SUBSTITUTION OF POTASSIUM BY SODIUM IN BANANA *Musa* (AAB GROUP) var. 'Nendran'

By
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2000

DECLARATION

I hereby declare that this thesis entitled **"Substitution of potassium by sodium in banana *Musa* (AAB group) var. 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 **"Substitution of potassium by sodium in banana *Musa* (AAB group) var. Nendran"** is a record of research work done independently by Ms. Lekshmy R. (97-11-31) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

1. INTRODUCTION

India is the largest producer of banana in the world. The production of banana in India is 130.95 lakh tonnes and the total area under banana cultivation is 4.33 lakh hectares during 1999. Kerala stands 9th in area and 10th in production.

Banana var. Nendran is one of the most important fruit crops of Kerala, having an area of 0.19 lakh ha, with a production of 2.50 lakh tonnes. Banana is an exhaustive crop and its demand for potassium is high compared to other major nutrients. In India, all the potassic fertilizers are being imported. As the value of rupee is eroding in the international foreign exchange market, the recent economic constraints of the country have focussed on the need for enhancing self reliance in the usage of indigenous fertilizers. Therefore it is highly warranted to concentrate our research efforts for assessing the efficiency of various indigenous fertilizer materials at least as partial substitutes for the costly inputs. If Na can replace K in the nutrition of banana, at least partially, common salt, a cheap indigenous material can be profitably utilized as a substitute for KCl. Total cost of fertilizers in banana cultivation is estimated around Rs.14227 ha^{-1} (Package of Practices Recommendations, 1996). Out of this, MOP contributes 39.53 per cent. If common salt can replace MOP to the extent of 50 per cent, a sum of Rs. 1928 can be saved.

Sodium can replace potassium to a large extent in some non-specific functions in the vacuole. The replacement within the vacuole makes potassium available for specific functions within the plant cell (Leigh and Wyn Jones, 1984). When potassium supply was low, sodium performed some of the normal functions of potassium such as maintenance of ionic balance necessary for physiological processes (Tisdale *et al.*, 1992).

The results obtained by George (1995) and Sudharmaidevi (1995) in sweet potato and cassava respectively emphasised the fact that Na can replace K, at least partially. Banana being a major fruit crop in this region and only few research findings are reported in fruit crops on the substitution of potassium with indigenous cheap materials such as common salt, the present study has been taken up with the following objectives.

1. To find out the extent of substitution of K by Na
2. If substitution is possible, to determine the most desirable level of substitution.
3. To work out the economics of substitution of K by Na.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana, the most important commercial fruit crop of Kerala has higher fertilizer requirements, especially K, a costly input. The possibility and extent of substitution of K by Na, a cheap source, in the nutrition of banana var. Nendran has been investigated in this study. The effect of potassium and sodium on growth, drymatter production, nutrient uptake, yield and quality of fruits are studied. Literature pertaining to these topics wherever found appropriate is reviewed as under.

2.1 Growth characteristics

2.1.1 Plant height and girth

2.1.1.1 Potassium

Lahav (1972) reported that height and circumference of banana suckers treated with 292 and 146 ppm of potassium were significantly greater than those treated with 73, 36 or 0 ppm. Jambulingam *et al.* (1975) in an experiment with banana cv. Robusta, noticed an increase in the height and girth of pseudostem as the K application in the soil increased.

Studies on K nutrition in rainfed banana cv. Palayankodan by Sheela (1982) revealed that the height of the pseudostem at late vegetative stage and shooting stage was influenced significantly when potassium supply increased from 0 - 600 g $plant^{-1}$.

George (1994) in banana cv. Nendran, observed that increasing levels of potassium application increased the height and girth of pseudostem at all growth stages.

Baruah and Mohan (1985) reported that height and girth of the pseudostem responded significantly to K application in banana cv. Jahaji and it was greatest when 250 g K_2O plant^{-1} was given. Shaikh *et al.* (1985) observed optimum plant height and girth at 786 kg K_2O ha^{-1}.

According to Fabregar (1986), girth of pseudostem increased with increasing rates of K application upto 800 kg ha^{-1} in banana cv. Umalag. Mustaffa (1987) recorded an increase in height and circumference of pseudostem at 400 g K_2O plant^{-1}.

Oubahou *et al.* (1987) observed an increase in plant height and pseudostem girth, in Giant Cavendish, when K level was increased from 350-550 g plant^{-1}.

Hegde and Srinivas (1991) reported that increasing K levels had no significant effect on plant height and pseudostem girth which increased significantly at 200 g compared with 100 g K_2O plant^{-1}.

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

Bhargava *et al.* (1992) reported increased growth in banana plants in red soils of Karnataka by K application at the rates of 0.2, 0.4 and 0.8 kg K_2O plant^{-1}. Parida *et al.* (1994) observed that increase in levels of K increased the height and pseudostem girth of banana cv. Robusta.

According to George (1994), in banana cv. Nendran, increased height and girth of pseudostem was noticed with increasing levels of potassium application especially from the shooting stage onwards. Sheela (1995) opined that significant increase in height and girth of pseudostem was observed due to potassium application in banana cv. Nendran.

Height and girth increased in Hindy banana plants grown in sand culture when the potassium levels increased (Shawky *et al.*, 1996). Sindhu (1997) in banana cv. Nendran reported that when the dose of K_2O increased from 0 - 600 g $plant^{-1}$, a corresponding increase was obtained in the height and girth of pseudostem.

2.1.1.2 Sodium

Indira (1978) in an experiment on cassava observed that the plant growth started declining when the concentration of NaCl increased from 0 - 2000 ppm and the toxicity symptoms started from 2000 ppm onwards.

Chavan and Karadge (1980) reported reduced shoot growth in *Arachis hypogea* L. with 0-200 mM NaCl. Mangal *et al.* (1986) observed a reduction in the plant height of coriander plants with increased salinity.

Plant height was found to decrease with increasing concentrations of NaCl from 6000 ppm to 10000 ppm in tuberose (Malini and Khader, 1989). According to Mills (1989), moderate concentration of NaCl (0-1 per cent) stimulated growth and phylloid production in asparagus.

Dhindwal *et al.* (1992) reported that plant height was reduced due to increased levels of salinity. According to Mangal *et al.* (1993) and Valia *et al.* (1993), plant height was reduced when salinity levels were increased.

In an experiment on the effect of salt tolerance of ornamental plants, *Mesembryanthemum* showed no reduction in plant height and growth when subjected to higher levels of salt application (Zurayk *et al.*, 1993).

George (1995) reported that the treatment with 50 per cent substitution of potassium by sodium produced maximum length of vine in sweet potato, i.e., 17.68 per cent more than the length of vine observed under no substitution. Sudharmaidevi (1995) observed that the growth in cassava, was maximum when 50 per cent MOP was given along with 50 per cent common salt.

In rice, the plant heights decreased to 93.74, 84.97 and 73.02 (per cent over control) at 50, 100 and 150 mM NaCl, respectively. Negative correlation coefficient was obtained between the NaCl concentrations and relative values of plant height (Khan *et al.*, 1997).

2.1.2 Number of leaves and leaf area index

2.1.2.1 Potassium

Jambulingam *et al.* (1975) reported that higher doses of K_2O significantly increased the leaf area in 'Robusta' banana. In their studies with 'Dwarf Cavendish', Ramaswamy *et al.* (1977) obtained significant increase in leaf area with increasing rates of potassium upto a level of 450 g $plant^{-1}$.

According to Turner and Barkus (1980), low levels of K reduced 20 per cent of the total leaf area in banana. It was also found that there was no correlation between the emergence of new leaves with the K content in the leaves. Sheela (1982) reported that higher levels of potassium application increased the number of leaves and leaf area in 'Palayankodan'. But there was no increase in the number of functional leaves under different levels of K.

Baruah and Mohan (1985) recorded the highest number of leaves in banana cv. 'Jahaji' at 340 g K_2O $plant^{-1}$. The results revealed that there were significant differences in the LAI at six months after planting and at the shooting stage due to potassium application.

Kohli *et al.* (1985) obtained significant increase in leaf area and leaf area index in banana cv. Robusta at 250 g K_2O plant^{-1}. Chattopadhyay and Bose (1986) observed that K application significantly increased the number of leaves in Dwarf Cavendish banana. The number of leaves produced was higher when 400 g K_2O plant^{-1} was applied (Mustaffa, 1987).

According to Singh *et al.* (1990), potassium application did not favourably increase the LAI in 'Dwarf Cavendish' banana. Baruah and Mohan (1991a) reported that higher levels of K from 0 to 250 g plant^{-1} increased the number of leaves plant^{-1}.

George (1994) observed an increasing trend on the total number of leaves and the number of functional leaves in banana cv. Nendran with increase in the K levels. But significant variations were observed only at the post shooting and bunch maturation stages.

Parida *et al.* (1994) reported that increase in the levels of K increased the number of leaves in Robusta banana.

Maximum number of leaves was observed at 600 g K plant^{-1} in banana cv. Nendran by Peters (1997). However, the number of leaves decreased when K level increased upto 900 g plant^{-1}. LAI at the fifth month stage was also highest at 600 g K ha^{-1}.

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 plant^{-1} produced most vigorous leaves.

2.1.2.2 Sodium

Bonjour (1971) reported a negative response of sugarbeet to Na application. The number of leaves decreased with increased rates of sodium. Draycott and Farley (1971) observed an increase in leaf area index in sugarbeet by sodium application under irrigated conditions.

Durrant *et al.* (1978) recorded an increase in leaf area index during the early stages of growth in sugarbeet after the application of sodium fertilizers. Maliwal and Paliwal (1979) reported that the length and width of leaves of carrot and radish decreased with increase in salinity of the growth medium.

According to Prema *et al.* (1987a), in an experiment on coconut, when K was substituted by Na to the extent of 0, 25, 50, 75 and 100 per cent, there was no influence of substitution on the number of functional leaves and the number of leaves produced palm^{-1} year^{-1}.

Kayani and Mujeeb (1988) reported that increasing the osmotic potential of the culture solution from 0 - 12.69 bar using NaCl reduced leaf area in maize.

Gupta and Srivastava (1989) in an experiment on wheat recorded a reduction in the leaf number and average leaf area by the application of NaCl. It was more pronounced in wheat cv. Kalyansona when compared to Kharchia-65.

In tuberose, the number of leaves and leaf area index were found to decrease with increase in the concentration of NaCl from 6000 to 10000 ppm (Malini and Khader, 1989). Yaseen *et al.* (1989) also obtained similar results in barley.

Increasing the concentration of NaCl in the irrigation water significantly reduced the number of green leaves plant^{-1} in *Sorghum bicolor* (Yang *et al.*, 1990). A reduction in the leaf area index was observed in coleus by Ibrahim *et al.* (1991) when NaCl concentration increased.

