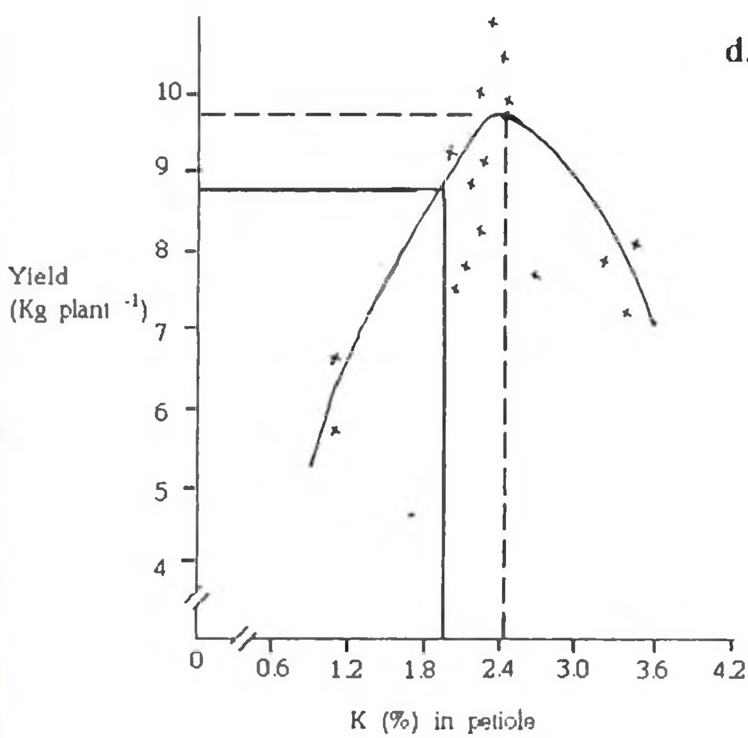
Fig:15 Critical K level in petiole of banana cv.Nendran





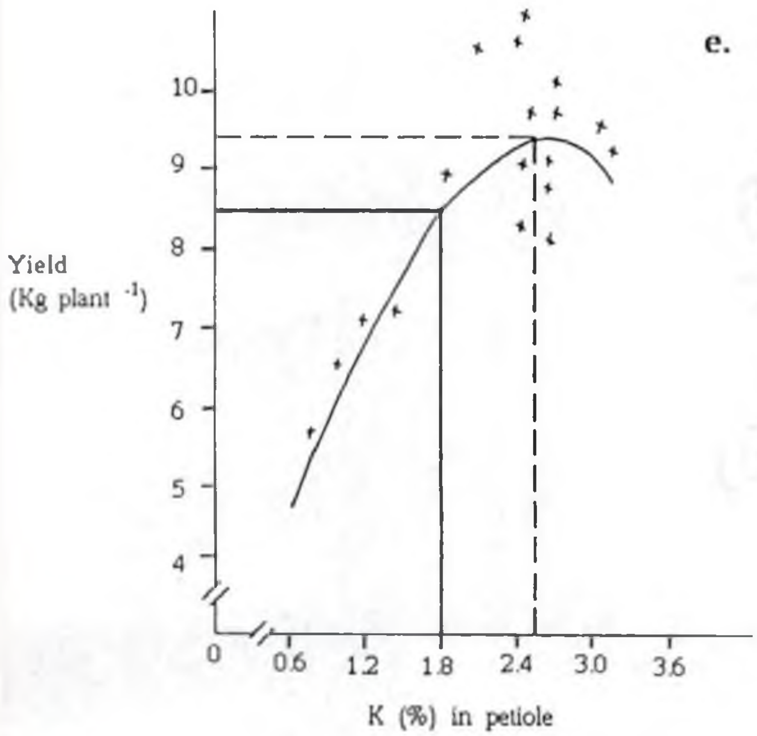
c. Shootingstage

$R^2 = 0.690$
$y = -0.26 + 10.50x - 2.89x^2$
critical level
for economic yield-1.36%
for maximum yield-1.80%



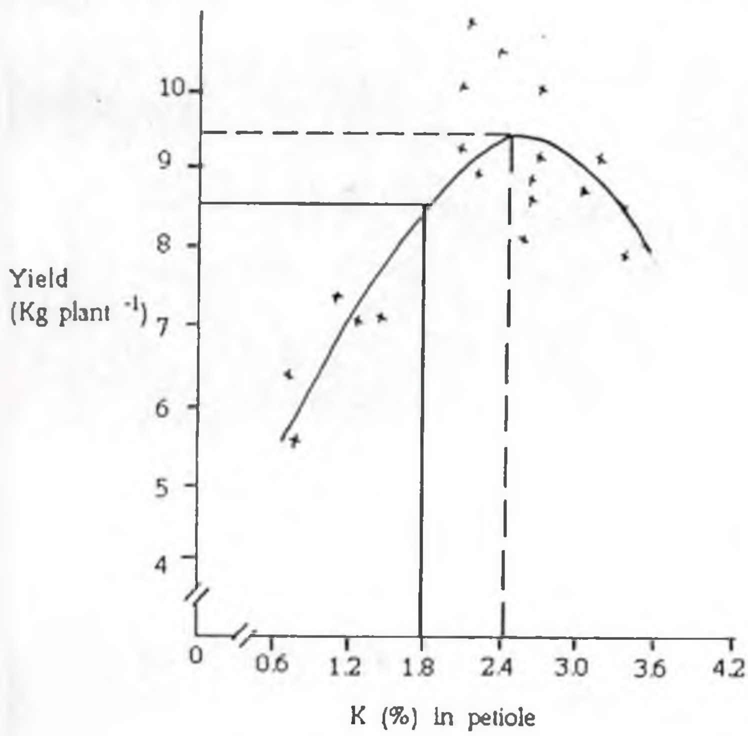
d. Postshootingstage

$R^2 = 0.608$
$y = -0.06 + 7.4x - 1.53x^2$
critical level
for economic yield -1.98%
for maximum yield - 2.43%



