PARTIAL SUBSTITUTION OF POTASSIUM WITH SODIUM IN SWEET POTATO

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled Partial substitution of potassium with sodium in sweet potato is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma associateship fellowship or other similar title of any other university or society

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CERTIFICATE

Certified that this thesis entitled **Partial substitution of potassium with sodium in sweet potato** is a record of research work done independently by **Mrs JOGGY MARIAM GEORGE** under my guidance and supervision and that it has not previously formed the basis for the award of any degree fellowship or associateship to her

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LIST OF ABBREVIATIONS

N	Nitrogen
P	Phosphorus
KCl	Potassium chloride
NaCl	Sodium chloride
Ca	Calcium
Mg	Magnesium
%	Per cent
kg ha^{1}	Kilogram per hectare
t ha^{1}	Tonnes per hectare
Rs ha^{1}	Rupees per hectare
g	Gram
mg	Milligram
m	Metre
cm	Centi meter
mM l^{1}	Milli moles per litre
ppm	Parts per million
lbs	Pounds
meq l^{1}	Milli equivalents per litre
g day^{1} $plant^{1}$	Gram per day per plant
g cm^{2} day^{1}	Gram per square centimeter per day
RGR	Relative growth rate
DAP	Days after planting
dSm^{1}	deci siemens per metre
EC	Electrical conductivity
CEC	Cation exchange capacity
CD	Critical difference
SE	Standard error
NS	Not significant

INTRODUCTION

1 INTRODUCTION

Fertilisers play a pivotal role in building up comfortable food grain buffer in our country Among the fertiliser elements potassium the quality element for crop production plays a very important role in maximising and sustaining agricultural production It is required by plants in large quantities almost equal to N or sometimes even higher and in tuber crops it plays a dynamic role in modifying the yield In tuber crops K is associated with starch synthesis leading to the promotion of tuber growth through the accelerated trans location of photosynthates from leaves to tubers Potassium affects the root yield of tuber crops more than any other element by increasing photosynthetic efficiency High potassium levels also increase leaf area duration and excessive leaf growth is suppressed resulting in higher root yield (Hahn 1977) Potassium being an important nutrient for tuber crops a good share of the cultivation expenses accounts for the cost of this particular nutrient In India the entire requirement for K fertilizer is met through imports only and hence a major share of our foreign exchange is drained out of the country As such it is the urgent need to assess the possibility of substituting K with some cheaper nutrient especially for tuber crops

Sweet potato (Ipomoea batatas L) being a major tuber crop with diversified uses this study is intended to assess the possibility of substituting K with Na in this crop Sweet potato tubers are eaten baked or boiled or converted into several food products like noodles flakes pickled sweet potato etc Sweet potato starch is used in textiles and paper industries and for the production of liquid glucose and high fructose syrup The young shoots and leaves are used as vegetables and also in animal feed

In terms of productivity per unit time it exceeds many crops of the tropics It is valued for its shorter duration of 90 120 days high yield of 25 t ha ^{1} mass production of calories at 120 kilo calories per 100 g of edible portion (Gopalan et al 1972) high starch content of 18-25 per cent on fresh weight basis (Theodor and Jacoby 1965) high carotene of 10 5 to 39 6 mg per g (Massey et al 1957) and ascorbic acid content of 25 mg per 100 g (Ananthanarayanan 1968) Sweet potato is a drought tolerant crop It possesses the unique capacity of utilising the solar radiation efficiently in terms of synthesis of carbohydrates and storing them in tubers The most important advantage of sweet potato cultivation is its low input requirement Being a short duration crop it fits well to system of relay cropping intercropping and rotations with various crops

NASA in USA has identified sweetpotato as a future crop for interplanetary missions

Considering the cost of cultivation of sweet potato 21 67 per cent is occupied by fertilizer out of this 45 per cent is for K fertilizers alone Therefore the cultivation expenses can be substantially reduced by substituting this expensive input by some other cheap material Apart from this the recent economic constraints imposed in the country along with eroding value of rupee in the international foreign exchange market have focussed the need for increasing self reliance in the usage of cheap indigenous fertilizer materials

It has been established in crops like tomato (Besford 1978) spinach (Lehr 1949) and barley (Lehr and Wybenga 1958) that potassium can to certain extent be replaced by sodium in crop nutrition In other crops like coconut where in though potassium is a highly preferred nutrient element Mathew et al (1984) found that substitution of K_2O by Na_2O to the extent of 50 per cent or even 75 per cent did not reduce the yield of nuts when the palms were grown in laterite soil

Partial substitution of potassium by sodium will enable the growers to reduce the cost of cultivation of sweet potato and thereby reap better profit besides its positive impact on solving the vexing problem of foreign exchange drain to a certain extent To reduce our dependence on import of potassic fertilizers the research and development work must be strengthened for exploring our indigenous resource materials as well Hence the present investigation on partial substitution of potassium by sodium in sweet potato was undertaken with the following objectives

1 To assess the possibility of substituting potassium with sodium in sweet potato

2 To determine the ideal Na K ratio for sweet potato

3 To work out the economics

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

The study enlightens the effect of substituting potassium with sodium in sweet potato variety Kanjangad Relevant information on the effect of potassium and sodium on growth dry matter production yield quality and nutrient uptake of sweet potato are presented Literature on related crops are also cited where ever found appropriate

2 1 Effect on growth and growth characters

2 1 1 Potassium

A great deal of research work had been conducted on the effect of potassium on growth and growth characters of sweet potato Some of the results are given below

Bautista and Santiago (1981) reported that length of vine and secondary branches increased with potassium application Oommen (1989) in an experiment with 50 75 and 100 kg K_2O ha $^{-1}$ found that the different levels of potassium had a significant influence on the length of vine with a maximum at 100 kg K_2O ha $^{-1}$ Similar result was observed by Sudha Devi (1990)

Nair (1987) reported that the different levels of potash had no influence on the length of vine Similar result was also observed by Nair and Nair (1992) and Nair (1994)

Oommen (1989) found that the number of branches increased with potassium application with a maximum at 100 kg K_2O ha 1

Sudha Devi (1990) in an experiment with 50 75 and 100 kg K_2O ha 1 found that the number of branches was not influenced by different levels of potassium Nair (1994) also reported similar observation

Bourke (1985) found that leaf area was increased with graded levels of K ranging from 0 375 kg K_2O ha 1 Mukhopadhyay _et al_ (1992) in an experiment with 25 50 75 and 100 kg K_2O ha 1 found that LAI CGR and TBR were maximum at 75 kg K_2O ha1 Nair (1994) reported that LAI was influenced by potassium

Oommen (1989) reported that different rates of applied potassium were not influential in producing significant variation in LAI during different growth stages Similar report was also made by Sudha Devi (1990)

Li and Yen (1988) found that application of 180 kg K_2O ha 1 increased the vine yield Oommen (1989) reported that maximum vine yield was obtained at 100 kg K_2O ha 1 Mukhopadhyay _et al_ (1992) reported that highest vine yield was obtained at 75 kg K_2O ha 1

Sudha Devi (1990) reported that different levels of K had no influence on vine yield Similar reports were made by Nair and Nair (1992) and Nair (1994)