Similar results were obtained by Pezeshki and Pan (1990) in rice and Valia *et al.* (1993) in passion fruit. Sudharmaidevi (1995) reported that at all stages of growth except at 8 MAP, the treatment 50 per cent MOP + 50 per cent common salt recorded maximum LAI in cassava. With increasing substitution of MOP by common salt, a general reduction in LAI was seen.

With increasing salinity levels, leaf area was decreased progressively and there was a negative correlation between the NaCl concentration and the green leaf area in rice (Khan *et al.*, 1997).

2.1.3 Drymatter production

2.1.3.1 Potassium

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

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

Increasing K supply increased drymatter production in banana which helped in increasing the uptake of most of the elements (Turner and Barkus, 1983). Investigations on the drymatter production and uptake of macronutrients by banana cv. Prata by Gomes *et al.* (1991) showed that uptake of all nutrients was correlated with drymatter production except that of K by the petiole.

According to Hegde and Srinivas (1991), increasing K application from 100 to 200 g K_2O plant^{-1} significantly increased the total drymatter production in both plant and ratoon crops of banana, but further increase in K to 300 g K_2O plant^{-1} had no significant effect except in the fruit drymatter in the plant crop. George (1994) reported that the total drymatter production was maximum for the treatment with 600 g K_2O plant^{-1}, in banana var. Nendran.

2.1.3.2 Sodium

Brownell (1965) reported that drymatter production in *Atriplex vesicaria* increased four times when fertilized with sodium. In sugarbeet plants, El-Sheikh *et al.*, (1967) found that when sodium was applied along with other nutrients, plant growth was increased.

Warcholowa (1973) in sugarbeet, observed that sodium increased the drymatter yield of roots and the effect was greatest when K was moderately deficient and also 50 per cent K_2O and 50 per cent Na_2O were supplied.

In cassava, plant growth was retarded beyond 2000 ppm Na in growth medium (Indira, 1978). Chavan and Karadge (1980) reported that high concentration of NaCl reduced the dry weight of all plant parts of peanut.

According to Khanna and Balaguru (1981b), dry weight of shoots, collar and roots in wheat increased significantly with the application of sodium up to 5.0 mM l^{-1}.

El-Sherbieny *et al.* (1986) obtained a negative response in drymatter yield of shoots and spikes in wheat with increasing levels of salinity. Al- Saidi *et al.* (1988) in grape vine reported that drymatter production was reduced when the plants were given a sodicity stress.

Fakultet and Sad (1988) in an experiment to study the reaction of two pea (*Pisum sativum*) varieties to sodium substitution for potassium observed that the drymatter production was greatest when 20 per cent of K was substituted with Na. According to Ohta *et al.* (1988), greatest fresh weight was obtained in *Amaranthus tricolor* when supplied with equal parts of NaCl and KCl.

Gupta and Srivastava (1989) in an experiment on wheat found that NaCl reduced the dry weight of the plant. Root weight was less reduced as compared to shoot showing an increased root : shoot ratio.

Do (1990) in an experiment on maize with different levels of sodium in nutrient solution (0, 0.05, 0.10, 0.25 and 0.50 per cent) found that the biomass production in young plants were unaffected when the K : Na ratio in plants was changed from 7.39 to 0.76. In *Phaseolus vulgaris,* addition of Ca at all levels of NaCl increased shoot and dry weight. (Kharazian ,1991)

Aljuburi (1992) studied the effect of NaCl on the growth of seedlings of four date palm varieties and noticed that irrigation with different concentrations of NaCl caused a significant reduction in shoot fresh weight of two cultivars as compared with control. Decrease in fresh weight increased with increase in concentrations and maximum reduction was observed at 1.8 per cent NaCl.

Dhindwal *et al.* (1992) observed an increased growth rate of barley seedlings at low levels of salinity. Garg *et al.* (1993) reported a progressive decrease in plant growth of Indian mustard when salinity was increased.

Cushnahan *et al.* (1995) found that Na increased cumulative drymatter yield in pasture, but the increase was not significant. Sudharmaidevi (1995) obtained maximum growth of plants in cassava, when 50 per cent of K was substituted with Na. But 75 and 100 per cent Na substitution depressed the growth.

According to Moraghan and Hammond, (1996), added K and Na caused a small but significant decrease in drymatter accumulation in flax, irrespective of the levels of sodium.

2.2 Yield and yield attributes

2.2.1 Potassium

Leigh (1969) reported that increasing supplies of potassium increased finger weight, rind thickness, finger length and finger circumference in banana. Application of 204 kg K_2O $acre^{-1}$ in four splits was recommended as the optimum level.

Nambiar *et al.* (1979) reported that the bunch weight in Nendran increased by the application of 450 g K_2O $plant^{-1}$ in two equal split doses during 30^{th} and 150^{th} days after planting. In banana cv. Palayankodan, bunch weight increased when the K levels increased from 0 - 600 g K_2O $plant^{-1}$ (Sheela, 1982).

Obiefuna (1984) in a trial using six levels of K (0-600 g K $plant^{-1}$ as MOP) found that an optimal dose of 300 g K $plant^{-1}$ increased the number of marketable fingers and finger weight $plant^{-1}$ over the control.

Shaikh *et al.* (1985) found 786 kg K_2O ha^{-1} as the optimum dose for banana with regard to plant growth and yield. Bunch weight of banana increased when the K_2O increased from 0 - 480 g $plant^{-1}$ (Chattopadhyay and Bose, 1986).

Mustaffa (1987) in Robusta banana, recorded the highest fruit yield of 45.4 t ha^{1} with 300 g K_2O $plant^{-1}$, 35 per cent higher than that of zero potash. A linear increase in yield was obtained upto 600 g K_2O $plant^{-1}$ for Nendran, grown in rice fallows. Hands and fingers $bunch^{-1}$ also increased with increasing levels of potassium (Nair, 1988).

Nair *et al.* (1990) obtained the highest yield by the application of N and K each in six splits @ 400 g N and 600 g K_2O $plant^{-1}$ in Nendran grown in rice fallows. Hegde and Srinivas (1991) observed an improvement in yield along with an increase in the number of hands, fingers and finger weight when the K_2O level increased from 0 - 300 g $plant^{-1}$.

Length and circumference of fingers in the second hand were increased in Dwarf Cavendish (Baruah and Mohan, 1992).

Pathak *et al.* (1992) reported that 300 g K_2O $plant^{-1}$ produced highest number of hands, fingers $bunch^{-1}$ and inturn increased the weight of hands in banana cv. Harichal.

Natesh *et al.* (1993) confirmed that the recommended dose of fertilizers i.e., 190 : 115 : 300 g NPK $plant^{-1}$ when applied in four splits had favourable effect on yield than when the same dose was applied in two splits, in banana cv. Nendran.

In Basrai banana, 300g K_20 plant $^{-1}$ was found to be the optimum with bunch yields of 74.9, 76.4 and 70.9 t ha^{-1} in the plant crop, in the first and second ratoon crops respectively. Further application did not produce any corresponding increase in yield and in some cases yield was declined (Ray *et al.*, 1993).

Agussalim *et al.* (1994) observed maximum yield in banana cv. Barangan when 600 g KCl $plant^{-1}$ was applied in two splits. George (1994) recorded maximum number of hands, fingers $bunch^{-1}$ and weight of hand with 225g K_2 0 plant $^{-1}$. Length, girth and weight of index finger showed an increase with the above dose.

In tissue cultured banana, cv. Nendran, Sheela (1995) noted an increase in length and weight of fingers with increasing levels of K. Peters (1997) also reported an increase in the number of fingers, number of hands and weight of hands with higher doses of K_2O.

Sindhu (1997) found out maximum bunch weight and fingers $bunch^{-1}$ at 450g K_2O $plant^{-1}$ while it declined with higher levels.

Moreno *et al.* (2000a) reported that finger diameter was maximum at 332 kg ha^{-1} in banana when three levels viz., 166, 332 and 498 kg ha^{-1} were tried. Moreno *et al.* (2000 b) recorded a highest yield of 6.2 t ha^{-1} in banana at 498 kg K ha^{-1}.

2.2.2 Sodium

According to Lancaster *et al.* (1953), when one third, half and two third of K was substituted with Na, the yield of cotton plants increased especially in

K deficient soils. Marshall and Stureis (1953) found that the yield of cotton was increased with the addition of 40 lbs of Na_2O.

Holmes *et al.* (1973) found that the most profitable level of common salt for sugarbeet was 377 kg common salt + 127 kg K_2O ha^{-1}.

Draycott and Durrant (1976 a) established that sodium salt can largely replace potassium fertilizer in sugarbeet and the elements K and Na increased root yield. The optimum level of Na and K for maximum yield in sugar beet as reported by Draycott and Durrant (1976 b) was 150 kg Na + 167 kg K ha^{-1}. Hamid and Talibudeen (1976) conducted an experiment on barley, sugarbeet and broad beans and concluded that yield of barley and sugarbeet were benefited from the added Na in the soil but that of broad beans was adversely affected. In barley, the maximum grain yield and straw yield were obtained at 23.2 mM Na above which the yield declined. In sugarbeet, maximum yield was obtained at 30.9 mM Na.

In cassava, maximum tuber yield was obtained at 200 kg NaCl ha^{-1} out of the three levels viz., 200, 400 and 600 kg NaCl ha^{-1} (Nair *et al.*, 1980).

According to Mathew *et al.* (1984) in coconut, substitution of K_2O by Na_2O to the extent of 75 or 50 per cent could maintain the same yield as 100 per cent K. Maximum increase in yield in coconut palms was obtained when 50 per cent K_2O was substituted by Na_2O (Prema *et al.* 1987 a). In another experiment on coconut, Prema *et al.* (1987 b) reported that when K was substituted with Na to the extent of 0-100 per cent, the treatments did not differ in their influence on copra weight nut^{-1}.

All the yield contributing characters like tuber number plant^{-1}, length of tuber and girth of tuber in sweet potato were highest at 50 per cent substitution of K by Na (George, 1995).

According to Sudharmaidevi (1995), the highest yield in cassava was obtained at 50 per cent substitution of K by Na while the yield was lowest at 100 per cent substitution.

2.3 Quality aspects

2.3.1 Potassium

In Taiwan, Chu (1961) reported that K application greatly increased the fruit yield and improved fruit quality and storage life in banana.

Ho (1968) observed improved fruit conditions in banana after 20 days to storage with increasing supply of K_2O. Van Uexkull (1970) found that, potassium improved the sugar/acid ratio and the keeping quality by increasing the thickness and firmness of rind in banana.

In banana cv. Robusta, appreciable improvement in the quality of fruits was observed with increasing levels of potassium when different K combinations were tried (Singh *et al.*, 1974). Jambulingam (1975) in banana cv. Robusta reported significant effect of K on soluble solids.

In banana cv. Robusta, total soluble solids increased with an increase in the levels of K_2O up to 300g plant^{-1}. Reducing, non reducing and total sugar content also increased with increasing doses of K_2O. Sugar/acid ratio was improved while acidity decreased (Vadivel and Shanmugavelu, 1988). Chattopadhyay *et al.* (1980) reported from his studies in banana cv. Giant

Governor that total sugar content in fruits varied with different K levels. A reduction in acidity was also noticed with increasing levels of K.

