PREDICTION OF POTASSIUM FERTILIZER REQUIREMENT OF BANANA, *MUSA* (AAB GROUP) 'NENDRAN'

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled "Prediction of potassium fertilizer requirement of 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 "Prediction of potassium fertilizer requirement of banana, Musa (AAB group) Nendran" is a record of research work done independently by Miss SINDHU.J. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship.

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LIST OF ABBREVIATIONS USED IN THIS THESIS

m	-	Metre
cm	-	Centi metre
mm	-	Milli metre
ppm	-	Parts per million
%	-	Percent
N	-	Normal
dS	-	Deci siemens
cmol	-	Centi mole
g	-	Gram
kg	-	Kilogram
t	-	Tonnes
^{o}C	-	Degree celcius
G	-	Granule
EC	-	Emulsifiable concetrate
cv	-	Cultivar
LAI	-	Leaf area index
TSS	-	Total soluble solid
MAP	-	Month after planting
ANOVA	-	Analysis of variance
df	-	Degree of freedom

INTRODUCTION

INTRODUCTION

Banana, the `Queen of tropical fruits' is one of the oldest fruits cultivated by man from pre-historic times, as evidenced from the vedic literature. It is the leading tropical fruit in the world market today with a highly organized and developed industry. The crop is grown extensively in India, African countries, Philippines and other tropical countries for home consumption as well as for export.

The importance of growing bananas in a tropical country like India is great, as it plays a vital role both in the internal and international trade. The country contributes 11 percent of world's production of bananas and ranks second among banana producing countries of the world.It occupies an area of 325 700 hectares with an annual production of 6 056 400 tonnes which corresponds to 9.75 percent of the total area and 21.45 percent of the total production of fruit crops in India.(Anon.,1990)

In Kerala, banana occupies an area of 72 146 hectares with a production of 573 668 tonnes(Anon.,1996). Of the various varieties of banana cultivated in Kerala, Nendran, belonging to French plantain group is the most popular commercial variety grown in 23 850 hectares. It is well known for its uses as a dessert and cooking variety and also forms the raw material for several processed foods such as flour, chips etc.

Eventhough Kerala ranks first in area, it has the seventh position in production within the country. Lack of location and soil specific management practices and fertilizer schedule is the reason for such a situation. Being an exhaustive crop, banana requires sound fertilizer programme for obtaining maximum yield.

It is observed that banana requires larger quantities of K, moderate quantities of N and relatively lower doses of P. Although potassium does not form part of the structure of plant constituents, it regulates many vital functions like carbon assimilation, translocation of proteins and sugars, water balance in plants, maintaining turgor pressure in the cell, root development, improving quality of fruits by maintaining desirable sugar to acid ratio, ripening of fruit and many other processes. Potassium is thus proved to be the most important nutrient influencing both the quantitative and qualitative aspects of the crop and proper management of this nutrient has become pertinent to obtain high yield of quality fruits. This prompted many scientists to undertake investigations in these aspects. But information on the reappraisal of the present fertilizer schedule for need based application of potassium fertilizer to ensure maximum efficiency is very limited.

Keeping this in view, the present study was conducted in farmer's field with the following objectives.

(i) To determine the effect of different doses of potassic fertilizer on the biometric, yield and quality parameters of banana cv. Nendran.

(ii) To standardise the index plant part for potassium status.

(iii) To find out the critical potassium level in the index plant part and in the soil for maximum response to yield.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Banana is one of the most important remunerative tropical fruit crops, requiring liberal supplies of water and nutrients for optimal growth and higher productivity. Among the plant nutrients, potassium is one of the most important elements for banana and the crop responds readily to the application of potassic fertilizers. Reports from all over the banana growing countries suggest that the efficient use of this nutrient plays a major role in increasing production as well as reducing the cost of cultivation.

Considerable research work has been done on the potassium nutrition of banana and the literature relevant to the subject under study are reviewed.

2.1 Potassium in banana nutrition.

Manurial experiments by Fawcett as early as in 1921 revealed that N and K are required in large amounts by banana.

Croucher and Mitchell (1940) reported that the demand for K in banana is invariably high, but the response to applied K depends upon its content in soil.

According to Norris and Ayyar (1942), banana plants require large quantities of K, moderate quantities of N and relatively little P for optimum production.The profound effect of K in banana was also reported by Hewitt and Osborne (1962) and Rajeevan (1985).

Twyford (1967) found that the content of potash was always the highest among the nutrients analysed; it is often between 2.2 and 4.6 times as that of N and critical manuring of N,P and K could be done in the ratio of 4:1:14.

Banana responds well to K when applied during shooting and fruit development stages (Yadav et al., 1988).

In an exhaustive work to study the effect of K in banana, Buragohain and Shanmughavelu (1990) found that banana plant contained a higher amount of K (2.99 percent) at shooting than any other nutrient.

2.2 Deficiency symptoms of K in banana.

According to Simmonds and Hutchinson (1953), K deficiency was expressed by satisfactory early growth, but afterwards the older leaves turned yellow at tip and distal margins with the yellowing rapidly spreading in proximal direction until the whole leaf withered.

In Gros Michel banana, the deficiency of K led to brown to purplish brown flecks along the edge and upper surface of the petiole. The older leaves showed yellowing through the midrib and the leaves curved with tip pointed towards the base. The plants were stunted in appearance. (Freiberg and Steward, 1960).

Hasselo (1961) reported that occurrence of pre-mature yellowing in 8-10 month old Lacatan banana was associated with a low leaf content of K which may be caused by the low K level in the soil.

Twyford (1965) observed yellowing and drying of leaves at shooting or at later stages of crop development, reduction in bunch weight and inferior fruit quality as a consequence of K deficiency.

In a sand culture experiment, Lahav (1973) noted that K starvation of banana caused growth reduction in terms of shorter pseudostem height and circumference, and smaller and thinner leaves.

Obiefuna and Onyele (1988) reported that insufficient K led to accelerated leaf senescence, lodging and delayed flowering for 2-3 months.

2.3 Effect of K on biometric characters.

The direct effect of fertilizers is first manifested on the morphology and growth of plants which in turn reflect on the yield. The influence of K on the vegetative growth characters is revealed by increased height and girth of plant, number of leaves, leaf area etc. Increased vigour and better plant development were reported in Lacatan banana (Wood, 1939) and Gros Michel banana (Hernandez Medina and Lugo Lopez, 1967)

2.3.1 Height and Girth of plant.

According to Ho (1968), the application of potash in the early stages gave the largest height and girth of stem in banana.

Turner and Bull (1970) observed that in banana cv. Robusta, higher rates of K application increased the pseudostem height and girth.

Based on the study conducted as a sand culture experiment receiving six levels of K ranging from 0 to 292 ppm, Lahav (1972 a) postulated that pseudostem height and circumference were smaller in plants receiving low K levels.

Report by Jambulingam et al. (1975) provide evidence for the increased height and girth of pseudostem in banana cv. Robusta by increasing K application in soil.

Studies on K nutrition in rainfed banana cv. Palayankodan, Sheela (1982) revealed that the different K levels tried ranging from 0 to 600 g K_2O per plant did not influence the girth of the pseudostem at any stage of the plant growth. The height of the pseudostem at late vegetative stage and shooting stage were influenced significantly.

Baruah and Mohan (1985) reported that height and diameter of the pseudostem responded significantly to K with highest effect at 250 g per plant in Cavendish banana.

According to Fabregar (1986), girth of pseudostem increased with increasing rates of K application upto 800 kg ha^{-1} yr^{-1} in banana cv.Umalag.

Mustaffa (1987) studied the effect of increasing doses of K fertilizer on banana cv.Robusta and found that increased K levels significantly increased the height and circumference of the pseudostem. In 1988, he observed maximum height and circumference of the pseudostem at 400 g K_2O per plant in Hill banana.

Oubahou and Dafiri (1987) reported that potassium increases height and girth of pseudostem.

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

Khoreiby and Salem (1991) found positive correlation between the highest level of K application and the height and basal circumference of the pseudostem in banana cv. Dwarf Cavendish.

Parida et al. (1994) reported that increase in levels of N,P and K increased the height and stem girth of banana cv. Robusta.

In banana cv. Nendran, Sumam George (1994) reported increased height and girth of pseudostem with increasing levels of K application at all growth stages. The effects were more pronounced from the shooting stage of the crop after it had received the full dose of K fertilizer.

Sheela (1995) demonstrated that application of K_2O could make a significant increase in height and girth of pseudostem in tissue cultured Nendran banana only from the fifth month after planting. This might be due to the increased hormonal activity at the flower initiation stage.

2.3.2 Number of functional leaves.

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

Yang and Pao (1962) observed that the number of functional leaves was not affected significantly by potassium in Fairyman banana. Contrary to this, Ho (1968) reported that application of K at the early stage gave the largest number of leaves in banana cv.Fairyman.

Lacoevilhe (1973) clearly indicated that K application influenced the number of functional leaves.

According to Sheela (1982), different levels of K application did not significantly influence the total number of functional leaves in banana cv.Palayankodan. However, a tendency for high leaf number with higher levels of K was noticed.

Baruah and Mohan (1985) reported that the number of leaves per plant increased with increasing K application from 0 to 250 g per plant in Cavendish banana.

Chattopadhyay and Bose (1986) observed that K application significantly increased leaf number in Dwarf Cavendish banana.

Mustaffa (1987) noticed largest number of leaves by the application of the highest level of K of 400 g per plant in Robusta banana.

In Cavendish banana, Baruah and Mohan (1991) found that the highest K dose produces the largest number of leaves.

Parida *et al.* (1994) reported that increase in levels of N,P and K increased the leaf number in Robusta banana.

Sumam George (1994) observed that the total number of leaves and number of functional leaves showed an increasing trend with increase in K applied at all growth stages of banana cv.Nendran with significant variations observed only at the post shooting and bunch maturation stages.

2.3.3 Leaf area and leaf area index

The effect of K on the growth and leaf area of banana was studied by Murray (1960) and he observed that leaf area was only half in K deficient plants after four months of growth compared to plants receiving full potassium.

Studies on the effect of K_2O on Fairyman banana by Yang and Pao (1962) showed that leaf area was not affected significantly by potassium.

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

Jambulingam et al .(1975) reported that in Robusta banana, higher rates of K_2O significantly increased leaf area.

In banana cv.Dwarf Cavendish, increased rate of K application upto a level of 450 g per plant produced significant increase in leaf area (Ramaswamy et al., 1977), while Turner and Barkus (1980) reported reduced leaf area in banana variety Williams' by 20 percent at low K levels.

According to Sheela (1982), different K levels did not significantly influence the leaf area index in banana cv.Palayankodan. However, a tendency for increased leaf area with higher levels of K was noticed. In 1995, based on the study in tissue cultured Nendran banana, the same author has reported that the role of K_2O is not significant in influencing the leaf area. But K starvation would significantly affect the leaf area.

Mustaffa (1987) opined that application of the highest level of K, 400 g per plant, produced the largest leaf area.

Khoreiby and Salem (1991) studied the effect of K on the vegetative growth and nutritional status of banana cv. Dwarf

Cavendish and found that the highest level of K application of 500 g K_2O per plant produced the most vigorous leaves resulting in greater surface area.

However, Sumam George (1994) could obtain significant variation in leaf area at only the post shooting and bunch maturation stages in Nendran banana grown with graded levels of K fertilizers.

2.4 Effect of K on yield attributing characters.

Potassic fertilizer application significantly influences yield and yield attributing characters in banana. Significant positive correlation between K application and yield attributing bunch characters like weight of bunch, number of hands, fruits per hand and size of fruit has been reported by many workers. Lahav et al .(1981) reported increase in yield of banana due to K_2O application. Beneficial effect on yield with different levels of K_2O has also been reported by Langenegger and Smith (1986) and Oubahou and Dafiri (1987).

2.4.1 Weight of bunch.

In Taiwan, Leigh (1969) reported increased bunch weight with increasing supplies of K.

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

The bunch weight in banana cv.Nendran was found to increase with K application upto 228 g per plant, beyond which it decreased. (Pillai et al., 1977).

Caldas et al. (1978) reported high positive correlation between weight of bunch and K content in the midrib in banana.

Nambiar et al. (1979) found that 450 g K_2O per plant in combination with 225 g N and 225 g P_2O_5 per plant gave the highest bunch weight in cv. Nendran.

Garcia et al. (1980) reported that heaviest bunches were obtained from plots receiving the highest rate of K, 750 g per plant.

Positive significant effect for K on bunch weight in banana cv.Palayankodan was reported by Sheela (1982). The highest bunch weight was obtained from the treatment having the highest level of K of 600 g per plant.

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

Garita and Jaramillo (1984) opined that bunch size increased as K_2O application increased from 250 to 1000 kg ha^{-1}, but bunch weight was greatest with 500 and 750 kg K_2O ha^{-1} yr^{-1} in banana cv.Giant Cavendish.

Cordero (1985) found 20 percent increase in bunch weight over control when 750 kg K_2O ha^{-1} was applied.

Bunch weight of banana was significantly increased by increasing K levels from 0 to 480 g K_2O per plant per year (Chattopadhyay and Bose, 1986).

In banana cv. Robusta, Mustaffa (1987) reported the highest yield of 45.2 t ha^{-1} when 300 g K_2O per plant was applied. This was 35 percent higher than the control.

Obiefuna and Onyele (1988) recommended an annual application of 500 g K_2O per plant for the heaviest bunch weight.

The bunch weight of banana cv. Nendran grown in rice fallows showed linear increase with higher levels of K (Nair et al., 1990).

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

Chong et al. (1992) obtained an yield of 11.6 t ha^{-1} by the application of 900-1200 kg K_2O ha^{-1}. They calculated that each kg of K_2O produced 10-12 kg of fruits.

Pathak et al. (1992) concluded that 300 g K_2O per plant along with 300 g N was most effective in increasing the size and weight of bunches in banana cv.Harichal.

A field trial conducted by Ray et al. (1993) in Basrai banana showed that the application of 300 g K_2O per plant was optimum with bunch yields of 74.9, 76.4 and 70.9 t ha^{-1} in the plant crop and in the first and second ratoon crops respectively. Further applications did not produce any corresponding increase in yields, and in some cases, yield declined.

Sumam George (1994) studied the effect of K levels in yield attributes of Nendran banana and opined that bunch weight showed an increasing trend with increase in the quantity of K applied upto 225 g K_2O per plant and then decreased gradually. The maximum bunch weight of 10.47 kg recorded at 225 g K_2O per plant was significantly higher than all other treatments. The lowest bunch weight of 5.17 kg was recorded by the control plot.

2.4.2 Number of hands and fruits per bunch and weight of hand.

Uexkull (1970) noted increase in the number of hands per bunch and fingers per hand as a result of K application to banana in South Taiwan.

Veeraraghavan (1972) reported significant increase in number of fruits in Nendran banana with the application of 450 g K_2O per plant along with 228 g each of N and P_2O_5 per plant.

Pillai et al. (1977) reported that in Nendran banana the number of fingers per bunch increased only upto 228 g K_2O per plant and beyond that there was only slight increase.

Ramaswamy *et al.* (1977) observed significant increase in the number of hands and fruits per bunch in Dwarf Cavendish banana by increasing the K level upto 450 g per plant.

Caldas *et al.* (1978) noticed a very high positive correlation between number of hands per bunch and K content in the midrib.

In banana cv. Palayankodan, the highest level of K application viz. 600 g per plant produced the highest number of hands per bunch, number of fingers per bunch and weight of hands per bunch. (Sheela, 1982).

Obiefuna (1984) revealed that the application of 300 g K_2O per plant at the 19th to 20th leaf stage (4-5 month after planting) significantly increased the number of marketable fingers by 33.7 percent.

Cordero (1985) obtained 18 percent increase both in number of hands and fingers per bunch over control when 750 kg K ha^{-1} was applied.

In a study on the nutritional requirement of Nendran banana in rice fallows, Geetha (1988) found that highest level of K viz. 600 g per plant produced maximum number of hands and fingers per bunch.

Tandon and Sekhon (1988) observed increased number of hands and fingers per bunch in banana cv. Robusta due to K application.

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

Hedge and Srinivas (1991) revealed an improvement in yield by way of increased number of hands and fingers per bunch upto a K level of 300 g per plant in Bangladesh.

Based on the study on the response of Dwarf Cavendish banana in Assam to K application, Baruah and Mohan (1992) reported an increase in the weight of the second hand, which proved to be a significant yield attributing character.

Pathak et al. (1992) reported that 300 g K_2O per plant along with 300 g N was the most effective in increasing the number of hands and fingers per bunch and weight of hand in banana cv. Harichal.

Sumam George (1994) reported that the different levels of K applied produced significant variation in the number of hands and fingers per bunch and weight of hand.

2.4.3 Length, Girth and Weight of finger.

Hewitt and Osborne (1962) reported that in the presence of adequate N and P, it was possible to double the weight of fruits by the application of K.

Leigh (1969) opined that increasing supplies of K increased finger weight, length and circumference of fingers.

Ramaswamy (1971) found significant increase in the size of fruits at harvest in banana cv. Dwarf Cavendish with higher levels of K.

Low K content in banana affected the length and circumference of finger as reported by Lahav (1972a)

Veeraraghavan (1972) reported significant increase in weight of fruits in banana cv. Nendran with the application of 456 g K_2O per plant along with 228 g each of N and P_2O_5.

Venkatarayappa et al. (1973) studied the effect of K on the fruit development of Cavendish banana and revealed that the application of K at the post shooting stage significantly increase the weight of fruits in both Giant Cavendish and Dwarf Cavendish banana. The length to girth ratios of fruits were more in K treated plants than in control plots.

Obiefuna (1984) obtained 44.2 percent increase in finger weight over the control in plantains by the application of 300 g K_2O per plant at floral initiation stage.

Hedge and Srinivas (1991) reported improvement in yield due to increased finger weight when K was applied at the rate of 300 g per plant.

Study conducted by Baruah and Mohan (1992) in Assam soil noticed significant increase in the length and circumference of the fingers by increasing the rate of K application in Dwarf Cavendish banana.

Pathak et al. (1992) in banana cv. Harichal revealed that application of 300 g K_2O per plant along with 300 g N was the most effective in increasing the size and weight of fingers.

Lopez Morales (1994) opined that the highest fruit weight could be obtained with an annual rate of 720 kg K_2O ha^{-1}

Sumam George (1994) reported that length, girth and weight of index finger showed an increasing trend with increase in rate of K application up to 225 g per plant in Nendran banana.

An experiment conducted by Sheela (1995) in tissue cultured Nendran banana revealed the significant influence of K on the length and weight of individual fingers.

2.5 Effect of K on fruit quality

Mineral nutrition reflects significantly on the quality of final product of all crops. Among the nutrients, potassium appears to have profound influence on the quality of fruits through its influence on size, appearance, colour, acidity, soluble solids, sugar content and vitamin content.

Singh et al. (1974) reported an appreciable improvement in fruit qualities with different K combinations in Robusta banana.

2.5.1 Acidity

Venkatarayappa et al. (1973) reported lowered acidity of the fruits with K application in Cavendish banana. Ramaswamy et al., (1977) and Chattopadhyay and Bose (1986) reported the same in Dwarf Cavendish banana.

Vadivel and Shanmughavelu (1978) in their study on the effect of K application on the quality of Robusta banana also noticed a decreasing trend in acidity with increased level of K application.

Sheela (1982) observed acidity to be in the range of 0.427 to 0.502 percent in banana cv. Palayankodan under different levels of K, the control plot showed the highest value.

Baruah and Mohan (1986) noted a decreasing trend in acidity with increasing levels of K application in Jahaji banana.

Mustaffa (1987) noticed an improvement in quality of banana cv. Robusta under high level of K due to the reduction in acidity. In 1988, he reported that at high K level (400 g K_2O per plant) acidity was reduced in Hill banana.

Contrary to the above results, Ram and Prasad (1989) could not get any significant effect of K_2O on the total titrable acidity.

According to Sheela (1995), increasing K levels resulted in the lowering of acidity in tissue cultured Nendran banana.

2.5.2 Total soluble solids

Jambulingam et al. (1975) reported the pronounced effect of K on soluble solids in Robusta banana.

Ramaswamy et al. (1977) found that higher level of K increased the total soluble solids in banana cv. Dwarf Cavendish.

In Palayankodan banana, Sheela (1982) reported increased content of total solids as a result of increasing the level of K application.

Baruah and Mohan (1986) revealed that increased K application significantly influenced the total soluble solid content in Jahaji banana, the highest K level of 330 g per plant producing the highest value of 23.88 percent.

Increasing the K level from 0 to 240 g K_2O per plant in Dwarf Cavendish (Chattopadhyay and Bose, 1986) and from 0 to 400 g K_2O per plant in Hill banana (Mustaffa, 1988) increased total soluble solids.

In banana cv. Campiergang local, Ram and Prasad (1989) noticed that increased level of K significantly increased the soluble solid content.

Hedge and Srinivas (1991) also reported the increased total soluble solid content in banana with increased rate of K application.

2.5.3. Total, Reducing and Non-reducing sugars

In a study conducted by Ramaswamy et al. (1977) in Dwarf Cavendish banana revealed that both reducing and non-reducing sugar content increase with increased level of K application. Higher reducing sugar content of 13.2 percent could be obtained from plants received the highest level of K of 550 g per plant.

Vadivel and Shanmughavelu (1978) reported that increasing level of K application increased the content of total and reducing sugars in banana cv. Robusta.

Sheela (1982) found that total and reducing sugar contents were significantly influenced by K treatment in banana cv. Palayankodan, but non-reducing sugar was not affected. However higher values for these characters were associated with higher K levels.

Total sugar content increased from 11 to 13.1 percent by soil application of K from 0 to 480 g per plant in Dwarf Cavendish banana (Chattopadhyay and Bose, 1986).

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

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

Sumam George (1994) studied the effect of K application on the quality parameters in banana cv. Nendran and the results indicated that K application increased the total and non-reducing sugar content. Reducing sugar content showed a decreasing trend with increasing level of K application.

2.5.4 Sugar/Acid ratio

Enhanced sugar/acid ratio with increased level of K application was reported by Vadivel and Shanmughavelu (1978) in banana cv. Robusta.

Zehler et al. (1981) also noticed that sugar/acid ratio was improved by K in banana.

Baruah and Mohan (1986) could obtain the maximum sugar/acid ratio of 134 at the highest level of K in Jahaji banana.

Improvement in sugar/acid ratio with increasing K application was reported by Uexkull and Bosshart (1987). Similar result has been reported in tissue cultured Nendran banana by Sheela (1995).

2.5.5 Pulp/Peel ratio

Sheela (1982) reported the pulp/peel ratio to be in the range of 2.95 - 3.5 under different K levels in banana cv. Palayankodan with the lowest value being recorded by the control plots.

Martin-Prevel (1989) opined that banana fruits receiving high K exhibited high pulp/peel ratios.

Contrary to other reports, Hedge and Srinivas (1991) reported that increased K levels decreased the pulp/peel ratio in banana.

Sumam George (1994) reported that pulp/peel ratio showed a steady increasing trend with increase in K application in Nendran banana.

2.5.6. Shelf life

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

Uexkull (1970) observed that K could produce better storage life of banana fruits due to the increase in thickness and firmness of the rind.

Zehler et al. (1981) also revealed the positive influence of K in improving the storage properties of banana fruit.

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

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

Sumam George (1994) found an improvement in the shelf life of fruit with increased K doses in banana cv.Nendran. Maximum mean shelf life of 6.33 days was recorded by the highest level of K of 600 g per plant.

2.6. K nutrition and Ca and Mg contents in soil

Fabregar (1986) reported the antagonistic behaviour of K with Ca and Mg as a result of monovalent-divalent interactions in banana soils.

According to Lopez Morales (1994), increasing rates of K increased soil K levels, but decreased soil Ca and Mg.

Sumam George (1994) concluded that exchangeable Ca and Mg contents in soil decreased as a result of K nutrition in banana cv. Nendran.

2.7. K nutrition and potassium concentration in banana

Randhawa *et al*. (1973) noticed significantly increased K content in the leaf tissue with increasing level of K application; the highest K level resulted in the highest K content.

Jambulingam *et al*. (1975) reported that the increased K content in leaves of Robusta banana was significant after the application of 360 g K_2O per plant in the soil.

Garcia *et al*. (1980) conducted a study in red soils of Cuba and observed that high K fertilization increased the K contents in the leaves.

Sheela (1982) reported that the K content in all plant parts increased with increasing level of K in banana cv. Palayankodan. A difference of 77 percent in the K content of fruits was observed between control and the highest level of 600 g K_2O per plant.

In a study conducted at Caribbean soils of Costa Rica, Garita and Jaramillo (1984) observed increased leaf K levels in banana cv. Giant Cavendish, with the increasing rate of K application.

K concentration steadily increased in banana cv. Grand Nain under increasing levels of K application in Puerto Rico (Irizarry et al., 1988).

Vadivel and Shanmughavelu (1988) reported that in spite of different levels and methods of K application, its concentration in the banana leaf remained constant, within a range of 4 to 5 percent.