Ashokan et al (1984) reported that weevil damage on tubers was not significantly influenced by K fertilizer application

2 1 2 Sodium

A number of research works carried out on the effect of sodium on growth and growth characters of various crop species are available However research results are scanty in respect of tuber crops Hence research works done on other crops are reviewed hereunder

According to Sadayappan and Srinivasan (1968) growth and tillering of rice was affected above 0 5 per cent NaCl Khanna and Balaguru (1981b) reported that the height of wheat plants increased significantly with an increase in the levels of sodium The maximum height of 18 1 cm was observed at 5 0 mM l^{1} each of K and Na

Kayani and Mujeeb (1988) reported that increasing the osmotic potential of the culture solution from 0 to 12 69 bar using NaCl reduced shoot growth RGR and leaf area in maize

Gupta and Srivastava (1989) in an experiment on wheat found that application of NaCl reduced the leaf number and average leaf area

Mathew et al (1984) in an experiment on coconut by substituting potassium with sodium to the extent of 0 25 50 75 and 100 per cent found that the number of leaves retained on the palm was not influenced by the treatments Prema et al (1987a) in an experiment on coconut by substituting K with Na to the extent of 0 25 50 75 and 100 per cent reported that substitution of K with Na had no influence on the number of functional leaves and the number of leaves produced per palm per year Coconut palms receiving 50 per cent substitution of KCl by NaCl retained maximum number of leaves (Prema et al 1992)

Chavan and Karadge (1980) in an experiment on peanut (Arachis hypogea L) with 0 to 200 mM NaCl found that high concentration of NaCl reduced shoot and root growth

Indira (1978) in an experiment on cassava with 0 4000 ppm NaCl found that retardation of plant growth and tuber initiation occurred when subjected to toxicity from 2000 ppm NaCl onwards

According to Hawker and Smith (1982) growth rate of cassava decreased with increasing NaCl concentration from 0 to 75 mM in nutrient solution

Besford (1978) conducted an experiment on tomato with 0 60 90 95 98 and 99 per cent of K replaced by Na and concluded that sodium when present upto 2 4 per cent of dry weight caused no reduction in the rate of growth

In tuberose the plant height number of leaves and leaf area index were found to decrease with increasing concentration of NaCl from 6000 ppm to 10 000 ppm (Malini and Khader 1989)

Gammon (1965) in an experiment on pangola grass with 0 100 and 200 lbs of KCl per acre and NaCl in amounts equivalent to K (0 78 and 187 lbs of NaCl per acre) observed that sodium can substitute for two third of potassium requirements without causing an appreciable reduction in growth Robinson and Downton (1985) found that in Suaeda australis growth was poor in the absence of added NaCl but was increased 5 fold by the addition of 50 mM NaCl According to Ohta et al (1987) 0 5 mM of NaCl enhanced the RGR in Amaranthus tricolor Mills (1989) conducted a study on asparagus (Asparagus officinalis) and concluded that moderate concentration of NaCl (0 5 1 per cent) stimulated growth and induced phylloid production in both shoot segment and plantlets

Volk (1946) reported that addition of sodium eliminated or reduced cotton rust in soils where K was deficient

2 2 Effect on dry matter production

2 2 1 Potassium

Bourke (1985) reported that increasing levels of potassium fertilizer increased the total plant dry weight

Application of 90 kg K_2O ha ^{1} recorded the highest total tuber dry matter production (Hossain et al 1987)

According to Oommen (1989) dry matter production of tuber and stem was significantly influenced by potassium and the maximum dry matter production was observed with 100 kg K_2O ha ^{1} Sudha Devi (1990) and Mukhopadhyay et al (1993) reported that different levels of potassium had significant influence on the dry matter production of all the plant parts with a maximum at 75 kg K ha ^{1}

Constantin et al (1977) in an experiment with different levels of potash ranging from 0 140 kg ha ^{1} found that as the rate of K increased the dry matter content decreased Sharafuddin and Voican (1984) also made similar reports Oommen (1989) found that leaf dry matter production was not influenced by different levels of K_2O Nair (1994) reported that the influence of added levels of potassium on the total dry matter production was not so marked

2 2 2 Sodium

Khanna and Balaguru (1981b) reported that in wheat dry weight of shoots collar and roots increased significantly with the application of sodium up to 5 0 mM l ^{1} Do (1990) in an experiment on maize with different levels of sodium in nutrient solution (0 0 05 0 1 0 25 and 0 5 per cent) found that the biomass production in young plant were not affected significantly when the K Na ratio in plants was changed from 7 39 to 0 755

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 increase in root shoot ratio

Warcholowa (1973) reported that in sugarbeet sodium increased the dry matter yield of roots and the effect was greatest when K was moderately deficient and 50 per cent K_2O and 50 per cent Na_2O were supplied According to Khanna and Balaguru (1981) maximum dry weight of shoots in sugarbeet was obtained when 2 5 mM ha ^{1} K was applied in combination with 7 5 mM l ^{1} Na and that of root with 5 0 mM l ^{1} each of K and Na

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 largest dry matter was obtained when 20 per cent of K was substituted with Na

Chavan and Karadge (1980) reported that high concentration of NaCl reduced the dry weight of all plant parts

Brownell and Nicholas (1967) in an experiment on Anabaena cylindrica with 0 004 to 4 meq l ^{1} NaCl reported that dry weight yields increased with sodium supply reaching a maximum in culture solutions containing approximately 2 meq l ^{1} NaCl

According to Brownell and Crossland (1972) C_4 plants showed significant dry weight responses when 0 1 meq l ^{1} NaCl was supplied to their culture solutions

2 3 Effect on yield and yield attributes

2 3 1 Potassium

A number of research works were carried out on the effect of potassium on yield and yield attributes of sweet potato Some of the results are given below

According to the reports of CTCRI (1985) the number of tubers per plant was significantly influenced by potassium application and the highest number of tubers per plant (2 51) was obtained at 75 kg K_2O ha ^{1} Patil et al (1992) in an experiment with 50 75 and 100 kg K_2O ha ^{1} found that 100 kg K_2O ha ^{1} produced maximum number of tubers per plant Application of 70 kg K ha ^{1} increased the number of tubers (Bao et al 1985) Oommen (1989) and Sudha Devi (1990) reported that 100 kg K_2O ha ^{1} produced the maximum number of tubers

According to Mukhopadhyay et al (1992) maximum number of tubers was produced at 75 kg K_2O ha ^{1} Similar results was also observed by Nair and Nair (1992) Nair (1994) reported that maximum number of tubers was obtained at 50 kg K_2O ha ^{1}

Significant increase in girth of tubers by potassium application was reported by Nair (1987) Oommen (1989) and Sudha Devi (1990) According to Nair (1994) girth of tubers increased upto 75 kg K_2O ha ^{1}

Oommen (1989) reported that maximum length of tuber was obtained at 100 kg K_2O ha [1] Similar result was reported by Sudha Devi (1990)

Nair and Nair (1992) and Nair (1994) reported that different levels of potassium had no influence on the length of tubers