Sheela (1982) obtained beneficial effects on total soluble solids, reducing sugars, total sugars, sugar/acid ratio and acidity with higher doses of K, in banana cv. Palayankodan.

In the studies on the effect of potassium on fruit quality of 'Jahaji' banana, results revealed that there was a significant response to potassium on the quality of fruits. TSS, total sugar, reducing and non reducing sugars increased with increasing levels of potassium whereas a reverse effect was observed with respect to titrable acidity (Baruah and Mohan, 1986).

Chattopadhyay and Bose (1986) reported that total sugar content increased from 11 - 13 per cent by soil application of K from 0 - 480 g $plant^{-1}$ in Dwarf Cavendish banana. Mustaffa (1987) found that in banana cv. Robusta, K increased the quality of the fruits by raising the TSS and decreasing the acidity.

Samra and Qadar (1990) opined that in banana, soil and foliar applications of K increased the contents of total and reducing sugars. Hegde and Srinivas (1991) also obtained an increase in TSS with increasing levels of K. But pulp / peel ratio of banana fruits was significantly decreased.

In banana cv. Nendran, total sugars, non reducing sugars and pulp / peel ratio increased with increasing levels of K. But reducing sugars showed a decreasing trend with higher levels of K. (George, 1994). In tissue cultured banana cv. Nendran, Sheela (1995) found that sugar/acid ratio improved with increase in K while acidity decreased.

In Nendran banana, higher values for TSS, total sugars, sugar / acid ratio and pulp / peel ratio were recorded by Sindhu (1997) when K_2O application increased from 0-600g $plant^{-1}$. A gradual decline in reducing sugars and acidity was also observed.

2.3.2 Sodium

Troug (1950) observed that application of sodium to sugarbeet increased the sugar content by 20 per cent. Hamid and Talibudeen (1976) found that the sugar concentration in the mature roots of sugar beet increased to a maximum between 9.1 and 23.2 mM Na. Genkel and Bakanova (1977) reported that seed treatment with 0.1 and 0.2 per cent NaCl increased the root sugar content in sugarbeet from 16.4 to 18.3 per cent.

Sodium application in sugarbeet increased the total soluble solids (Khanna and Balaguru, 1981 a). Guerrier (1988) reported an increase in sugar content of the seedlings with increase in NaCl in the germination medium. Adam and Ho (1989) observed an increase in the sugar content of the fruit juice of tomato with increased levels of salinity.

Chandler *et al.* (1989) found that sugars and sucrose content of sugar beet increased slightly in direct proportion with Na concentration.

According to Khan *et al.* (1989), reducing and non reducing sugar contents decreased in sorghum, with an increase in sodium levels.

George (1995) recorded higher contents of sugars, protein and starch in sweet potato when K and Na ions were applied in 50 : 50 ratio. Sudharmaidevi (1995) reported an increase in reducing sugar content when cassava plants were supplied with 50 per cent MOP and 50 per cent common salt.

2.4 Uptake of nutrients

2.4.1 Potassium

Hewitt and Osborne (1962) reported that heavy application of K decreased the concentration of K in the leaves of Lactan banana. Ho (1969) found that increased levels of K fertilizers depressed the leaf concentration of Ca, Mg and N in banana cv. Fairyman.

Lahav (1973) observed an antagonism between K and Na ions. Randhawa *et al.* (1973) found that the K content in the leaf tissue of the banana plants increased with increasing levels of K application. In Robusta banana, the increase in K content was significant when the dose was increased beyond 360 g K_2O plant^{-1} (Jambulingam *et al.*, 1975).

Mengel *et al.* (1976) reported that low K levels favoured uptake of Mg and Ca in banana. According to Lahav (1977), a synergistic relationship existed between K and P and antagonism between K and Mg in banana cv. Williams.

In a study conducted in red soils of Cuba, high K fertilization increased K content in leaves of banana plants (Garcia *et al.*, 1980).

Sheela (1982) reported that K content in all plant parts increased with increased levels of K in banana cv. Palayankodan. Turner and Barkus (1983) observed that increased K supply increased the plant uptake of P while it decreased that of N, Ca and Mg.

K fertilizers decreased Ca and Mg levels in cv. Robusta. But the K concentration in leaves was almost constant within the range of 4.0 to 5.0 per cent from large to shot stages (Vadivel and Shanmughavelu, 1988). According to Baruah and Mohan (1991b), in Jahaji banana, the highest concentration of leaf potassium (3.38 per cent), was at the shooting stage when treated with 258 g K $plant^{-1}$.

Hegde and Srinivas (1991) reported that increased K fertilization significantly increased the uptake of N, K and Ca. Miao *et al.* (1993) studied the effects of K application on absorption of other elements in banana and found that the contents of N, Ca and Mg decreased with increased levels of K.

According to Albelda (1995) in a trial with five varieties of banana, Bungulan banana had the highest potassium uptake of 5.91 per cent. In banana cvs. Nanica and Prata and Ana, potassium uptake increased with increasing levels of potassium (Zaidan, 1998).

2.4.2 Sodium

When Na^+ and K^+ were present in equivalent concentrations, the rate of absorption of K^+ in barley increased and the total rate of absorption of K^+ and Na^+ mainly reflected the absorption characteristics of Na^+ (Rains and Epstein, 1967). Barrant (1975) reported that increased application of Na decreased the K uptake in coconut. Similarly, increased application of K fertilizers depressed the Na uptake.

Shultz *et al.* (1979) found that added Na decreased the uptake of K in lucerne and white clover. Ando *et al.* (1979) observed a marked decrease in Na uptake with higher levels of K in *Chloris gayana*.

Chavan and Karadge (1980) found that Na accumulated in all plant parts in peanut with an increase in NaCl concentration, whereas K content was decreased in leaf and stem. Khanna and Balaguru (1981a) reported that Na concentration of all plant parts in sugarbeet increased with application of sodium but decreased with an increase in K application. According to Khanna and Balaguru (1981b), with increasing levels of sodium application, Na content increased and K content decreased in wheat.

Mathew *et al.* (1984) reported that, Na and K content of leaves were influenced by Na substitution in coconut. Maximum K and Na contents were for 100 per cent K and 100 per cent Na respectively.

In coconut palm, substitution of K by Na showed no significant difference in their effect on total N, P, Ca, Mg and Cl content of leaves, whereas K and Na contents of leaves were significantly influenced by the treatments (Prema *et al.*, 1987a). Substitution of K with Na, in coconut did not have any influence on the N, P and K contents of copra (Prema *et al.*,1987b). The uptake of N, P, Ca and Mg by coconut palms were not affected significantly by the substitution of K with Na, but the palms receiving higher amount of K and Na retained higher amounts of K and Na (Prema *et al.*, 1992).

Cushnahan *et al.* (1995) reported that Na application in pasture tended to decrease K concentration in shoots but intermediate rates of Na caused significant increase in K concentration. They further observed that the total cation concentration in herbage initially declined with increasing rate of Na application, but then increased.

According to Sudharmaidevi (1995), in cassava, the K uptake was maximum with 50 per cent substitution of MOP by common salt. But the Na uptake was maximum in the treatment which received no Na.

George (1995) reported that sweet potato plants receiving 50 per cent substitution of KCl by NaCl showed better nutrient content and uptake over the plants that received full dose of KCl.

Moraghan and Hammond (1996) found that added Na increased and added K decreased Na concentration in both vegetative tissue and seeds of flax. In rice, concentrations of Na increased with increasing salinity levels. But a decreasing tendency in K ion accumulation was observed with increasing salinity levels except in Pokkali which showed static concentrations of K at all levels of salinity (Khan *et al.*, 1997).

Ashraf and Ahmad (2000) reported that accumulation of Na^+ in cotton did not show any significant relation with the uptake of Cl^-, K^+, Ca^{2+} and N.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

3.1 Experiment site and soil

The field experiment was laid out in block IV of the Instructional Farm, Vellayani. Geographically, the area is located at 8.5^0 N latitude and 76.9^0 E longitude, at an altitude of 26 m above mean sea level.

The soils of the experimental area belongs to the Vellayani series under the taxonomic class 'Loamy Kaolinitic Isohyperthermic Aeric Tropic Fluvaquents' and having the following properties.

Table 1 Physico chemical properties of soil

1. Mechanical analysis (per cent)

Coarse sand	-	47.20
Fine sand	-	23.60
Silt	-	6.00
Clay	-	22.80

Chemical properties

1. pH - 4.9	5. Available N - 206.38 kg ha^{-1}
2. CEC - 3.8 C mol kg^{-1}	6. Available P - 19.50 kg ha^{-1}
3. EC < 0.04 dS m^{-1}	7. Available K - 119.00 kg ha^{-1}
4. Organic carbon - 0.43 per cent	8. Available Na - 17.30 kg ha^{-1}