e. **Bunchmaturationstage**

R^2 = 0.690
y = $0.75+6.92x-1.38x^2$
critical level
for economic yield -1.80%
for maximum yield -2.50%



f. **Harveststage**

R^2 = 0.631
y = $2.19+5.89x-1.19x^2$
critical level
for economic yield -1.80%
for maximum yield - 2.47%

The critical level for economic yield was then determined on the basis of the definition for the same put forward by Tisdale *et al.* (1985) and Rathore and Manohar (1990). According to them it is a point in the bend of the curve relating nutrient concentration to yield at which yield is 10 per cent less than the maximum. Yield values 10 per cent less than the maximum were worked out, petiole K concentrations corresponding to these located on the graph and designated as critical level for economic yield.

The critical levels determined in this way at the different stages of crop growth are given below.

Stage	Critical K level (%) for	
	Maximum yield	Economic yield
S1	1.30	1.02
S2	1.28	1.06
S3	1.80	1.36
S4	2.43	1.98
S5	2.50	1.80
S6	2.47	1.80

The critical level for economic yield determined graphically was then verified on the basis of response at this level to addition of input. For this the response in terms of increase in yield per unit increase in K concentration was worked out at a definite interval. Illustration of the same is presented below taking the late vegetative stage of the crop as the example as K concentration in the petiole at this stage showed the maximum relationship with yield (R^2 = 0.777)

K concentration in petiole	Yield (kg $plant^{-1}$)	Yield increase per unit increase in K concentration (Kg $plant^{-1}$)
1.00	8.0	---
1.02	8.2	0.2
1.04	8.4	0.2
1.06	8.7	0.3
1.08	8.8	0.1
1.10	8.9	0.1

The critical level at this stage was fixed at 1.06 per cent as the response in terms of yield increase per unit increase in input was maximum at this level. This level actually coincided with that fixed by graphical method also. The results confirm with the definition for critical level put forward by Prevot and Ollagnier (1957) which states that it is the level at which response is maximum and above which response to further increment of input occurs at a diminishing rate.

As the critical nutrient level is dependent on a multitude of genetic and agroclimatic factors, the results of the present investigation can not be compared with the results cited in other literature especially as work of similar nature has not been carried out so far in banana cv. Nendran under Kerala conditions. However critical K levels of 2.9 per cent, 4.0 per cent and 3.1 per cent were reported by Twyford and Walmsley (1973), Vadivel (1976) and Ramaswamy *et al.* (1977) respectively in banana cv. Robusta

5.13 Critical K level in soil for economic yield

The critical K level in the soil was determined both graphically and statistically.

The Scatter diagram technique developed by Cate and Nelson (1965) was adopted to determine the critical K level graphically. The available K content of the soil showed high positive correlation with yield at all the growth stages of the crop. Per cent yield values (Y axis) were plotted against soil test K values (X axis) and the points distributed into four quadrants using plastic over lays. The intersecting point of the line on X axis drawn parallel to Y axis was taken as the soil critical K level at each growth stage of the crop (Figures 16 a to f).

The statistical method of partitioning the soil test-yield variable into two classes proposed by Cate and Nelson (1971) was also followed for determining the soil critical K level. The extract of the important calibrations followed in the determination is given in Appendix 1.

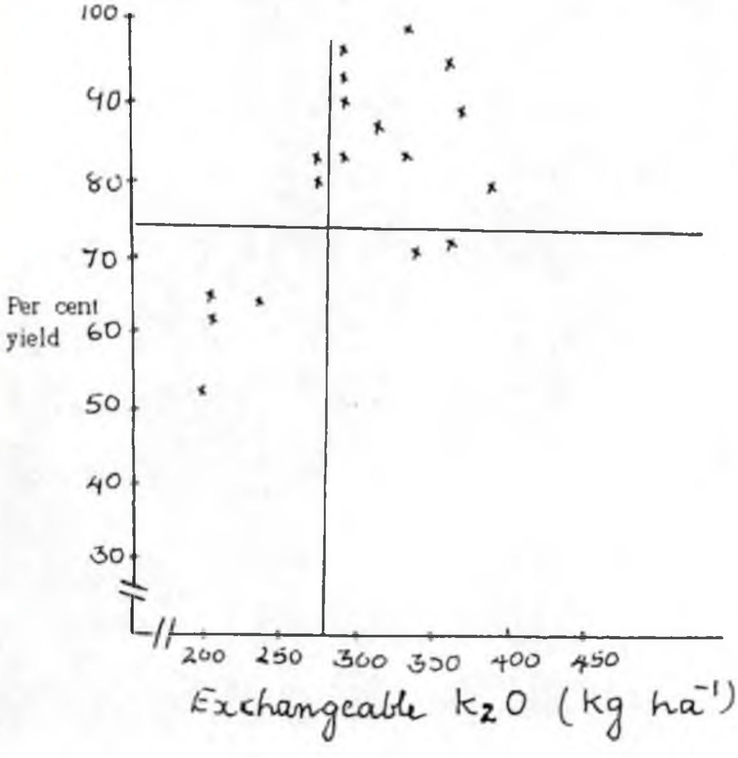
The critical K levels determined by both the methods are presented below. They showed almost agreeing values.