According to Bautista and Santiago (1981) potassium application increased the tuber yield Ashokan *et al* (1984) in an experiment with 30 60 and 90 kg K_2O ha [1] obtained the maximum yield of 15 8 t ha [1] at 60 kg K_2O ha [1] and the optimum and economic doses of K_2O was worked out to be 60 4 and 60 1 kg ha [1] respectively Hammett *et al* (1984) found that marketable tuber yield was higher at higher rates of potassium application

According to Bao *et al* (1985) yield always increased by potassium application Potassium influenced the tuber yield through an increased diversion of dry matter to the tubers (Bourke 1985) Oommen (1989) and Sudha Devi (1990) also obtained similar results

Nicholaides *et al* (1985) obtained a linear increase in yield due to potassium application especially in soils of low potash Hegde *et al* (1986) in an experiment with 30 60 and 90 kg K_2O ha [1] obtained the highest yield of 116 39 q ha [1] with 90 kg K_2O ha [1]

Prasad and Rao (1986) in an experiment with 50 75 and 100 kg K_2O ha [1] reported that tuber yield increased with an increase in potassium level upto 75 kg K_2O ha [1] and thereafter decreased Similar reports were made by Mukhopadhyay et al (1992) and Nair and Nair (1992) Gregor and Tasso (1988) recommended 120 kg K_2O ha [1] for higher tuber yields Elizabeth and Kunju (1989) observed an increasing trend in tuber yield of sweet potato in response to the application of incremental doses of potassium According to Gowda et al (1990) tuber yields were higher with 40 kg potash Nair (1994) observed that maximum tuber yield was obtained with 50 kg K_2O ha^{-1}

Muthuswamy et al (1981) reported that potassium had no effect on the tuber yield Similar report was also made by Wargiono (1981)

2 3 2 Sodium

Sodium was found to influence the yield and yield attributes of many crops Some of the results are given below

Cooper et al (1953) reported that in cotton 30 lbs of K_2O and 10 lbs of Na_2O produced the highest yield of 1 005 lbs of seed cotton ha [1] Lancaster et al (1953) in an experiment on cotton where Na was substituted for one third half and two third of K found that Na increased the yield 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

According to them sodium can serve as a partial substitute for potassium in functions common to the basic ions or to Na as a nutrient element in the growth of cotton

Holmes *et al* (1973) found that the most profitable dressing for sugarbeet was 377 kg common salt + 127 kg K_2O ha ^{1} Draycott and Durrant (1976b) from a number of trials on sugarbeet found that Na was essential for maximum profit and the most profitable application was 150 kg Na ha ^{1} + 150 kg K ha ^{1} Draycott and Durrant (1976a) established that sodium salt can largely replace potassium fertilizer in sugarbeet and both elements (K and Na) increased root yield Genkel and Bakanova (1977) reported that in sugarbeet seed treatment with 0 1 and 0 2 per cent NaCl solution increased the weight of roots from 211 5 g per root without NaCl to 274 5 and 225 8 g respectively Further increase in NaCl concentration decreased it Strnad (1970) in field trial on sugarbeet in chernozem soils found that NPNa increased yield of roots by 2 6 per cent and leaves by 1 7 per cent compared with NPK

Rowell and Erel (1971) observed that the addition of sodium had no effect on the yield of sugarbeet

Troug *et al* (1953) investigated the response of nine economic plants to fertilisation with sodium Results showed that corn alfa alfa and potatoes responded only slightly the yield of beets rutabagas carrot and celery were notably increased But barley and oats were intermediate in response

Hamid and Talibudeen (1976) conducted an experiment on barley sugarbeet and broad beans and concluded that yield of barley and sugarbeet were benefitted from the added Na in the soil but that of broad beans was always 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

Nair et al (1980) conducted an experiment on cassava with 200 400 and 600 kg NaCl ha ^{1} and found that application of 200 kg NaCl ha ^{1} recorded maximum tuber yield

According to Hawker and Smith (1982) tuber weight of cassava was reduced to be 50 per cent between 30 50 mM NaCl in the nutrient solution

Mathew et al (1984) reported that 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 In coconut palms maximum increase in yield was obtained when 50 per cent K_2O was substituted by Na_2O (Prema et al 1987a) Prema et al (1987b) in another experiment on coconut with Na substituting K to the extent of 0 25 50 75 and 100 per cent found that the treatments did not differ in their influence on copra weight per nut and percentage oil recovery

Cope *et al* (1953) reported that the yields of oats clover sudan grass alfa alfa and corn were increased when half of the potassium was substituted by sodium ie application of 100 lbs of K + an equivalent quantity of Na Eshel (1985) reported that the fresh weight of *Suaeda monoica* and *Suaeda aegyptiaca* was increased by 150 mM l^{1} NaCl

Wallace *et al* (1982) in an experiment on Atriplex with 100 200 and 400 meq l^{1} NaCl found that NaCl increased the yield of stem Soufi and Wallace (1982) reported that in *Atriplex hymenelytra* maximum yield was obtained when it was supplied with 5 x 10^{3} normal NaCl

2 4 Effect on tuber quality

2 4 1 Potassium

Starch protein and total sugar content of sweet potato was found to be influenced by potassium Some of the research results are reviewed here under

Bodniuk *et al* (1971) observed that in sweet potato deficiency of potassium caused a reduction in starch content Muthuswamy *et al* (1981) reported that increased rates of potassium increased the starch content of tubers on fresh weight basis from 15 12 per cent in control to 16 0 per cent in 100 kg K_2O ha^{1} Significant increase in starch content by potassium application was reported by Ashokan and Nair (1984) and Bao *et al* (1985)

Das and Behera (1989) observed a progressive increase in starch content as the dose of potash was increased from 0 to 150 kg ha ^{1}

Mukhopadhyay <u>et al</u> (1993) in an experiment with 25 50 75 and 100 kg K_2O ha ^{1} found that starch content was influenced by potassium application with a maximum at 100 kg K_2O ha ^{1} Oommen (1989) Patil <u>et al</u> (1990) and Sudha Devi (1990) also obtained similar results Nair (1994) observed that increased rates of potassium application enhanced the starch content of sweet potato with a maximum at 75 kg K_2O ha ^{1}

Muthuswamy and Krishnamoorthy (1976) reported that potash application significantly increased the protein content of tuber upto 50 kg ha ^{1} beyond which the protein content decreased According to Sharafuddin and Voican (1984) higher doses of potassium increased the protein content of sweet potato Similar results were reported by Oommen (1989) and Patil <u>et al</u> (1990)

Constantin <u>et al</u> (1977) observed that potassium application reduced the protein content of tuber Nair and Nair (1992) and Sudha Devi (1990) reported that different levels of potassium had no significant effect on crude protein content of tuber

Ashokan <u>et al</u> (1984) reported that increased rate of potassium caused a decrease in the sugar content of sweet potato Similar result was also observed by Sudha Devi (1990)

Bao *et al* (1985) observed an increase in reducing sugar and total sugar content of sweet potato by enhanced rate of potassium application Patil *et al* (1990) also made similar reports According to Nair (1994) sugar content increased upto 75 kg K_2O ha ^{1}

2 4 2 Sodium

Sodium was found to influence the sugar starch and protein content of many crops Results of some research works are given below