3.2 Layout of the experiment

Design	-	Randomised Block Design
Treatments	-	6

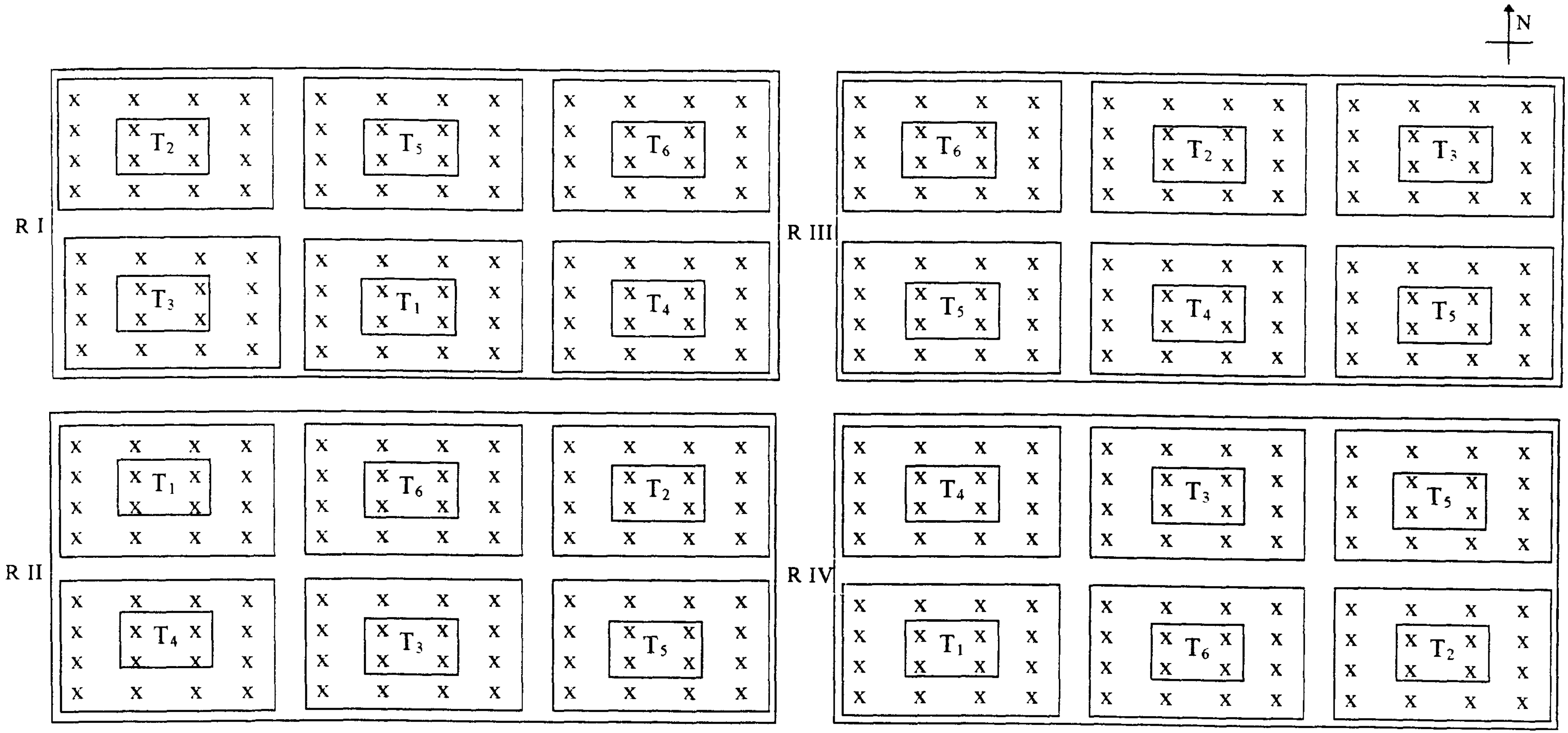


Fig. 1 Layout plan of the experiment

Replications - 4

Variety - Nendran (*Musa* AAB group)

Plot size - 8 x 8 m^2

Spacing - 2 x 2 m^2

Number of treatment plants per plot - 4

Treatment	Notation
Recommended dose of K as KCl (100 per cent K as KCl)	T_1
K 75 per cent as KCl + Na 25 per cent as NaCl	T_2
K 50 per cent as KCl + Na 50 per cent as NaCl	T_3
K 25 per cent as KCl + Na 75 per cent as NaCl	T_4
Na 100 per cent as NaCl	T_5
Control - K Zero and Na Zero	T_6

All the plants received uniform doses of cattle manure, N and P $plant^{-1}$ as per Package of Practices (1996) for this crop recommended by Kerala Agricultural University. Banana suckers were selected on uniform weight basis. 25 - 100 per cent of K was substituted by Na on equivalent basis. There were 16 plants $plot^{-1}$ to have four plants for each treatment. Observations on these four plants were taken and average of the same were considered for further analysis and interpretation of results.

3.3 Weather parameters

The major weather parameters during the season were monitored.

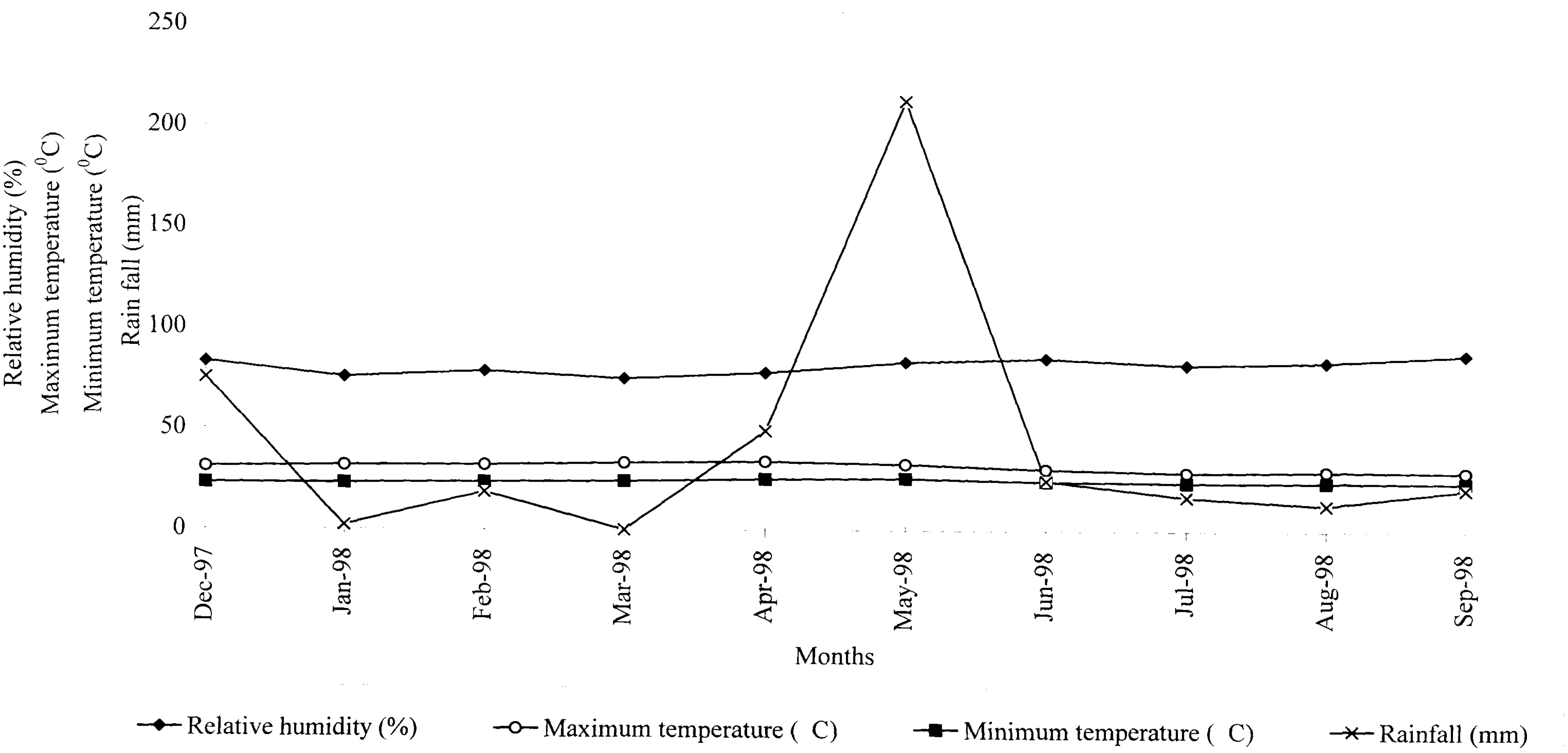
Maximum temperature - 30.67 to 34.14 ^{0}C

Minimum temperature - 23.1 to 25.9 ^{0}C

Relative humidity - 75.05 to 87.55 per cent

Total rainfall - 1189 mm

Fig. 2 Main meteorological parameters during the cropping season (December 1997 to September 1998)



3.4 Season

The period of crop growth was from December 1997 to September 1998.

3.5 Planting materials

Three months old disease free Nendran suckers collected from the Instructional Farm, Vellayani were selected for planting. The rhizomes were dipped in cowdung slurry, smeared with 0.2 per cent. HCH and wood ash, dried in the sun for four days and stored for 15 days in shade before planting.

3.6 Planting

The rhizomes were planted in pits of size 50 x 50 x 50 cm at a spacing of 2 x 2 m during December 1997.

3.7 Fertilizer application

Nitrogen was applied as urea (46 per cent N), phosphorus as rock phosphate (28.4 per cent, P_2O_5), potassium as KCl (LR grade 52.44 per cent K) and sodium as NaCl (LR grade 39.34 per cent Na). FYM @ 10 kg $plant^{-1}$ was applied. The levels of N and P were kept constant for all the treatments. N 190 g $plant^{-1}$ was applied in six equal splits, first as basal and the remaining at one, two, four, five and six months after planting. P_2O_5, 115 g $plant^{-1}$ was applied in two splits, first as basal and second, one month after planting. K was applied as KCl and Na as NaCl both in five equal splits, first as basal and the rest at one, two, four and five months after planting.

3.8 Maintenance of the crop

Four treatment plants with border plants were maintained in each plot.

3.9 Irrigation

Irrigation was given at weekly intervals @ 20 litres water plant^{-1} upto third month and 40 litres plant^{-1} up to harvest.

3.10 Weeding

Hand weeding was resorted to as and when required.

3.11 Plant protection measures

Phorate (10 per cent G) was applied uniformly to all plants at the rate of 25 g plant^{-1} at 20th, 65th and 165th days after planting as a prophylatic measure against the bunchy top insect vector, *Pentalonia nigronervosa*.

3.12 Incidence of pests and diseases

No serious problem was noticed.

3.13 Growth characters

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

3.13.1 Height of plant

Height of the plant was measured from the base of the pseudostem at the soil level to the axil of the youngest unopened leaf at vegetative, shooting and harvest stages.

3.13.2 Girth of pseudostem

Girth of the pseudostem at the soil level, at 20 cm and 100 cm above the soil level was measured using a flexible measuring tape at vegetative, shooting and harvest stages.

3.13.3 Number of leaves plant^{-1}

The total number of functional leaves per plant was recorded at the three stages viz., three months after planting, six months after planting and nine months after planting.

3.13.4 Leaf area index

Leaf area index was computed from the values of the total leaf area of the plant and the geographical area occupied by it using the formula.

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

The leaf area of the functional leaves was calculated using the formula.

Leaf area = L x B x 0.8 (a constant)

Where L = Length of lamina

B = Width of lamina

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

3.13.5 Total drymatter

Drymatter content of each part of the banana plant was determined according to the methods suggested by Piper (1967). Pseudostem, midrib petiole, lamina and rhizome were separated and fresh weight of each was recorded. Fresh sample of 500 g from each plant part was washed, air dried and then oven dried at 70^0C to constant weight for calculating the moisture content. Total drymatter content was calculated using the values for percentage moisture and fresh weight of each part.

3.14 Yield and yield attributes

3.14.1 Bunch characters

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

3.14.2 Weight of bunch

The weight of bunch including the peduncle was recorded.

3.14.3 Number of hands bunch^{-1}

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

3.14.4 Length of bunch

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

3.14.5 Weight of hand

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

3.14.6 Distance between hands in a bunch

The distance between adjacent hands in a bunch was recorded and the mean value calculated for a bunch.

3.14.7 Number of fingers bunch^{-1}

The total number of fingers in a bunch was counted.

3.14.8 Finger characters

The middle finger in the top row of the second hand was identified as the index finger and the following characters were recorded.

3.14.9 Length of finger

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

3.14.10 Girth of finger

The girth of finger was measured in the middle portion of the finger.