According to Sumam George (1994), K concentration showed an increase with increase in K application rate in all plant parts and at all stages of crop growth in Nendran banana. In most cases, the maximum values were recorded by the highest level of K, 600 g per plant and the lowest by the control.

2.8 K nutrition and concentration of N,P,Ca and Mg in banana

Increase or decrease of one element may increase or decrease substantially the other element, thereby causing complete deprivation of one particular element to the plant. Such antagonism or synergism between nutrient elements affects growth and development of banana plant considerably.

Dumas and Martin-Prevel (1958) had reported that yields depended largely on the balance of K with N, Ca and Mg.

In a sand culture experiment, Murray (1960) pointed out strong antagonism between K and Ca and K and Mg.

Brezesowsky and Biesen (1962) reported that K in the leaf had a depressing effect on the leaf Mg.

Hewitt and Osborne (1962) opined that heavy application of K decreased leaf N in Lacatan banana.

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

The content of K was negatively correlated with Ca and Mg at all the stages of growth (Fernandez *et al*., 1973)

Lahav (1973) reported that antagonism existed between K and Mg, K and Ca, K and N and also K and Na. However a synergistic relationship was observed between K and P.

Mengel *et al*. (1976) reported that low K levels in soil solution favoured uptake of Mg and Ca and resulted in lower plant yields than high K levels.

In studies with Williams banana, Lahav (1977) noticed synergistic relationship between K and P and antagonism between K and Ca and K and Mg.

Turner and Barkus (1983) observed that increased K supply increased the plant uptake rate of P while it decreased that of N, Ca and Mg.

In the cv. Giant Cavendish grown in Caribbean soils, Garita and Jaramillo (1984) noticed that as the rate of K_2O application increased from 250 kg to 1500 kg ha^{-1} yr^{-1}, leaf K level and leaf K/Mg ratio increased whereas the leaf K/N ratio decreased.

The study by Rajeevan (1985) revealed synergism between K and P.

Antagonism between K and Ca and K and Mg was confirmed by Barber (1986).

Hedge and Srinivas (1991) reported that increasing K fertilization significantly increased the uptake of N, K and Ca which was mainly the consequence of increased drymatter production.

An experiment conducted by Miao et al. (1993) to study the effects of K application on the absorption of other elements in banana revealed that as the K rates increased, the contents of N, Ca and Mg were reduced.

Lopez Morales (1994) revealed that increasing rates of K decreased leaf Ca and Mg contents in banana.

In banana cv. Nendran, Sumam George (1994) concluded that uptake of N, P and K showed increasing trend with increasing K supply, the highest K level of 600 g per plant recorded 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.

2.9. Standardisation of index plant part for foliar analysis

Foliar analysis has come to be accepted as an important tool in modern soil fertility and plant nutrition investigations. It indicates a precise interrelationship between the amount of fertilizer added to the soil and its utilization by the crop. The practical aim of leaf tissue analysis is to determine the nutritional status of the plant at various growth stages, remedy deficiencies or excesses or imbalances discovered and thereby improve final yield. (Randhawa et al., 1973)

Systematic foliar diagnosis in bananas was carried out for the first time by Hewitt (1955) in Jamaica and tentative nutrient values were established using the third leaf as the standard leaf for sampling.

Boland (1960) found that the middle lamina halves of the second leaf before shooting was the best for foliar analysis.

Murray (1960), working in Trinidad with Dwarf Cavendish banana confirmed the choice of third leaf as the most indicative for the nutrition of the plant due to its higher content of N, P and K.

Bhangoo et al. (1962) observed the third leaf to be the best for foliar analysis in banana.

The first leaf that had fully emerged was selected as standard leaf for nutrient analysis of banana. (Brezesowsky and Biesen, 1962; Martin-Prevel and Motagut, 1966).

Twyford (1967) standardised the fourth youngest leaf to assess the critical level of nutrients in banana.

Considering the impracticability of taking the whole leaf for sampling, Uexkull (1970) suggested that central portion of the lamina of the third fully unfurled leaf without midrib to be the index part in banana.

Lahav (1972b) found that petiole analysis provided more information than the blade for cations especially K.

Veerannah et al. (1976) conducted nutrient uptake studies in Robusta and Poovan and suggested that sheath was the specific tissue for diagnosing K.

Langenegger and Du Plessis (1977) suggested that lamina and corresponding portion of the midrib of third leaf taken at an advanced stage of flowering should be taken for most promising results of nutrient contents in banana cv. Dwarf Cavendish.

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

Messing (1978) confirmed the use of whole strip taken from the centre of lamina of third leaf as the most suitable single diagnostic tissue to get good range of values of determination for N and K.

Guijarro et al. (1980) compared five sampling methods in order to decrease the sample volume required for banana leaf analysis. A 10 cm transverse band from the middle of the leaf blade was recommended.

Bhargava and Reddy (1992) suggested that the petiole of the third fully opened leaf at the 20th leaf stage would be the ideal sample for the nutritional diagnosis of banana.

In a study conducted by Sumam George (1994) in banana cv. Nendran, petiole of the third leaf 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.

2.10. Critical K level in leaf tissues

The nutrient status of the banana plant at a particular stage may be indicated by the concentrations of nutrient elements in the leaf or any other specific plant part. (Randhawa et al., 1973).

Hewitt (1955) reported the critical level of K in Lacatan banana as 3.3. percent.

Boland (1960) found that 3.8 - 4.0 percent K was the optimum level in banana.

Based on the studies conducted on Gros Michel' in the Cameroons, `Poyo' in the Ivory coast and Petite Naine' in Guinea, Dumas (1960) emphasised that potash content of the plants should be approximately 5.8 percent, 4.0 percent and 3.6 percent respectively for the above varieties.

Hewitt and Osborne (1962) observed that leaf K concentration of 4.0 percent was essential for securing higher yields.

Under Caribbean conditions. Twyford and Coulter (1964) suggested a level of 3.8 percent in banana cv. Robusta to be critical.

Twyford (1967) fixed the critical level for K as 3.8 percent in banana.

Ho (1969) obtained the highest yield and the largest number of fingers per hand at a K value of 5.0 percent or more at 3 months before harvest.

Sunder Singh (1972) reported leaf K content of 3.89 percent in the fifth month and 4.36 percent in the seventh month as optimum for variety Robusta for high yield.

Jambulingam et al. (1975) reported that leaf K should be above 4.3 percent for optimum production of Robusta banana.

Vadivel (1976) reported that at shooting, leaf K concentration was in the range of 4 - 4.5 percent in Robusta banana under garden land conditions.

Ashokkumar (1977) observed a range of 3.6 - 5 percent K to be critical in banana cv. Robusta.

Bhavanishanker (1980) reported that at shooting stage, the critical leaf concentration of K in Nendran banana was 3.18 - 3.47 percent.

When the available moisture in soil was maintained at 60 percent, the critical leaf concentration of K at shooting stage ranged from 3.97 to 4.19 percent. (Krishnan and Shanmughavelu, 1980).

Falcon and Fox (1985) reported 3.2 percent K as critical level in banana cv. Giant Cavendish, while Langenegger and Smith (1986) reported a critical level of 3.5 - 4 percent K in Dwarf Cavendish banana.

Ray et al.(1988) revealed that a leaf content of 3.8 percent K at shooting was considered a good indicator of satisfactory K level for good productivity in banana cv. Robusta.

Bhargava et al. (1992) noted a critical level of 4.2 percent K in the third fully opened leaf for maximum production of banana in a red soil of Bangalore.

Sumam George (1994) reported that in banana cv. Nendran, the late vegetative stage was selected as the optimum stage for sampling and the critical K level in the third leaf at that stage was 1.28 percent for maximum yield and 1.06 percent for economic yield.

2.11. Potassic fertilizer recommendations for banana

Katyal and Chadha (1961) reported that under North Indian conditions, 1.8 - 2.3 kg K_2SO_4 per plant was found essential.

Application of 204 kg K_2O per acre per annum in 3 - 4 splits was recommended by Leigh (1969) in Taiwan.

Pillai et al.(1977) worked out the optimum dose of K for maximum yield as 301 g K_2O per plant per year for Nendran banana under Kerala conditions.

According to Garita and Jaramillo (1984), 750 kg K_2O per ha per year was found essential for Giant Cavendish banana in Caribbean soils.

Obiefuna and Onyele (1988) suggested that an annual application of 500 g K_2O per plant was the most economic in Ivory coast.

Yadav et al. (1988) recommended application of K in 3 split doses at the rate of 300 g per plant to get the best results in Dwarf Cavendish.

Pathak et al. (1992) emphasised that 300 g K_2O per plant was the most effective and was designated as critical level in soil for maximum production in banana cv. Harichal.

The `Package of Practices Recommendations' stipulate that application of 300 and 400 g K_2O per plant is optimum for Nendran (irrigated) and Palayankodan (rainfed) bananas respectively. For other varieties, 320 - 400 g should be applied depending upon soil fertility level. (KAU, 1993).

According to Ray et al. (1993), 300 g K_2O per plant was recommended for Basrai banana in alkaline calcareous soils.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation on prediction of potassium fertilizer requirement of banana, Musa (AAB group) `Nendran' was undertaken as a farmer's field trial.

3.1 Experimental site

The experimental site lies at $8^{O}34'N$ latitude, 76^{O} 56'E longitude and at 46 m above mean sea level, is a raised, levelled, well drained garden land and is located about 5 km South of the College of Agriculture, Vellayani at Ookkode in Kalliyoor village, Neyyattinkara Taluk of Thiruvananthapuram district.

3.2 Soil

Soil of the experimental field comes under the taxonomic class Loamy Kaolinitic Isohyperthermic Rhodic Haplustox. Soil samples were collected from the experimental site initially and at periodic intervals, air dried in shade, gravel and roots removed, gently powdered with a wooden plank and passed through a 2 mm sieve. These processed samples were subjected to laboratory analyses for their important physico-chemical properties. The methods employed for the analyses are presented hereunder.

3.6 Field preparation

The land was prepared by digging. Raised beds were taken with channels for proper drainage all around and pits of size 50 cm^3 were dug on these beds at a spacing of 2x2 m.

3.7 Experimental design and layout

Layout plan of the experiment is presented in Figure 1. The details of the layout are as follows

Design	:	Randomised Block Design
Total number of treatments	:	5
Number of replications	:	4
Spacing	:	2x2 m
Variety	:	*Musa* (AAB group) Nendran
Plot size	:	4x4 m
Number of plants per plot	:	4
Treatments	:	Five levels of K where K represents the Package of Practices Recommendations of Kerala Agricultural University for Potassium for irrigated

Sl. No.	Characteristics	Methods followed
1.	Mechanical composition	International pipette method (Gupta and Dakshinamoorthi,1980)
2.	Soil reaction (pH)	Direct reading using pH meter (Elico-model L1.120) in 1:2.5 soil water suspension (Jackson, 1973)
3.	Electrical conductivity	Direct reading using Elico Soil Bridge (Type CM.84) in 1:2.5 soil water suspension (Jackson, 1973)
4.	Cation exchange capacity	Ammonium saturation using Neutral Normal ammonium acetate. (Jackson, 1973)
5.	Organic carbon	Walkely and Black's rapid titration method (Jackson, 1973)
6.	Available N	Alkaline permanganate method (Subbiah and Asija, 1956)
7.	Available P	Bray extraction and Klett Summerson photoelectric colourimeter making use of chlorostannous reduced molybdo phosphoric blue colour in HCL system (Jackson, 1973)
8.	Exchangeable K	Neutral Normal ammonium acetate extraction and flame photometry (Stanford and English, 1949)
9.	Exchangeable Ca, Mg	Neutral Normal ammonium acetate extraction and atomic absorption spectrophotometry. (Jackson, 1973)

3.3 Climate

The experimental site enjoyed a humid tropical climate and received a good amount of rainfall through South-West and North-East monsoons. The data on various weather parameters (monthly rainfall, maximum temperature, minimum temperature and relative humidity) during the cropping period (May 1995 to February 1996) are presented in Appendix I.

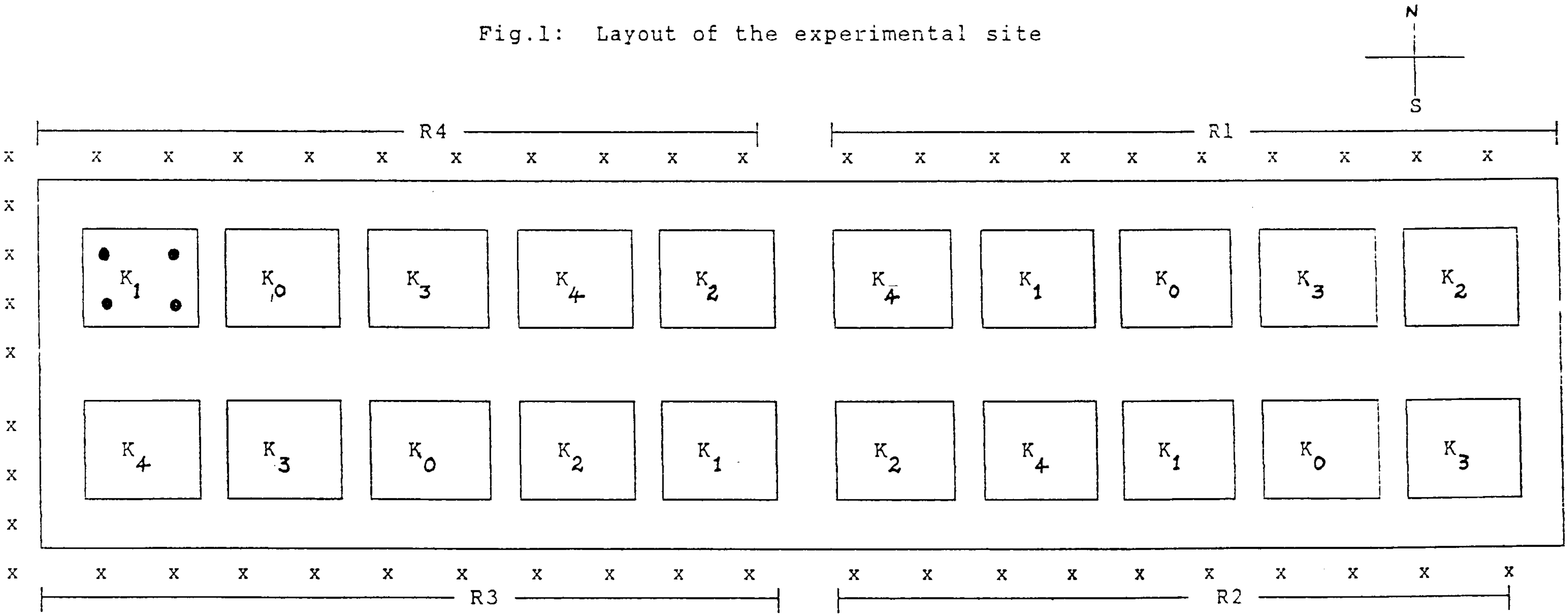
3.4 Variety

The variety selected for the study was `Nendran' coming under the subgroup `plantain' with `AAB' genome. This is the most popular dual purpose commercial cultivar of Kerala having good fruit qualities. Nendran is mainly grown as an irrigated crop in Kerala.

3.5 Preparation of the planting material

Suckers of uniform weight and age (3 months old) were selected from a bunchy top disease free area and pseudostems were cut at a length of about 15-25 cm from the corm. Old roots removed and the rhizomes were dipped in cowdung slurry treated with 0.2 percent BHC, dried in sun for 3 days and stored in shade for 15 days before planting.

Fig.1: Layout of the experimental site



K0 - Zero potassium

K1 - 150 g K_2O per plant

K2 - 300 g K_2O per plant

K3 - 450 g K_2O per plant

K4 - 600 g K_2O per plant

R1, R2, R3, R4 - Replications

● - Treatment plants

x - Border plants

PLATE NO. 1

AN OVERVIEW OF THE EXPERIMENTAL FIELD

Nendran banana (300 g K_2O per plant) in five equal splits. (KAU, 1993)

Notation	Quantity of K
Ko	Zero K
K1	150 g K_2O per plant
K2	300 g K_2O per plant
K3	450 g K_2O per plant
K4	600 g K_2O per plant

3.8 Planting

Planting was done on 1st May 1995. Suckers were planted upright in the centre of pits with 5 cm of pseudostem remaining above the soil level.

3.9 Fertilizer application

Farmyard manure at the rate of 10 kg per plant was applied basally to all pits. Urea (46 percent N), Mussoorie rock phosphate (22 percent P_2O_5) and Muriate of potash (60 percent K_2O) were used as the sources of N,P and K respectively. The levels of N and P were kept constant for all treatments (as per

Package of Practices Recommendations of KAU). Fertilizers were applied 60-75cm around the plant. 190 g N per plant was applied in 6 splits first as basal and then one, two, four, five and six months after planting. 115 g P_2O_5 was applied in two splits, first as basal and the second, one month after plating. K was applied in five equal splits, first as basal and then one, two, four and five months after planting.

3.10 Maintenance of the crop

Hand weeding was resorted to as and when required. Mulching was provided at the basin till suckers established well. During dry period, irrigation was given to the plants once in 3 days with 40 litres of water per plant. Suckers were prevented from emerging by smoothering them on the very first day of emergence after retaining two suckers per plant

3.11 Plant protection measures

25 g phorate (10%G) was applied to each plant 20 days after planting followed by leaf axil filling of 12.5 g each at 75 and 165 days after planting as a prophylactic measure against the aphid, Pentalonia nigronervosa which transmits bunchy top disease.

The major pest observed in the field was leaf caterpillar, *Spodoptera sp*. which was effectively controlled by spraying 0.1 per cent Malathion (50 percent EC) at three and four months after planting.

The only disease noted was sigatoka leaf spot, but its occurrence was very limited. A spray of 1 percent Bordeaux mixture was given to the plants for controlling the disease.

3.12 Sampling stages.

Five stages during the growth period of the crop were identified for recording the observations and taking soil and plant samples for analysis.

Two months after planting	-	Early vegetative stage
Four months after planting	-	Late vegetative stage
Six months after planting	-	Shooting stage
Eight months after planting	-	Bunch maturation stage
Nine months after planting	-	Harvest stage

The biometric, yield and quality characters were observed.

3.13 Biometric characters

3.13.1 Height of the plant

Height of the plant (cm) was recorded from the soil level to the base of the youngest unopened leaf. Observations were recorded at two, four, six, eight and nine months after planting. From the data, plant height during various growth stages were computed.

3.13.2 Girth of the pseudostem at 20 cm height

Girth of the pseudostem (cm) was recorded at 20 cm above the ground level at various growth stages of the crop.

3.13.3 Total number of functional leaves

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

3.13.4 Total leaf area

The total leaf area was calculated using the equation developed by Murray (1960)

$$LA = L \times W \times 0.8$$

LA = leaf area per leaf

L = length of lamina

W = width of lamina

The length of lamina was measured from the base of the leaf to the tip and the width at the broadest part of the lamina. The sum of the area of all the functional leaves in a plant was then computed at different growth stages and taken as total leaf area.

3.13.5 Leaf area index (LAI)

The leaf area index was calculated using the following formula suggested by Watson (1952)

$$LAI = \frac{\text{Total leaf area of a plant}}{\text{Geographical area occupied by the plant}}$$

3.14 Yield characters

Bunches were harvested when fully matured as indicated by the disappearance followed by rounding of fruit angles. (Stover and Simmonds, 1987). The following observations were made on the bunch characters

3.14.1 Weight of bunch

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

3.14.2 Number of fingers per bunch

The total number of fingers in each of the bunches were counted and the values recorded.

3.14.3 Number of hands per bunch

The total number of hands in each bunch was noted.

3.14.4 Weight of hand

All the hands in a bunch were detached and weighed separately. The mean value of the weights of different hands on a bunch was calculated and recorded as the weight of hand in kilograms.

3.14.5 Length, Girth and Weight of finger

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

The weight of the index finger was taken as the mean finger weight. Length and girth were measured using fine thread and scale. Length was measured from the tip of the finger to the point of attachment of the peduncle and girth of the finger was recorded at the middle portion.

3.15 Quality characters

The fully ripe index fingers collected from bunches of different treatments were used for quality analysis. Known weight of samples taken from three portions (top, middle and bottom) of sample fruit were macerated in a blender and made upto a known volume. Aliquots taken from this were used for the analysis of the following characters of the fruit.

3.15.1. Titrable acidity

Titrable acidity was determined following the procedure proposed by Ranganna (1977). An aliquot from the sample was titrated against 0.1 N NaOH and the results were expressed as percent anhydrous citric acid.

3.15.2. Total soluble solid (TSS)

Total soluble solid content was determined using a pocket refractometer and expressed as percentage (Ranganna, 1977).

3.15.3. Total sugars

Total sugar content was determined by the copper reduction method using Fehling's solution, after HCl digestion and expressed as percentage.(Chopra and Kanwar, 1976).

3.15.4. Reducing sugars

Reducing sugar was determined by following copper reduction method using Fehling's solution proposed by Chopra and Kanwar (1976) and expressed as percentage.

3.15.5. Non-reducing sugars

Non-reducing sugar content was computed using the following formula

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

3.15.6. Sugar/Acid ratio

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

3.15.7. Pulp/Peel ratio

The pulp and peel weights of index finger was recorded separately in grams and the ratio between these were worked out for calculating pulp/peel ratio.

3.15.8. Shelf life at room temperature

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

3.16. Soil analysis

Soil samples were collected at all the five growth stages of the crop, one day before the fertilizer application. Samples were taken from a depth of 0 - 30 cm from four points around the plant within a lateral distance of 0 - 30 cm.(Mohan and Madhava-Rao, 1985). Composite sample prepared from this was airdried, gently powdered, passed through a 2 mm sieve and analysed for soil reaction(pH), organic carbon, available N, available P, exchangeable K, exchangeable Ca and exchangeable Mg as per the methods described earlier.

3.17. Plant analysis

The third leaf counted from the top of the plant upto the sixth month (Hewitt, 1955) and the flag leaf thereafter (Sumam George , 1994) were collected and separated into petiole, midrib and lamina portions as shown below. (Martin- Prevel *et al*., 1986).

Petiole - distal half portion

Midrib - 5 cm long piece of midrib at the middle portion of the leaf

Lamina - 5 cm wide strip across the leaf on either side of the midrib sample

The samples were collected at two, four, six, eight and nine months after planting, ovendried to constant weight at 80°C, ground in a Wileymill and analysed for the different nutrients. The methods adopted for the chemical analysis are described below.

Sl. No.	Estimated character	Methods followed
1.	N	Microkjeldahl digestion in sulfuric acid and distillation (Jackson, 1973)
2.	P	Nitric - Perchloric - Sulfuric acid (10:4:1) digestion and Klett Summerson photoelectric colourimeter making use of Vanado-molybdate yellow colour in Sulfuric acid medium (Jackson, 1973)

3.	K	Nitric - Perchloric - Sulfuric acid (10:4:1) digestion and flame photometry (Piper, 1967)
4.	Ca	Nitric - Perchloric - Sulfuric acid (10:4:1) digestion and atomic absorption spectrophotometry (Piper, 1967)
5.	Mg	Nitric - Perchloric - Sulfuric acid (10:4:1) digestion and atomic absorption spectrophotometry. (Piper, 1967)

3.18. Benefit/Cost ratio calculation

The economics of cultivation was worked out considering all aspects of cost of cultivation and the income derived from the plant for all treatments.

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

3.19. Statistical analysis

The data collected on different biometric, yield and quality characters and generated from the plant and soil analyses were subjected to statistical analysis using analysis of variance (ANOVA) technique (Panse and Sukhatme, 1967), correlation and regression analysis (Snedecor and Cochran, 1967).

RESULTS

RESULTS

The banana plant is well known to be extremely demanding for nutrients and it depletes the soil of major and minor nutrients in large quantities. Among the major nutrients, potassium is of prime importance in controlling the growth, yield and quality parameters of banana. The present investigation was undertaken in a farmer's field to study the effect of different levels of K viz., 0,150,300,450 and 600 g K_2O per plant on the biometric, yield and quality characters of banana cv. Nendran. The study also envisaged standardisation of the index plant part for K status and determination of the critical level of K in the index part for maximum and economic yield.

The results of the investigation are presented in this chapter.

4.1 Soil.

The important initial physico-chemical characteristics of the soil of the experimental area are given in Table 1.

The texture of the soil studied indicated that the percentage of coarse sand, fine sand, silt and clay recorded

Table 1. Initial soil physico-chemical characteristics of the experimental field

Sl. No.	Estimated character	Content in soil
1.	Mechanical Composition	
	Coarse sand	48.5%
	Fine sand	22.3%
	Silt	6.0%
	Clay	22.8%
2.	Soil reaction (pH)	5.2
3.	Electrical conductivity	<0.05 ds m^{-1}
4.	Cation exchange capacity	2.09 cmol(p+) kg^{-1}
5.	Organic carbon	0.32%
6.	Available N	216.38 kg ha^{-1}
7.	Available P	18.48 kg ha^{-1}
8.	Exchangeable K	101.00 kg ha^{-1}
9.	Exchangeable Ca	84.00 kg ha^{-1}
10.	Exchangeable Mg	22.00 kg ha^{-1}

48.5 percent, 22.3 percent, 6.0 percent and 22.8 percent respectively, with a textural class of sandy clay loam. The soil used for the experiment was acidic in nature (pH - 5.2) with electrical conductivity less than o.05 dS m^{-1}. The cation exchange capacity of the soil was 2.09 cmol (p+) kg^{-1}. The analytical data also revealed that the soil of the experimental plot was low in organic carbon (0.32 percent), available N (216.38 kg ha^{-1}), available P (18.48 kg ha^{-1}) and exchangeable K (101.00 kg ha^{-1}). Exchangeable Ca and Mg contents were 84.00 kg ha^{-1} and 22.00 kg ha^{-1} respectively.