Hale (1948) reported that addition of sodium to sugarbeet produced an increase in the sugar content Hamid and Talibudeen (1976) found that in sugarbeet sugar concentration in the mature roots increased to a maximum between 9 1 and 23 2 mM Na With further increase in Na concentration sugar content decreased 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 and 17 0 per cent

Khan *et al* (1989) in an experiment on sorghum using 50 100 and 1500 meq l ^{1} NaCl reported that reducing and non reducing sugar content decreased with an increase in Na concentration

According to Khanna and Balaguru (1981) sodium application to sugarbeet increased the crude protein of shoots upto 5 mM l^{-1} NaCl at all levels of K Total soluble solids also increased with 5 0 mM l^{-1} each of K and Na

Hawker and Smith (1982) observed that the starch concentration in cassava remained unaffected with different levels of NaCl (0 75 mM) in the nutrient solution Nair et al (1980) reported that in cassava starch content and HCN content in the tuber were not affected by different levels of NaCl

2 5 Effect on plant nutrient content and uptake

2 5 1 Potassium

Feliciano and Lopez (1976) reported that potassium absorbed by sweet potato was not consistently related to the amount applied Tsuno (1981) observed that the content of potassium in sweet potato was relatively low It was highest at the time of initiation of growth after which it rapdily decreased

Hammett et al (1984) and a positive response between increased rate of potassium application and potassium content in tubers Oommen (1989) found that different levels of potassium influenced the K and P uptake whereas N uptake was not influenced Similar report was made by Sudhadevi (1990)

Mukhopadhay et al (1993) and Nair (1994) found that N and K uptake showed a steady increase with the increase in potassium application whereas the P uptake was not influenced

2 5 2 Sodium

Mathew *et al* (1984) reported that in coconut Na and K content of leaves were influenced by Na substitution Maximum K and Na content were seen when 100 per cent K and 100 per cent Na were applied respectively According to Prema *et al* (1987a) 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 content of leaves were significantly influenced by the treatments Prema *et al* (1987b) reported that in coconut substitution of K with Na did not differ significantly in their influence on the N P and K content of copra Increasing rate of Na application resulted in corresponding increase in the Na content of copra The uptake of N P Ca and Mg by coconut palms was not affected significantly by the substitution of K with Na but the palms receiving higher amount of K and Na retained higher amount of these elements (Prema *et al* 1992)

Khanna and Balaguru (1981a) reported that in sugarbeet Na concentration of all plant parts increased with application of sodium but decreased with an increase in K application Hawker and Smith (1982) found that in cassava with an increase in the NaCl concentration in the nutrient solution the Na^+ increased in all the tissues whereas the K^+ levels deceased

Khanna and Balaguru (1981b) reported that in wheat the Na content increased and the K content decreased with sodium application Do (1990) in an experiment on maize with different levels of Na in nutrient solution (0 0 5 per cent) found that increasing sodium concentration decreased plant N, P and K content and markedly increased the sodium content

Besford (1978) in an experiment on tomato found that in nutrient solution having the highest K/Na ratio most of the Na taken up by the plant accumulated in root but as the K was progressively replaced by sodium an increasing proportion of total Na absorbed was transported to the leaves

Chavan and Karadge (1980) found that in peanut with an increase in NaCl concentration Na accumulated in all plant parts whereas K content was decreased in leaf and stem and increased in root

Lancaster et al (1953) observed that in cotton application of Na increased the total uptake of Na

Ohta et al (1987) reported that in *Amaranthus tricolor* the Na uptake was increased by sodium application of 0 5 mM l^{1} NaCl but the potassium uptake was not affected

According to Cope et al (1953) corn sudan grass and alfalfa absorbed very little Na even when this element was applied But in clover application of Na increased the absorption of both Na and K

The literature reviewed above revealed the differential response of sweet potato to potassium application and the response of various crops to sodium application The review also showed that very little work has been carried out on the effect of sodium on tuber crops Literature reviewed also showed that partial substitution of potassium with sodium increased the yield and quality of various crops

Potassium is an important nutrient for sweet potato Package of Practices Recommendation for the crop is 75 kg K ha^{1} (KAU 1993) Therefore a good share of the cultivation expenses of the crop accounts for the cost of this particular nutrient Hence partial substitution of potassium with sodium which is a cheaper nutrient will enable the growers to reduce the cost of cultivation of sweet potato

MATERIALS AND METHODS

3 MATERIALS AND METHODS

The present investigation was carried out with an objective to assess the possibility of substituting potassium with sodium and to determine the ideal Na K ratio for sweetpotato and to work out the economics

The details of the materials used and the methods adopted in the experiment are given below

3 1 Materials

3 1 1 Experimental site

The experiment was conducted at Instructional Farm attached to College of Agriculture Vellayani situated at 8°18 N latitude and 76°51 E longitude and at an altitude of 29 m above MSL

3 1 2 Weather conditions

The weekly averages of temperature relative humidity and rainfall during the cropping period collected from the meteorological observatory attached to College of Agriculture Vellayani are presented in figure 1 and appendix I

In general weather conditions were favourable for the satisfactory growth of the crop

3 1 3 Soil

The soil of the experimental area was laterite and belong to the classoxisol The physico chemical properties of the soil are presented in Table 1

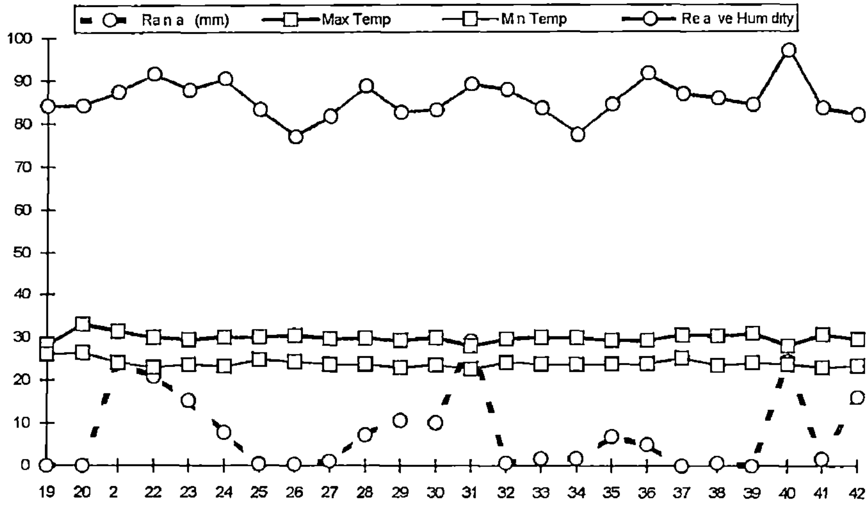


Fig 1 Weather data during the cropping season (weekly averages)
(from 7 5 1994 to 21 10 1994)

Table 1a Mechanical analysis of the soil of the experimental site

Sl No	Fractions	Content in soil (%)	Methods used
1	Coarse sand	46 7	
2	Fine sand	22 7	Bouyoucos
3	Silt	6 0	Hydrometer method
4	Clay	22 8	(Bouyoucos 1962)
5	Textural class	Sandy clay loam	