3.14.11 Weight of finger

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

3.15 Chemical analysis of plant parts and fruits

The individual plant parts such as the lamina, petiole, midrib, pseudostem, rhizome flower and fruit were collected at the respective stages of sampling were finally chopped, air dried and then oven dried at a temperature of 70^{0}C in a hot air oven. The dried material was powdered uniformly and stored in air tight containers for chemical analysis.

Sl. No.	Characteristics	Method followed	References
1.	N	Microkjeldhal digestion in sulfuric acid and distillation	Jackson, 1973
2.	P	Nitric-perchloric - sulfuric acid (10 : 1 : 4) digestion and reading in Klett Summerson photo electric colorimeter	Jackson, 1973
3.	K	Nitric-perchloric - sulfuric acid digestion and flame photometry	Piper, 1967
4.	Na	Nitric-perchloric - sulfuric acid digestion and flame photometry	Piper, 1967

3.16 Indexing of plant parts

For indexing the plant part in banana for K, the third leaf was collected and separated into petiole, lamina and midrib portions as given below (Prevel *et al.*, 1986).

Petiole - distal half portion

Midrib - 5 cm long piece of midrib exactly half way along the leaf

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

3.17 Analysis of ripe fruits

3.17.1 Quality of fruits

The ripe fruits after removing the skin were made into a pulp in a homogeniser, filtered and made up to known volume. Aliquots from this were used for the analysis of the following characters as detailed below.

	Method adopted	References
Total soluble solids	Direct reading using hand refracto metre	Ranganna (1977)
Titrable acidity	Titration against 0.1 N NaOH	Ranganna (1977)
Reducing sugars	Copper reduction method using Fehling's solution	Chopra and Kanwar (1976)
Total sugars	Copper reduction method using Fehling's solution after HCl digestion	Chopra and Kanwar (1976)
Non reducing sugars	Non reducing sugars = (Total sugar - reducing sugars) x 0.95	Chopra and Kanwar (1976)
Sugar - acid ratio	Total sugar/acidity	Chopra and Kanwar (1976)

3.18 Soil analysis

Soil samples were collected from the pits at the harvest stage. The composite sample drawn from each pit was air dried, powdered, sieved through a 2 mm sieve and analysed for various chemical properties (Jackson, 1973).

Sl. No.	Method	References
1. Mechanical composition	International pippette method	Gupta and Dakshinmoorthi, 1980
2. pH	pH meter	Jackson, 1973
3. CEC	Ammonium saturation using Neutral Normal Ammonium acetate	Jackson, 1973
4. Organic carbon	Walkely and Black's rapid titration method	Jackson, 1973
5. Available N	Alkaline permanganate method	Subbiah and Asija, 1956
6. Available P	Using Klett Summerson photoelectric colorimeter	Jackson, 1973
7. Available K	Flame photometry	Piper, 1967
8. Available Na	Flame photometry	Piper, 1967

3.19 Statistical analysis

The data generated from the field experiment were subjected to statistical analysis by applying the technique of analysis of variance for RBD.

3.20 Correlation studies

Simple correlations were worked out (Snedecor and Cochran, 1967) to study the relationship between uptake of nutrients, available nutrients and yield of banana.

RESULTS

4. RESULTS

Any technology to replace or substitute potassium, a costly input in crop production should be an area of research which has to be given top priority. The investigation entitled "Substitution of potassium by sodium in the nutrition of banana *Musa* (AAB group) var. Nendran" was taken up to study the effect of substitution of potassium with sodium in varying levels in banana var. Nendran. The salient results of this study are presented in this chapter.

4.1 Growth characteristics

4.1.1 Height of pseudostem

The mean values on the height of pseudostem for the different treatments at the three growth stages of the crop are given in Table 2.

Plant height did not vary significantly in the vegetative stage due to the treatments. At the flowering stage, maximum plant height of 301 cm was recorded in T_3, which was on par with T_1 and T_4. Beyond 50 per cent substitution of K with Na, plant height showed a declining trend. The control plot which received no potassium and no sodium (T_6) registered the lowest value of 281.63 cm which was on par with T_5.

In the harvest stage also the treatment T_3 showed a significantly higher plant height (302.6 cm) when compared to other treatments and T_6 (283.68 cm), the lowest.

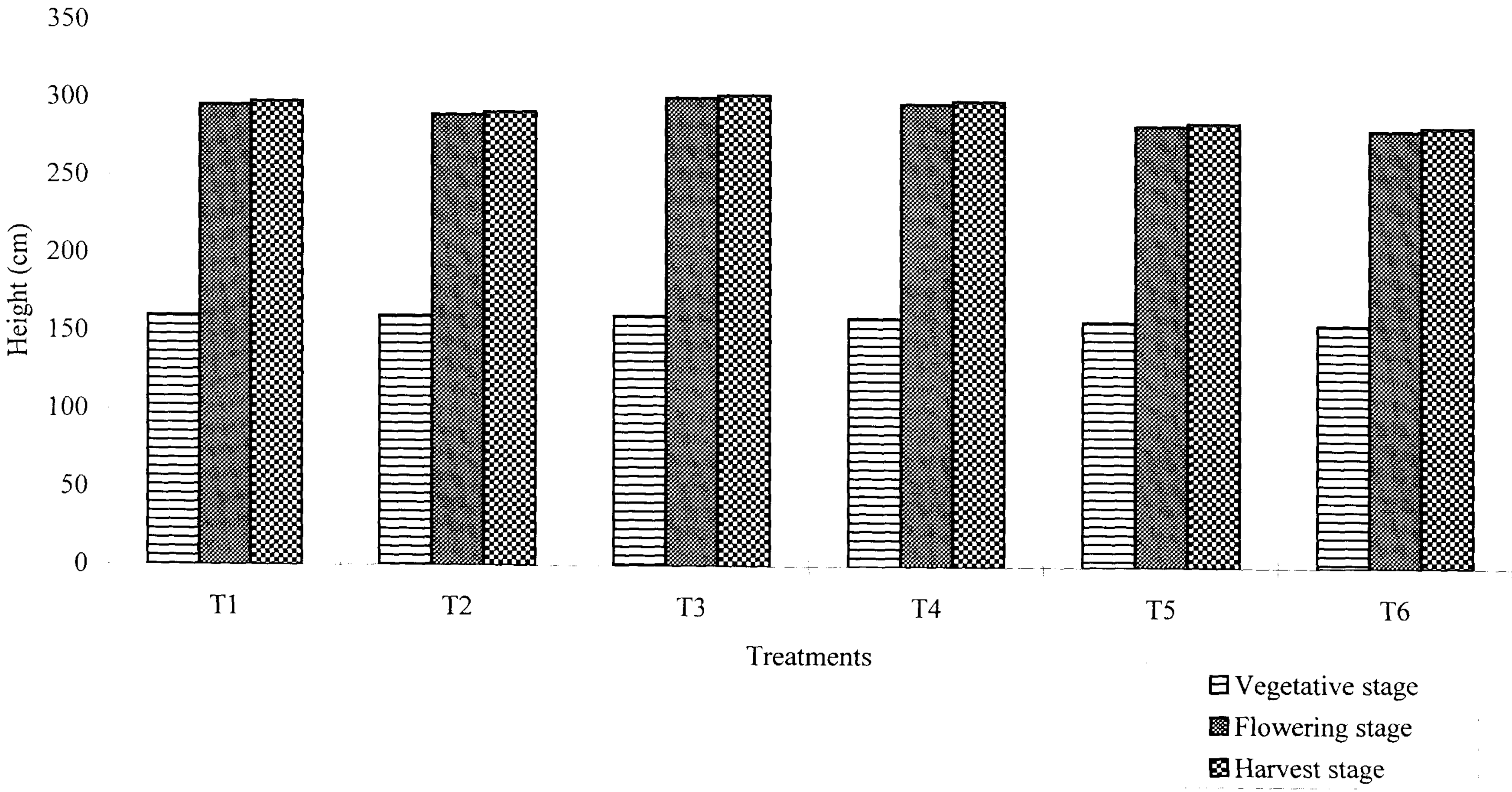
Table 2 Height of pseudostem at different growth stages (cm)

Treatments	Vegetative stage	Flowering stage	Harvest stage
T_1	160.05	295.585	297.85
T_2	160.33	289.83	291.73
T_3	160.60	301.00	302.60
T_4	159.65	297.45	299.53
T_5	157.83	284.212	285.88
T_6	156.28	281.625	283.68

F	1.016^{ns}	3.389^{ns}	4.014*
SE	3.121	3.924	3.838
CD	6.65	11.826	11.569

ns - Not significant
* Significant at 5 per cent level

Fig. 3 Height of pseudostem at different stages (cm)



4.1.2 Girth of pseudostem

The girth of pseudostem at the base, 20 cm and 100 cm above the ground level recorded at the three growth stages are presented in Table 3.

Maximum girth of pseudostem was recorded in T_3 at all the stages of growth. The control plot (T_6) showed the lowest values in all the three stages, which was on par with T_5 (100 per cent NaCl). The treatment T_3 recorded 60.40 cm, 58.63 cm and 50.60 cm in the harvest stage at base, 20 cm and 100 cm respectively. In the flowering stage also T_3 recorded the highest values for plant girth i.e., 61.85 cm, 59.25 cm and 50.65 cm at base, 20 cm and 100 cm respectively.

4.1.3 Total number of leaves

Table 4 indicates the number of leaves produced in three growth stages. In all the three growth stages, the treatment plants did not differ significantly in the total number of leaves. It was maximum at the vegetative stage with an average of 13.33 leaves per plant which decreased to 9.13 at shooting stage and reached a value of 4.25 at harvest. Even though a slight variation in the number of leaves at various stages was noticed, it did not show any appreciable difference indicating the lack of treatment effect on this character. Total number of leaves was highest for the treatment T_2 (4.75) at harvest. The lowest value for number of leaves was registered by the treatments T_5 and T_6 (4.00).