4.2. Effect of K levels on biometric characters of banana cv. Nendran

4.2.1. Height of plant

The results of the study on the effect of different levels of K on the height of plants are presented in Table 2.

The data indicated that increasing levels of K increased the height of plants in the different growth stages of the crop. In all the stages, control plants which received zero K showed minimum values for plant height. There was no significant

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

Treatments	Plant height (cm)					Pseudostem girth (cm)				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
KO	77.00	240.00	304.75	301.25	303.00	19.25	47.00	48.88	46.25	46.00
K1	88.25	258.00	332.75	336.25	342.50	22.00	50.25	56.25	55.88	55.25
K2	91.50	273.75	361.00	361.50	361.50	23.50	55.50	60.50	58.75	58.00
K3	94.50	269.75	361.25	367.50	373.50	21.50	53.75	62.38	60.00	60.50
K4	83.25	272.25	362.50	384.25	384.50	19.50	50.00	61.00	60.75	60.63
CD (0.05)	NS	NS	NS	37.98**	38.56**	NS	NS	4.35**	4.38**	4.14**

NS Not significant

MAP - Month after planting

** Significant at 0.01 level

difference among the treatments for this character till shooting stage. But the treatments showed singificant difference in the bunch maturation and harvest stages.

During the bunch maturation stage, the treatment K4 (600 g K_2O per plant) showed the highest mean value for plant height (384.25 cm) followed by K3 (450 g K_2O per plant) and K2 (300 g K_2O per plant) recording 367.50 cm and 361.50 cm respectively. All these three treatments were statistically on par. The lowest value (301.25 cm) for plant height was recorded by the control plants (KO).

Among the five treatments during harvest stage also, K4 recorded the highest plant height (384.50 cm) which was on par with K3 (373.50 cm) and K2 (361.50 cm), while KO recorded the lowest plant height (303.00 cm).

4.2.2. Girth of pseudostem

The results of the study are presented in Table 2.

From the data, it is revealed that the different K levels caused significant variation in the girth of pseudostem only at the later stages of growth like shooting, bunch maturation and harvest stages. The data also showed that the girth was minimum for control plants in all the growth stages studied.

At the shooting stage, K3 recorded the highest mean value (62.38 cm) followed by K4 (61.00 cm) and K2 (60.50 cm). These three treatments were statistically on par. The lowest girth was recorded in KO (48.88 cm).

The treatment K4 recorded the highest mean value of 60.75 cm during bunch maturation stage which was on par with K3 (60.00cm) and K2 (58.75 cm).KO recorded the minimum mean value of 46.25 cm.

During harvest stage also, girth of pseudostem was maximum in K4 (60.63 cm) which was statistically on par with K3 (60.50 cm) and K2 (58.00 cm), while the control plots registered the lowest value (46.00 cm).

4.2.3. Number of functional leaves

The mean data are presented in Table 3.

The number of functional leaves, in general, showed an increasing trend with increase in K applied at all growth stages

Table 3. Effect of K levels on number of functional leaves, total leaf area and leaf area index (mean tab

Treatments	Number of functional leaves					Total leaf area (m^2)					Leaf area index				
	2MAP	4MAP	6MAP	8MAP	9MAP	2MAP	4MAP	6MAP	8MAP	9MAP	2MAP	4MAP	6MAP	8MAP	9M
KO	7.75	14.25	12.50	6.25	3.75	1.04	6.85	5.09	4.71	2.27	0.26	1.71	1.27	1.18	0.
K1	8.00	15.75	13.00	7.25	4.50	1.17	7.61	6.51	4.81	2.94	0.29	1.90	1.63	1.20	0.
K2	8.00	15.50	13.75	7.25	4.25	1.28	5.95	5.19	4.82	2.75	0.32	1.49	1.30	1.21	0.
K3	6.50	14.50	14.25	7.25	4.00	1.17	6.85	6.69	5.12	2.85	0.29	1.71	1.67	1.28	0.
K4	7.50	15.25	14.75	9.50	5.00	1.08	6.74	5.94	5.88	3.82	0.27	1.69	1.61	1.47	0.
CD (0.05)	NS	NS	NS	1.92*	NS	NS	NS	1.13*	0.67*	0.70**	NS	NS	NS	0.17*	0.

NS Not significant

MAP - Month after planting

* Significant at 0.05 level

** Siginificant at 0.01 level

of the crop. No significant differences were observed among the treatments in any of the growth stages except bunch maturation stage.

At bunch maturation stage, K4 recorded the maximum number of functional leaves with mean value of 9.50. The treatment was significantly superior to all other treatments. The treatments KO, K1, K2 and K3 were statistically on par.

4.2.4. Total leaf area

The results are furnished in Table 3.

It is evident from the data that significant variations among treatments were observed only after completion of the vegetative growth stages.

During the shooting stage, K3 recorded the highest total leaf area (6.69 m^2) which was statistically on par with K1 (6.51 m^2) and K4 (5.94 m^2). Control plants produced leaves with the lowest leaf area(5.09 m^2).

In both bunch maturation and harvest stages, K4 showed superiority over the other treatments with significant mean values of 5.88 m^2 and 3.82 m^2 respectively. All other treatments were statistically on par, while KO recorded the lowest value.

4.2.5. Leaf area index

Table 3 presents the mean data on the leaf area index under different levels of K.

The treatments produced significant variation only at the bunch maturation and harvest stages.

Among the treatments, control plots registered the minimum values at bunch maturation and harvest stages. At these stages, K4 resulted in the highest leaf area index, the values being 1.47 and 0.96 respectively which was significantly superior to all other treatments.

4.3. Effect of K levels on yield characters of banana cv. Nendran

The important yield characters studied were weight of bunch, number of fingers per bunch, number of hands per bunch, weight of hand, weight of finger, length of finger and girth of finger.

Table 4. Effect of K levels on yield characters (mean table)

Treatments	Weight of bunch (kg)	Number of fingers $bunch^{-1}$	Number of hands $bunch^{-1}$	Weight of hand (kg)	Weight of finger (g)	Length of finger (cm)	Girth of finger (cm)
KO	6.19	29.50	3.25	1.70	161.30	22.65	11.95
K1	7.08	33.00	4.00	1.54	197.70	24.43	12.95
K2	9.68	40.00	4.50	1.96	211.90	25.75	13.30
K3	11.12	43.25	4.75	2.15	284.48	29.03	14.50
K4	10.61	41.00	4.75	2.05	246.22	27.98	13.38
CD	1.73**	5.42**	0.61**	0.36**	32.95**	1.74**	0.91**

* Significant at 0.05 level

** Significant at 0.01 level

The results of the study are presented in Table 4 and Plates 2,3 and 4.

The data revealed that all the yield attributing characters studied recorded the highest mean value towards the treatment K3 and the lowest towards the control plants except weight of hand which is lowest for K1 treatment. Results also showed that all the parameters were highly significant except weight of hand which was significant only at 5 percent level. All the yield attributes showed an increasing trend with increase in K dose upto K3 level.

4.3.1. Weight of bunch

The highest bunch weight recorded by K3 (11.12 kg) was on par with K4 (10.61 kg) and K2 (9.68 kg), while KO recorded the lowest mean value of 6.19 kg.

4.3.2. Number of fingers per bunch

Total number of fingers per bunch again followed the same trend as that of bunch weight, with K3 recorded the highest mean value of 43.25.

4.3.3. Number of hands per bunch

Number of hands per bunch showed an increasing trend with increase in the quantity of K applied with the maximum mean value of 4.75 recorded by the K3 and K4 treatments which was on par with K2

4.3.4. Weight of hand

Maximum hand weight of 2.15 kg given by K3 treatment was statistically on par with K4 (2.05 kg) and K2 (1.96 kg).

4.3.5. Weight of finger

The highest weight of finger was recorded in K3 (284.48 g) which was on par with K4 (246.22 g).

4.3.6. Length of finger

The length of finger again followed the same trend as that of weight of finger. K3 recorded the highest mean value (29.03 cm) followed by K4 (27.98 cm), the two treatments being statistically on par.

4.3.7. Girth of finger

The girth of finger showed the maximum mean value (14.50 cm) in K3 level which was significantly superior to all other treatments.

4.4. Effect of K levels on quality characters of banana cv. Nendran

Table 5 presents the mean data on the quality characters as influenced by different levels of K application. The characters studied were acidity, total soluble solids, reducing, non-reducing and total sugars, sugar/acid ratio, pulp/peel ratio and shelf life. Results revealed that different K levels significantly influenced all quality characters studied except pulp/peel ratio.

4.4.1. Acidity

Increasing levels of K fertilizer application lowered the titrable acidity of fruits. The lowest mean value for acidity was recorded by K4 level (0.17 percent) which was on par with K2 (0.22 percent) and K3 (0.23 percent). The highest acidity was recorded by the fruits from the control plots (0.34 percent).

Table 5. Effect of K levels on quality of fruit (mean table)

Treatments	Acidity (%)	Total soluble solids (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar/acid ratio	Pulp/peel ratio	Shelf life (days)
KO	0.34	15.08	17.39	11.17	5.82	52.46	2.97	3.25
K1	0.26	16.85	18.50	9.90	8.17	74.17	3.03	4.00
K2	0.22	16.73	19.48	9.46	9.51	88.86	2.99	5.00
K3	0.23	17.63	20.28	8.41	11.28	93.02	3.35	5.00
K4	0.17	18.05	22.82	9.07	13.06	146.63	3.41	5.75
CD (0.05)	0.08**	1.85*	2.16**	1.34**	2.38**	37.75**	NS	1.34*

NS Not significant

* Significant at 0.05 level

** Significant at 0.01 level

4.4.2. Total Soluble Solids

The highest mean value for total soluble solids recorded by the K4 level (18.05 percent) was on par with all other treatments except control.

4.4.3. Total, Reducing and Non-reducing Sugars

The total sugar content of fruit showed variation in different treatments. The highest total sugar content observed in K4 (22.82 percent) was significantly superior to all other treatments. This treatment was followed by K3 (20.28 percent), K2 (19.48 percent) and K1 (18.50 percent) which were statistically on par.

The reducing sugar content was lowest for K3 (8.41 percent), which was on par with K4 (9.07 percent) and K2 (9.46 percent). The highest mean value for reducing sugar was recorded by KO (11.17 percent).

K4 recorded the highest content of non-reducing sugar with mean value of 13.06 percent followed by K3 (11.28 percent). The two treatments were statistically on par. Control plants registered the lowest value of 5.82 percent.

4.4.4. Sugar/Acid ratio

The sugar/acid ratio showed a steady increasing trend with increase in the rate of K application. K4 treatment recorded significantly superior mean value of 146.63 which was followed by K3 (93.02), K2 (88.86) and K1 (74.17).

4.4.5. Pulp/Peel ratio

The data revealed that the different treatments had no significant effect on the pulp/peel ratio of the fruit.

4.4.6. Shelf life

The maximum mean shelf life of 5.75 days was recorded by K4 which was on par with K3 and K2, both recorded a mean value of 5.00 days. The control plots showed minimum mean value of 3.25 days.

4.5. Effect of K levels on soil chemical properties

4.5.1. Soil pH

The mean data on the pH of the soil at different growth stages of the crop are furnished in Table 6.

Table 6. Effect of K levels on soil pH (mean table)

Treatments	Soil pH				
	2MAP	4MAP	6MAP	8MAP	9MAP
K0	4.58	5.00	5.15	5.10	5.70
K1	5.05	4.83	5.10	5.35	5.70
K2	4.63	4.43	4.98	5.40	5.83
K3	4.98	4.88	5.03	5.68	5.73
K4	5.23	4.90	5.25	5.23	5.63
CD (0.05)	0.46*	NS	NS	NS	NS

NS Not Significant MAP - Month after planting

* Significant at 0.05 level.

The results showed that the difference among the treatments were not significant at all growth stages of the crop except at the early vegetative stage. At this stage, the significance was only at 5 percent level.

4.5.2. Electrical conductivity

Electrical conductivity for all the soil samples of different treatments were less than 0.05 dS m^{-1}, indicating low salt concentration in the soil solution. So the data were not subjected to statistical analysis.

4.5.3. Soil organic carbon

Table 7 shows the organic carbon content in soil as influenced by different treatments. The data revealed that the different levels of K fertilizer application had no significant effect on the organic carbon content of soil at all the growth stages.

4.5.4. Available N

The data presented in Table 8 showed the status of available N in soil at various growth stages of the crop. The results

Table 7. Effect of K levels on soil organic carbon (mean table)

Treatments	Orgnic carbon (%)				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
KO	0.32	0.32	0.31	0.30	0.27
K1	0.37	0.32	0.30	0.27	0.28
K2	0.34	0.33	0.33	0.30	0.30
K3	0.35	0.34	0.36	0.29	0.29
K4	0.35	0.33	0.33	0.31	0.29
CD (0.05)	NS	NS	NS	NS	NS

NS Not significant MAP - Month after planting

Table 8. Effect of K levels on available nitrogen in the soil (mean table)

Treatments	Available nitrogen (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
KO	225.01	227.35	175.61	148.96	150.92
K1	200.70	204.62	163.86	159.94	147.00
K2	225.79	209.33	162.88	139.55	137.20
K3	243.29	225.01	170.52	164.64	148.96
K4	233.90	217.95	154.45	159.15	153.86
CD (0.05)	NS	NS	NS	NS	NS

NS Not significant MAP - Month after planting

showed that the differences among the treatments were not significant at all growth stages.

4.5.5. Available P

Results of the study are presented in Table 9. Available P content of the soil was not significantly influenced by the different treatments.

4.5.6. Exchangeable K

The mean data on the exchangeable K content of the soil at different growth stages are presented in Table 10. The different treatments significantly influenced the K content of soil at all growth stages except harvest stage. In general, the exchangeable K content of soil showed an increasing trend with increase in the level of K supply.

At the early vegetative stage, K3 registered the maximum soil K content (176.40 kg ha^{-1}) which was statistically on par with K4 (162.40 kg ha^{-1}). the lowest mean value was recorded by K1 (103.60 kg ha^{-1}) which was on par with the control plot (109.25 kg ha^{-1}).

Table 9. Effect of K levels on available phosphorus in the soil (mean table)

Treatments	Available phosphorus (Kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
KO	63.00	58.24	41.57	40.23	20.44
K1	66.64	45.08	45.52	41.19	29.68
K2	62.05	46.48	41.95	37.40	28.00
K3	59.92	53.76	44.87	38.12	38.64
K4	58.65	55.16	45.01	35.33	24.92
CD (0.05)	NS	NS	NS	NS	NS

NS Not significant MAP - Month after planting

Table 10. Effect of K levels on exchangeable potassium in the soil (mean table)

Treatments	Exchangeable potassium (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
KO	109.25	106.40	100.80	95.20	79.80
K1	103.60	137.20	201.60	184.80	169.40
K2	145.60	187.60	249.20	235.20	239.40
K3	176.40	187.55	263.20	243.60	235.20
K4	162.40	204.40	288.40	268.80	263.20
CD (0.05)	15.96**	37.58**	43.05**	93.10*	NS

NS Not Significant MAP - Month after planting

* Signifiant at 0.05 level

** Significant at 0.01 level

K4 recorded the maximum value (204.40 kg ha^{-1}) at the late vegetative stage which was on par with K2 (187.60 kg ha^{-1}) and K3 (187.55 kg ha^{-1}). Control plot recorded the lowest exchageable K (106.40 kg ha^{-1}).

At the shooting stage, again K4 recorded the highest value (288.40 kg ha^{-1}) which was on par with K3 (263.20 kg ha^{-1}) and K2 (249.20 kg ha^{-1}), while the lowest value was recorded by the KO level (100.80 kg ha^{-1}).

At the bunch maturation stage, the highest mean value recorded by K4 (268.80 kg ha^{-1}) was on par with all other treatments except KO which showed the lowest value of 95.20 kg ha^{-1}.

4.5.7. Exchangeable Ca

Table 11 presents the mean data on the exchangeable Ca content of the soil at different growth stages of the crop.

At all the major growth stages, exchangeable Ca content showed a decreasing trend with increase in the rate of K application. But significant difference was observed only at

Table 11. Effect of K levels on exchangeable calcium in the soil (Mean table)

Treatments	Exchangeable calcium (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
K0	94.35	97.39	106.52	106.52	115.44
K1	106.53	91.31	94.35	112.61	94.35
K2	91.31	94.35	85.22	100.44	88.26
K3	88.26	82.18	88.26	85.22	79.14
K4	82.18	76.10	76.09	79.13	76.09
CD(0.05)	9.09**	NS	NS	NS	NS

NS Not significant   MAP- month after planting.

** Significant at 0.01 level

the early vegetative stage. At this stage, K1 showed superiority with a significant mean value of 106.53 kg ha^{-1}, followed by KO with mean value of 94.35 kg ha^{-1}. K4 recorded the lowest value (82.18 kg ha^{-1}) which was on par with K3 (88.26 kg ha^{-1}).

4.5.8. Exchangeable Mg

Table 12 shows the mean data on the soil content of exchangeable Mg at various growth stages.

At all the stages, exchangeable Mg content tended to show a decrease with increase in the rate of K fertilizer application. The treatments differed significantly at all growth stages except at the late vegetative stage.

At the early vegetative stage, KO recorded the highest value (35.65 kg ha^{-1}) which was on par with K2 (32.70 kg ha^{-1}) and K3 (27.74 kg ha^{-1}), while K4 registered the lowest value of 21.83 kg ha^{-1}.

At the shooting stage, the maximum content of exchangeable Mg was at KO level (29.48 kg ha^{-1}) which was on par with K2 (24.78 kg ha^{-1}), while the lowest content was at K3 level

Table 12. Effect of K levels on exchangeable ma gnesium in the soil (Mean table)

Treatments	Exchangeable mangesium (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
K0	35.65	32.61	29.48	31.48	33.56
K1	25.48	28.70	19.66	25.39	27.65
K2	32.70	23.65	24.78	27.57	23.74
K3	27.74	19.83	15.74	20.57	22.61
K4	21.83	21.90	15.92	14.87	17.91
CD(0.05)	8.45*	NS	8.5*	8.93*	9.66*

NS Not significant MAP - Month after planting

* Significant at 0.05 level

(15.74 kg ha^{-1}) which was on par with K4 treatment (15.92 kg ha^{-1}) and K1 treatment (19.66 kg ha^{-1}).

The maximum mean value for exchangeable Mg was at KO level (31.48 kg ha^{-1}) during the bunch maturation stage which was on par with K2 (27.57 kg ha^{-1}) and K1 (25.39 kg ha^{-1}). The lowest Mg content was recorded by K4 (14.87 kg ha^{-1}) which was on par with K3 (20.57 kg ha^{-1}).

At the harvest stage, again KO recorded the highest value (33.56 kg ha^{-1}) which was on par with K1 (27.65 kg ha^{-1}), while K4 recorded the lowest content of soil exchangeable Mg (17.91 kg ha^{-1}).

4.6. Effect of K levels on concentration of nutrients in different parts of leaf at various growth stages of banana cv. Nendran

4.6.1. Concentration of N

Table 13 presents the mean data on the concentration of N in different parts of leaf at various growth stages as influenced by different levels of K application.

Table 13. Effect of K levels on nitrogen concentration in different parts of leaf at various growth stages (mean table)

Treat-ments	Concentration of Nitrogen (%)														
	2 MAP			4 MAP			6 MAP			8 MAP			9 MAP		
	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib
K0	2.74	1.92	1.13	3.09	1.27	1.17	3.19	1.78	1.23	3.13	1.67	1.21	2.86	1.35	1.04
K1	2.62	1.92	0.95	2.94	1.14	1.10	2.97	1.65	1.17	2.91	1.71	1.14	2.89	1.58	0.96
K2	2.44	1.91	1.04	2.45	1.21	1.03	3.01	1.46	1.10	2.84	1.56	1.13	2.65	1.42	0.90
K3	1.34	1.68	0.99	1.62	1.55	1.10	2.83	1.42	1.16	2.64	1.36	1.13	2.75	1.27	1.03
K4	1.27	1.53	0.90	1.65	1.25	1.05	2.90	1.26	0.98	2.70	1.35	0.98	2.51	0.88	0.85
CD (0.05)	0.37**	0.16**	NS	0.31**	0.16**	NS	NS	0.29**	NS	0.31*	NS	NS	0.26*	0.32**	NS

NS Not significant

MAP - Month after planting

* Significant at 0.05 level

** Significant at 0.01 level

In all leaf tissues and at all stages of crop growth, N concentration showed a decreasing trend with increased level of K application. In most cases, the maximum values were recorded by the control plants and minimum by the K4 treatment. The results also revealed that the N contents in the lamina and petiole showed significant variation under the influence of treatments.

At the early vegetative stage, both the lamina and petiole showed significant variation due to treatments. In the lamina, the highest mean value was recorded by the control (2.74 percent) which was on par with K1 (2.62 percent) and K2 (2.44 percent). The lowest value was recorded by K4 (1.27 percent). Petiole also followed the same trend as that of lamina showing the highest value for control (1.92 percent) and the lowest for K4 treatment (1.53 percent).

At the late vegetative stage also, the N contents of the lamina and petiole were significantly influenced by different K levels. In the lamina, control plants re corded the maximum N content of 3.09 percent, followed by K1 (2.94 percent), the two treatments being statistically on par. The lowest mean value recorded by K3 (1.62 percent) was on par with K4 treatment (1.65 percent). In the petiole, highest mean value recorded by K3 (1.55 percent) was significantly superior to all other treatments, while the lowest N content was showed by K1 with mean value of 1.14 percent.

The petiole alone showed significant variation at shooting stage with KO recorded the maximum N content (1.78 percent) which was on par with K1 (1.65 percent), while K4 recorded the minimum N content with mean value of 1.26 percent.

At the bunch maturation stage, the nitrogen content in lamina alone was significantly influenced by the treatments. The KO treatment showed the highest value (3.13 percent) which was on par with K1 (2.91 percent) and K2 (2.84 percent). The lowest N content was recorded by K3 treatment (2.64 percent).

At the harvest stage, both lamina and petiole were significantly influenced by the treatments. In the lamina, K1 recorded the highest mean value (2.89 percent) which was on par with all other treatments except K4 (2.51 percent). In the petiole also, maximum value recorded by K1 (1.58 percent) was on par with all other treatments except K4 (0.88 percent).

4.6.2. Concentration of P

The mean data on the concentration of P at different growth stages under varying levels of K application are furnished in Table 14.

The results revealed that the P content showed an increasing trend with increased level of K application.

At the early vegetative stage, petiole and midrib showed significant variation due to different treatments. In the petiole, the maximum P content recorded by K4 treatment (0.33 percent) was on par with all other treatments except KO which recorded the lowest mean value of 0.27 percent. In the midrib, K4 recorded the highest mean value (0.31 percent) followed by K2 (0.28 percent), these two treatments were statistically on par. The lowest value was recorded by the control plants with mean P content of 0.25 percent.

At the late vegetative stage, no part was significantly affected by different K levels.

Table 14. Effect of K levels on phosphorus concentration in different parts of leaf at various growth stages (mean table)

Treat-ments	Concentration of Phosphorus (%)														
	2 MAP			4 MAP			6 MAP			8 MAP			9 MAP		
	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib
K0	0.27	0.27	0.25	0.27	0.24	0.16	0.23	0.25	0.16	0.23	0.22	0.15	0.22	0.20	0.13
K1	0.32	0.30	0.26	0.28	0.28	0.22	0.24	0.24	0.17	0.23	0.23	0.16	0.23	0.22	0.13
K2	0.33	0.32	0.28	0.29	0.29	0.22	0.25	0.26	0.18	0.24	0.25	0.16	0.24	0.24	0.14
K3	0.34	0.32	0.26	0.30	0.29	0.23	0.25	0.26	0.20	0.26	0.26	0.17	0.23	0.24	0.14
K4	0.36	0.33	0.31	0.29	0.31	0.27	0.26	0.27	0.20	0.26	0.25	0.19	0.25	0.25	0.16
CD (0.05)	NS	0.04*	0.04*	NS	NS	NS	0.02*	NS	NS	0.02*	NS	NS	0.02*	0.03*	NS

NS - Not significant

MAP - Month after planting

* - Significant at 0.05 level

** - Significant at 0.01 level

Lamina alone showed significant variation in P content at the shooting stage. The maximum mean value recorded by K4 (0.26 percent) was on par with K3 and K2, both recorded total P content of 0.25 percent. The lowest value was recorded by the control plants (0.23 percent).