Table 1b Physico chemical properties of the soil of the experimental site

Sl No	Parameter	Content	Rating	Method used
1	Available N	266 56 kg ha^{1}	Medium	Alkaline permanganate method (Subbiah and Asija 1956)
2	Available P_2O_5	47 80 kg ha^{1}	Medium	Bray colourimetric method (Jackson 1973)
3	Available K_2O	100 80 kg ha^{1}	Low	Ammonium acetate method (Jackson 1973)
4	Available Na_2O	22 40 Kg ha^{1}		Ammonium acetate method (Jackson 1973)
5	pH	5 2	Acidic	1 2 5 soil solution ratio using pH meter with glass electrode (Jackson 1973)
6	EC	< 0 05	dSm^{1}	Conductivity bridge
7	Water holding capacity	21 33%		Gupta and Dakshinamoorthi (1980)
8	Water stable aggregates	1 1		Yoder s wet sieving method (Yoder 1937)

3 1 4 Cropping history of the field

The experimental area was previously cropped with banana and was lying fallow for one year before the experiment

3 1 5 Season

The experiment was conducted during the period from May 1994 to October 1994

3 1 6 Crop variety

The sweet potato variety Kanjangad having a duration of 115 120 days the most popular variety in Kerala was used for the experiment

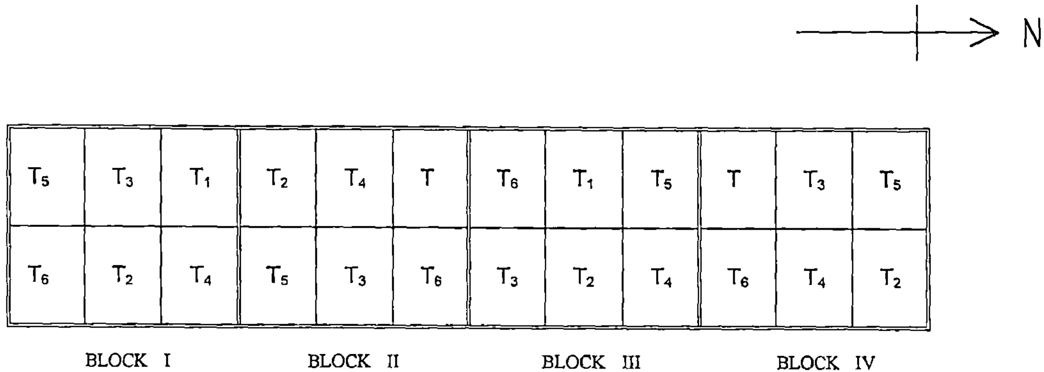
The vines obtained from Instructional Farm College of Agriculture Vellayani were used as the planting material

3 1 7 Manures and fertilizers

Farm yard manure (0 4% 0 3% 0 2% N P_2O_5 K_2O) urea (46% N) Mussoriephos (20% P_2O_5) and muriate of potash (60% K_2O) were used as sources of organic manure nitrogen phosphorus and potassium respectively

3 1 8 Nursery

Vines were planted in a well prepared nursery area of 1 25 m^2 (5 4 per cent of the main field area) The vine cuttings



T_1 100% K basal
T_2 87 5% K + 12 5% Na as basal
T_3 75% K + 25% Na as basal
T_4 50% K + 50% Na as basal
T_5 5% K + 75% Na as basal
T_6 50% K as potassium bicarbonate + 50% Na as sodium bicarbonate

F g 2 Layout Plan

were planted on 7th May 1984 in nursery at a spacing of 25 cm on ridges formed 60 cm apart Regular irrigations were given and the crop was topdressed with urea after weeding 15 days after planting Cuttings were taken from the nursery on the 45th day and used for planting in the experimental field

3 2 Methods

3 2 1 Design and Layout

The experiment was laid out in randomised block design with 4 replications The layout plan of the experiment is given in Fig 2 The technical programme is given below

3 2 2 Treatments

Number of treatments 6

1 *100 per cent K basal (0 per cent substitution)

2 87 5 per cent K + 12 5 per cent Na as basal (12 5 per cent substitution)

3 75 per cent K + 25 per cent Na as basal (25 per cent substitution)

4 50 per cent K + 50 per cent Na as basal (50 per cent substitution)

5 25 per cent K + 75 per cent Na as basal (75 per cent substitution)

6 50 per cent K as potassium bicarbonate + 50 per cent Na as sodium bicarbonate (50 per cent substitution)

K and Na was substituted on equivalent basis

Number of replications 4

Total number of plots 24

Method of planting Ridge method

* As per Package of Practices Recommendation ie 75 50 75 kg NPK ha ^{1} (KAU 1993)

Quantity of KCl and NaCl applied is presented in Appendix III

3 2 3 Plot size and spacing

Plot size	4 8 m x 4 8 m (gross)
	2 4 m x 4 4 m (net)
Spacing	60 x 20 cm

One row on each side and one plant each on opposite sides were left out for nullifying border effect One row on right side of the plot next to the border row was used for destructive sampling In the destructive row three plants were uprooted for recording observations Destructive sampling was done thrice before harvest To avoid the sampling effect one plant each was left undisturbed on each side of the sample unit The row adjacent to the destructive sample row was also left out to avoid sampling effect

3 3 Land preparation

The land was prepared by digging The plots were laid out according to the design of the experiment The experimental area was leveled 550 kg farmyard manure was applied and ridges of 30 cm height were taken at a spacing of 60 cm

3 4 Planting

Healthy vines collected from the nursery were cut into pieces of 25 cm length with three or four nodes in each cutting The vines were planted on the ridges at 20 cm apart on 17th June 1994

3 5 Gap filling

Gap filling was done on the seventh day to secure uniform stand of the crop

3 6 Application of fertilizers

Half the quantity of nitrogen was applied as basal and half as topdressing at 30 DAP Full dose of phosphorus was given as basal application

Muriate of potash and sodium chloride were applied as per treatment at planting

3 7 After cultivation

Crop was first weeded on the 20th day after planting on 7th July 1994 and earthed up after topdressing Turning of vines was done regularly

3 8 Irrigation

The vines were uniformly irrigated daily by pot watering for the initial 10 days to facilitate establishment of the crop Thereafter uniform irrigation was given as and when necessary

3 9 Plant protection

As a prophylatic measure the vines were dipped in 0 05 per cent monocrotophos suspension for 5 10 minutes prior to planting for the control of sweet potato weevil Infestation of weevil was observed and as a control measure the field was sprayed with 0 05 per cent monocrotophos one month after planting and subsequently three more times at tri weekly interval

There was no severe incidence of diseases during the growth period

3 10 Harvesting

The crop was harvested on 21st October 1994 when the leaves started turning yellow Three plants were selected for recording biometric observations from the net plot area and were uprooted one day prior to harvest The crop was harvested from the net plot after leaving the border rows which were harvested separately

3 11 Observations

3 11 1 Pre harvest observations

Three plants were selected at random from each net plot and were tagged The following observations were recorded and the mean values were worked out

3 11 1 1 Length of vine

The length of vine was measured from the base to the tip of the longest vine of each plant in cm at 30 DAP 75 DAP and at harvest