Stage of crop growth	Critical K level (Kg K_2O ha^{-1}) Graphical method	Statistical method	Mean
S1	282	291	286.5
S2	274	279	276.5
S3	268	274	271.0
S4	239	239	239.0
S5	244	246	245.0
S6	234	238	236.0

The results of both the techniques show higher values for soil critical K level at the vegetative stage of the crop compared to later stages implying the need for fertilizer application in the initial stages of crop growth. The relative low levels registered at the later stages might be due to the initial high contents of total and non exchangeable forms of K in the soil which indicate the possibility of only a very slow rate of depletion of exchangeable K from the soil even in spite of heavy crop uptake.

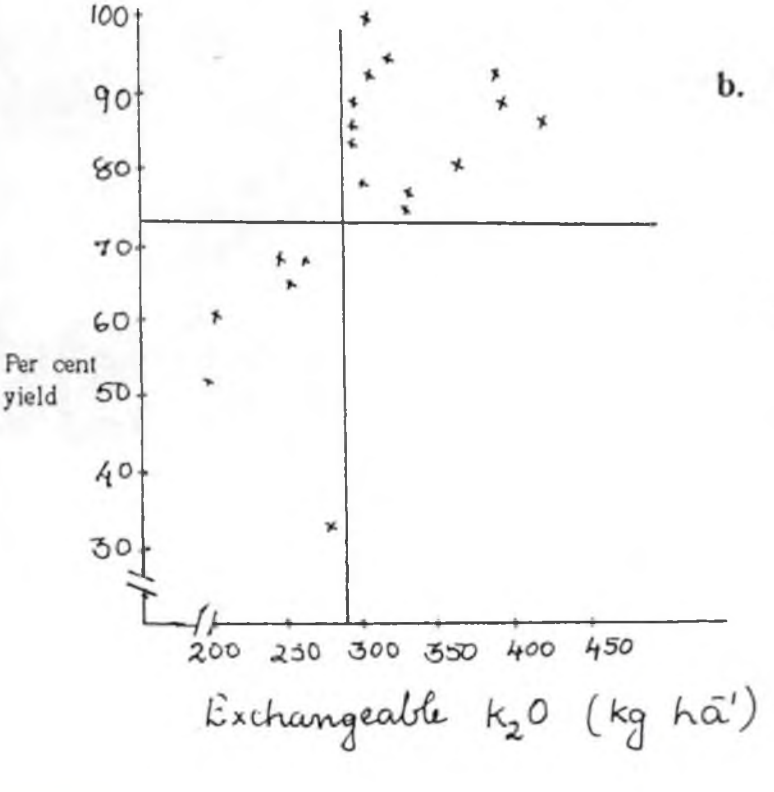
Fig:16 Critical K level in soil under banana cv.Nendran