At the bunch maturation stage also, P concentration of the lamina alone varied significantly due to different treatments. The highest value recorded by K3 and K4 treatments (0.26 percent) was on par with K2 (0.24 percent), while KO recorded the lowest value (0.23 percent).

At the harvest stage, both lamina and petiole showed significant variation with different levels of K. In the lamina, K4 recorded the highest value (0.25 percent) which was on par with all other treatments except KO. In the petiole also, the maximum value was recorded by K4 treatment (0.25 percent). This treatment was on par with all other treatments except KO which recorded the lowest value of 0.20 percent.

4.6.3. Concentration of K

Table 15 presents the mean data on the content of K in different leaf tissues at various growth stages under different levels of K application.

In all leaf tissues and at all growth stages of the crop, K content showed an increasing trend with increase in the level of K application. In all the cases, lowest values were recorded by the control.

At the early vegetative stage, K content in the lamina and petiole varied significantly due to different treatments. In the lamina, K3 and K1 resulted in the highest mean value of 2.82 percent which was on par with all other treatments except KO. In the petiole, the maximum content recorded by K3 (3.36 percent), was on par with K4 (3.32 percent) and K2 (3.22 percent), while the control plants registered the lowest value (2.09 percent).

Lamina, petiole and midrib showed significant variation at the late vegetative stage. In the lamina, K4 recorded the highest mean value (3.12 percent) which was on par with K1 (2.99

Table 15. Effect of K levels on potassium concentration in different part of leaf at various growth stages (mean table)

Treatments	Concentration of Potassium (%)														
	2 MAP			4 MAP			6 MAP			8 MAP			9 MAP		
	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib
K0	1.93	2.09	1.70	1.66	1.98	1.57	1.59	1.76	1.66	1.37	1.62	1.66	1.35	1.59	1.61
K1	2.82	2.98	1.85	2.99	2.94	2.15	1.80	2.08	1.93	2.33	2.36	2.09	2.31	2.26	2.05
K2	2.58	3.22	2.04	2.44	3.04	2.24	2.06	2.39	2.23	2.39	2.87	2.14	2.40	2.70	2.34
K3	2.82	3.36	2.58	2.96	3.17	2.87	2.09	2.46	2.46	2.77	3.17	2.50	2.69	3.07	2.40
K4	2.74	3.32	2.60	3.12	3.15	2.80	2.26	2.41	2.29	2.91	3.17	2.40	2.85	3.08	2.33
CD (0.05)	0.32**	0.34**	NS	0.44**	0.31**	0.27**	0.28**	NS	0.43*	0.14**	0.18**	0.37**	0.13**	0.25**	0.15**

NS Not significant

MAP - Month after planting

* Significant at 0.05 level

** Significant at 0.01 level

percent) and K3 (2.96 percent), while the control treatment recorded the lowest mean value (1.66 percent). In the petiole, the maximum K concentration recorded by K3 (3.17 percent) was on par with all other treatments except KO which recorded the lowest K content of 1.98 percent. In the midrib, K3 recorded the highest mean value (2.87 percent) followed by K4 (2.80 percent), the two treatments were statistically on par. KO recorded the lowest value (1.57 percent) which was significantly inferior to all other treatments.

At the shooting stage, the lamina and midrib showedsignificant variation in K content. In the lamina, K4 registered the highest mean value (2.26 percent) which was on par with K3 (2.09 percent) and K2 (2.06 percent), while the control plants recorded the lowest value (1.59 percent). In the midrib, the maximum K content was recorded by K3 treatment (2.46 percent), which was on par with K4 (2.29 percent) and K2 (2.23 percent). The minimum K content was recorded again by KO treatment (1.66 percent).

Lamina, petiole and midrib recorded significant difference in K content at the bunch maturation stage. K4 recorded the maximum K content in both lamina and petiole with mean values of 2.91 percent and 3.17 percent respectively which was on par with K3 with mean values of 2.77 percent and 3.17 percent respectively. Control plants showed the minimum K content in both the cases with mean values of 1.37 percent and 1.62 percent respectively. In the midrib, K3 recorded the highest mean value (2.50 percent) which was on par with K4 (2.4 percent) and K2 (2.14 percent), while the control plants registered the lowest mean value (1.66 percent).

At the harvest stage, lamina, petiole and midrib showed significant variation in K content. In the lamina, K4 was significantly superior (2.85 percent) followed by K3 (2.69 percent), while KO was significantly inferior (1.35 percent). In the petiole, K4 recorded the highest mean value (3.08 percent), which was on par with K3 (3.07 percent), while the lowest value was registered by the control plants (1.59 percent). K3 recorded the maximum K content (2.40 percent) in the midrib followed by K2 (2.34 percent) and K4 (2.33 percent), the three treatments being statistically on par. Lowest value for K concentration was recorded again by KO treatment (1.61 percent).

4.6.4. Concentration of Ca

The mean data on the concentration of Ca in different leaf tissues under different levels of K application at various growth stages are presented in Table 16.

Calcium level in the leaf tissues recorded a decreasing trend with increase in the level of K application. In most cases, the maximum values were recorded by the control and the minimum by the K4 treatment.

During the early vegetative stage, lamina, petiole and midrib showed significant variation due to different treatments. In the lamina, KO recorded the highest Ca level (0.88 percent) which was significantly superior to all other treatments, while K4 registered the lowest value (0.56 percent). In the petiole, the highest mean value recorded by KO (0.79 percent) was on par with K1 (0.67 percent) and K3 (0.64 percent). K4 treatment registered the lowest Ca level with mean value of 0.50 percent. Midrib showed the highest Ca content of 0.69 percent at KO treatment, which was on par with K1 (0.61 percent) and K2 (0.57 percent), while the lowest value of 0.43 percent was recorded by K3.

Table 16. **Effect of K levels on calcium concentration in different part of leaf at various growth stage (mean table)**

Treat-ments	Concentration of Calcium (%)														
	2 MAP			4 MAP			6 MAP			8 MAP			9 MAP		
	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib
KO	0.88	0.79	0.69	0.95	0.83	0.84	1.17	1.11	0.98	1.14	1.14	0.94	0.79	0.92	0.80
K1	0.75	0.67	0.61	0.83	0.76	0.69	1.02	0.83	1.07	0.98	1.02	0.92	0.75	0.84	0.73
K2	0.63	0.58	0.57	0.69	0.70	0.67	0.95	0.72	0.94	1.03	0.82	0.80	0.72	0.88	0.67
K3	0.72	0.64	0.43	0.68	0.67	0.69	0.82	0.73	0.77	0.94	0.71	0.80	0.69	0.53	0.58
K4	0.56	0.50	0.48	0.63	0.60	0.60	0.68	0.67	0.71	0.72	0.61	0.58	0.72	0.45	0.60
CD (0.05)	0.09**	0.18*	0.14*	0.09**	NS	NS	0.13**	0.13**	0.19**	0.16**	0.15**	0.11**	NS	0.26**	NS

NS Not significant

MAP - Month after planting

* Significant at 0.05 level

** Significant at 0.01 level

Lamina alone showed significant variation in Ca content at the late vegetative stage. The highest mean value was recorded by KO (0.95 percent), which was followed by K1 (0.83 percent). These two treatments differed significantly from other treatments. The lowest value was recorded by K4 (0.63 percent).

At the shooting stage, lamina, petiole and midrib showed significant variation in Ca content. In the lamina, KO recorded significantly superior value of 1.17 percent, followed by K1 (1.02 percent) and K2 (0.95 percent). The lowest value of 0.68 percent was in the K4 treatment. In the petiole, KO showed superiority over the other treatments with significant mean value of 1.11 percent, while K4 registered the lowest value of 0.67 percent. Midrib showed the highest Ca level of 1.07 percent at K1, which was on par with KO (0.98 percent) and K2 (0.94 percent). The lowest Ca content was at K4 (0.71 percent) which was on par with K3 (0.77 percent).

At the bunch maturation stage, again lamina, petiole and midrib showed significance in Ca content under the influence of different K levels. In the lamina, KO produced the highest Ca content of 1.14 percent which was on par with K2 level (1.03 percent). The lowest content of 0.72 percent was in the K4 treatment. The petiole Ca content registered the highest value of 1.14 percent by the control plot which was on par with K1 level (1.02 percent). The lowest value showed by K4 treatment (0.61 percent) was on par with K3 (0.71 percent). In the midrib, the highest concentration of 0.94 percent was registered by the control plants which was on par with K1 (0.92 percent). The K4 treatment was significantly inferior to all other treatments with mean value of 0.58 percent.

Among the leaf tissues, petiole alone recorded significant variation in Ca content at the harvest stage. The highest value recorded by the control plants (0.92 percent) was on par with K2 (0.88 percent) and K1 (0.84 percent), while K4 recorded the lowest value of 0.45 percent.

4.6.5. Concentration of Mg

The mean data on Mg content at different growth stages of banana cv. Nendran under of different levels of K application are presented in Table 17.

Table 17. **Effect of K levels on magnesium concentration in different parts of leaf at various growth stages (mean table)**

Treat-ments	Concentration of Magnesium (%)														
	2 MAP			4 MAP			6 MAP			8 MAP			9 MAP		
	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib	Lamina	Petiole	Midrib
K0	0.20	0.15	0.14	0.22	0.19	0.17	0.28	0.25	0.21	0.32	0.31	0.20	0.21	0.20	0.17
K1	0.18	0.12	0.12	0.19	0.18	0.14	0.25	0.22	0.18	0.26	0.23	0.17	0.24	0.18	0.15
K2	0.16	0.13	0.12	0.18	0.16	0.16	0.22	0.21	0.17	0.28	0.22	0.16	0.21	0.18	0.13
K3	0.16	0.12	0.12	0.18	0.14	0.15	0.23	0.22	0.15	0.26	0.23	0.13	0.20	0.18	0.13
K4	0.13	0.13	0.12	0.16	0.13	0.12	0.21	0.18	0.13	0.23	0.20	0.13	0.19	0.14	0.10
CD (0.05)	0.03**	NS	NS	0.03**	0.03**	NS	0.03**	NS	0.04**	0.03**	0.05**	0.05*	0.01**	0.03*	0.03**

NS Not Significant

MAP - Month after planting

* Significant at 0.05 level

** Significant at 0.01 level

The concentration of Mg in the leaf showed a decreasing trend with increase in K supply. Higher values in most cases were recorded by the control and the lower by the K4 treatment.

At the early vegetative stage, the lamina alone showed significant difference in Mg content under different levels of K supply. In the lamina, KO resulted in the highest Mg content (0.20 percent) which was on par with K1 (0.18 percent), while the K4 treatment recorded the lowest value of 0.13 percent.

Mg content of lamina and petiole varied significantly under the treatments at the late vegetative stage. In the lamina, the highest value for Mg recorded by the control plants (0.22 percent) was on par with K1 (0.19 percent), while the K4 treatment showed the lowest value of 0.16 percent. The petiole registered the highest Mg content of 0.19 percent at KO level which was on par with K1 (0.18 percent). The lowest value, 0.13 percent was at K4 level which was on par with K3 (0.14 percent).

At the shooting stage, Mg concentration in the lamina and midrib showed significant variation between the treatments. In the lamina, control plants showed the highest value (0.28

percent) which was on par with K1 (0.25 percent). While the lowest value recorded by K4 (0.21 percent) was on par with K2 (0.22 percent) and K3 (0.23 percent). Treatment KO produced the highest Mg content (0.21 percent) in the midrib which was on par with K1 (0.18 percent) and K2 (0.17 percent). The lowest Mg content of 0.13 percent was at K4 level.

At the bunch maturation stage, concentration of Mg in the lamina, petiole and midrib varied significantly due to different treatments. In the lamina, KO recorded superiority over other treatments with mean value of 0.32 percent. The lowest value recorded by K4 (0.23 percent) was on par with K3 (0.26 percent). KO showed significantly superior value (0.31 percent) in the petiole. The lowest value of Mg content in the petiole was recorded by K4 (0.20 percent) which was on par with all other treatments except KO. In the case of midrib, KO produced the highest Mg content of 0.20 percent which was on par with K1 (0.17 percent) and K2 (0.16 percent), while K4 as well as K3 recorded the lowest mean value of 0.13 percent.

At the harvest stage of the crop, Mg content in the lamina, petiole and midrib varied significantly as a result of different levels of K application. In the lamina, K1 recorded a significantly higher value of 0.24 percent. This treatment was followed by KO and K2 both recorded a mean Mg content of 0.21 percent. The K4 treatment recorded a significantly lower value of 0.19 percent. In the petiole, the highest value of 0.20 percent was registered by KO level which was on par with all other treatments except K4 which recorded the lowest Mg content of 0.14 percent. The highest Mg content in the midrib was recorded by the control plants (0.17 percent). This was on par with K1 (0.15 percent). K4 treatment resulted in the lowest Mg content of 0.1 percent which was on par with K3 as well as K2 (0.13 percent).

4.7. Correlation and Regression studies

4.7.1. Correlation analysis between yield and biometric characters in banana cv. Nendran.

Table 18 gives the coefficients of correlation between biometric characters and yield characters in Nendran banana. Correlations between biometric characters (height of plant, girth of pseudostem, number of functional leaves and total leaf area) and yield characters (weight of bunch, number of fingers

Table 18. Coefficient of correlation between yield and biometric characters in banana.

Biometric characters	Yield characters						
	Weight of bunch	Number of fingers bunch^{-1}	Number of hands bunch^{-1}	Weight of hand	Weight of finger	Length of finger	Girth of finger
Plant Height	1	2	3	4	5	6	7
2 MAP	0.1045	0.1804	0.2165	0.0289	0.2478	0.2390	0.3604
4 MAP	0.4278	0.4700*	0.2028	0.4825*	0.3236	0.4882*	0.1534
6 MAP	0.6456**	0.6855**	0.5791**	0.4821*	0.4349	0.5949**	0.4171
8 MAP	0.7437**	0.7019**	0.6936**	0.5431*	0.6065**	0.7060**	0.5554*
9 MAP	0.7372**	0.6802**	0.6976**	0.5314*	0.6315**	0.6997**	0.6177**
Pseudostem girth							
2 MAP	0.0695	-0.0221	0.1542	-0.0894	0.0553	-0.0171	0.3126
4 MAP	0.4049	0.3403	0.4221	0.2460	0.3234	0.3736	0.4071
6 MAP	0.7758**	0.6342**	0.6656**	0.5762**	0.6797**	0.7255**	0.6611**
8 MAP	0.7312**	0.6256**	0.6824**	0.4997*	0.6627**	0.7129**	0.6331**
9 MAP	0.7954**	0.6582**	0.7333**	0.5305*	0.7202**	0.7669**	0.6624**

Contd...

Functional leaves	1	2	3	4	5	6	7
2 MAP	-0.5329*	-0.4157	-0.3175	-0.4779*	-0.3579	-0.4392	-0.2424
4 MAP	-0.0583	0.0229	0.0583	-0.1176	-0.0413	-0.0598	0.1084
6 MAP	0.2977	0.2150	0.1495	0.4320	0.2549	0.3288	0.3779
8 MAP	0.2734	0.2817	0.3186	0.2035	0.3162	0.3415	0.4065
9 MAP	-0.1323	0.1097	0.0874	-0.1408	0.0198	0.0650	0.0863
Total leaf Area							
2 MAP	-0.0585	0.0661	0.0430	-0.1289	0.1058	-0.0089	0.2104
4 MAP	-0.2034	-0.1462	-0.1798	-0.1865	-0.1242	-0.0947	-0.0846
6 MAP	0.1206	0.0797	0.1081	0.1339	0.3401	0.2790	0.4869*
8 MAP	0.3769	0.2233	0.2799	0.3908	0.4783*	0.4424	0.4814*
9 MAP	0.2170	0.2609	0.3055	0.1802	0.3155	0.3835	0.2564

* Significant at 0.05 level

** Significant at 0.01 level

MAP - month after planting

per bunch, number of hands per bunch, weight of hand, weight of finger, length of finger and girth of finger) were studied.

The biometric characters, height of plant and girth of pseudostem at shooting, bunch maturation and harvest stages showed positive and highly significant linear relationship with yield characters. The plant height at bunch maturation stage showed highest value for correlation coefficient with weight of bunch (r = 0.7437**), number of fingers per bunch (r = 0.7019**), weight of hand (r = 0.5431*) and length of finger (r = 7060**). The plant height showed highest correlation coefficient value with number of hands per bunch (r = 0.6976**), weight of finger (r = 0.6315**) and girth of finger (r = 0.6177**) at harvest stage. The girth of pseudostem at harvest stage revealed high positive correlation with weight of bunch (r = 0.7954**), number of finger per bunch (r = 0.6582), number of hands per bunch (r = 0.7333**), weight of finger (r = 0.7202**), length of finger (r = 0.7669**) and girth of finger (r = 0.6624**). The girth of pseudostem at shooting stage recorded highest value for coefficient of correlation with weight of hand (r = 0.5762**).

Correlation between number of functional leaves and yield characters such as weight of bunch and weight of hand were noted at early vegetative stage only. The correlations were negative and significant at 0.05 level only with `r' values being -0.5329 and -0.4779 respectively.

Total leaf area showed positive correlation with girth of finger at shooting and bunch maturation stages with `r' values being 0.4869* and 0.4814* respectively. At bunch maturation stage total leaf area also showed positive correlation with weight of finger (r = 0.4783*).

4.7.2. Correlation analysis between soil exchangeable K at various growth stages and yield characters in banana cv. Nendran.

Correlation between soil exchangeable K at various growth stages of the crop and yield contributing characters such as weight of bunch, number of fingers per bunch, number of hands per bunch, weight of hand, weight of finger, length of finger and girth of finger are furnished in Table 19.

Table 19. Coefficient of correlation between exchangeable K in soil and yield characters in banana

Yield characters	Exchangeable K (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
Weight of bunch	0.7954**	0.7246**	0.7394**	0.7603**	0.6712**
No. of fingers	0.7629**	0.6010**	0.6484**	0.6362**	0.4206
No.of hands	0.6449**	0.7148**	0.6574**	0.7355**	0.5776**
Weight of hand	0.7459**	0.5227*	0.5532*	0.5316*	0.4606*
Weight of finger	0.8101**	0.6585**	0.7243**	0.7080**	0.5529*
Length of finger	0.8259**	0.7147**	0.7705**	0.7415**	0.5939**
Girth of finger	0.6670**	0.4693*	0.5909**	0.6376**	0.5434*

* Significant at 0.05 level MAP - Month after planting

** Significant at 0.01 level

The results showed positive and significant correlation of soil exchangeable K with all yield attributing characters at all growth stages. At early vegetative stage, soil exchangeable K manifested the highest coefficient of correlation with weight of bunch (r = 0.7954**), number of fingers per bunch (r = 0.7629**), weight of hand (r = 0.7459**), weight of finger (r = 0.8101**), length of finger (r = 0.8259**) and girth of finger (r = 0.6670**). The maximum association of soil exchangeable K with number of hands per bunch was noticed at bunch maturation stage with `r' value being 0.7355**).

4.7.3. Correlation analysis between K concentration in lamina, petiole and midrib at various growth stages and bunch weight in banana cv. Nendran.

K concentration in all plant parts studied such as lamina, petiole and midrib showed positive and significant correlation with yield except the lamina at early vegetative stage as revealed by Table 20. K content in lamina, petiole and midrib showed highly significant correlation with yield at harvest stage with `r' values being 0.7464**, 0.7819** and 0.7357** respectively. The results also revealed that among the three

Table 20. Coefficient of correlation between K concentration in lamina, petiole and midrib and bunch weight in banana.

Stages	K Concentration		
	Lamina	Petiole	Midrib
2 MAP	0.3947	0.6463**	0.6654**
4 MAP	0.5923**	0.7354**	0.7072**
6 MAP	0.7312**	0.4768*	0.5350*
8 MAP	0.7276**	0.7720**	0.6961**
9 MAP	0.7464**	0.7819**	0.7357**

* Significant at 0.05 level MAP - Month after planting

** Significant at 0.01 level

parts studied, K concentration in the petiole at harvest stage showed the maximum relationship with yield (r = 0.7819**).

4.7.4. Step-wise regression analysis for standardising index plant part for K status in banana cv. Nendran.

Step-wise regression analysis (Draper and Smith, 1966) was applied to select the best plant part out of lamina, petiole and midrib for foliar analysis of K status in banana cv. Nendran. The results of the step-wise regression analysis are presented in table 21. It could be observed that the K concentration in petiole at nine month after planting (harvest stage) emerged as the most important variable and it explained nearly 61.14 percent of variation in bunch yield (R^2= 0.6114), followed by midrib at two month after planting (early vegetative stage) for which contribution to bunch weight was only 6.71 percent, then lamina at early vegetative stage which contributed 3.47 percent variability to bunch yield. All the fifteen K concentrations in plant parts were ranked with midrib at four month after planting (late vegetative stage) emerged as the last variable (R^2= 0.9764).

Table 21. Step-wise regression analysis of the K contents in plant parts influencing bunch weight in banana

Order of inclusion	Plant part - MAP	Coefficient of determination R^2	R^2 (adjusted for df)
1	Petiole - 9 MAP	0.6114	0.6114
2	Midrib - 2 MAP	0.6954	0.6785
3	Lamina - 2 MAP	0.7434	0.7132
4	Petiole - 4 MAP	0.8414	0.8117
5	Petiole - 2 MAP	0.8915	0.8625
6	Midrib - 9 MAP	0.9147	0.8842
7	Lamina - 6 MAP	0.9262	0.8921
8	Midrib - 8 MAP	0.9344	0.8961
9	Lamina - 8 MAP	0.9389	0.8944
10	Petiole - 8 MAP	0.9472	0.8997
11	Midrib - 6 MAP	0.9615	0.9184
12	Lamina - 4 MAP	0.9694	0.9274
13	Lamina - 9 MAP	0.9749	0.9319
14	Petiole - 6 MAP	0.9900	0.9683
15	Midrib - 4MAP	0.9938	0.9764

MAP-Month after planting

It is concluded that K concentration in the petiole at harvest stage was most highly correlated with bunch yield. Since petiole showed the highest predictability on yield, it was selected as the index part for foliar analysis for K in banana cv. Nendran.

4.7.5. Correlation analysis between soil exchangeable K at various growth stages and K content in the index plant part in banana cv. Nendran.

Table 22 shows highly significant positive correlation between soil exchangeable K at various growth stages and content of K in the index plant part (petiole) at harvest stage.

4.7.6. Quadratic regression model to find out critical K level in the index plant part in banana cv. Nendran for maximum response to yield.

The K content in the petiole at harvest stage was related to bunch yield using quadratic regression model of the type, $Y = a + bx + cx^2$ where Y is the bunch yield and x, the K content (%) in the petiole at harvest stage. Appendix II gives the analysis of variance (ANOVA) table.

Table 22. Coefficient of correlation between exchangeable K in soil and K concentration in petiole at harvest stage in banana

K concentration	Exchangeable K (kg ha^{-1})				
	2 MAP	4 MAP	6 MAP	8 MAP	9 MAP
Petiole-9MAP	0.8384**	0.8774**	0.8656**	0.7979**	0.6077**

** Significant at 0.01 level MAP - Month after planting

The estimated quadratic regression equation was,

$$Y = -2.9997 + \underset{(5.4474)}{6.8055\,x} - \underset{(1.1302)}{0.7878x^2} \qquad \underset{(\text{adj.for df})}{R^2 = 60.12}$$

(Figures given in brackets denote standard error)

The petiole K concentrations for different treatments at harvest stage corresponding to the bunch yield were located on the graph (Fig.16) and the nutrient concentration corresponding to the point in the bend of the curve is marked as critical K level for maximum yield. The graphical method also showed critical K level of 4.3 percent for maximum yield.

Yield below 10 percent of the maximum was worked out and the petiole K content corresponding to this was located on the graph and marked as critical K level for economic yield (3.1 percent).

4.7.7. Critical K level in soil and computation of fertilizer requirement

The soil K content at late vegetative stage (4 MAP) was related to bunch yield using quadratic regression model of the type $Y = a + bx + cx^2$, where Y is the bunch yield and x, the soil K content. The late vegetative stage was considered because correction in the fertilizer schedule is practicable at this stage. Appendix III gives the analysis of variance (ANOVA) table.

The estimated quadratic regression equation was,

$$Y = -5.2369 + \underset{(0.0285)}{0.1444x} - \underset{(0.00007)}{0.0003x^2} \qquad R^2(\%) = 54.4 \text{ (adjusted for df)}$$

(Figures given in brackets denote standard error)

The soil K content for different treatments at the late vegetative stage corresponding to the bunch yield were located on the graph (Fig.17) and the K content corresponding to the point in the bend of the curve is marked as critical soil K level for maximum yield. The graphical method showed soil critical K level of 218 kg ha^{-1} for maximum yield.

Yield below 10 percent of the maximum was worked out and the soil K content corresponding to this was located on the graph and marked as soil critical K level for economic yield (164 kg ha^{-1}).