4.1.4 Leaf area index

At all stages of growth, the treatment T_3 registered the maximum leaf area index. With increasing substitution of KCl by NaCl, a general reduction

Table 3 Girth of pseudostem at different growth stages (cm)

Treatments	Girth at base			Girth at 20cm			Girth at 100cm		
	Vegetative stage	Flowering stage	Harvest stage	Vegetative stage	Flowering stage	Harvest stage	Vegetative stage	Flowering stage	Harvest stage
T_1	41.55	59.45	57.05	39.70	56.3	56.23	30.83	48.08	47.58
T_2	40.25	60.43	58.78	38.53	57.53	57.78	30.25	49.34	48.85
T_3	42.08	61.85	60.4	39.78	59.25	58.63	31.70	50.65	50.60
T_4	40.03	58.85	57.25	37.88	53.75	56.43	30.00	47.80	47.80
T_5	37.15	54.58	52.90	33.7	49.79	51.00	24.73	43.43	42.73
T_6	36.53	52.95	51.38	32.93	48.73	48.73	23.10	40.48	40.34
F	28.65	11.98	16.95	40.46	24.69	22.32	30.38	15.46	23.05
SE	0.60	1.42	1.19	0.67	1.22	1.194	0.92	1.39	1.16
CD	1.28	3.04	2.54	1.43	2.59	2.54	1.96	2.97	2.47

Fig. 4 Girth of pseudostem at base at different growth stages (cm)

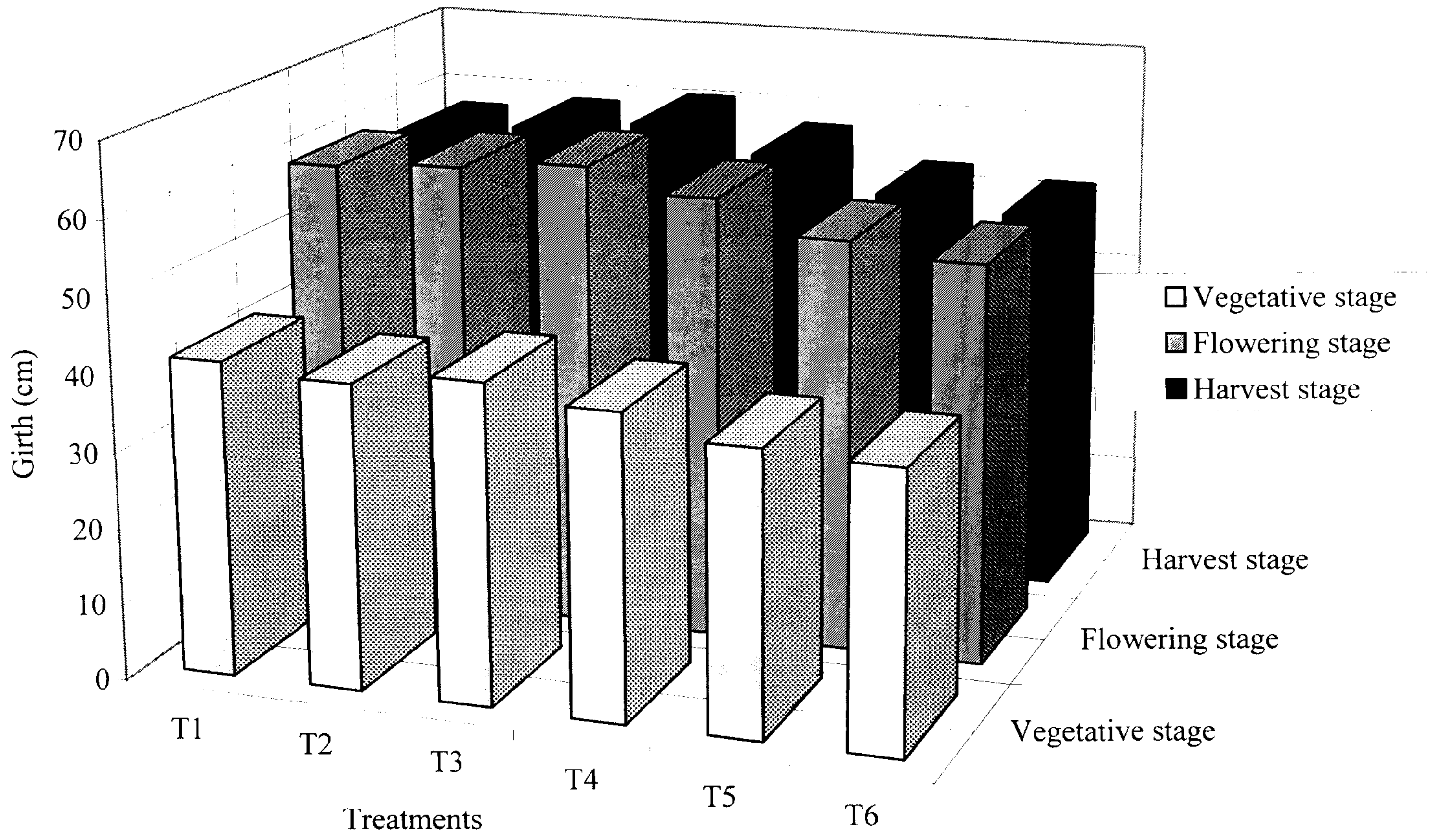


Fig. 5 Girth of pseudostem at 20 cm at different growth stages (cm)

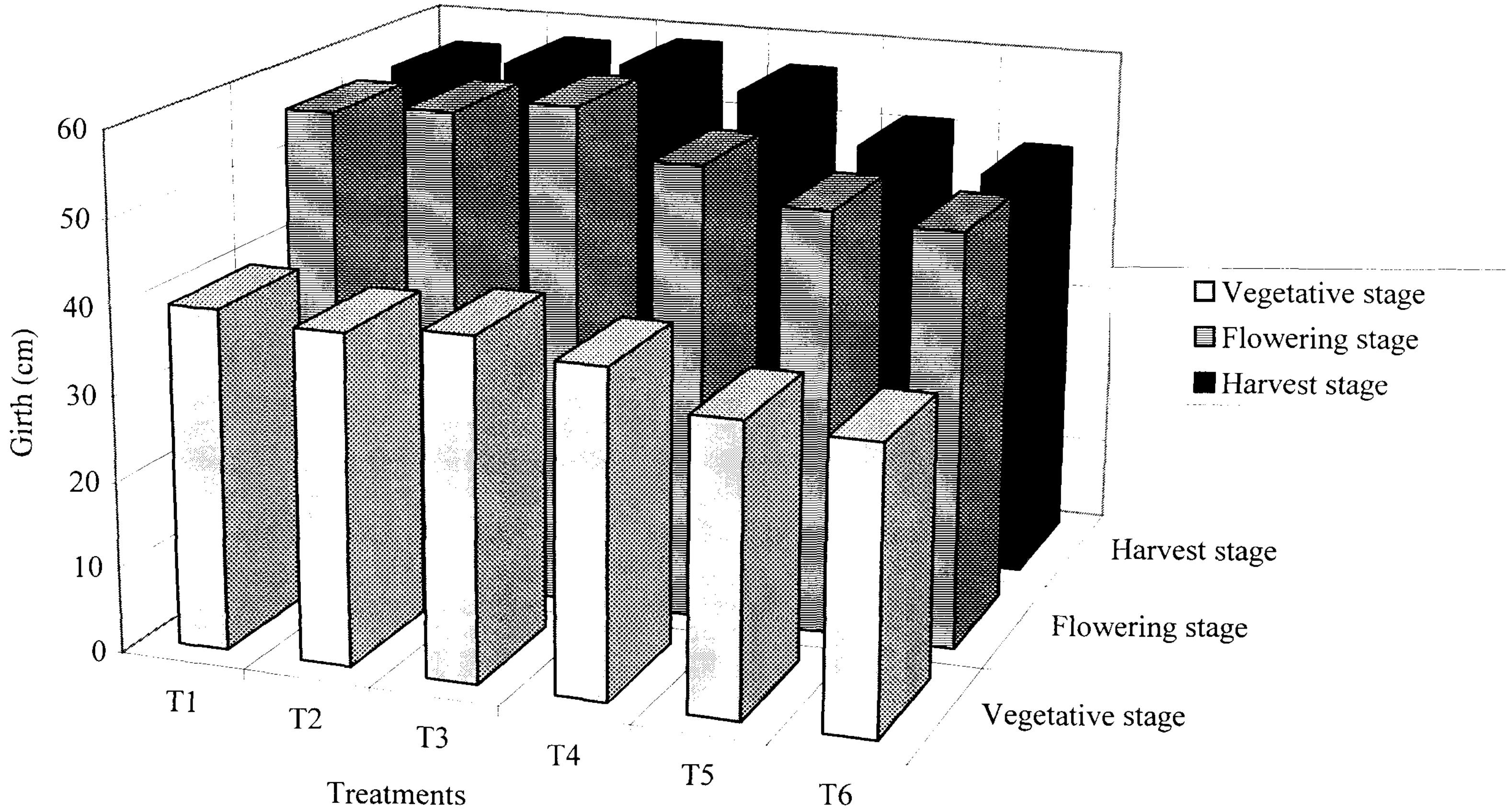


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Fig. 6 Girth of pseudostem at 100 cm at different growth stages (cm)

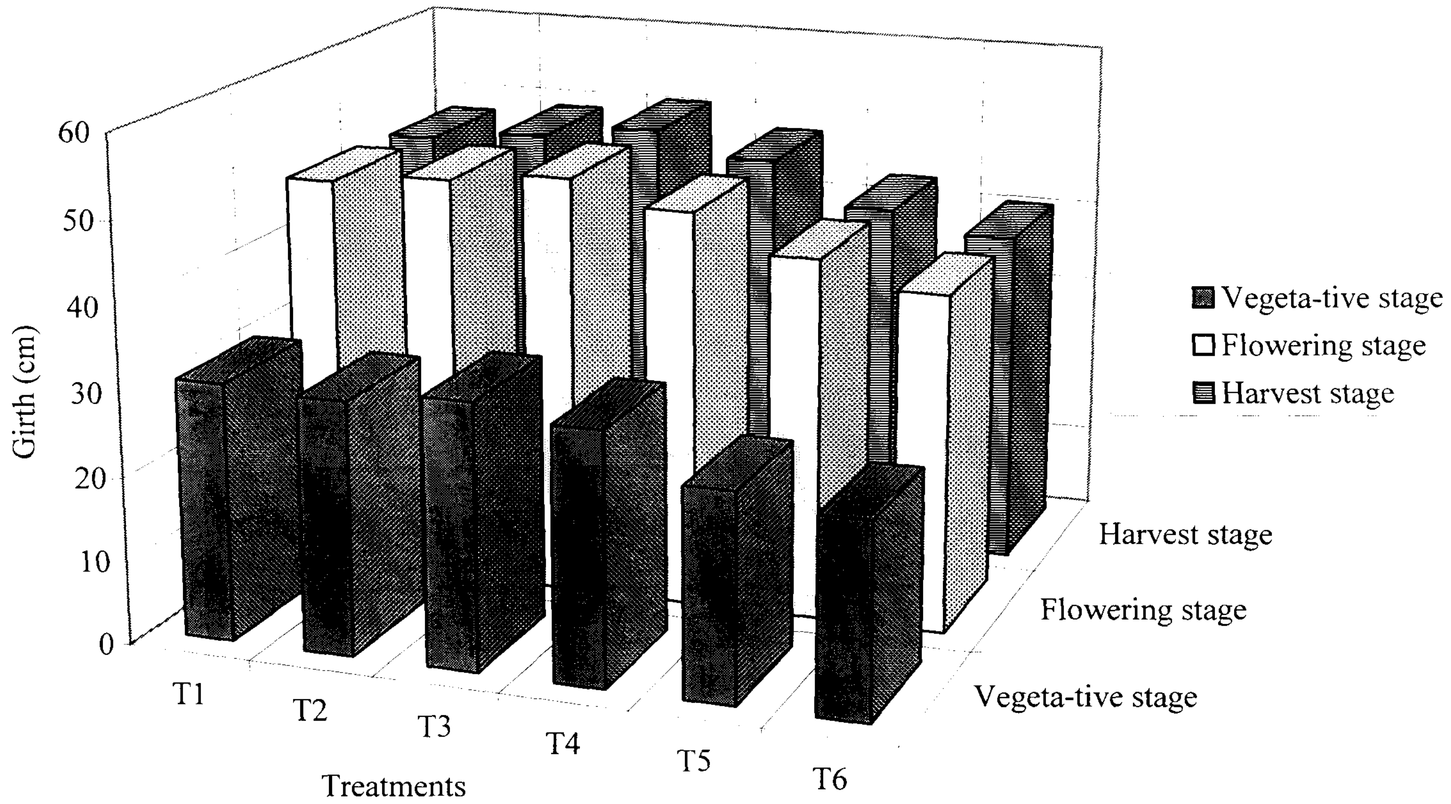

Table 4 Total number of leaves plant $^{-1}$ at different stages

Treatments	Vegetative stage	Flowering stage	Harvest stage
T_1	13.75	9.75	4.25
T_2	13.25	9.25	4.75
T_3	13.75	10.0	4.25
T_4	13.50	9.00	4.25
T_5	12.75	8.50	4.00
T_6	13.00	8.25	4.00