a. Early vegetative stage

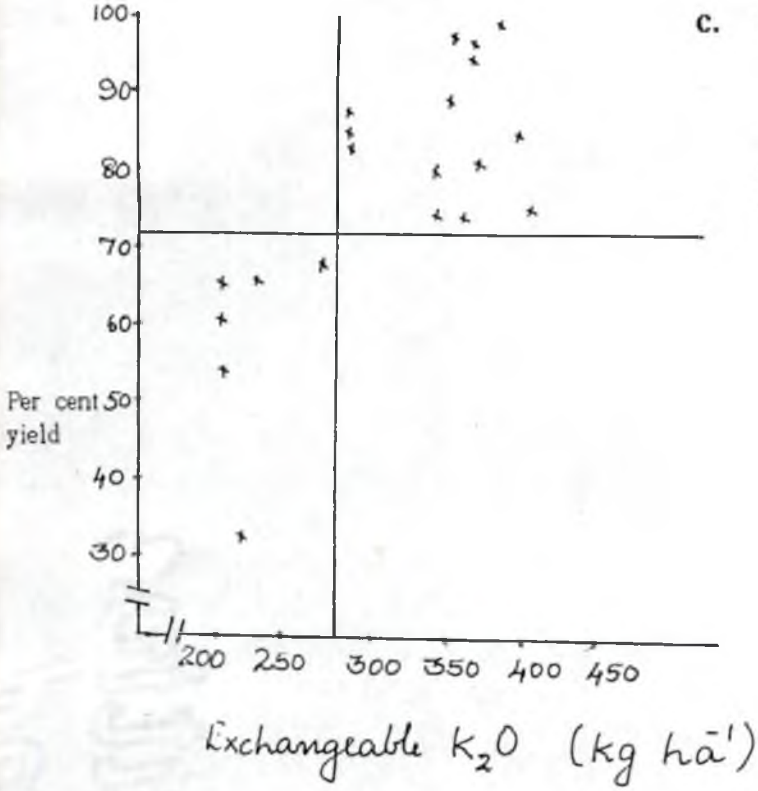


r=0.576**
critical level - 282 Kg K2O ha -1

b. Late vegetative stage

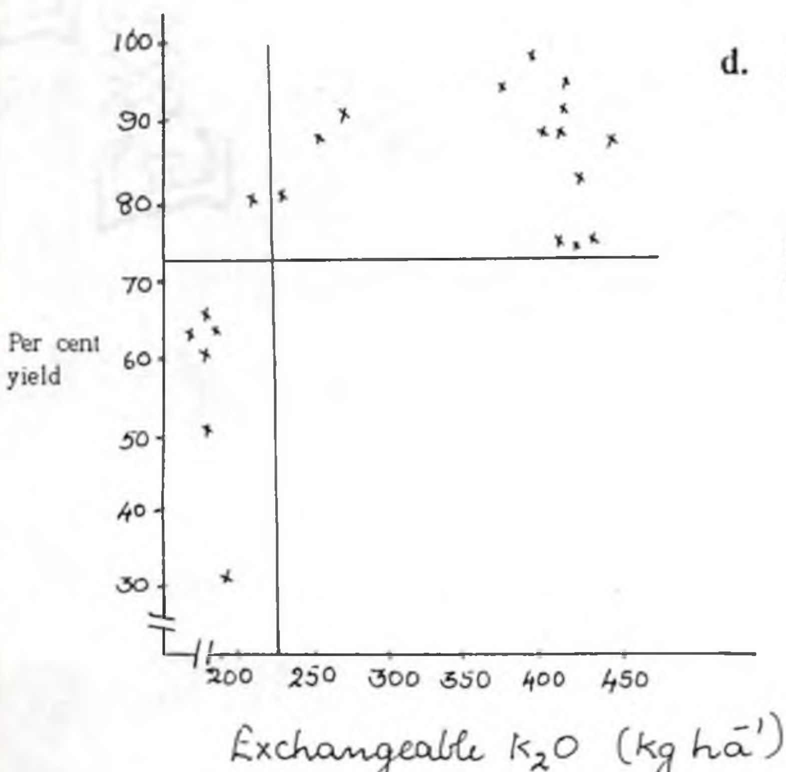


r=0.544**
critical level - 274 Kg K2O ha -1



c. **Shooting stage**

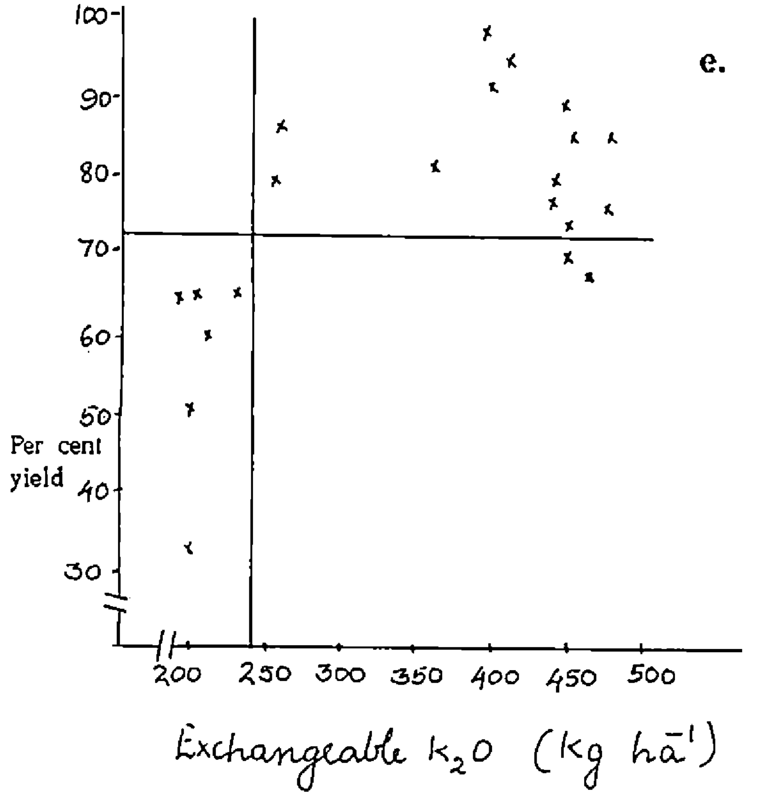
r = 0.703**
critical level - 268 Kg K_2O ha^{-1}



d. **Post shooting stage**

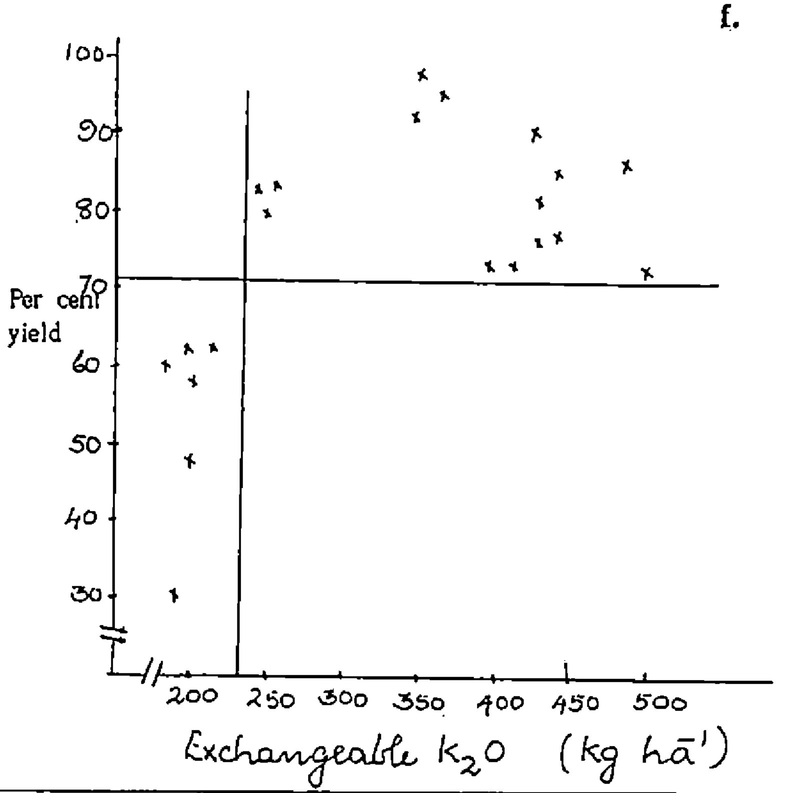
r = 0.638**
critical level - 239 Kg K_2O ha^{-1}