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 equation was developed relating the exchangeable K content of the soil at that stage (Y) to the different fertilizer doses tried (x)

The estimated linear regression equation for late vegetative stage was,

$$Y = 115.36 + \underset{(0.0262)}{0.1642}\,x \qquad r^2(\%) = 68.6$$

(Figure given in bracket denotes standard error)

For the above said stage, soil critical K level of 218 kg ha^{-1} is substituted for Y and solving the equation for x, it may be predicted that 250 g K_20 per plant is to be applied at the late vegetative stage for maximum yield and 118.5 of per plant for economic yield.

4.8. Economic analysis

The detailed calculation of cost of cultivation for different treatments is furnished in Appendix IV. The abstract of economics (Benefit/cost ratio) is presented in Table 23.

The table showed that the highest Benefit/Cost ratio of 2.35 was realised by K3 treatment followed by K4 (2.17) and K2 (2.12). The lowest value was recorded by the control treatment (1.57).

Table 23. Economic analysis (ha $^{-1}$)

Treatments	Total bunch yield(Kg ha^{-1})	Income from bunches (Rs)	Income from suckers (Rs)	Total Income (Rs)	Total cost of cultivation	Net Profit (Rs)	B:C ratio
K0	15 475	139 275	22 500	161 775	103 297	58 478	1.57
K1	17 700	159 300	22 500	181 800	109 546	72 254	1.66
K2	24 200	217 800	22 500	240 300	113 156	127 144	2.12
K3	27 925	251 325	22 500	273 825	116 765	157 060	2.35
K4	26 525	238 725	22 500	261 225	120 374	140 851	2.17

DISCUSSION

DISCUSSION

The results generated from the present study can be discussed in the light of published information and fundamental theoretical considerations.

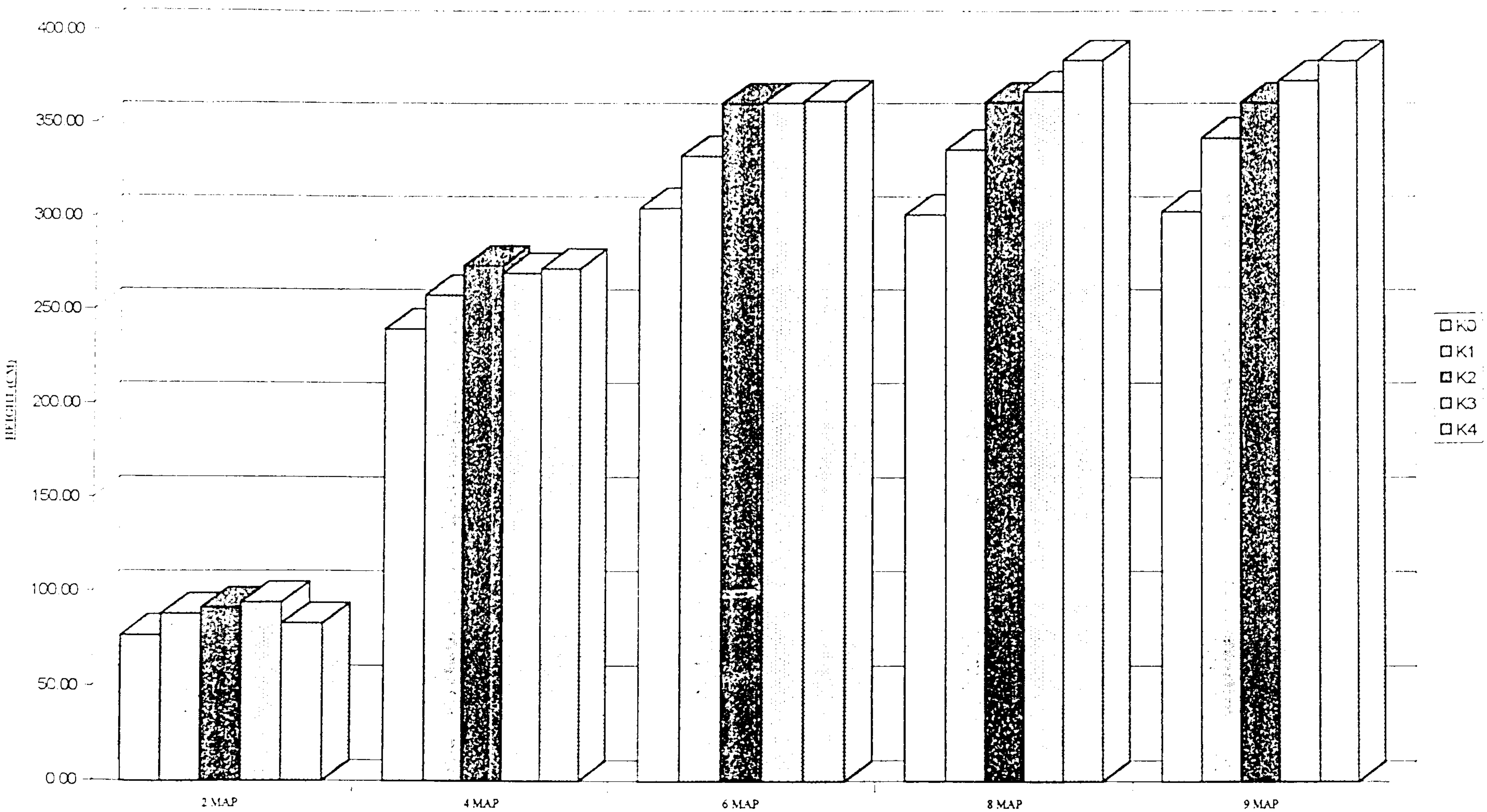
5.1. Effect of K levels on biometric characters of banana cv. Nendran.

5.1.1. Height of plant

The results revealed that in the early growth stages, plant height remained more or less not affected by the treatments. However during the bunch maturation and harvest stages, it varied significantly under the influence of different levels of K fertilizer application. In general, the plant height was found to increase with increasing level of K application from 0 to 600 g per plant in all the stages and the control plants recorded lowest value (Table 2 and Figure 2).

The effect of treatments variedsignificantly during bunch maturation and harvest stages. This could be explained on the basis of differential requirement of K. The development of meristem into various primordial structures that determine the future bunch size will be completed by about eighth month.

Fig. 2. EFFECT OF K LEVELS ON HEIGHT OF PLANTS



Hence more nutrients especially K are needed in these stages as evidenced by the significant treatment differences at bunch maturation and harvest stages (Summerville, 1944).

The considerable increase in height of pseudostem noticed from the fifth month after planting might be due to the increased hormonal activity at the flower initiation stage which occured at this time (Sheela, 1995). Sumam George (1994) attributed the absence of significance for K treatments at the early growth stages to the lack of competition between plants for sunlight at the early stages.

Enhanced height of plant as a result of increasing levels of K application has also been reported by many workers (Turner and Bull, 1970; Jambulingam et al., 1975; Sheela, 1982; Mustaffa, 1987; Khoreiby and Salem, 1991; and Sumam George, 1994).

In the present study, the control plants which received zero K recorded lowest plant height. This is in accordance with the findings of Freiberg and Steward (1960) and Lahav (1972 a). They reported that in K starved plants, the leaves develop just one above the other with only small distance between the petioles leading to reduced pseudostem height.

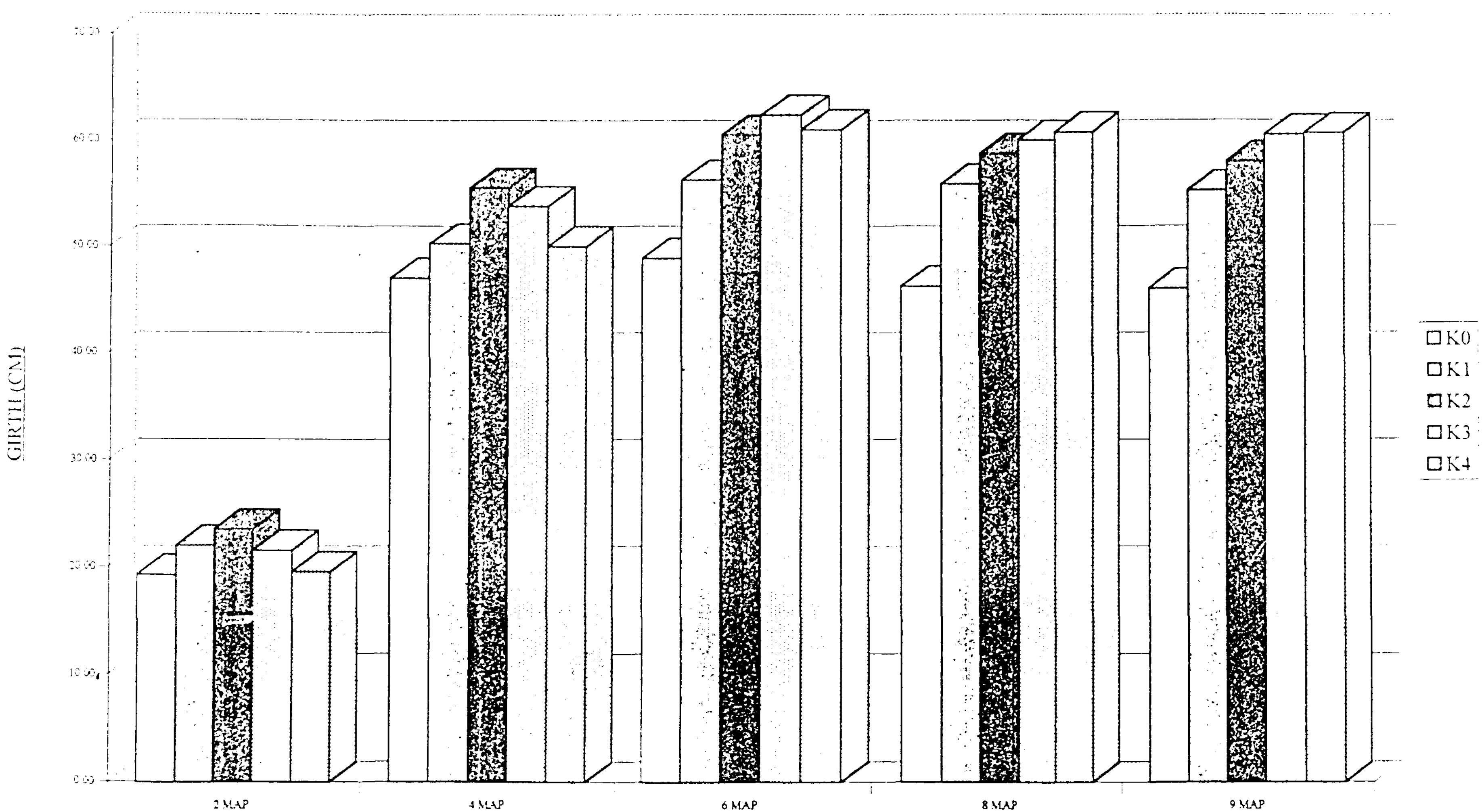
5.1.2. Girth of pseudostem

The treatments did not show any significant influence on the girth of plants during the vegetative growth period. After shooting, the girth was found to increase with increase in the level of K application (Table 2 and Figure 3). The girth was lowest for control plants in all the growth stages studied.

Positive effect of K on girth of pseudostem has been documented by Turner and Bull (1970), Lahav (1972 a), Jambulingam et al.(1975), Fabregar (1986), Mustaffa (1987), Hedge and Srinivas (1991), Sumam George (1994) and Sheela (1995).

The satisfactory rate of photosynthesis and meristematic activity under adequate supply of K would have contributed to the increased plant girth at higher levels of K. Senescence of leaves leading to shrinkage of tissues of leaf sheath as well as lesser production of leaves after bunch maturation stage might have reduced the girth of pseudostem at harvest stage of the crop.

FIG.3. EFFECT OF K LEVELES ON GIRTH OF PSEUDOSTEM AT 20 CM HEIGHT



The non-significant effect during the vegetative growth may be due to the absence of competition for sunlight during early growth stages.

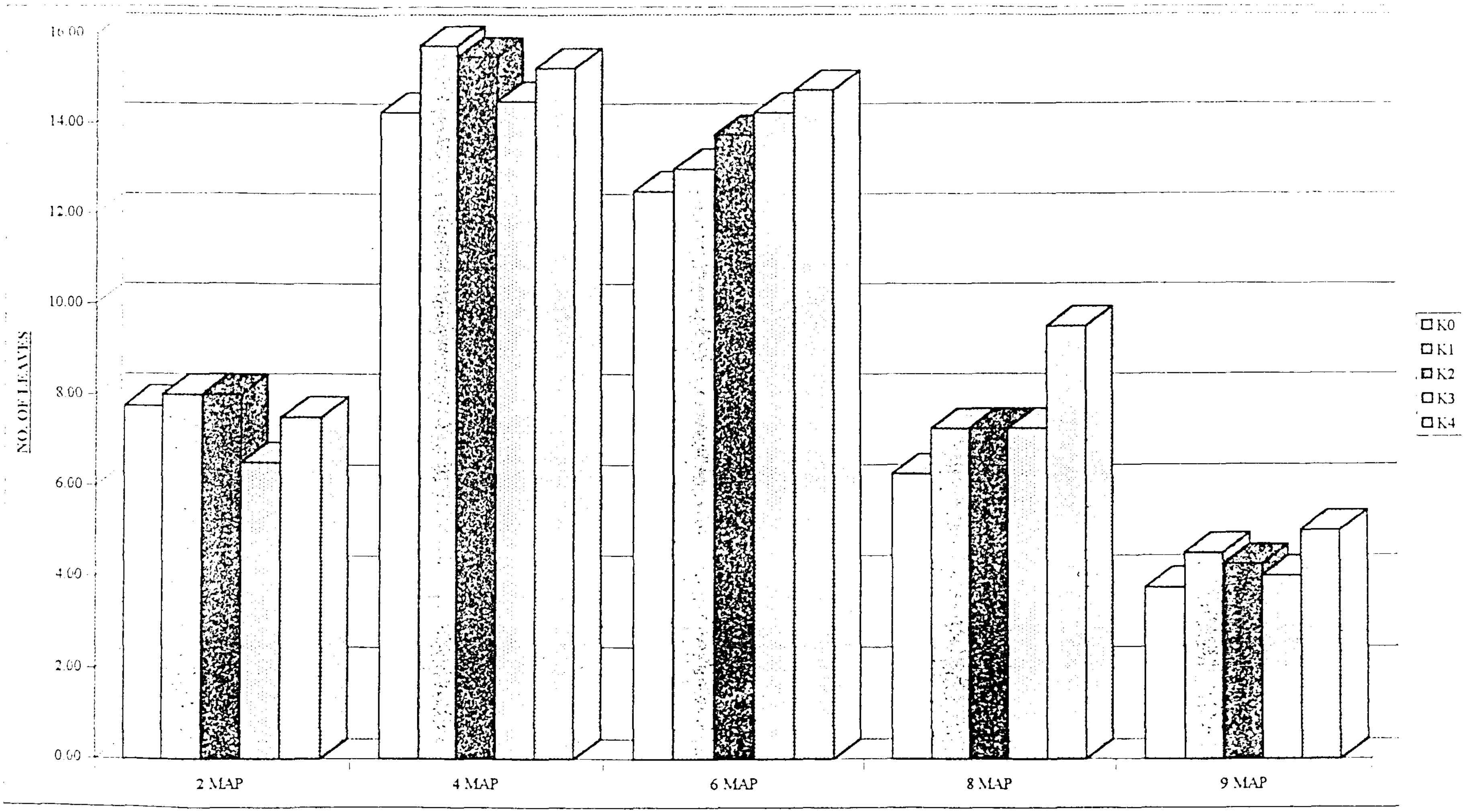
Correlation studies suggested significant positive correlation between yield characters and pseudostem height and girth at shooting, bunch maturation and harvest stages. The positive correlation between the height, girth of pseudostem and the yield in banana has been reported by earlier workers also (Croucher and Mitchell, 1940; Fernandez et al. 1973; Warner et al. 1974; Azhakiamanavalan, 1979 and Sumam George, 1994).

5.1.3. Number of functional leaves

The results revealed that the number of functional leaves, in general showed an increasing trend with increase in the level of K applied at all growth stages of the crop. But the treatments differed significantly during the bunch maturation stage only (Figure 4).

The increased vigour and meristematic activity of the plant brought about as a result of increased K application might be the reason for increased leaf number. The influence of mineral

FIG.4. EFFECT OF K LEVELS ON NO. OF FUNCTIONAL LEAVES



nutrition on the rate of leaf production was reported by Murray (1960). At bunch maturation stage, the significant effect may be due to more photosynthesis need for starch synthesis to enrich the fruit.

Similar findings have been reported by Brezesowsky and Biesen (1962), Ho (1969), Mustaffa (1987), Baruah and Mohan (1991), Parida et al. (1994) and Sumam George (1994).

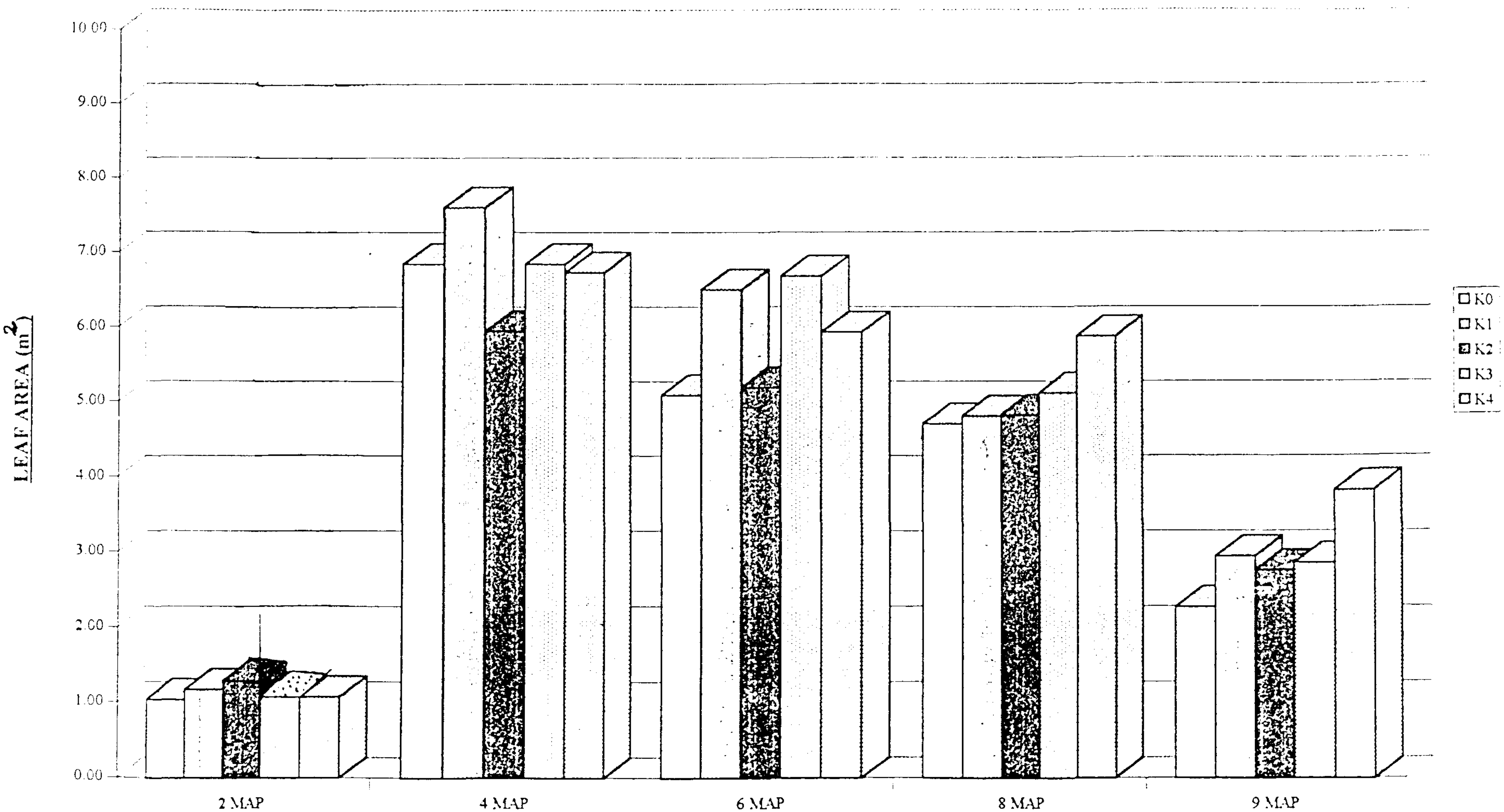
5.1.4. Total leaf area and leaf area index

In the present study, significant variation in total leaf area and leaf area index due to treatments were observed only after completion of the vegetative growth stages. Among the treatments, control plants registered lowest values and K4 treatment (600 g K_2O per plant) registered highest values at bunch maturation and harvest stages. (Table 3 and Figure 5).

Similar observations were made by Murray (1960), Lahav (1972 a), Ramaswamy et al. (1977), Mustaffa (1987), Khoreiby and Salem (1991) and Sumam George (1994).

According to Lahav (1972 a), in K deficient banana plants, the leaves were smaller and their longivity shorter, thus reducing the total foliage area.

FIG. 5. EFFECT OF K LEVELS ON TOTAL LEAF AREA



Sumam George (1994) opined that the last split of K fertilizer application coincided with the shooting stage of the crop. Hence the effects of the different treatments were manifested from this stage onwards. She also observed that, 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.

Significant positive correlation was obtained between total leaf area and yield characters like weight of finger and girth of finger at shooting and bunch maturation stages. Positive and significant correlation between bunch yield and total leaf area at shooting stage in banana cv. Robusta as a consequence of enhanced photosynthesis was reported by Krishnan and Shanmughavelu (1983). Correlation between these characters has also been documented by Croucher and Mitchell (1940), Venkatesam et al. (1965), Turner (1970) and Pillai (1975).

5.2. Effect of K levels on yield characters in banana cv. Nendran.

In banana, the characters number of hands per bunch, number of fingers per bunch, weight of hand and length, girth and weight of finger are considered as determinants of yield. (Stover and Simmonds, 1987). The present study indicated that all the yield attributing characters studied (weight of bunch, number of fingers per bunch, number of hands per bunch, weight of hand, weight of finger, length of finger and girth of finger) recorded the highest mean value in the treatment K3 (450 g K_2O per plant) followed by K4 (600 g K_2O per plant) and the lowest in the control plants, lending support to the findings of Obiefuna and Onyele (1988). According to their reports, an annual application of 500 g K_2O per plant produced the heaviest bunches in plantains.

Among the morphological characters, the girth of pseudostem at shooting was reported to be a determinant of yield by Krishnan and Shanmughavelu (1983) and Rosamma and Namboothiri (1990). In the present study, K3 (450 g K_2O per plant) registered the highest girth of pseudostem at 20 cm height at shooting stage. This might have contributed to the high yield recorded by K3 treatment.

From the present study, it could be noted that K supply below 450 g per plant caused a gradual decline in yield

PLATE NO. 2
EFFECT OF K-LEVELS ON BUNCH SIZE.

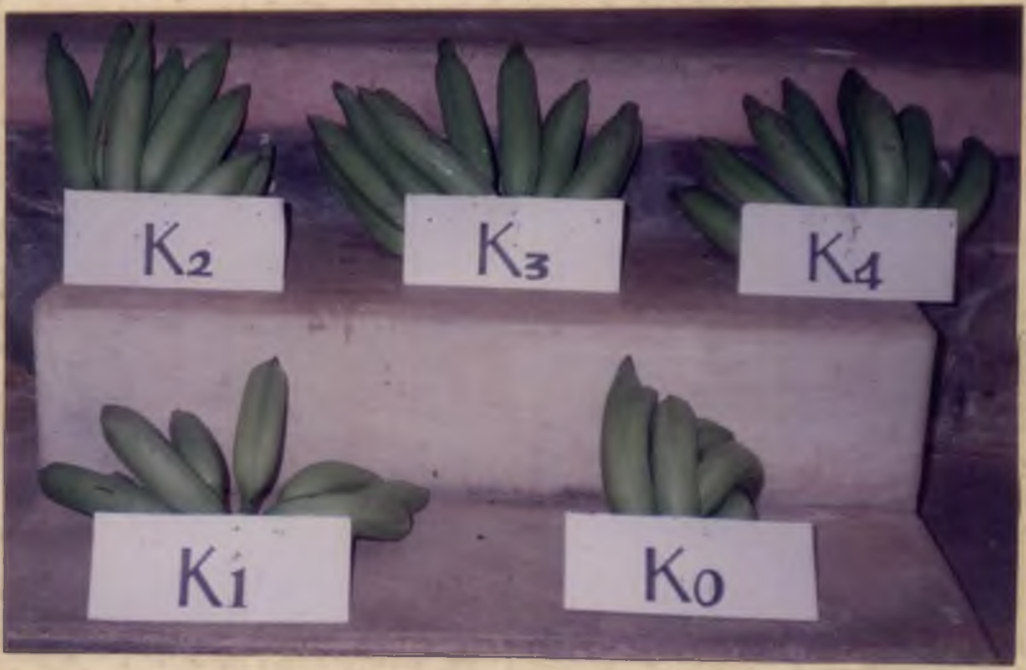


PLATE NO. 3
EFFECT OF K- LEVELS ON HAND SIZE

characters. Insufficient K supply might have reduced the total drymatter production of banana plant and the distribution of drymatter within the plant. The organ most drastically affected could be the bunch and hence a reduction in yield (Sindhu Prabhakar, 1996). Malavolta et al. (1962) reported a reduced photosynthesis and increased respiration due to low levels of potash. The translocation of photosynthates to the bunch is weakened by the reduced photosynthesis and hence yield is reduced at lower doses of K application.