F	1.363^{ns}	1.38^{ns}	2.625^{ns}
SE	0.349	0.363	0.2108
CD	1.053	0.773	0.635
Mean	13.33	9.125	4.25

ns - Not significant

in LAI was seen. Significant effect of treatments was noted at the harvest stage. T_3 recorded the highest LAI of 1.62 and T_6 the lowest (1.40) which was on par with T_5. The highest value was recorded for T_3 (0.61) in the vegetative stage of the crop which was on par with T_4. In the flowering stage also T_3 (2.21) registered the highest LAI and T_6 (1.88) showed the lowest LAI (Table 5).

4.1.5 Total dry matter yield

Total dry matter content was maximum for the treatment T_3 (23789.56 kg ha^{-1}). The lowest dry matter content was registered for the treatment T_6 (17927.45) (Table 6).

4.1.6 Number of days from planting to harvesting

The days taken from planting to shooting, shooting to harvesting and planting to harvesting did not differ significantly (Table 7). Maximum value for planting to harvesting was for the treatment T_4 (273.00). The lowest value was registered by the treatment T_5 (264.25).

4.2 Yield and yield attributes

4.2.1 Length of bunch

The treatments did not differ significantly in the length of bunch. All the treatments were on par with each other indicating that the treatments had no specific influence on this character. T_3 registered maximum bunch length (48.18 cm). Lowest bunch length (47.3 cm) was showed by the treatments T_4 and T_6 (Table 8).

Table 5 Leaf area index plant^{-1}

Treatments	Vegetative stage	Flowering stage	Harvest stage
T_1	0.54	2.15	1.51
T_2	0.56	2.19	1.53
T_3	0.61	2.21	1.62
T_4	0.50	2.04	1.49
T_5	0.48	1.94	1.42
T_6	0.47	1.88	1.40
F	16.75	64.53	70.61
SE	0.0184	0.0243	0.0132
CD	0.0392	0.0517	0.028

**Significant at 1 per cent level

Table 6 Total drymatter content at harvest stage (kg ha^{-1})

Treatments	Drymatter production
T_1	20889.53
T_2	20535.77
T_3	23789.56
T_4	21823.29
T_5	19378.70
T_6	17927.45

F	5352.5**
SE	326.52
CD	695.814

** Significant at 1 per cent level

Table 7 Numbers of days taken from planting to harvesting

Treatments	Planting to shooting	Shooting to harvesting	Planting to harvesting
T_1	189.00	81.25	270.25
T_2	188.50	80.00	268.50
T_3	186.00	78.25	271.00
T_4	192.00	81.00	273.00
T_5	191.00	80.00	264.25
T_6	188.50	81.25	269.75
F	1.79^{ns}	1.51^{ns}	2.94^{ns}
SE	2.23	1.33	2.44
CD	5.16	3.07	5.63

ns - not significant

4.2.2 Bunch weight

The highest mean bunch weight of 10.00 kg $plant^{-1}$ was recorded by the treatment T_3, which received 50 per cent KCl + 50 per cent NaCl. Bunch weights of 9.84 and 9.65 kg $plant^{-1}$ was registered by the treatments T_4 and T_2 respectively which was on par with the treatment T_3. The treatments T_5 (8.27 kg $plant^{-1}$) and T_6 (7.67 kg $plant^{-1}$) showed significantly lower yields when compared to other treatments. It should be noted that the treatment T_3 showed a conspicuously higher yield when compared to the treatment T_1 (8.74 kg $plant^{-1}$), the POP recommendation.

4.2.3 Average weight of hand

There was significant difference on the average weight of hands due to the treatments. The maximum weight of 1.64 kg $hand^{-1}$ was recorded in T_3 followed by T_4 (1.63 kg). T_5 showed the lowest weight of 1.36 kg which was on par with the treatment T_6. The treatment T_1 (1.49 kg) and T_2 (1.57 kg) were on par with each other also showed a lower weight of hand than T_3.

4.2.4 Number of hands

As per Table 8, there was no significant difference between the treatments on the number of hands produced $bunch^{-1}$. The highest number of hands was registered in T_4 (5.25) followed by T_2, T_3 and T_5 (5.0). T_6 showed the lowest number of hands (4.5).

4.2.5 Fingers bunch^{-1}

It can be noted from Table 8, that there was significant difference in the number of fingers in the various treatments. Maximum number of fingers bunch^{-1} (38.25) was noticed in T_3 and T_4. The number of fingers in T_6 (35.75 was significantly lower than all the other treatments. T_2 (37.50) was on par with T_3. The number of fingers bunch^{-1} was lower (36.25) for the treatment T_1.

4.2.6 Length of finger

It may be seen from the Table 8, that the length of fingers in treatments T_3, T_4 and T_5 did not show any significant variation. T_3 recorded the highest value (21.90 cm) while the treatment T_6 registered the lowest value(20.18 cm). T_1 registered the value of 20.18 cm, which was on par with T_2 and T_6.

4.2.7 Girth of finger

Significant difference between the treatments was noticed on this character (Table 8). T_3 registered maximum girth of finger (13.83 cm) followed by T_4 (13.78 cm). The treatments T_1 (13.20 cm), T_5 (13.33 cm) and T_6 were on par with each other. T_6 recorded a lowest value of 13.15 cm.

4.2.8 Weight of finger

As evident from Table 8, the treatment effect was significant on the weight of fingers. The maximum finger weight of 209.44 g was recorded in T_3 which was on par with T_1 (207.20 g), T_2 (207.75 g) and T_4 (208.06 g). The lowest weight of finger (205.38 g) was recorded by the treatments T_5 and T_6.

Table 8 Yield and yield attributes

Treatments	Weight of bunch (kg)	Number of hands bunch $^{-1}$	Length of bunch (cm)	Average weight of hand (kg)	Number of fingers bunch $^{-1}$	Length of finger (cm)	Girth of finger (cm)	Weight of finger (g)	Pulp/ peel ratio
T1	8.74	4.75	48.08	1.49	36.25	20.28	13.20	207.20	3.82
T2	9.65	5.00	48.13	1.57	37.50	21.38	13.58	207.75	3.77
T3	10.00	5.00	48.18	1.64	38.25	21.90	13.83	209.44	3.91
T4	9.84	5.25	47.30	1.63	38.25	21.85	13.78	208.06	3.53
T5	8.27	5.00	47.70	1.36	36.75	21.70	13.33	205.38	3.33
T6	7.67	4.50	47.30	1.41	35.75	20.18	13.15	205.38	3.24
F	20.88**	1.99 ^{ns}	1.16 ^{ns}	12.96**	10.43**	22.36**	5.61**	4.11	17.91**
SE	0.207	0.183	0.101	0.032	0.32	0.168	0.1232	0.785	0.092
CD	0.625	0.389	0.215	0.097	0.976	0.507	0.372	2.365	0.214

ns Not significant
* Significant at 5% level
* * Significant at 1% level

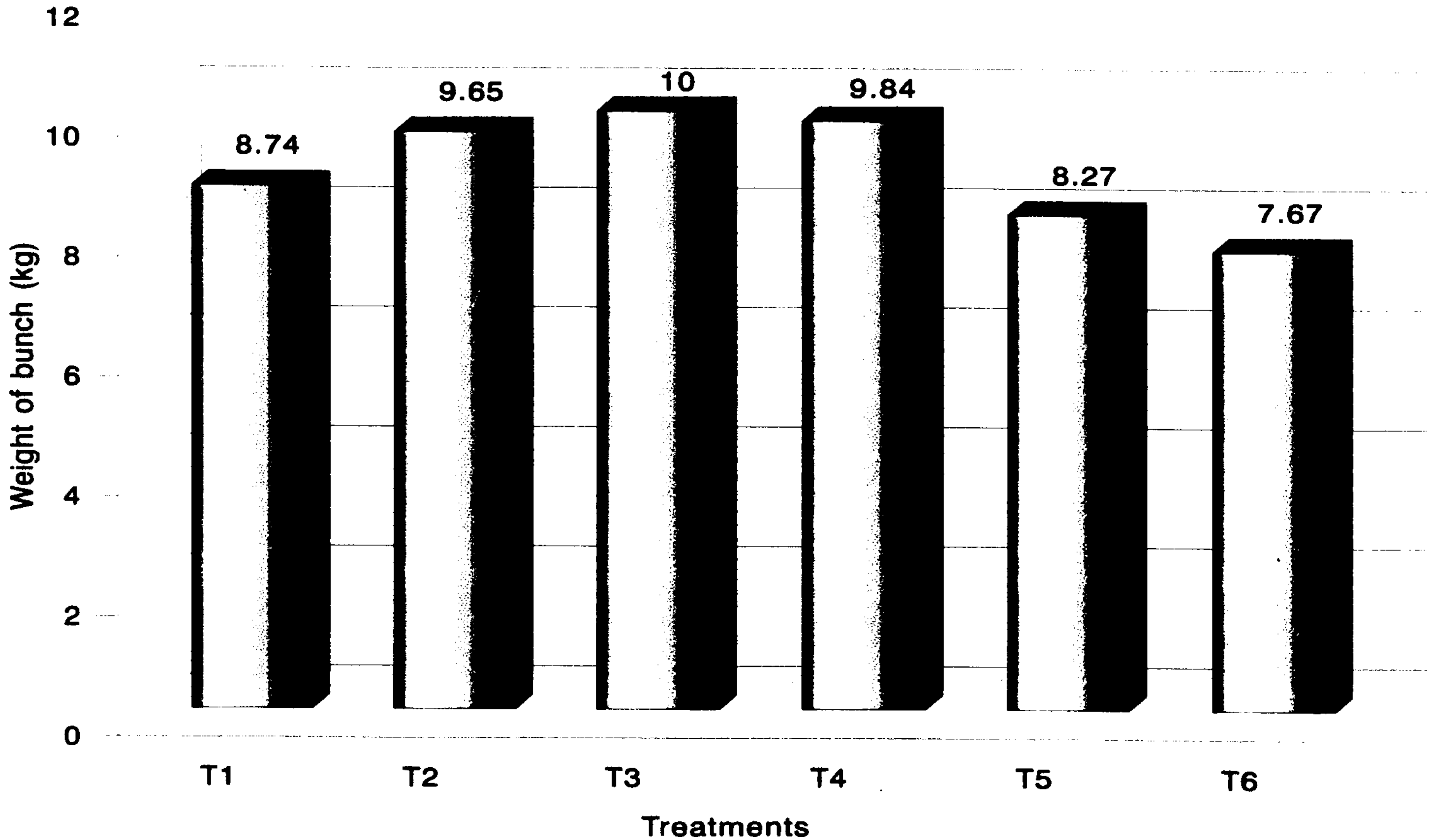

Fig. 7. Weight of bunch (kg plant^{-1})