3 11 1 2 Number of branches per plant

The total number of branches were counted at 30 DAP 75 DAP and at harvest

3 11 1 3 Leaf area index

The leaf area was found out using the leaf area meter The leaf area index (LAI) was worked out by the following formula suggested by Watson (1947)

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

3 11 2 Post harvest observations

3 11 2 1 Number of tubers per plant

The tubers from the observational plants were separated and counted

3 11 2 2 Length of tuber

The length of three randomly selected tubers were measured and the mean values were recorded in cm

3 11 2 3 Girth of tuber

Girth measurements were recorded from those tubers which were used for length measurements Girth values were recorded at three places of the tubers one at the centre and the other two at half way between the centre and both ends of tuber The average of these three measurements was taken as the girth of the tuber and expressed in cm

3 11 2 4 Vine yield

The total weight of vines from the net plot was recorded at the time of harvest and expressed in t ha ^{1}

3 11 2 5 Marketable tuber yield

Tubers from the net plots were harvested by digging and the fresh weight of marketable tubers was recorded in t ha ^{1}

3 11 3 Quality attributes

3 11 3 1 Starch content

Starch content of the tubers was estimated by the procedure as reported by the A O A C (1960) The values were expressed as percentage on dry weight basis

3 11 3 2 Crude protein content

The nitrogen content of the tuber was determined by the modified microkjeldhal method (Jackson 1973) and the crude protein was computed by multiplying the nitrogen values by the factor 6 25 (Simpson et al 1965)

3 11 3 3 Total sugars

Total sugars were determined as per the method described by Ranganna (1977) The results were expressed as percentage on fresh weight basis

3 11 3 4 Cooking quality

Cooking quality of fresh tubers were assessed by organoleptic method as suggested by Swaminathan (1974)

A random sample of about 200 g of fresh tubers was taken from each plot The samples were used for the cooking quality test The samples were cut into pieces washed and cooked for uniform time

The acceptability trials on panel members were done using the scoring method A score card developed for the study is presented in appendix II The major quality attributes included in the score card were appearance taste colour and texture Each of the above quality was assessed by five point rating scale

3 11 3 5 Pest scoring

The intensity of damage in tubers of three random plants from each plot was assessed and the damage grade index (DGI) was worked out using a six point scale as detailed below

0 No weevil damage

1 External feeding damage and oviposition marks on less than 25 per cent of tuber surface but without internal damage

2 External feeding damage on more than 25 per cent tuber surface but without internal damage

3 Internal damage extending over less than 25 per cent portion of tuber

4 Internal damage 25 to 50 per cent

5 Internal damage above 50 per cent

The grade points awarded to the tubers collected from each plot were added and mean value was taken as DGI of the sample

3 12 Growth analysis

3 12 1 Dry matter production and partitioning

Dry matter production was recorded at 30th 75th and 115 DAP At each harvest three plants were carefully pulled out the tubers were collected and the tops were separated into vines and leaves Samples were dried in shade first and then in the hot air oven at 80±5°C to a constant weight and the dry weight of the various plant parts were determined and recorded

3 12 2 Tuber bulking rate (TBR)

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth

It is expressed in g day ^{1} plant ^{1} (dry weight)

$$TBR \quad \frac{W_2 \quad W_1}{t_2 \quad t_1}$$

Where W_1 and W_2 are the dry weight of tubers at time t_1 and t_2 respectively

3 12 3 Net assimilation rate (NAR)

The rate of increase in dry weight per unit leaf area per unit time was worked out during the period of crop growth (Williams 1946)

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

L_1 and W_1 are the leaf area and dry weight of the plant at time t_1 and L_2 and W_2 are the leaf area and dry weight of the plant at time (t_2) and expressed in g cm^{-2} day^{-1}

3 12 4 Crop growth rate (CGR)

It is the absolute growth rate per unit area grown This was calculated by the formula CGR NAR x LAI (Watson 1958) and expressed in g cm^{-2} day^{-1}

3 13 Chemical analysis

3 13 1 Plant analysis

Nitrogen phosphorus potassium and sodium contents of the tuber were analysed at harvest The tuber used for drymatter determination was ground into fine powder using a Wiley Mill for chemical analysis

3 13 1 1 Nitrogen

Total nitrogen content in the tuber was determined by the modified microkjeldhal method (Jackson 1973)

3 13 1 2 Phosphorus

The phosphorus content in tuber was estimated by the Vando Molybdophosphoric yellow colour method (Jackson 1973)

3 13 1 3 Potassium and sodium

The potassium and sodium content in tuber were determined by ammonium acetate method using the Systronics flame photometer (Jackson 1973)

3 13 2 Uptake studies

Uptake of nitrogen phosphorus potassium and sodium at harvest was estimated from the sample plants uprooted and dried for the purpose The vines as well as the tuber were analysed and the uptake was calculated by multiplying with drymatter

3 14 Soil analysis

Soil samples were taken before and after the experiment A representative soil sample of the field obtained by mixing the soil samples collected from different parts of the field was used for the initial analysis The initial analysis was done for the various parameters as per the method given in Table I Plot wise analysis of soil samples for available potassium and sodium pH EC water holding capacity and water stable aggregates were done soon after the experiment and the values were computed

3 14 1 Available potassium and sodium

Available potassium and sodium were extracted by neutral normal ammonium acetate solution and determined by a Systronics flame photometer (Jackson 1973)

3 14 2 Soil pH and EC

The pH was determined with the Elico pH meter (Jackson 1973) and EC was determined with the conductivity bridge

3 14 3 Water holding capacity

Core samples were collected from 0 30 cm depth from each plot and water holding capacity was determined as described by Gupta and Dakshinamoorthi (1980)

3 14 4 Water stable aggregates

Aggregate analysis was carried out by Yoder s wet sieving method (Yoder 1937) The samples were wetted slowly and using a set of sieves mean weight diameter was determined Mean weight diameter was taken as the structural index (Van Bavel 1949)

3 15 Method of calculating nutrient use efficiencies (NEU)

The agronomic efficiency physiological efficiency and recovery fraction have been calculated according to the formula given by Novoa and Loomis (1981)

$$\text{Agronomic Efficiency (AE)} \quad \frac{\text{kg of tuber}}{\text{kg of nutrient added}}$$

$$\text{Physiological Efficiency (PE)} \quad \frac{\text{kg of tuber}}{\text{kg of nutrient absorbed}}$$

$$\text{Recovery Fraction (RF)} \quad \frac{\text{kg of nutrient absorbed}}{\text{kg of nutrient applied}}$$

3 16 Economic analysis

The economics of cultivation was worked out based on the various input costs

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

Net returns per rupee invested

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

Net income = Gross income - cost of cultivation

3 17 Statistical analysis

The data generated from the experiment was subjected to analysis of variance (ANOVA) technique as applied to randomised block design described by Cochran and Cox (1965) The data were analysed using a Keltron Versa IWS computer system

RESULTS

4 RESULTS

Field experiment was conducted at the Instructional Farm College of Agriculture Vellayani to find out the possible extent of substitution of potassium with sodium in sweet potato and the ideal Na K ratio The results obtained are presented below