Very high levels of K might have caused nutrient imbalances in plant causing yield reduction as indicated by a slight decline in yield above K3 level (450 g K_2O per plant) in the present study. 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.

Reports highlighting the scope of yield increase by increasing the level of K application have been given by Pillai et al. (1977), Sheela (1982), Geetha (1988), Baruah and Mohan (1992) and Sumam George (1994) in different varieties of banana.

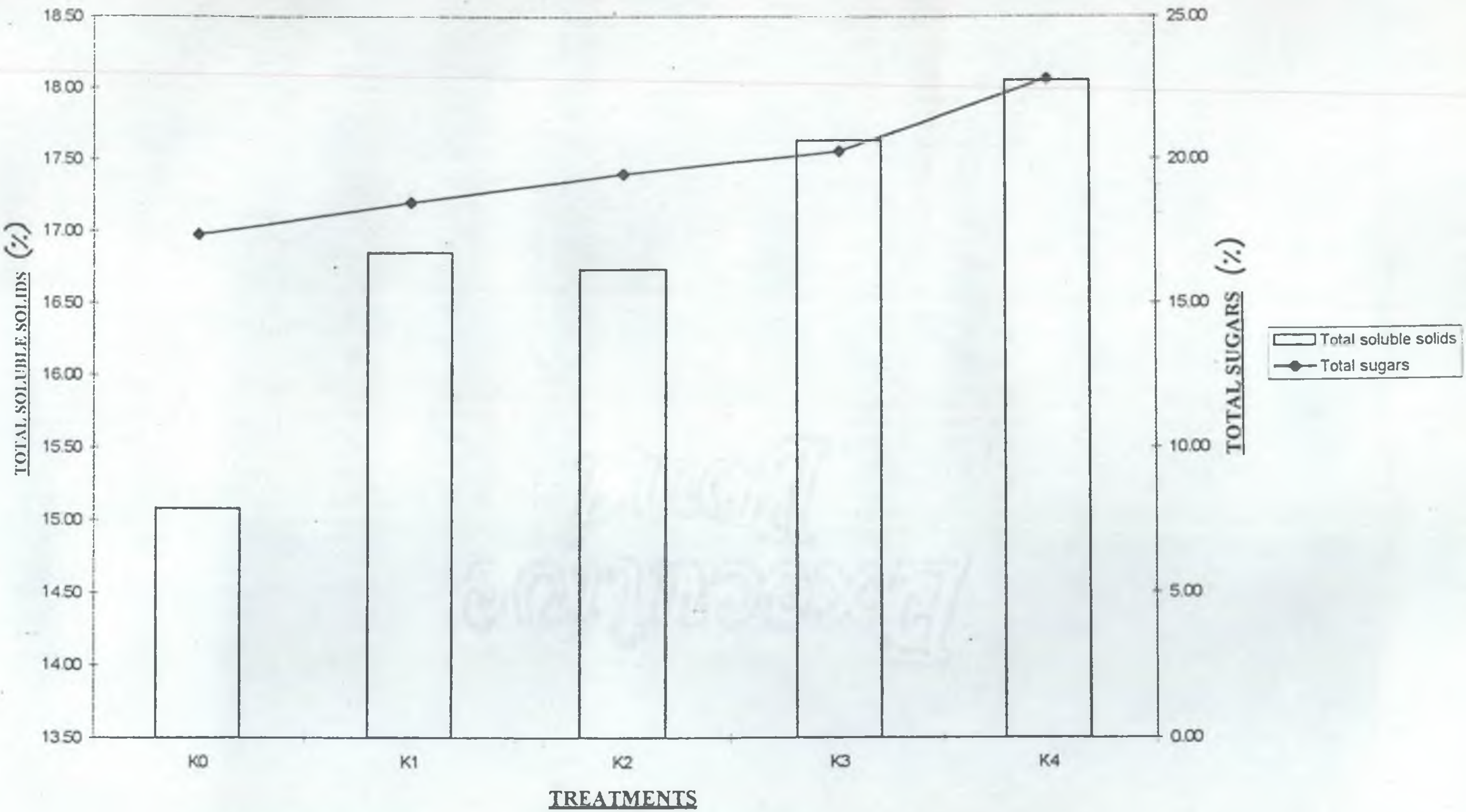
5.3. Effect of K levels on quality characters of banana cv. Nendran.

The quality characters included in the present study are acidity, total soluble solids, total, reducing and non-reducing sugars, sugar/acid ratio, pulp/peel ratio and shelf life. Results showed that different K levels significantly influenced all quality characters studied except pulp/peel ratio (Table 5).

Increasing K levels lowered the titrable acidity of fruits. According to Tisdale et al.(1985), reduction in acidity with increased K level in the tissues was due to neutralisation of organic acids. Lowering of acidity due to increasing K application was reported by many scientists (Venkatarayappa et al., 1973; Ramswamy et al., 1977; Sheela, 1982; Baruah and Mohan, 1986).

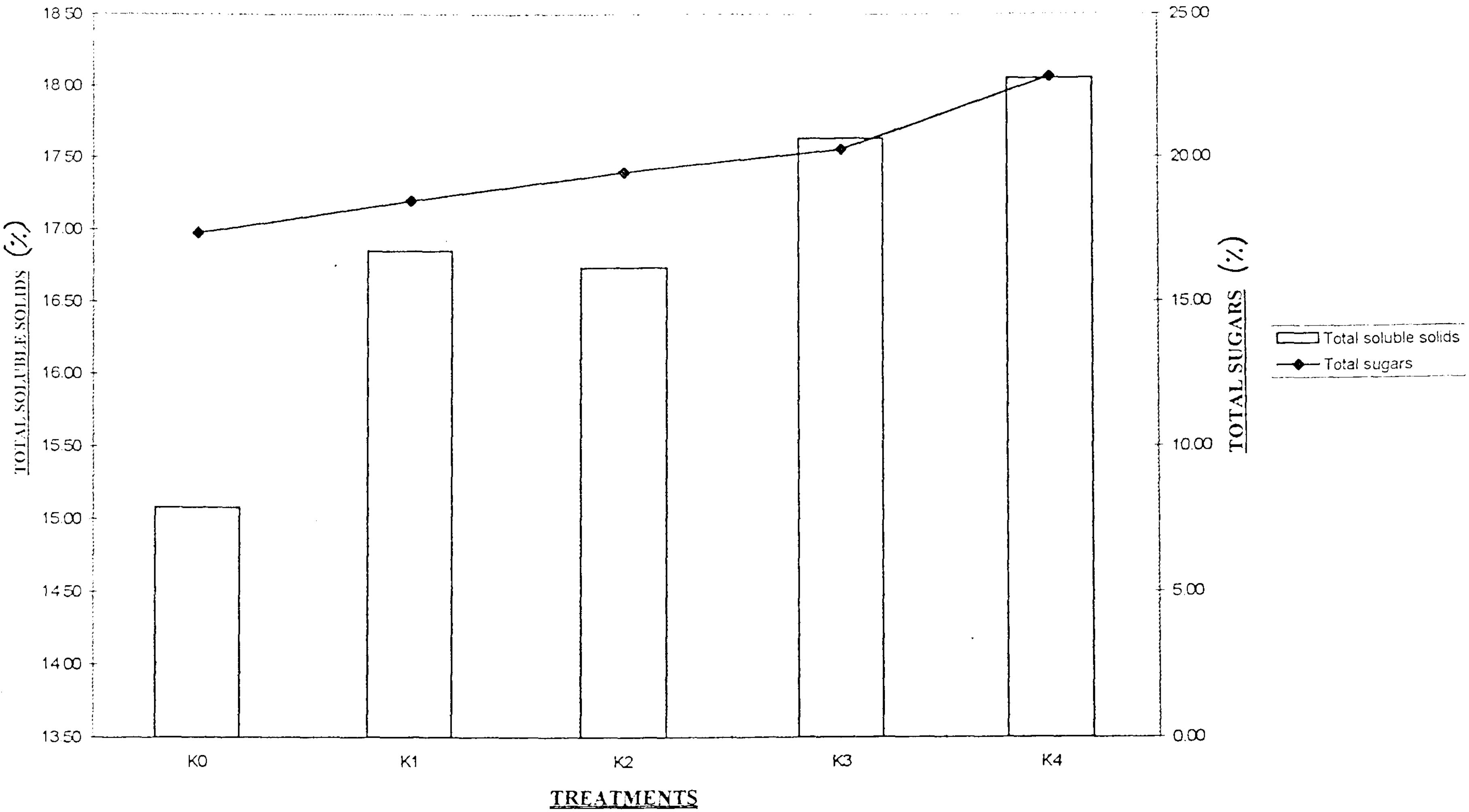
The highest mean value for total soluble solids was recorded by the K4 treatment (600 g K_2O per plant) and lowest by the control plants. This result is in confirmity with the reports of Ramaswamy et al. (1977), Chattopadhyay and Bose (1986), Mustaffa (1988) and Hedge and Srinivas (1991).

FIG. 6. **EFFECT OF K LEVELS ON TOTAL SOLUBLE SOLIDS & TOTAL SUGARS OF FRUIT**



The total, reducing and non-reducing sugars also showed variation in different treatments. The highest total sugar content observed in treatment K4 (600 g K_2O per plant) was significantly superior to all the other treatments, while the lowest content was shown by the control plants. But the reducing sugar content followed a reverse order with highest content in control plants. Nitsos and Evans (1969) reported 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 and hence reducing sugar content was maximum at zero level of K. On the other hand, an adequate K supply ensured optimal functioning of sucrose synthetase and suppression of hydrolytic enzymes leading to greater quantity of sugars in the proplastids. Jauhari and Singh (1971) also reported that K is known to help in sugar translocation in plants and thus its application increased sugar content in fruits. The non-reducing sugar content, being a computed derivative of the total and reducing sugar contents, followed the same trend as that of total sugars showing increasing trend with increase in K levels. This is in accordance with the report by Sumam George (1994).

FIG. 6. EFFECT OF K LEVELS ON TOTAL SOLUBLE SOLIDS & TOTAL SUGARS OF FRUIT

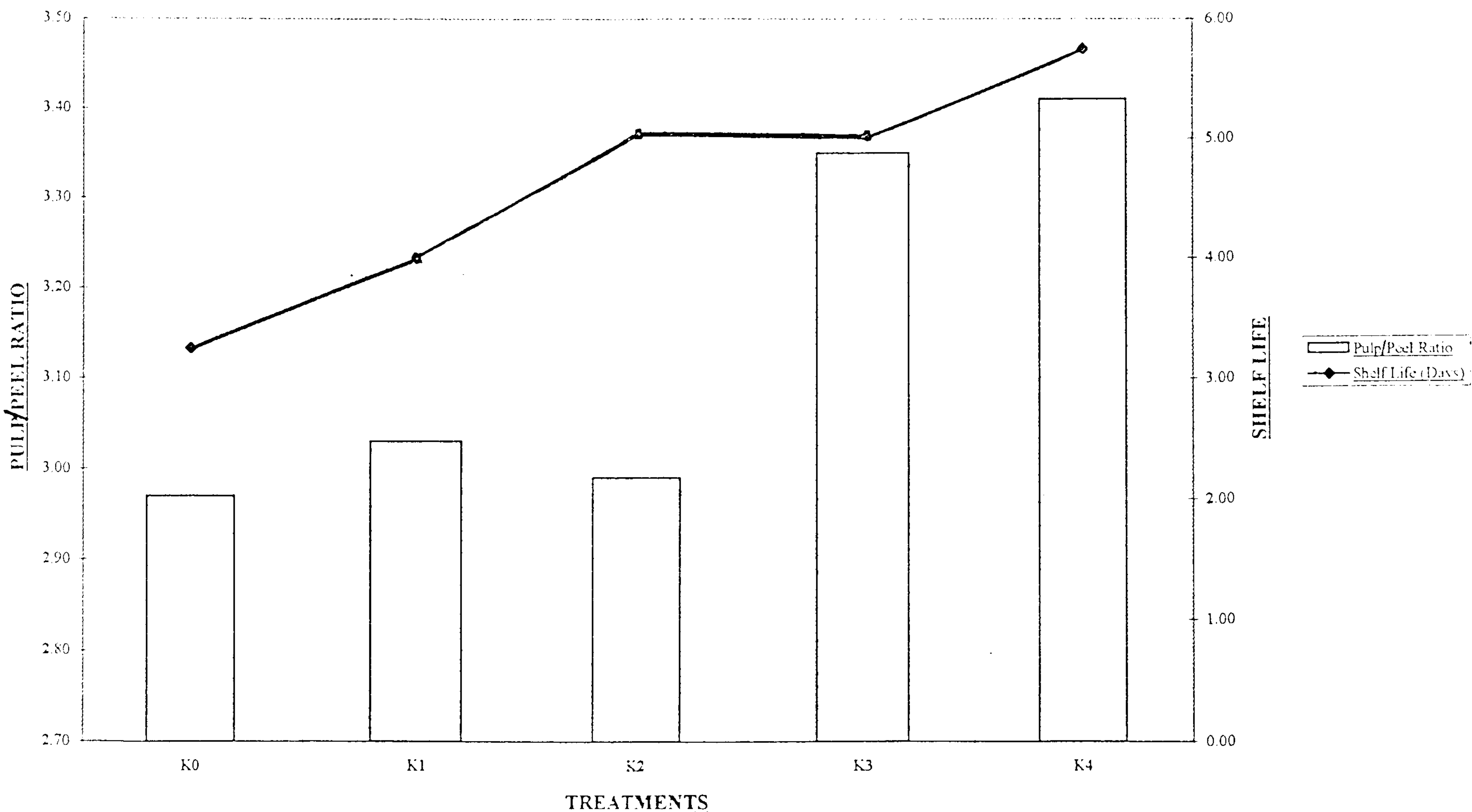


Sugar/acid ratio showed a steady increasing trend with increase in K application. This was mainly due to significant reduction in acidity with higher K levels and the result is in agreement with the reports of Vadivel and Shanmughavelu (1978), Zehler et al. (1981), Baruah and Mohan (1986) and Sheela (1995).

Though statistically not significant, the pulp/peel ratio showed definite improvement with the increase in K levels. This 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 higher K levels (Sheela, 1982 and Martin-Prevel, 1989).

The highest shelf life of 5.75 days was recorded by K4 (600 g K_2O per plant) and lowest of 3.25 days by KO treatment. Uexkull (1970) noted the effect of K on improving the storage life of banana as a result of the increased thickness and firmness of the rind. Martin-Prevel (1989) observed an enhanced production of ascorbic acid under higher K levels which was responsible for the slowing down of oxidation processes responsible for enzymatic browning on the peel of fruit. Almazan (1991) reported increased respiration under K deficiency

FIG. 7. EFFECT OF K LEVELS ON PULP PEEL RATIO & SHELF LIFE OF FRUIT



to produce ATP to compensate for low production of the same. This led to cell wall degradation due to enzymatic activity, thereby reducing shelf life of fruits.

Figure 6 shows the effect of K levels on total soluble solids and total sugars of fruit and Figure 7 shows the efect of K levels on sugar/acid ratio and shelf life of fruit.

5.4. Effect of K levels on soil chemical properties at various growth stages of banana cv. Nendran.

The soil chemical properties included in the study were soil pH, electrical conductivity, organic carbon, available N, available P, exchangeable K, exchangeable Ca and exchangeable Mg. The results revealed that the different K levels significantly influenced the exchangeable K, Ca and Mg contents of the soil only. Soil pH, organic carbon, available N and available P were not significantly altered by the different treatments.

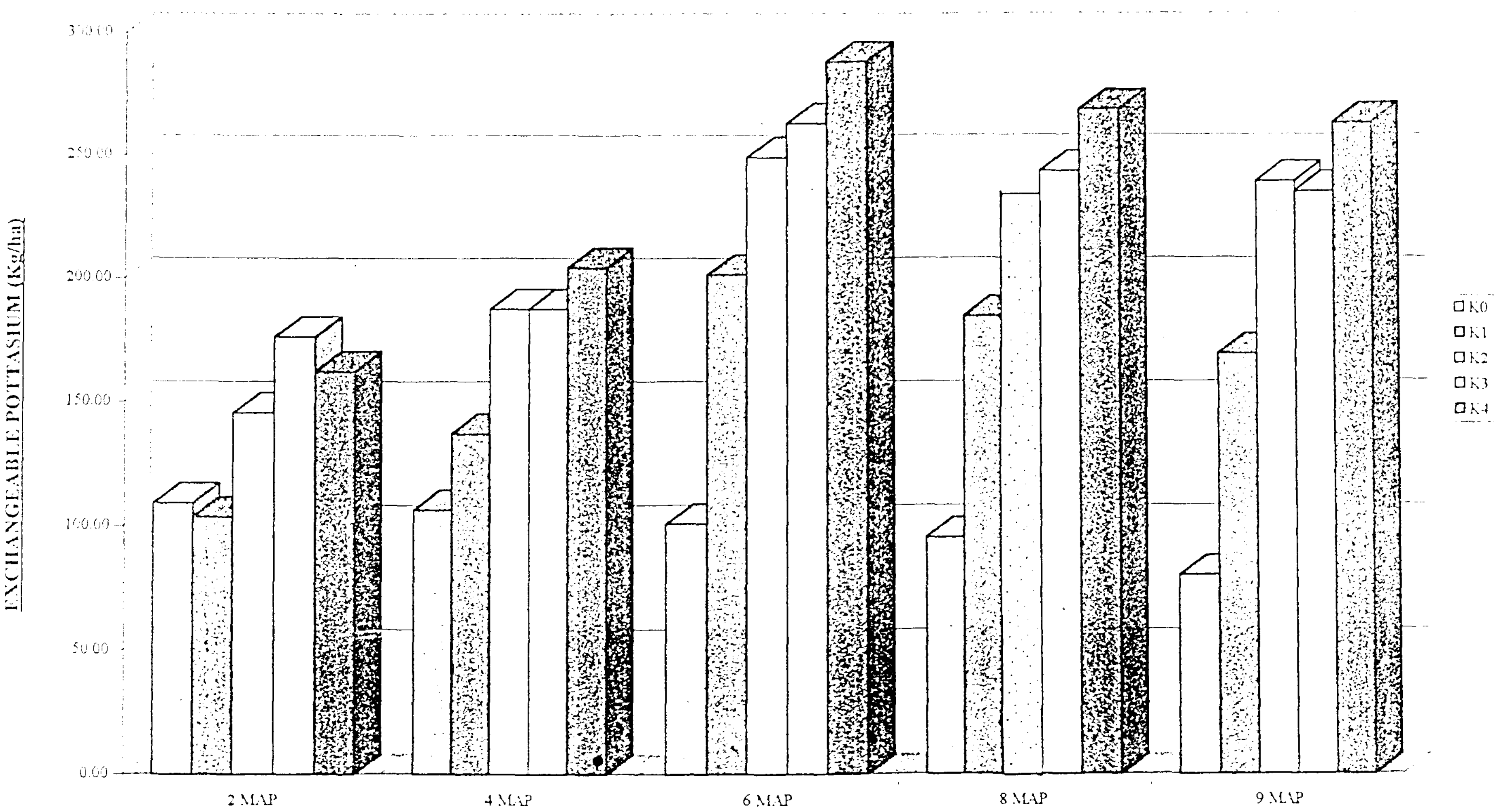
Figure 8, 9 and 10 represents the effect of K levels on exchangeable K, Ca and Mg contents of the soil respectively.

The different treatments significantly influenced the K content of the soil at all growth stages except harvest stage. In general, the exchangeable K content of soil showed an increasing trend with the increase in the level of K supplied from 0 to 600 g per plant. After the shooting stage, exchangeable K content showed a decreasing trend for all the applied K levels. No fertilizer application after this stage might be the reason for this phenomena. Yet another reason is the higher requirement and uptake of K by the banana crop after the vegetative growth period as quoted by Simmonds (1987) to look after the vegetative as well as reproductive needs.

Correlation studies suggested that the exchangeable K content of the soil at all stages of crop growth showed positive and significant relationship with yield. This was in accordance with the report of Sumam George (1994).

At all growth stages, exchangeable Ca and Mg contents of the soil tended to show a decrease with increase in the rate of K application. The high values being recorded by the control or

FIG. 8. EFFECT OF K LEVELS ON EXCHANGABLE POTASSIUM CONTENT OF THE SOIL



by the lower levels of K application. Addition of potassic fertilizers can increase the K/Ca+Mg ratio (Tisdale *et al.*, 1985) which simultaneously reflects on increased ionic concentration of K in the solution in equilibrium with the soil and decreased that of Ca and Mg. The antagonistic behaviour of K with Ca and Mg as a result of monovalent-divalent interaction have also been reported by Fabregar (1986), Martin-Prevel (1989), Lopez Morales (1994) and Sumam George (1994).

5.5. Effect of K levels on concentration of nutrients in different parts of leaf at various growth stages in banana cv. Nendran.

The results of leaf analysis indicated a precise inter relationship between the amount of fertilizer added to the soil and its utilization by the crop. It also served as a diagnostic tool in understanding the inner physiology of the plant at various phases of growth of banana (Hewitt, 1955 and Turner and Barkus, 1970).