Plate 1 100 per cent K as KCl

Plate 2 75 per cent K as KCl + 25 per cent Na as NaCl

Plate 3 50 per cent K as KCl + 50 per cent Na as NaCl

Plate 4 25 per cent K as KCl + 75 per cent Na as NaCl

Plate 5 100 per cent Na as NaCl

Plate 6 Control - Zero K and zero Na

Plate 1

Plate 2

Plate 3

Plate 4

Plate 5

Plate 6

4.2.9 Pulp/peel ratio

There was no significant difference among the treatments on pulp/peel ratio. It was highest in the treatments T_3 (3.91) and T_1 (3.82) followed by T_2 (3.77) and T_4 (3.53). Pulp/peel ratio was lowest in the treatment T_6 (3.24) which was on par with T_5 (3.33).

4.3 Quality parameters

The quality parameters viz., total soluble solids, total sugars, reducing sugars, non reducing sugars, acidity, sugar : acid ratio, shelf life of fingers and total uptake of Na and K in fruit are presented in Table 9.

4.3.1 Total soluble solids

Fruits produced by the treatment T_2 recorded the highest content of total soluble solids (21.68 per cent) which was on par with the treatments T_3 (21.40 per cent), T_4 (20.93 per cent) and T_1 (20.90 per cent). The treatments T_5 (19.73 per cent) and T_6 (19.40 per cent) were on par with each other.

4.3.2 Acidity

Maximum acidity was recorded in T_1 (0.25 per cent) followed by T_4 and T_5 both with 0.23 per cent. The treatments T_1, T_2 and T_3 were on par with each other. The values in the various treatments ranged from 0.23 to 0.25 per cent.

4.3.3 Sugars

Significant differences were observed on total sugars, reducing sugars and non reducing sugars in various treatments (Table 9).

The highest value for total sugars was recorded in the treatment T_5 (20.53 per cent) followed by T_4 (20.25 per cent). T_4 and T_5 were on par. The treatment T_6 showed the lowest value (19.18 per cent) which was on par with the treatments T_1 and T_2.

Reducing sugars also showed the same trend as total sugars. The treatment T_5 registered the highest value of 14.53 per cent and T_1 the lowest value (13.23 per cent). The treatments T_4, T_3 and T_2 were on par with T_5.

With regard to the non reducing sugars (Table 9), T_1 recorded the highest value (5.92 per cent). The treatment T_6 registered the lowest value (5.15 per cent) for this character. All the other treatments were on par with each other.

4.3.4 Shelf life of fingers

No significant difference was noticed between the treatments on this character. Maximum shelf life of 7.50 days was noted in treatments T_1, T_5 and T_6 and the minimum of 7.25 days was for the treatments T_2, T_3 and T_4. All the treatments were on par with each other with a shelf life ranging from 7.25 - 7.50 days.

4.3.5 Sugar : acid ratio

Sugar : acid ratio was maximum for the treatment T_5 (89.68). It was lowest for the treatment T_1 (79.23). All the treatments did not differ significantly on this character.

Table 9 Quality parameters of ripe banana fruits

Treat-ments	Total soluble solids (%)	Titrable acidity	Reducing sugars (%)	Total sugars (%)	Non reducing sugars (%)	Sugar - acid ratio	Shelf life of fingers
T_1	20.90	0.25	13.23	19.38	5.92	79.23	7.50
T_2	21.68	0.24	14.15	19.60	5.89	84.09	7.25
T_3	21.40	0.24	13.83	19.98	5.84	85.25	7.28
T_4	20.93	0.23	14.20	20.25	5.77	87.22	7.00
T_5	19.73	0.23	14.53	20.53	5.18	89.68	7.50
T_6	19.40	0.23	13.50	19.18	5.15	84.09	7.25
F	7.78**	0.29^{ns}	1.986^{ns}	19.19**	1.059**	0.996^{ns}	0.21
SE	0.327	0.021	0.342	0.119	0.348	7.47	2.63
CD	0.986	0.045	1.031	0.359	1.05	15.92	5.60

ns Non significant

* significant at 5 per cent level
** significant at 1 per cent level

4.3.6 Total uptake of K in fruit

Maximum uptake of K was shown by the treatment T_3 (56.88). The lowest K uptake was shown by the treatment T_6 (46.95) (Table 10).

4.3.7 Total uptake of Na in fruit

Na content also followed the same trend as that of K. T_3 (3.90) recorded the highest Na uptake while T_6 (3.05) the lowest.

4.4 Uptake of nutrients

The data on the uptake of nutreints by the plant at harvest stage are presented in Table 12 to 15.

4.4.1 Nitrogen

Uptake of nitrogen at harvest stage is given in Table 12. N uptake was highest for the treatment T_2 (226.98 kg ha^{-1}) which was on par with the treatments T_1 (223.18 kg ha^{-1}) and T_3 (226. 00 kg ha^{-1}). T_4 and T_5 were on par with each other. T_6 showed the lowest uptake of 204.58 kg ha^{-1}.

4.4.2 Phosphorus

The P uptake was maximum in the treatment T_3 (46.75 kg ha^{-1}). This treatment showed significantly higher uptake than other treatments. A decline in the uptake by the treatment T_5 (40.78 kg ha^{-1}) was noted. T_6 showed the lowest uptake (39.58 kg ha^{-1}) and it was on par with T_5.

Table 10 Total uptake of K in fruit (kg ha^{-1})

Treatments	Uptake of K
T_1	53.40
T_2	54.25
T_3	56.88
T_4	51.35
T_5	48.10
T_6	46.95

F 18.262
SE 0.886
CD 1.888

Table 11 Total uptake of Na in fruit (kg ha^{-1})

Treatments	Uptake of Na
T_1	3.48
T_2	3.73
T_3	3.90
T_4	3.53
T_5	3.38
T_6	3.05

F 6.768**
SE 0.112
CD 0.238

** Significant at 1 per cent level

Table 12 Total uptake of nitrogen (kg ha^{-1})

Treatments	Uptake of N
T_1	223.18
T_2	226.98
T_3	226.00
T_4	217.28
T_5	211.10
T_6	204.58

F 34.432**
SE 1.523
CD 3.245

** Significant at 1 per cent level

Table 13 Total uptake of phosphorus (kg ha^{-1})

Treatments	P Uptake
T_1	44.38
T_2	40.75
T_3	46.75
T_4	42.33
T_5	40.78
T_6	39.58

F 9.432**
SE 0.876
CD 1.866

** Significant at 1 per cent level

4.4.3 Potassium

It may be seen from Table 14 that T_3 registered maximum uptake (209.45 kg ha^{-1}). Substitution at higher levels did not favour potassium uptake very much. T_1 showed an uptake of 206.15 kg ha^{-1} which was on par with T_2 (206.58 kg ha^{-1}). Lowest uptake was noted in T_6 (183.68 kg ha^{-1}). T_5 showed an uptake of 192.33 kg ha^{-1}.

4.4.4 Sodium

Sodium uptake showed the same trend as that of potassium. T_3 showed a significantly higher uptake of 14.18 kg ha^{-1}. T_6 showed the lowest uptake (10.6 kg ha^{-1}). The treatments T_1, T_2, T_4 and T_5 were on par with each other.

4.5 Available nutrients

Table 16 to 19 indicate the available nutrient status in the soil after the harvest of the crop.

4.5.1 Available nitrogen

Significant difference among the treatments was noted. Maximum value for available nitrogen was recorded by the treatment T_1 (292.43 kg ha^{-1}). T_6 registered the lowest value for available N (271.95 kg ha^{-1}).

4.5.2 Available P

Significant difference between the treatments was evident. T_3 (24.65 kg ha^{1}) recorded the highest value for available P. This was followed by T_2 (22.43

Table 14 Total uptake of potassium (kg ha^{-1})

Treatments	K Uptake
T_1	206.15
T_2	206.58
T_3	209.45
T_4	200.10
T_5	192.33
T_6	183.68

F 57.63**
SE 1.311
CD 2.793

** Significant at 1 per cent level

Table 15 Total uptake of sodium (kg ha^{-1})

Treatments	Na uptake
T_1	12.80
T_2	12.93
T_3	14.18
T_4	12.88
T_5	12.10
T_6	10.60

F 17.59
SE 0.281
CD 0.598

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SUBSTITUTION OF POTASSIUM BY SODIUM IN BANANA *Musa* (AAB GROUP) var. 'Nendran'

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ABSTRACT OF THE THESIS
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'ABSTRACT

A field experiment was carried out in the Instructional Farm. College of Agriculture, Vellayani during December 1997 to September 1998 to study the possibility and extent of substitution of K by Na in banana var. Nendran. Substitution of K was tried at four levels viz., 25, 50, 75 and 100 per cent of the recommended dose. The important growth characters of the crop viz., height and girth of pseudostem, total number of leaves, total leaf area and leaf area index showed an increasing trend upto 50 per cent substitution of K by Na. The total drymatter production was significantly higher upto 50 per cent substitution. The maximum value for bunch yield was recorded by the treatment T_3 (50 per cent KCl + 50 per cent NaCl). The lowest yield was registered by the treatment T_6 which received no potassium and sodium.

Total and reducing sugars were highest for the treatment T_5 (100 per cent substitution). Non reducing sugars was highest for POP recommendation. Shelf life did not show significant variation among the treatments.

Uptake of nitrogen was highest for the treatment T_2. But the P uptake was maximum in the treatment T_3. Maximum value for available nitrogen was recorded by the treatment T_1. Available P was highest in T_3. T_1 registered maximum value for available K while T_5 maximum for available Na.

Significant positive correlations were obtained between the uptake of nutrients and bunch weight. Quality characters also showed significant correlations between the uptake of nutrients.

The highest benefit : cost ratio was recorded by the treatment T_3.

From this study it is to be concluded that there is a possibility of substitution of potassium by sodium to a level of 50 per cent in banana var. Nendran without much deleterious effects especially on the yield and quality of the fruits.