e. **Bunchmaturationstage**



$r = 0.640^{**}$
critical level - 244 Kg K_2O ha^{-1}

f. **Harveststage**



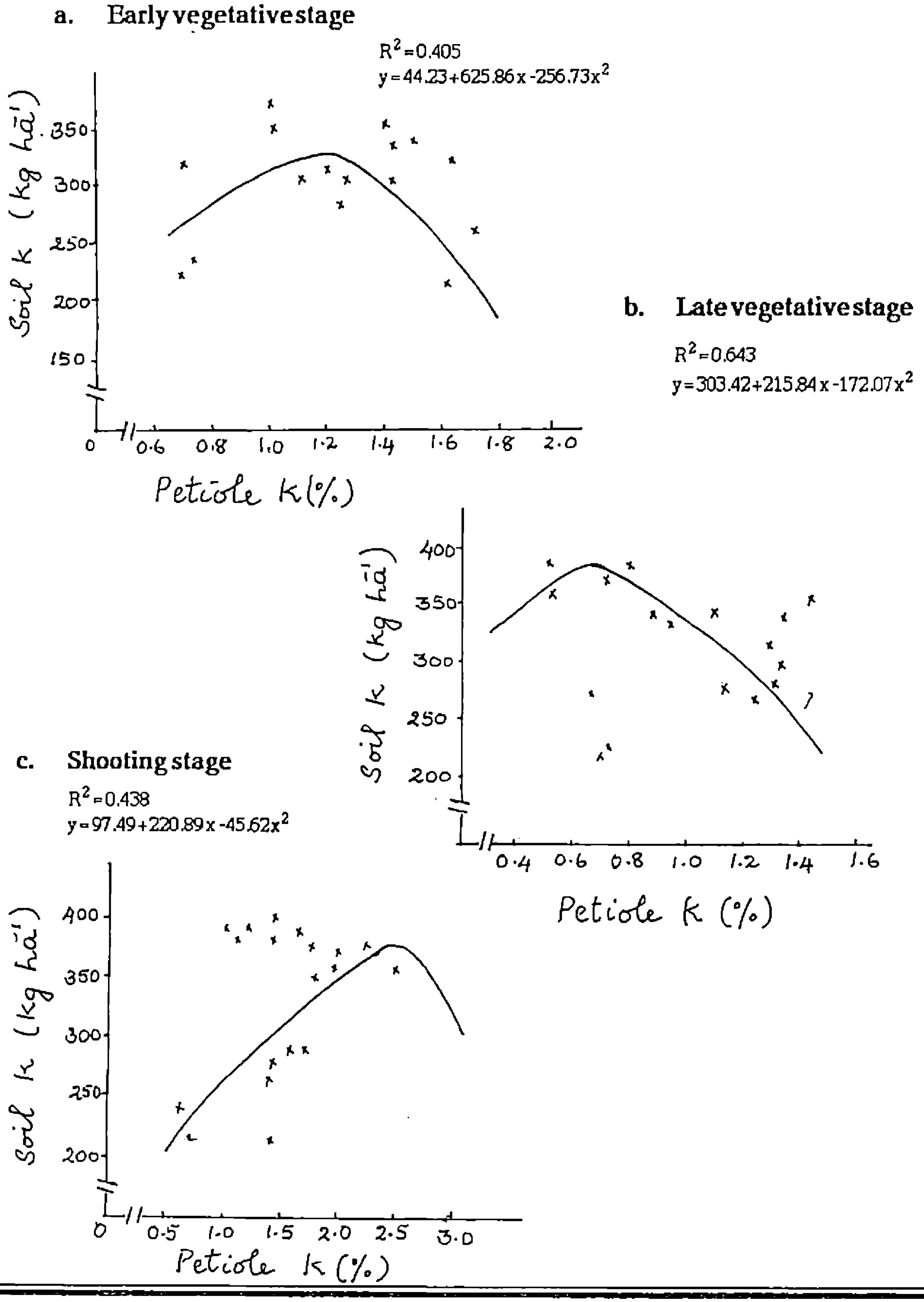
$r = 0.616^{**}$
critical level - 234 Kg K_2O ha^{-1}

5.14. Scheduling of fertilizer application based on plant and soil critical levels

In an ideal soil crop management programme soil and plant analyses should be considered integral mutual supplements. Soil analysis provides quantitative information on the nutrients in the place of their source where as plant analysis provide information on the nutrients in the place of their actual utilization.