FIG. 9. EFFECT OF K LEVELS ON EXCHANGEABLE CALCIUM CONTENT OF THE SOIL

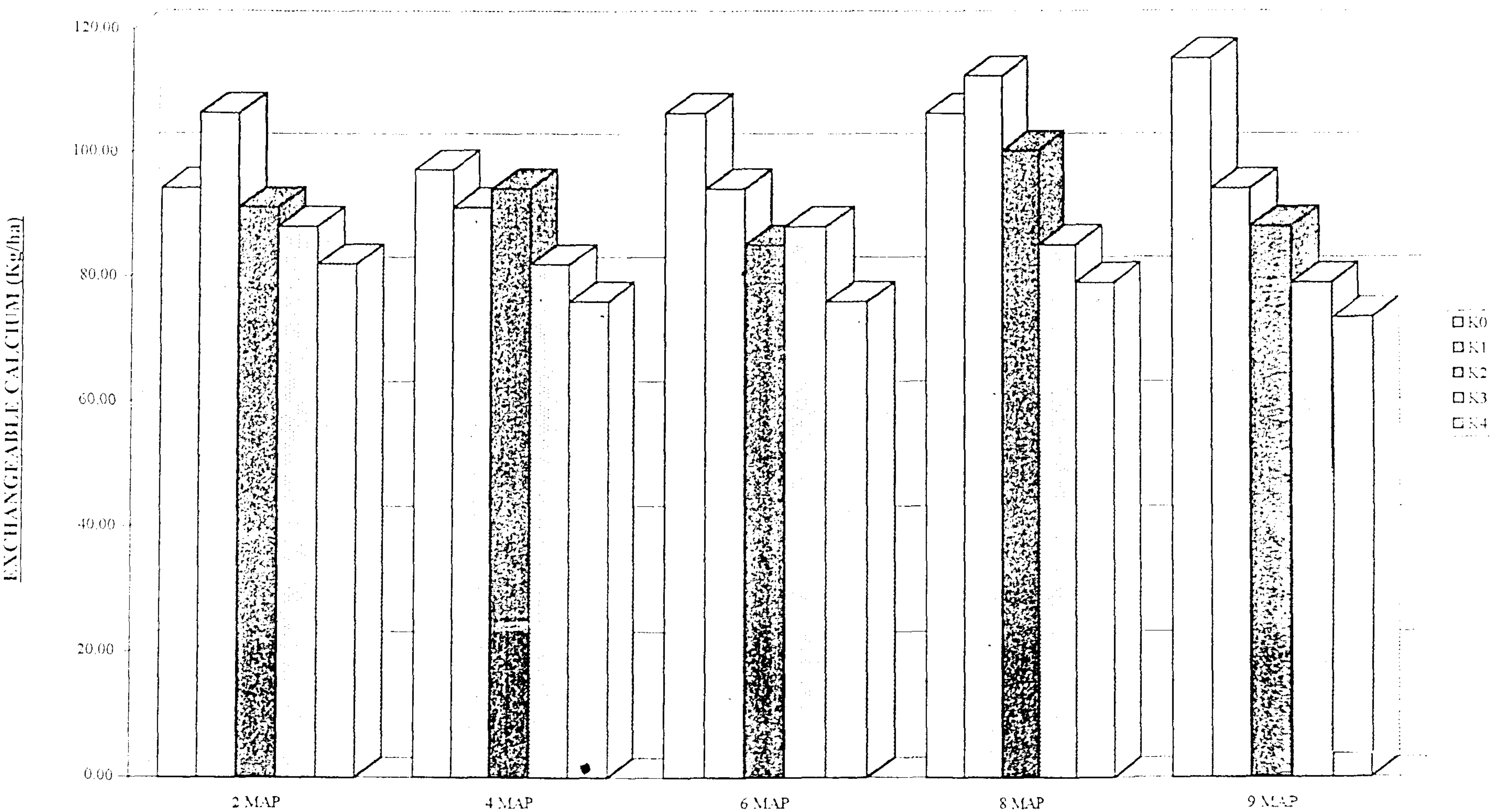
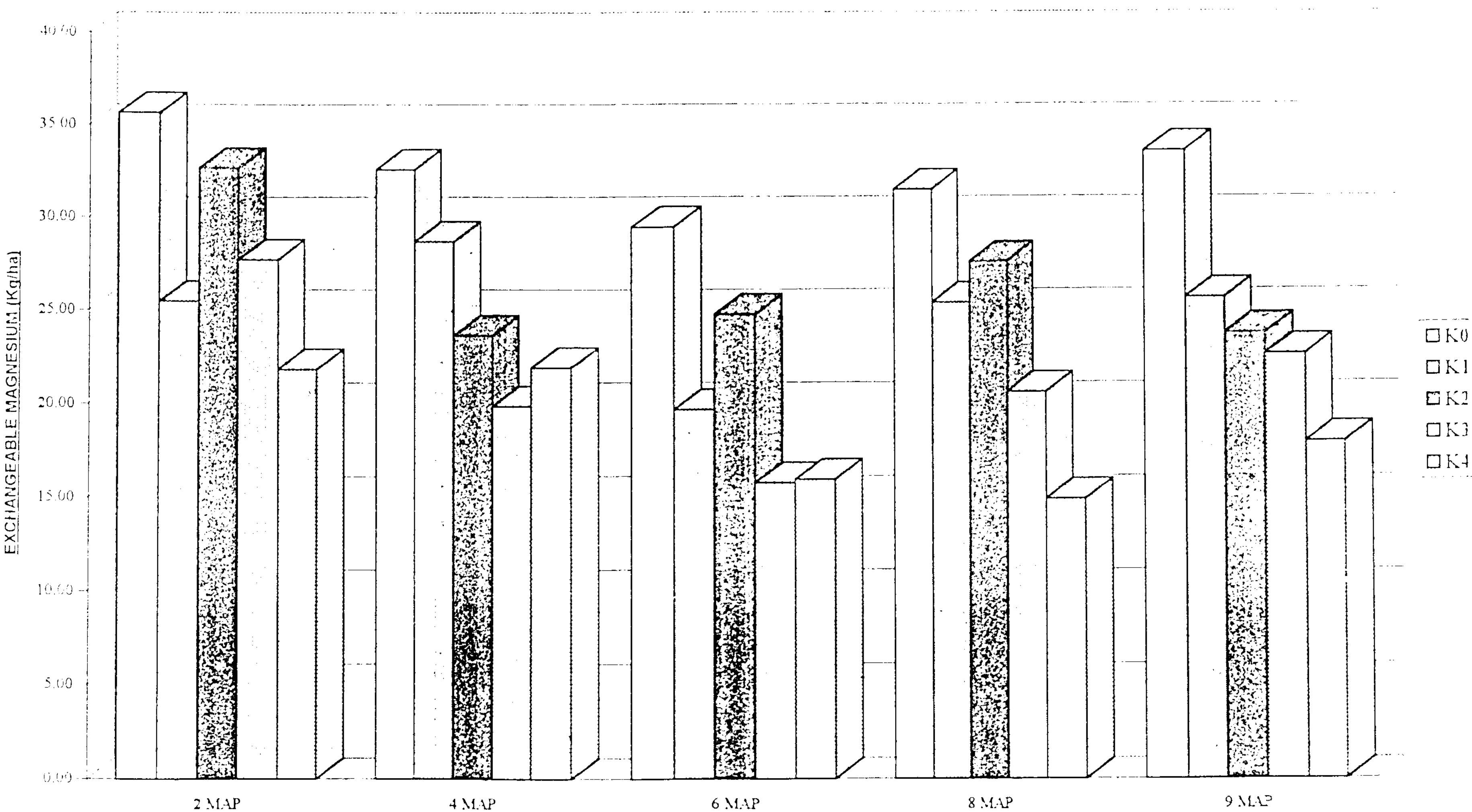


FIG. 10. EFFECT OF K LEVELS ON EXCHANGEABLE MAGNESIUM CONTENT OF THE SOIL



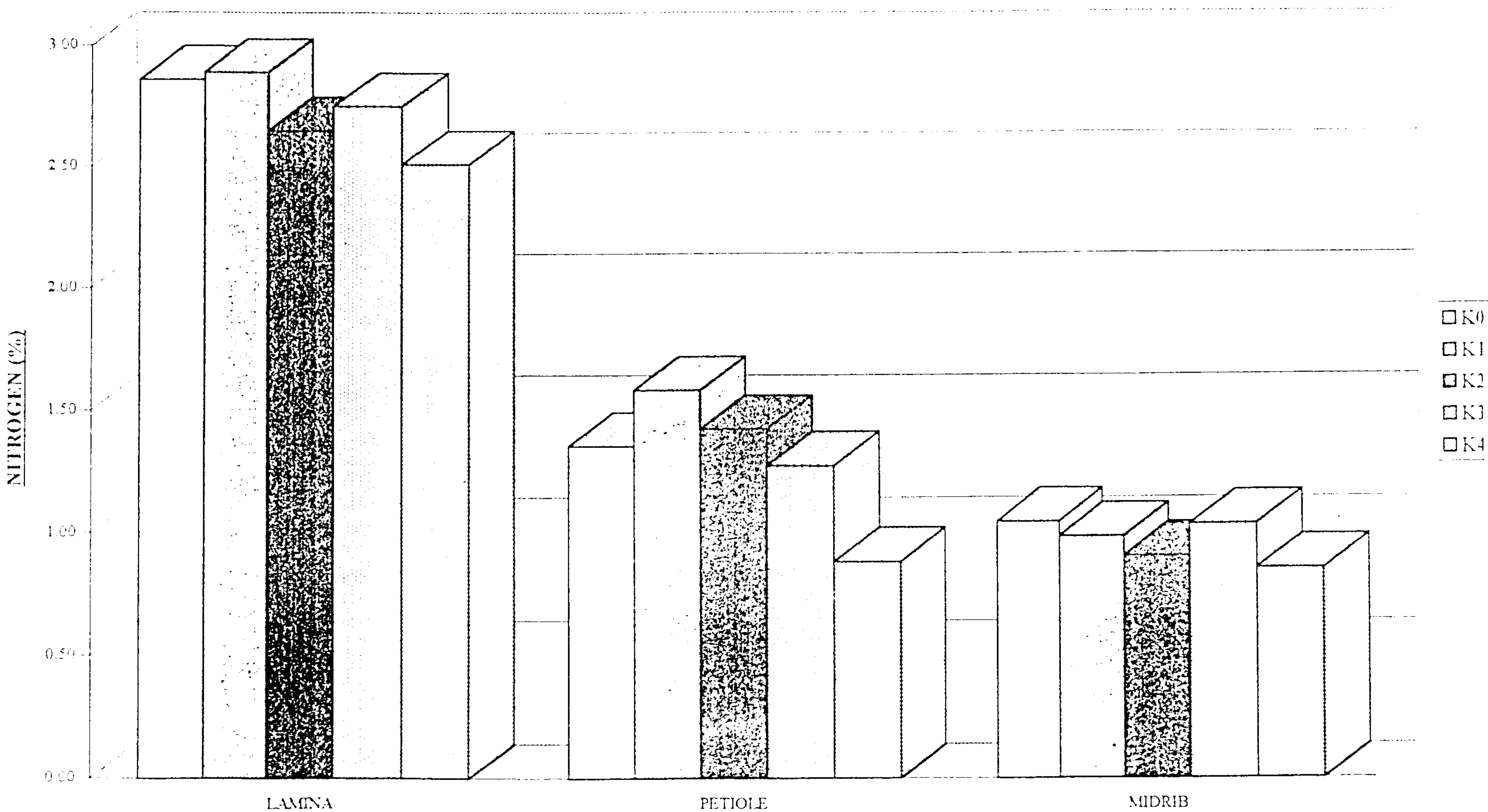
In all the parts studied namely lamina, petiole and midrib, the concentration of nutrients showed a gradual decreasing trend from shooting to harvest stage. This might be due to its translocation from one organ to another having more sink capacity ie., from vegetative to the reproductive organs. At full bunch maturity, a part of nutrients move from the mother plant to suckers also (Balakrishnan, 1982). The dilution effect of nutrients caused by the increased drymatter production might be another reason.

5.5.1. Leaf N

A decreasing trend was noticed in leaf N concentration at all growth stages with increased level of K application. In most cases, higher values were recorded by the control plants (Figure 11).

The antagonistic relationship between K and N was reported by Hewitt and Osborne (1962), Ho (1969), Lahav (1973) and Sindhu Prabhakar (1996).

FIG. 11. EFFECT OF K LEVELS ON NITROGEN CONTENT IN DIFFERENT PARTS OF LEAF AT HARVEST STAGE



5.5.2. Leaf P

The results revealed that the P content showed an increasing trend with increased level of K application. This may be due to the synergistic relationship between K and P (Figure 12).

Similar findings were given by Lahav (1973), Turner and Barkus (1985) and Sumam George (1994).

5.5.3. Leaf K

Among the nutrients, the concentration of K was the highest in banana compared to N and P. The key role played by K in the synthesis of sugars and maintaining the water relations of the plant might be the cause for the requirement of this element in large quantities. (Martin-Prevel, 1962).

In the present study, K content showed an increasing trend with increase in the level of K application in all leaf tissues and at various growth stages. In all the cases, lower values were recorded by the control plants (Figure 13). The increase in tissue K concentration subsequent to K fertilization was reported by Randhawa et al.(1973), Jambulingam et al.(1975), Garcia et al. (1980), Sheela (1982), Garita and Jaramillo (1984), Irizarry et al.(1988) and Sumam George (1994).

FIG. 12. EFFECT OF K LEVELS ON PHOSPHOROUS CONTENT IN DIFFERENT PARTS OF LEAVES AT HARVEST STAGE

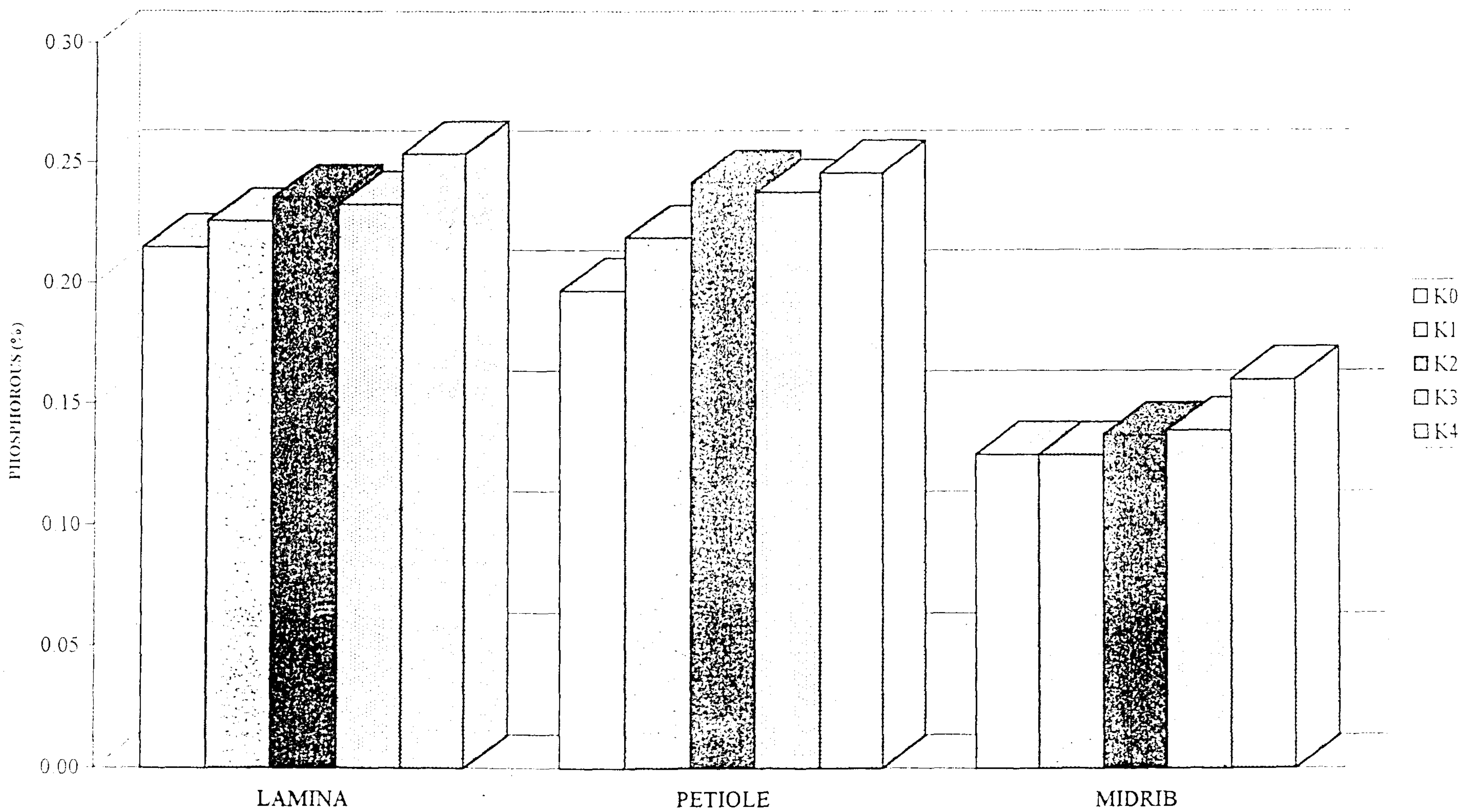
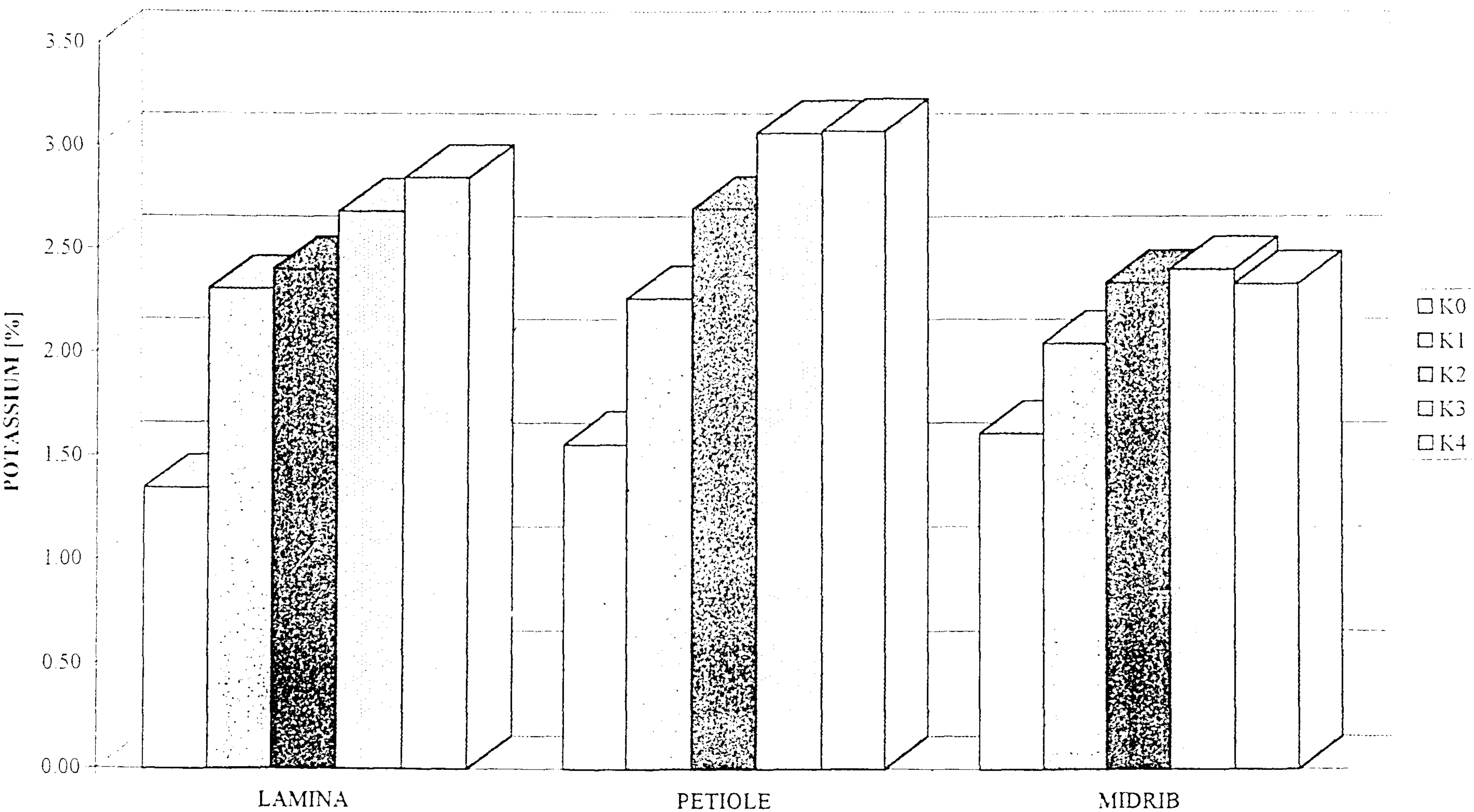


FIG. 13. EFFECT OF K LEVELS ON K CONTENTS IN DIFFERENT PARTS OF LEAVES AT HARVEST STAGE



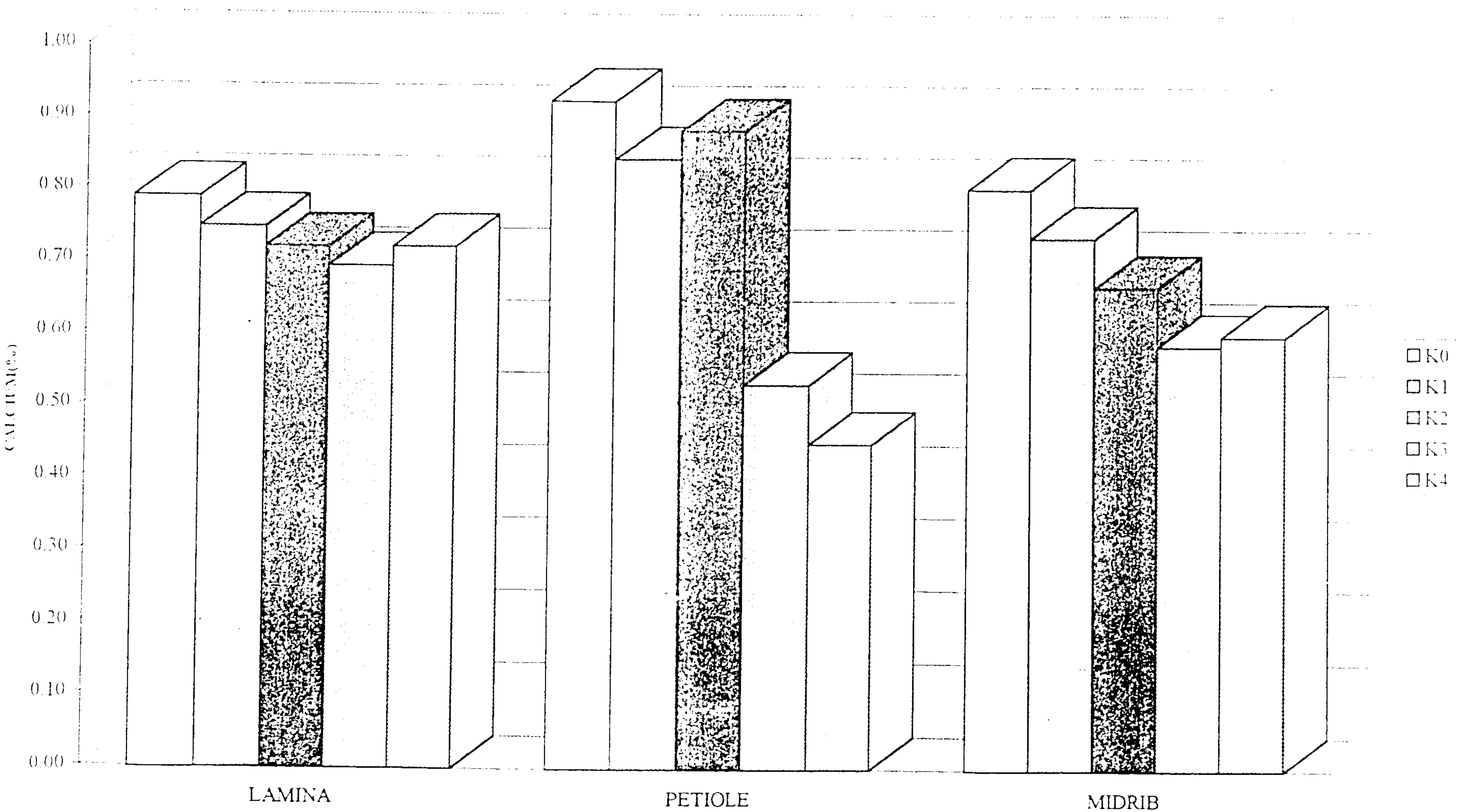
A remarkable feature in this context is that the concentration of K was the highest in petiole in all the growth stages proving it to be the most sensitive organ to changes in supply of K.

Correlation studies indicated a significant positive correlation between K content in lamina, petiole and midrib and bunch yield. The maximum relationship was noticed at harvest stage. The results also revealed that among the three leaf tissues, K concentration in the petiole at harvest stage showed highest correlation with yield. This is in agreement with the correlation study between K uptake and yield conducted by Sumam George (1994).

5.5.4. Leaf Ca

Calcium level in the leaf tissue recorded a decreasing trend with increase in the level of K application. In most of the cases, high values were recorded by the control and the low values by the K4 treatment (Figure 14). A number of reasons can be attributed to explain the antagonistic behaviour of K and Ca, one of which is that put forth by Mengel and Kirkby (1982). According to them, cation species are attracted by the negative

FIG. 14. EFFECT OF K LEVELS ON CALCIUM CONTENT IN DIFFERENT PARTS OF LEAVES AT HARVEST STAGE



electro potential of the cell which is being continuously regenerated by H^+ extrusion. Cations which enter the cell through plasma membrane rapidly, depress the uptake of others. Most of the plants absorb K^+ at a faster rate and these act as competitors for the absorption of other ions especially Ca.

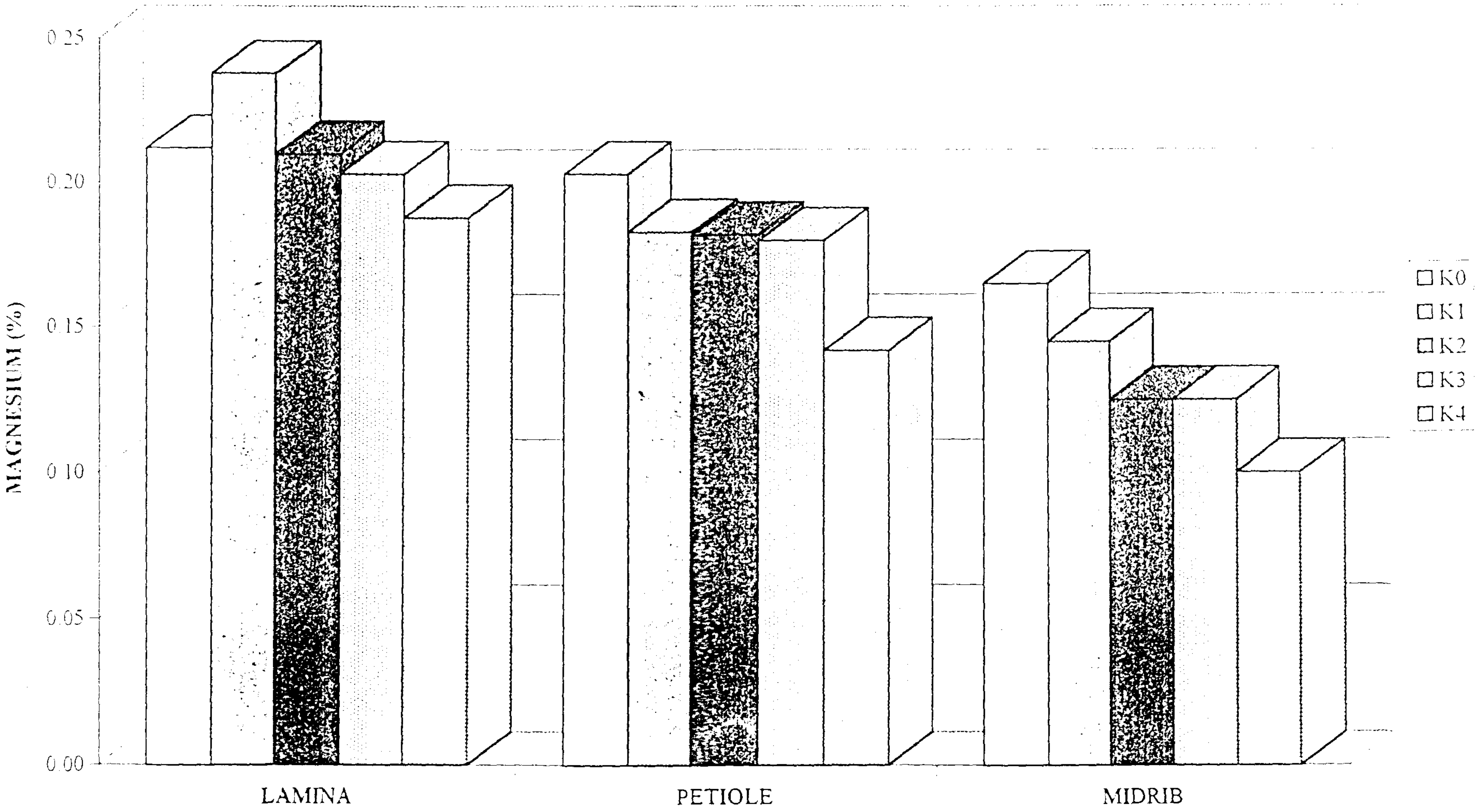
The reports of Murray(1960), Ho (1969), Lahav (1973), Garcia et al. (1980), Mengel et al. (1976) and Sumam George (1994) confirm the result of the present study.