4 1 Growth and growth attributes

4 1 1 Length of vine

Effect of substituting potassium with sodium in varying degrees on length of vine was studied at three growth stages of the crop (30 75 and 115 DAP) and is furnished in Table 2

Perusal of the data showed that at 30 DAP 12 5 per cent level of substitution recorded a maximum vine length of 55 cm which was on par with 25 and 50 per cent substitution and significantly superior to 0 and 75 per cent levels of substitution At 75 DAP 50 per cent substitution recorded a maximum vine length of 98 08 cm which was on par with 0 12 5 and 25 per cent substitution and significantly superior to 75 per cent substitution

At 115 DAP also 50 per cent substitution recorded a maximum vine length of 111 25 cm which was on par with 12 5 and 25 per cent substitution and significantly superior to 0 and 75 per cent substitution

Sources failed to show any significant influence on the length of vine during different growth stages

4 1 2 Number of branches per plant

Data on number of branches at various growth stages as influenced by potassium sodium substitution given in Table 3

At all growth stages branching was maximum at 25 per cent substitution which was on par with 0 12 5 and 50 per cent substitution During the initial stages 25 and 50 per cent sub stitution were significantly superior to 75 per cent substi tution But at later growth stages 75 per cent substitution also behaved similarly with all other treatments

4 1 3 Leaf Area Index (LAI)

Data on the effect of treatments on LAI at three growth stages of the crop are given in Table 4

At 30 DAP 50 per cent substitution recorded maximum LAI of 2 02 which was on par with 0 12 5 and 25 per cent substi tution and significantly superior to 75 per cent substitution

At 75 DAP also 50 per cent substitution recorded maximum LAI of 5 58 and was significantly superior to all other treatments But 0 12 5 and 25 per cent substitution were on par

Table 2 Effect of potassium substitution by sodium on length of vines (cm) during various growth stages

Treatments	Days after planting		
	30	75	115
100% K basal	41 33	86 17	94 54
87 5% K + 12 5% Na as basal	55 00	86 67	100 04
75% K + 25% Na as basal	48 12	88 09	101 04
50% K + 50% Na as basal	47 34	98 08	111 25
25% K + 75% Na as basal	41 00	75 58	87 05
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	45 59	91 50	100 63
SE	3 276	5 729	4 406
CD	9 872	17 267	13 279

Table 3 Effect of potassium substitution by sodium on number of branches plant $^{-1}$ during various growth stages

Treatments	Days after planting		
	30	75	115
100% K basal	5 09	7 33	10 50
87 5% K + 12 5% Na as basal	5 67	7 75	11 08
75% K + 25% Na as basal	6 00	8 50	11 67
50% K + 50% Na as basal	6 00	7 92	11 25
25% K + 75% Na as basal	4 34	6 08	9 42
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	5 58	7 42	10 67
SE	0 449	0 897	0 863
CD	1 353	NS	NS

Table 4 Effect of potassium substitution by sodium on Leaf Area Index during different growth stages

Treatments	Days after planting 30	75	115
100% K basal	1 27	3 06	2 95
87 5% K + 12 5% Na as basal	1 62	3 71	3 24
75% K + 25% Na as basal	1 89	4 15	3 54
50% K + 50% Na as basal	2 02	5 58	3 75
25% K + 75% Na as basal	1 01	2 79	2 69
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	1 35	3 58	3 16
SE	0 283	0 395	0 445
CD	0 853	1 190	NS

At harvest effect due to all the treatments were on par with a maximum of 3 75 at 50 per cent substitution

Both at 30 and 115 DAP sources had no significant influence on LAI But at 75 DAP 50 per cent substitution as KCl and NaCl was significantly superior to potassium bicarbonate and sodium bicarbonate at the same level of substitution

4 2 Yield and yield attributes

4 2 1 Yield attributes

The data on the effect of treatments on length girth and number of tubers per plant are present in Table 5

Effect due to various treatments did not have any significant influence on length girth and number of tubers per plant All these attributes were higher at 50 per cent substitution which recorded 2 42 tubers per plant 19 76 cm tuber length and 14 09 cm tuber girth Sources also showed no influence on the length girth and number of tubers per plant

4 2 2 Marketable tuber yield and vine yield

The data on the effect of varying degrees of potassium sodium substitution on marketable tuber and vine yield are presented in Table 6

Marketable tuber yield was significantly influenced by different levels of substitution Fifty per cent substitution

Table 5 Effect of potassium substitution by sodium on number of tubers plant $^{-1}$ length of tubers (cm) and girth of tubers (cm)

Treatments	Number of tubers per plant	Length of tuber (cm)	Girth of tuber (cm)
100% K basal	2 17	16 63	13 24
87 5% K + 12 5% Na as basal	2 33	15 38	13 38
75% K + 25% Na as basal	2 33	17 94	13 66
50% K + 50% Na as basal	2 42	19 76	14 09
25% K + 75% Na as basal	1 84	14 73	12 20
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	2 17	16 24	13 15
SE	0 218	1 759	0 784
CD	NS	NS	NS

Table 6 Effect of potassium substitution by sodium on marketable tuber yield and vine yield (t ha $^{-1}$)

Treatments	Marketable tuber yield	Vine yield
100% K basal	11 03	12 00
87 5% K + 12 5% Na as basal	11 27	14 95
75% K + 25% Na as basal	11 64	15 32
50% K + 50% Na as basal	12 62	15 94
25% K + 75% Na as basal	9 55	10 66
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	11 03	11 90
SE	0 494	0 984
CD	1 490	2 965

registered the maximum marketable tuber yield of 12 62 t ha ^{1} which was on par with 12 5 and 25 per cent substitution and significantly superior to 0 and 75 per cent substitution It was seen that sources of nutrient also had a profound influence on tuber yield Yield realised by the combined application of KCl and NaCl was significantly superior to the combined application of potassium bicarbonate and sodium bicarbonate at the same level of nutrient supply Seventy five per cent substitution with sodium registered an yield which was significantly inferioı to 12 5 25 and 50 per cent substitution levels But 0 per cent substitution 50 per cent substitution as bicarbonates and 75 per cent substitution registered comparable yields

Regarding the vine yield 12 5 25 and 50 per cent had a similar effect with a maximum of 15 94 t ha ^{1} at 50 per cent substitution This was significantly superior to 0 and 75 per cent substitution Zero and 12 5 per cent substitution failed to show any significant influence on vine yield Sources showed profound influence on vine yield 50 per cent substitution as KCl and NaCl registered more vine yield than 50 per cent substitution as bicarbonates

4 3 Quality parameters

4 3 1 Quality attributes of tubers

The data on the quality of tubers as influenced by potassium and sodium are presented in Table 7

Table 7 Effect of potassium substitution by sodium on quality attributes of tubers

Treatments	Starch (%) (Dry weight basis)	Protein (%) (Dry weight basis)	Total Sugar (%) (Fresh weight basis)
100% K basal	46 69	3 85	2 83
87 5% K + 12 5% Na as basal	47 89	3 85	2 93
75% K + 25% Na as basal	47 86	4 11	2 95
50% K + 50% Na as basal	48 30	4 19	2 93
25% K + 75% Na as basal	47 69	3 64	2 83
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	48 09	3 50	2 90
SE	0 636	0 257	0 035
CD	NS	NS	0 107