On the basis of plant and soil critical values fertilizer programming can be rescheduled at each growth stage of the crop. If the K content in the petiole at a stage is known the soil K status at that stage can be predicted. For this the K contents in the petiole at different growth stages were related to soil K contents using quadratic regression models, $y = a + bx + cx^2$ where y represents the soil K content and x, the petiole K content. Based on these models graphs were plotted for the early vegetative, late vegetative and shooting stages of the crop (Figures 17 a to c). These stages cover the period during which fertilizer application is usually practiced by farmers in Kerala for banana cv. Nendran. These graphs provide

Fig:17 Relationship between soil K and petiole K in banana cv.Nendran



information on the exchangeable K content of the soil if the petiole K content is known.

If the soil test value at a particular stage shows a value higher than the critical value, fertilizer application at that stage can be dispensed with. But if the value is lower than the critical value even after the normal fertilizer application additional fertilizer should be applied to ensure economic yield. To calculate the quantity of fertilizer that is to be applied at a stage to raise the soil test level to the critical level, linear regression equations were developed relating the exchangeable K content of the soil at different growth stages (y) to the different fertilizer doses tried (x).

Stage of crop growth	Regression equation	r	R^2
S_1	y = 250.61+0.21x	0.901**	0.812
S_2	y = 240.57+0.26x	0.898**	0.806
S_3	y = 245.00+0.27x	0.762**	0.581
S_4	y = 211.53+0.44x	0.838**	0.701
S_5	y = 200.18+0.51x	0.833**	0.693
S_6	y = 175.07+0.52x	0.818**	0.668

In the above equations the critical soil level is substituted for y and solving the equation for x gives the quantity of fertilizer that is to be applied for economic yield at that particular stage.

SUMMARY

6. SUMMARY

A field experiment in banana cv. Nendran, the most popular commercial fruit of Kerala was conducted in the B block of the Palappoor area of the Instructional farm attached to College of Agriculture, Vellayani during the period August, 91 to May,92. The main objectives were the selection of the index part for foliar diagnosis for K at different growth stages of the crop and to fix the critical K levels in the index part and in soil for maximum response to fertilizer application and yield. Study of the growth, yield and quality characters of the crop and estimation of the uptake of various nutrients under different levels of K application were undertaken. The quantities of nutrients that could be recycled back to soil by a crop of this variety were also estimated.

The soil belonged to the taxonomic class 'Loamy kaolinitic isohyperthermic aeric tropic fluvaquents' and was medium in N and P and high in K status. The treatments were seven levels of K,viz OK, 0.25K, 0.5K, 0.75K, K, 1.50K and 2K where K represents the Package of Practice recommendation of Kerala Agricultural University for Nendran banana viz 300g

K_2O plant^{-1} The stages fixed for sampling and analysis were early vegetative stage (2 MAP), late vegetative stage (4 MAP), shooting stage (6 MAP), post shooting stage (7 MAP), bunch maturation stage (8 MAP) and harvest stage (9 MAP). The salient findings generated in the course of the study are summarised below.

* The important growth characters of the crop namely height and girth of pseudostem, total number of leaves, functional leaves, total leaf area and leaf area index showed increasing trend with increasing level of K application of all growth stages. The effects of the treatments were more pronounced from the shooting stage of the crop after it had received the full dose of K fertilizer application.

* The total dry matter production was significantly higher at higher levels of K application at the shooting, post shooting, bunch maturation and harvest stages of the crop. At all stages till harvest pseudostem was found to be the largest repository of dry matter followed by leaf blade and rhizome. At harvest the bunch constituted the second richest source of dry matter.

* Uptake of N,P and K showed increasing trend with increasing K supply, the highest K level recording the maximum values in most cases. Ca uptake showed a negative relationship with increasing K application at early stage of growth. Mg uptake showed an inconsistent pattern.

* Uptake of micronutrents Fe,Mn, Cu and Zn showed a general trend of increase upto K_3 level (225 g K_2O plant^{-1})

* Soil content of exchangeable K increased while that of Ca an Mg contents decreased at higher levels of K supply.

* The maximum values for bunch yield (26.18 t ha^{-1}) and yield attributes like number of hands bunch^{-1}, number of fingers bunch^{-1} and weight of hand were recorded at K_3 level (225 g K_2O plant^{-1}) which were significantly superior to the values recorded by all other treatments. The maximum values for other yield attributes like length, girth and weight of finger were also obtained at this level.

* Path coefficient analysis of yield attributes showed that the character, number of fingers bunch^{-1} is having the maximum direct effect on yield followed by girth of fruit and weight of fruit. The largest substantial indirect effect on yield was for the character weight of fruit through the character girth of fruit followed by the character number of hands bunch^{-1} through the character number of fingers bunch^{-1}.

* Quality characters like total sugars, non reducing sugars, shelf life and flesh peel ratio showed increasing trend with increase in K supply. The level K_3 recorded values for these characters which were on par with the maximum values.

* Correlation studies indicated that total K uptake at harvest was maximum correlated with yield (r = 0.861*), Total K uptake at shooting was highly and positively correlated with number of fingers bunch^{-1} (r = 0.475*), total sugar (r = 0.791**) and flesh peel ratio (r = 0.723**). Length and weight of fruit showed positive and significant correlation with total K uptake at late vegetative stage (r = 0.577** and 0.463* respectively)

Soil available K status at all growth stages showed significant and positive correlation with yield. The status at shooting stage had the maximum correlation ($r = 0.703^{**}$).