5.5.5. Leaf Mg

The concentration of Mg in the leaf showed a decreasing trend with increase in K supply in all leaf tissues and at all growth stages (Figure 15). Similar findings were reported by Murray (1960), Ho (1969), Lahav (1973) and Garcia et al. (1980).

In the present study, high leaf Mg concentration in most cases were recorded by the control treatment. This is in agreement with the findings of Mengel et al. (1976), who reported that low K levels in soil solution favoured the uptake of Mg and this resulted in lower plant yields than high K levels.

FIG. 15. EFFECT OF K LEVELS ON MAGNESIUM CONTENT IN DIFFERENT PARTS OF LEAVES AT HARVEST STAGE



5.6. Standardisation of index plant part for K status in banana cv. Nendran.

The impracticability of analysing the whole banana plant led scientists to choose specific or index plant parts, the analysis of which will give equal information as whole plant analysis. Systematic foliar diagnosis in bananas was carried out for the first time by Hewitt (1955) in Jamaica and tentative nutrient values were established using the third leaf of Lacatan banana at the time of shooting as the standard leaf for sampling. Similar finding in Giant Cavendish banana was made by Bhangoo et al. (1962) and Warner and Fox (1977).

But because of its large size, taking the whole leaf as the sample is difficult. Variation in nutrient contents were also considerable, both transversely and longitudinally. Hence, as a part of the study, indexing of plant part especially for K status was also included.

In the present study, the lamina, petiole and midrib portions of the third leaf upto shooting (Hewitt, 1955) and that of the flag leaf thereafter (Sumam George, 1994) were selected for foliar analysis. The samples were analysed for their K contents at specific growth stagesnamely early vegetative stage, late vegetative stage, shooting stage, bunch maturation stage and harvest stage. Then the K concentrations (%) were related to corresponding bunch yield using step-wise regression analysis to select the best plant part, among lamina, petiole and midrib for K status. From the results of the analysis (Table 21), it was evident that K concentration in the petiole at harvest stage was most highly correlated with bunch yield as it explained 61.14 percent of variation in bunch yield. Since K content in the petiole at harvest stage showed highest predictability of yield, it was selected as the index part for foliar analysis for K in banana cv. Nendran. Lahav (1972 b) found that petiole analysis provided more information than the blade for cations especially K. Bhargava and Reddy (1992) and Sumam George (1994) also found petiole to be the index part for nutrient diagnosis of banana.

Among the different growth stages of the crop,the harvest stage was found to be appropriate for sampling, as the K content of the petiole of flag leaf at that stage was found to hold the maximum association with yield.

However, though K concentration in petiole at harvest stage gave the highest R^2 value (0.6114), correction in the fertilizer schedule is not practicable at this stage, as K fertilization programme is terminated at the fifth month of planting in this variety of banana. Hence from the point of view of K management, the petiole at the fourth month after planting, coinciding with the late vegetative growth, which is next to nineth month after planting in the order of step-wise regression analysis (Table 21) can be considered as the standard reflect for plant analysis for K.

5.7. Critical K level in the index plant part for maximum response to yield.

Critical K level may be indicated by the concentration of K in the index plant part for maximum response to yield.

In the present study, K content in the petiole at harvest stage was related to bunch yield on the basis of the quadratic regression equation,

$$Y = -2.9997 + \underset{(5.4474)}{6.8055\,x} - \underset{(1.1302)}{0.7878x^2} \qquad R^2 = 60.12 \text{ (adj.for df)}$$

(Figures given in brackets denote standard error) where Y is the bunch yield and x, the K content (%) in the petiole at harvest stage. A graph was plotted relating the K content in the index part to bunch yield (Fig.16) and this also showed the critical level of 4.3 percent K for maximum yield.

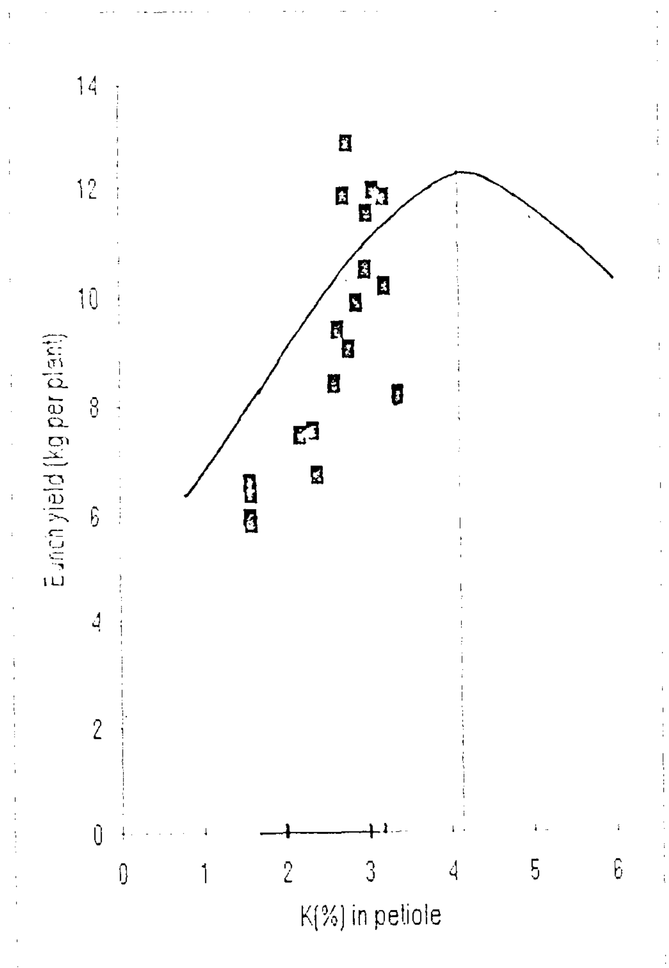
Yield below 10 percent of the maximum was workedout and the petiole K content corresponding to this marked on the graph, was designated as critical K level for economic yield (3.1 percent). This was on the basis of the concept of critical level for economic yield put forward by Tisdale et al.(1985) and Rathore and Manohar (1990).

The result obtained is in confirmity with the report of several workers. Critical K levels of 3.8 percent, 4.36 percent, 4-4.5 percent and 3.6-5 percent were reported by Twyford and Coulter (1964), Singh et al. (1974), Vadivel (1976) and Asokkumar (1977) respectively in banana cv. Robusta. Bhavanishanker (1980) reported critical K level of 3.18 - 3.47 percent in Nendran banana and Langenegger and Smith (1986) reported 3.5-4 percent K in Dwarf Cavendish banana.

FIG.16. CRITICAL K LEVEL IN PETIOLE AT HARVEST STAGE

$$Y = -2.99 + 6.81x - 0.79x^2$$

Critical K level
for maximum yield - 4.3%
for economic yield - 3.1%



5.8. Critical K level in soil and computation of fertilizer requirement

The soil K content (x) at late vegetative stage was related to bunch yield (Y) using the quadratic regression equation,

$$Y = -5.2369 + \underset{(0.0285)}{0.1444\, x} - \underset{(0.00007)}{0.0003\, x^2} \qquad \underset{(\text{adj. for df})}{R^2(\%) = 54.4}$$

(Figures given in brackets denote standard error)

Graph was plotted relating the soil K content to bunch yield (Fig. 17) and this showed the soil critical K level of 218 kg ha^{-1} for maximum yield. Yield below 10 percent of the maximum was worked out and the soil K content corresponding to this marked on the graph was designated as critical soil K level for economic yield (164 kg ha^{-1}).

Linear regression equation of the type Y = a + bx was developed relating the exchangeable K content of the soil at a stage (Y) to the different fertilizer doses tried (x). The equation for late vegetative stage was,

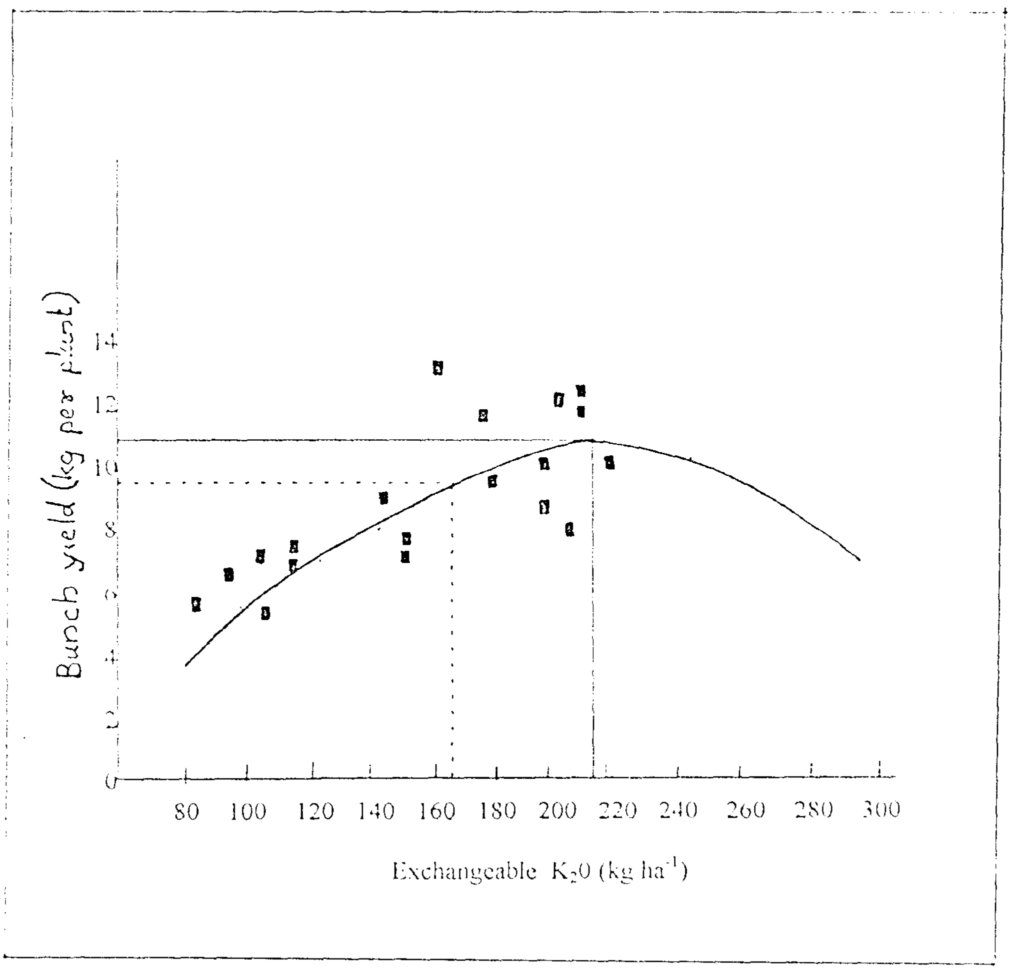
$$Y = 115.36 + \underset{(0.0262)}{0.1642\, x} \qquad r^2(\%) = 68.6$$

(Figure given in bracket denotes standard error)

FIG. 17. CRITICAL K LEVEL IN SOIL AT LATE VEGETATIVE STAGE

$$Y = -5.24 + 0.15x - 0.0003\ x^2$$

Critical K level in soil
for maximum yield - 218kg ha^{-1}
for economic yield - 164 kg ha^{-1}



In this equation, soil critical K level of 218 kg ha^{-1} is substituted for Y and solving for x revealed that 250 g K_2O per plant is to be applied at the late vegetative stage for maximum yield and 118.5 g per plant for economic yield.

Pathak et al. (1992) reported that 300 g K_2O per plant was the most effective and was designated as critical level in soil for maximum production in banana cv. Harichal. Sumam George (1994) reported soil critical K level of 276.5 kg ha^{-1} at the late vegetative stage in Nendran banana.

5.9. Economic analysis

In the present investigation, application of 450 g K_2O per plant (K3) resulted in the highest yield in terms of bunch weight and all other yield attributes. While considering the economics, this treatment again showed superiority over other treatment as revealed by the highest Benefit/Cost ratio of 2.35.

SUMMARY

SUMMARY

The present investigation on `Prediction of potassium fertilizer requirement of banana, Musa (AAB group) Nendran' was undertaken in the field (well drained, garden land) of a local farmer at Ookkode, about 5 km South of the College of Agriculture, Vellayani in Kalliyoor village, Neyyattinkara Taluk of Thiruvananthapuram district during the period May, 1995 to January,1996. The main objectives were to study the effect of different doses of potassium on the biometric, yield and quality characters of irrigated Nendran banana. The study also envisaged standardisation of the index plant part for K status and determination of the critical level of K in the index part and in the soil for maximum and economic yields.

The soil of the experimental site belonged to the taxonomic class `Loamy Kaolinitic Isohyperthermic Rhodic Haplustox' and was low in N,P and K status with a textural class of sandy clay loam. The treatments were five levels of K viz., 0,150,300,450 and 600 g K_2O per plant. The biometric observations and soil and plant sample collection were carried out at early vegetative stage (2 MAP), late vegetative stage (4 MAP), shooting stage (6 MAP), bunch maturation stage (8MAP) and harvest stage (9 MAP).

The results of the investigation are briefly summarised below.

1. Increasing level of K application from zero to 600 g K_2O per plant increases all the biometric characters studied namely plant height, pseudostem girth, number of functional leaves, total leaf area and leaf area index. In most cases, the maximum values for these characters were recorded by the plants receiving the highest level of K (600 g K_2O per plant) and minimum by the control plants. The effects of the treatments were more pronounced from the shooting stage of the crop, receiving the full dose of K fertilizer.

2. All the yield attributing characters namely bunch weight, number of fingers per bunch, number of hands per bunch, weight of hand, weight of finger, length of finger and girth of finger showed an increasing trent with increase in K dose upto K_3 level (450g K_2O per plant).

3. Different K levels significantly influenced all the quality characters studied except pulp/peel ratio. The maximum values for total soluble solids, total sugars, non-reducing sugars, sugar/acid ratio and shelf life and the minimum values for acidity and reducing sugars were recorded at highest dose of

K of 600 g K_2O per plant which was on par with 450 g K_2O per plant in most cases. Control plants showed inferiority for all the quality attributes.

4. Soil chemical properties namely pH, electrical conductivity, organic carbon, available N, availbale P, exchangeable K, exchangeable Ca and exchangeable Mg were studied at specific growth stages of the crop. The exchangeable K, Ca and Mg contents were significantly influenced by the different treatments. Increasing K levels increased exchangeable K and decreased exchangeable Ca and Mg in soil.

5. Lamina, petiole and midrib of the third leaf upto shooting and flag leaf thereafter were sampled for N,P,K, Ca and Mg contents. The results indicated that increasing level of K application from zero to 600 g K_2O per plant increased the concentration of P and K and decreases the concentration of N, Ca and Mg in these parts at all the growth stages.

6. Correlation studies indicated that plant height and girth had high positive correlation with yield characters at shooting, bunch maturation and harvest stages. Soil exchangeable K status at all growth stages showed significant and positive

correlation with yield. Correlation studies also revealed that the K concentration in lamina, petiole and midrib at harvest stage was correlated maximum with yield. In comparison, K content of petiole showed the maximum correlation with yield ($r=0.7819^{**}$).

7. Step-wise regression models were fitted relating the K contents in lamina, petiole and midrib at all growth stages of the crop with bunch yield to determine the index part for foliar analysis of K. Petiole was selected as the index part for K status in Nendran banana.

8. Among the different growth stages, harvest stage was found to be appropriate for sampling, as the K content of the petiole at that stage showed the maximum relationship with bunch yield ($R^2=0.6114$). Correction in the fertilizer schedule is not possible at this stage and hence from the practical point of view of K management, the petiole at the late vegetative stage (4 MAP) which is coming next to harvest stage (9 MAP) in the order of step-wise regression analysis can be considered as the standard reflect for plant analysis for K.

9. Critical K level in the index part (Petiole at harvest stage) was determined both statistically (using quadratic regression model) and graphically which indicated the level to be 4.3 percent for maximum yield and 3.1 percent for economic yield.

10. Critical K level in the soil at late vegetative stage was determined both statistically using quadratic regression model and graphically. These methods indicated the soil critical K level to be 218 kg ha^{-1} for maximum yield and 164 kg ha^{-1} for economic yield at late vegetative stage.

11. Linear regression model was developed relating the soil K content to fertilizer dose, to determine the quantity of fertilizer to be applied to bring the soil K level to the critical K level for maximum yield. It may be predicted that 250 g K_2O per plant is to be aplied at the late vegetative stage for maximum yield and 118.5 g per plant for economic yield.

12. Economic analysis revealed that the treatment K_3 (450 g K_2O per plant) recorded the highest benefit/cost ratio of 2.35.

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* Original not seen

APPENDICES

Appendix II

ANOVA of the multiple regression analysis to fix the critical K level in petiole

Source	Degree of freedom	Sum of squares	Mean sum of squares	F ratio
Regression	2	62.005	31.003	13.996**
Error	17	37.657	2.215	
Total	19	99.662		

** Significant at 0.01 level

Appendix III

ANOVA of the multiple regression analysis to fix the soil critical K level

Source	Degree of freedom	Sum of squares	Mean sum of squares	F ratio
Regression	2	56.648	28.324	11.195**
Error	17	43.014	2.530	
Total	19	99.662		

** Significant at 0.01 level

Appendix IV

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

Details	Treatments														
	K0			K1			K2			K3			K4		
	No of labourers Rs.80/lbr	Quantity	amount (Rs)	No of labourers Rs.80/lbr	quantity	amount (Rs)	No of labourers Rs.80/lbr	Quantity	amount (Rs)	No.of labourers Rs.80/lbr	Quantity	amount (Rs)	No.of labourers Rs.80/lbr	Quantity	amount (Rs)
1 Clearing of land	36		2880	36		2880	36		2880	36		2880	36		2880
2 Earthing up	48		3840	48		3840	48		3840	48		3840	48		3840
3 Making irrigation and drainage channels	6		480	6		480	6		480	6		480	6		480
4 Taking pits	25		2000	25		2000	25		2000	25		2000	25		2000
5 Planting material (considering 5% mortality rate)		2625	7875		2625	7875		2625	7875		2625	7875		2625	7875
6 Planting	10		800	10		800	10		800	10		800	10		800
7 Cowdung-10kg plant		25t	8750		25t	8750		25t	8750		25t	8750		25t	8750
8 Cowdung application	10		800	10		800	10		800	10		800	10		800
9 Irrigation after planting for one month (once in 3 days)	100		8000	100		8000	100		8000	100		8000	100		8000

10. Cost of fertilizers										
i. Urea-Rs.3.4/kg	1032.5kg	3510.87	1032.5kg	3510.87	1032.5kg	3510.87	1032.5kg	3510.87	1032.5kg	3510.8
ii. M P-Rs.2.25/kg	1306.8kg	2940.34	1306.8kg	2940.34	1306.8kg	2940.34	1306.8kg	2940.34	1306.8kg	2940.3
iii. M.O.P-Rs.5.25/kg	-	-	625kg	3281.25	1250kg	6562.5	1875kg	9843.75	2500kg	13125.0
11. Fertilizer application										
i. at planting	10	800	15	1200	15	1200	15	1200	15	1200
ii. 1 map	10	800	15	1200	15	1200	15	1200	15	1200
iii. 2 map	5	400	10	800	10	800	10	800	10	800
iv. 4 map	5	400	10	800	10	800	10	800	10	800
v. 5 map	5	400	10	800	10	800	10	800	10	800
vi. after complete flowering	-	-	5	400	5	400	5	400	5	400
12. Irrigation after 6 fertilizer application	30	2400	30	2400	30	2400	30	2400	30	2400
13. Irrigation during summer months(once in 2 days for 2 months)	200	16000	200	16000	200	16000	200	16000	200	16000

14. Clearing of channels	6	480	6	480	6	480	6	480	6	480
15. Weeding-2times	50	4000	50	4000	50	4000	50	4000	50	4000
16. Desuckering	5	400	5	400	5	400	5	400	5	400
17. Phorate-Rs.55kg-1	150kg	8250	150kg	8250	150kg	8250	150kg	8250	150kg	8250
18. Application of phorate	10	800	10	800	10	800	10	800	10	800
19. Propping	20	1600	20	1600	20	1600	20	1600	20	1600
20. Cost of propping material Rs. 5 plant-1		12500		12500		12500		12500		12500
21. Wrapping of bunches	15	1200	15	1200	15	1200	15	1200	15	1200
22. Harvesting & transporting bunches	20	1600	20	1600	20	1600	20	1600	20	1600
23. Interest on working capital 10% yr-1		10330		10955		11316		11676		12037
Total Expenditure incurred		103297		109546		113156		116765		120374

PREDICTION OF POTASSIUM FERTILIZER REQUIREMENT OF BANANA, *MUSA* (AAB GROUP) 'NENDRAN'

BY

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ABSTRACT OF THE THESIS
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ABSTRACT

A study was undertaken in the field of a local farmer from May, 1995 to January, 1996 to assess the effect of application of different doses of potassium on the growth, yield and quality of banana cv. Nendran. The experiment also envisaged standardisation of the index plant part for K status and determination of K level in index plant part and soil for maximum and economic yield. The experiment was laid out in RBD with five levels of K (0,150, 300, 450 and 600 g K_2O per plant) as treatments replicated four times. The soil, low in N,P and K status belonged to the taxonomic class `Loamy Kaolinitic Isohyperthermic Rhodic Haplustox'.

All the biometric characters studied namely height of plant, girth of pseudostem, number of functional leaves, total leaf area and leaf area index showed an increasing trend with increase in the dose of K application from 0 to 600 g K_2O per plant and the effects were more pronounced from the shooting stage of the crop after it had received the full dose of K supply.

The maximum bunch yield was recorded by K_3 level (450 g K_2O per plant). This level also resulted in maximum values for all the yield atr ibuting characters like number of fingers per bunch, number of hands per bunch, weight of hand, and weight, length and girth of finger.

Quality characters of the fruit namely total soluble solids, total sugars, non-reducing sugars, sugar/acid ratio, pulp/peel ratio and shelf life showed significant positive trend and acidity and reducing sugars showed significant negative trend towards increasing level of K nutrition.

Soil content of exchangeable K increased while exchangeable Ca and Mg contents decreased at higher levels of K supply. But different K doses did not show any influence on pH, electrical conductivity, organic carbon, available N, and available P status of the soil.

Lamina, petiole and midrib of the third leaf upto shooting and flag leaf thereafter were analysed for N,P,K, Ca and Mg contents. Concentration of P and K showed increasing trend while N, Ca and Mg showed decreasing trend with increase in K supply from 0 to 600 g K_2O per plant.

Correlation studies indicated high positive correlation of yield characters with important crop characters, soil exchangeable K status and also with K concentrations in plant parts. K content of petiole at harvest stage was found to be correlated maximum with yield.

Petiole at harvest stage was found to be appropriate for sampling, as the K content of the same showed the maximum relationship with bunch yield. But from the practical point of K management, the petiole at late vegetative stage (4 MAP) which is coming next to harvest stage (9 MAP) in the order of stepwise regression analysis can be considered as the standard reflect for plant analysis for K. The critical K level in the petiole at harvest stage for maximum as well as economic yield was determined which was found to be 4.3 percent for maximum yield and 3.1 percent for economic yield.

Critical K level in the soil at late vegetative stage was determined both statistically and graphically which was 218 kg ha^{-1} for maximum yield and 164 kg ha^{-1} for economic yield. Linear regression model was developed relating the exchangeable

K content of the soil at late vegetative stage with different fertilizer doses tried and it may be predicted that 250 g K_2O per plant is to be applied at the late vegetative stage for maximum yield and 118.5 g per plant for economic yield.

Considering the economics, the treatment K_3 (450 g K_2O per plant) showed superiority in terms of highest benefit/cost ratio of 2.35.