* The lamina, midrib and petiole portions of the third leaf upto shooting and of the flag leaf there after were sampled to find out the best among them for foliar diagnosis for K. For this the K content in each part at different growth stages was determined. Quadratic regression models were fitted relating the K content in each part with bunch yield. Petiole was selected as the index part as the K content of the same was found to have the maximum relationship with yield at all growth stages.

* The late vegetative stage of the crop (4 MAP) was found to be the most optimum stage for sampling as the K content of the petiole at that stage showed the maximum relationship with bunch yield ($R^2 = 0.777$)

* Graphs were plotted relating the K content in the petiole to bunch yield which provide information on the

critical level of K in the petiole for maximum yield and also the critical level below which maximum response to applied K can be expected. These levels were 1.30 per cent and 1.02 per cent respectively at early vegetative stage, 1.28 per cent and 1.06 per cent respectively at late vegetative stage, 1.80 per cent and 1.36 per cent respectively at shooting stage, 2.43 per cent and 1.98 per cent respectively at post shooting stage, 2.50 per cent and 1.80 per cent respectively at bunch maturation stage and 2.47 per cent and 1.80 per cent respectively at harvest stage.

* Soil critical K level for maximum response was determined both graphically and statistically. The mean of the values obtained by both methods indicated the soil critical K level to be 286.5Kg K_2O ha^{-1} at early vegetative stage, 276.5Kg K_2O ha^{-1} at late vegetative stage, 271.0kg K_2O ha^{-1} at shooting stage, 239.0Kg K_2O ha^{-1} at post shooting stage, 245.0Kg K_2O ha^{-1} at bunch maturation stage and 236.0Kg K_2O ha^{-1} at harvest stage.

* Available K status of the soil at different growth stages could be predicted from the graphs plotted

relating the petiole K content to soil available K content on the basis of quadratic regression analysis.

* Linear regression models were developed relating the soil K content to fertilizer dose to find out the quantity of fertilizer to be applied to bring the soil K level to the critical K level for maximum response if it is below the critical level.

* A balance sheet of nutrients in soil after harvest of the crop was worked out which indicated that 173 Kg ha^{-1} N, 44 Kg ha^{-1} P, 523 Kg ha^{-1} K, 69 Kg ha^{-1} Ca, and 8 Kg ha^{-1} Mg could be recycled back to soil by incorporating the crop residues left after removal of the bunch alone. This operation ensures positive values for the final soil status for all nutrients over the initial status (123 per cent for N, 283 per cent for P, 344 per cent for K, 127 per cent for Ca and 125 per cent for Mg)

* The experiment was conducted in a soil having high status for available K. As per the soil test based recommendation of the department of Agriculture, Kerala, the fertilizer recommendation is 50 per cent of the

normal Package of Practice Recommendation if the available K status of the soil is high. But in the present study yield response could be obtained upto K_3 level of application (225 g K_2O plant^{-1}) which works out to 75 per cent of the package Recommendation for banana. It is generally accepted that banana requires more K for quality improvement than what is required for bunch yield. Considering both yield and quality aspects of the produce, K application level of 225 g K_2O plant^{-1} can be recommended for the sandy clay loam soil of Vellayani having high status for available K. By adopting this recommendation a net fertilizer saving of 75g K_2O plant^{-1} can be achieved which is equivalent to 312.5 kg of muriate of potash costing Rs. 2000 at the present market rate. Over and above this increase in yield obtained by doing so is 4500 kg ha^{-1}. Additional income that could be generated by the way of sale of this at the rate of Rs. 8 kg^{-1} works out to Rs. 36000. Thus a total saving of Rs. 38000 ha^{-1} can be achieved by following the suggested recommendation.

Future line of work

The result of the present investigation especially indexing of plant part and fixing up of critical plant and soil nutrient levels for economic yield need field verification in farmers fields on an extensive scale before they can be commercially recommended. Similar studies may be undertaken in different agroclimatic regions of the state especially in rice fallows using other popular cultivars of banana besides Nendran. Potassium being an element which is not organically tied up in the plant cell, water extract of the same is bound to give results similar to that by traditional extractants. If a step in this line can be achieved, it will mean considerable saving of time and money on the part of a plant scientist.

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* Original not seen

APPENDICES

Appendix I

Main matcorological paramoters (monthly mean) during the cropping period (August, 1991 to May, 1992).

Month	Relative Humidity (%)	Temperature °C Maximum	Temperature °C Minimum	Total Rainfall (mm)
August, 1991	80.7	29.4	23.4	154.5
September, 1991	76.9	30.7	24.1	22.4
October, 1991	80.5	30.8	23.7	205.8
November, 1991	81.6	30.2	23.2	247.1
December, 1991	74.3	30.4	21.9	20.2
January, 1992	72.0	30.3	20.4	35.0
February, 1992	75.3	30.9	21.9	0
March, 1992	72.5	32.1	22.2	0
April, 1992	75.6	33.0	25.4	6.0
May, 1992	80.0	31.7	25.0	90.9

Appendix II

Extract of calibration steps followed in the determination of soil critical K level (Cate and Nelson, 1971)

Stage of crop growth	Postulated	Population I		Population II		R^2
	$\bar{X}$	Mean	CSS1	Mean	CSS_2	
Early vegetative stage	291*	53.12	27.98	87.68	200.07	0.88
	317	64.48	802.27	87.80	199.77	0.48
	327	73.36	1748.53	93.73	1.32	0.10
	353	75.25	1819.96	84.20	0.04	0.06
Late vegetative stage	279*	53.12	27.98	87.68	200.07	0.88
	305	64.48	802.27	87.80	199.77	0.48
	337	73.36	1748.53	83.73	1.32	0.10
	369	75.25	1819.96	84.20	0.04	0.06
Shooting stage	274*	53.12	27.98	87.68	200.07	0.88
	357	64.48	802.27	87.80	199.77	0.48
	372	69.45	1098.08	98.95	183.81	0.33
	375	72.37	1268.73	91.41	147.75	0.27
Post shooting stage	239*	53.12	27.98	87.68	200.07	0.88
	402	64.78	802.27	87.80	199.77	0.48
	411	73.76	1748.53	83.73	1.32	0.10
	418	75.25	1819.96	84.20	0.04	0.06
Bunch maturation stage	246*	53.12	27.98	87.68	200.07	0.88
	383	64.48	802.27	87.80	199.77	0.48
	433	73.36	1748.53	83.73	1.32	0.10
	444	75.56	1844.97	83.43	0.76	0.05
Harvest stage	238*	53.12	27.98	87.68	200.07	0.88
	249	64.48	802.27	87.80	199.77	0.48
	409	73.36	1748.53	83.73	1.32	0.10
	413	75.56	1844.97	83.43	0.76	0.05

* Critical K level at that stage

ABSTRACT

A field experiment in Musa (AAB group) Nendran, the most popular commercial fruit crop of Kerala was undertaken from August, 1991 to May, 1992 with seven graded levels of K as treatments replicated thrice. The soil, medium in N and P and high in K status belonged to the taxonomic class 'loamy kaolinitic isohyperthermic aeric tropic fluvaquents'

The effects of higher levels of K on all important growth characters of the crop like height of pseudostem, girth of pseudostem at different heights from the ground level, total number of leaves, number of functional leaves, total leaf area, leaf area index and total dry matter production were more pronounced from the shooting stage of the crop after the plants had received the full dose of K supply.

Uptake of major nutrients N,P and K showed increasing trend with increase in K supply. Uptake of Ca showed a negative relationship with increasing K application

while Mg uptake showed an inconsistent pattern. Uptake of micronutrients Fe, Mn, Cu and Zn were maximum at K_3 level of application (225 g K_2O plant^{-1}). Soil content of available K increased while exchangeable Ca and Mg contents decreased at higher levels of K supply.

The maximum bunch yield of 26.18 t ha^{1-} which was significantly higher than all other treatments was recorded at K_3 level (225 g K_2O plant^{-1}) This level also resulted in maximum values for all the yield attributing characters like number of hands bunch^{-1}, number of finger bunch^{-1}, weight of hand, length of finger, girth of finger and weight of finger. By adopting this recommendation a net fertilizer saving of 75g K_2O plant^{-1} can be achieved which is equivalent to 312.5 kg of muriate of potash costing Rs. 2000 at the present market rate. Over and above this, increase in yield obtained by doing so is 4500 kg ha^{-1}. Additional income that could be generated by the way of sale of this at the rate of Rs. 8 kg^{-1} works out to Rs. 36000. Thus a total saving of Rs. 38000 ha^{-1} can be achieved by following the suggested recommendation.

Path coefficient analysis of yield attributes showed that the character number of finger bunch^{-1} is having the maximum direct effect on yield followed by girth of fruit and weight of fruit.

Quality characters of the fruit namely total and non reducing sugars, shelf life and flesh peel ratio showed significant and positive trend towards K nutrition. Correlation coefficient were worked out between bunch yield and important crop characters. Balance sheet of nutrients in soil after harvest of the crop was worked out to assess the final soil status of nutrients in relation to the initial status.

Petiole of the third leaf up to shooting stage of the crop and that of the flag leaf there after was selected as the index of K status of the plant as the K content of the same was found to hold the maximum relationship with bunch yield at all the growth stages. The critical K levels in the petiole for maximum yield as well as maximum response to fertilizer application at each stage were determined which were found to be 1.30 per cent and 1.02 per cent respectively at early vegetative stage, 1.28 per cent and 1.06 per cent respectively at late vegetative stage, 1.80 per cent and 1.36 per cent respectively at shooting stage, 2.43 per cent and

1.98 per cent respectively at post shooting stage, 2.50 per cent and 1.80 per cent respectively at bunch maturation stage and 2.47 per cent and 1.80 per cent respectively at harvest stage. The critical K content in soil for economic yield worked out to 286.5 kg K_2O ha^{-1} at early vegetative stage, 276.5 kg K_2O ha^{-1} at late vegetative stage, 271.0 kg K_2O ha^{-1} at shooting stage, 239.0 kg K_2O ha^{-1} at post shooting stage, 245.0 kg K_2O ha^{-1} at bunch maturation stage and 236.0 kg K_2O ha^{-1} at harvest stage. Graphs were plotted relating petiole K content to soil K content at important growth stages of the crop based on quadratic regression models to provide information on soil K content at a particular stage if the petiole K content at that stage is known. Linear regression models were developed relating soil K content to fertilizer dose to find out the quantity of fertilizer to be applied to bring the soil level to the critical level.