The effect due to various treatments registered no significant influence on starch and protein content whereas total sugar content differed significantly with treatments Twenty five per cent substitution registered the maximum sugar content of 2 95 per cent which was on par with 12 5 and 50 per cent sub stitution and significantly superior to 0 and 75 per cent substi tution Sources failed to show any significant influence on starch protein and sugar content of tubers

4 3 2 Cooking quality of tubers

Effect of substituting potassium with sodium in varying degrees on the cooking quality of tubers are given in Table 8

None of the treatments showed any significant influence on the texture of the tubers But the appearance taste and colour of tubers differed significantly

Regarding the appearance 50 per cent substitution gave the best appearance which was on par with 12 5 and 25 per cent substitution The appearance of tubers receiving 0 and 75 per cent substitution was not appealing compared to those receiving 50 per cent substitution

Regarding the taste all the treatments that received varying degrees of substitution were on par with the best at 25 per cent substitution Tubers that received only potassium registered a poor taste compared to 25 per cent substitution

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Table 8 Effect of potassium substitution by sodium on cooking quality of tubers

Treatments	Appearance	Taste	Colour	Texture
100% K basal	2 97	2 51	3 36	3 26
87 5% K + 12 5% Na as basal	3 26	3 15	2 58	2 90
75% K + 25% Na as basal	3 28	3 38	3 46	3 00
50% K + 50% Na as basal	4 01	3 15	3 25	2 92
25% K + 75% Na as basal	2 33	2 70	2 51	2 62
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	3 63	3 10	3 84	2 96
SE	0 314	0 277	0 292	0 238
CD	0 947	0 835	0 881	NS

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Fifty per cent substitution as bicarbonates registered the best colour which was similar to 0 25 and 50 per cent substitution Seventy five per cent substitution was not found attractive when compared to 25 per cent substitution and 50 per cent substitution as bicarbonates

Sources of nutrients failed to show any significant influence on the appearance taste colour and texture

4 3 3 Pest scoring of tubers

The data on pest scoring are presented in Table 9

The incidence of pest was minimum at 50 per cent substitution as bicarbonates This level of substitution recorded a score of 0 13 at 75 DAP and the value was significantly inferior to 0 and 12 5 per cent substitution ie the susceptibility of the crop to the incidence of pest was reduced by increasing the degree of substitution up to 50 per cent

But the effect was not reflected at the harvest stage At this stage all the treatments were on par Sources of nutrients had no influence on the incidence of pest at both stages

4 4 Physiological parameters

4 4 1 Tuber Bulking Rate (TBR)

Tuber bulking rate was studied at two stages and the result is furnished in Table 10

Table 9 Effect of potassium substitution by sodium on pest scoring of tubers

Treatments	Days after planting	
	75	115
100% K basal	1 05	0 75
87 5% K + 12 5% Na as basal	0 66	0 75
75% K + 25% Na as basal	0 43	0 63
50% K + 50% Na as basal	0 43	0 56
25% K + 75% Na as basal	0 40	0 94
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	0 13	0 06
SE	0 153	0 365
CD	0 460	NS

Table 10 Effect of potassium substitution by sodium on physiological parameter

Treatments	TBR g day^{-1} plant^{-1} 30 60 DAP	TBR g day^{-1} plant^{-1} 60 115 DAP	AR g cm^{-2} day^{-1} 30 75 DAP	AR g cm^{-2} day^{-1} 75 115 DAP	CGP g cm^{-2} day^{-1} 30 75 DAP	CGP g cm^{-2} day^{-1} 75 115 DAP
100% K basal	1 07	2 00	0 00051	0 00011	0 00110	0 00030
87 5% K + 12 5% Na as basal	1 08	2 15	0 00044	0 00016	0 00113	0 00049
75% K + 25% Na as basal	1 11	2 15	0 00045	0 00010	0 00130	0 000 6
50% K + 50% Na as basal	1 07	2 42	0 00 41	0 00011	0 00155	0 00053
25% K + 75% Na as basal	0 97	1 88	0 00063	0 00016	0 00120	0 00041
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	1 07	2 29	0 00062	0 00010	0 00155	0 00035
SE	0 070	0 445	0 000077	0 000035	0 00020	0 00007
CD	NS	NS	NS	NS	NS	0 000213

None of the treatments registered any significant influence on TBR Sources of nutrients also failed to show any influence

4 4 2 Net Assimilation Rate (NAR) and Crop Growth Rate (CGR)

Net assimilation rate and crop growth rate were studied at two stages and the result is furnished in Table 10

None of the treatments showed any significant influence on NAR at both stages

During first stage the treatments failed to show any significant influence on CGR But at later stage 50 per cent substitution recorded maximum CGR of 0 00053 which was on par with 12 5 25 and 75 per cent substitution and significantly superior to 0 per cent substitution

Sources of nutrients had no influence on NAR and CGR at both stages

4 5 Dry matter production

The data on the dry matter content of leaves stem and tubers during different growth stages are presented in Table 11

Treatments failed to show any significant influence on dry weight of leaves at 30 DAP and at harvest Fifty percent substitution recorded maximum dry weight of leaves at these

Table 11 Effect of potassium substitution by sodium on dry matter (g plant -1) during various growth stages

Treatments	Leaves			Stem			Tuber	
	[illegible]0 DAP	75 DAP	115 DAP	[illegible]0 DAP	75 DAP	115 DAP	75 DAP	115 DAP
100% K basal	13 75	14 [illegible]8	12 25	10 25	20 50	18 75	45 81	59 61
87 5% + [illegible] 5 Na as basal	13 75	18 38	12 75	10 25	21 50	2[illegible] 50	46 38	61 95
75% K + 25% Na as basal	14 00	19 88	18 25	10 75	24 50	24 00	48 59	65 04
50% K + 50 Na as basal	15 75	20 25	19 00	10 50	23 25	25 25	57 73	79 12
25 K + 75% Na as basal	10 00	1[illegible] 50	12 50	7 50	15 25	18 00	48 56	64 65
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	11 25	13 50	6 25	7 75	23 25	18 75	56 91	77 56
SE	2 770	2 587	1 817	1 588	3 108	2 317	6 902	9 851
CD	NS	7 798	NS	NS	NS	NS	NS	NS

stages At 75 DAP 12 5 25 and 50 per cent behaved similarly with 50 per cent substitution having a maximum dry weight of 20 25 g Sources had a significant effect on leaf dry weight at 75 DAP Fifty per cent substitution as KCl and NaCl was superior to 50 per cent substitution as bicarbonates Seventy five per cent substitution recorded a leaf dry weight significantly inferior to 25 and 50 per cent substitution

No significant influence was observed on stem dry weight with respect to treatments Twenty five per cent recorded maximum dry weight at 30 and 75 DAP whereas 50 per cent substitution recorded maximum dry weight at 115 DAP

Tuber dry weight was not significantly influenced by treatments However a higher degree dry weight was observed at 50 per cent substitution at both stages

Sources also had no influence on the dry weight of stem and tuber

4 6 Nutrient content of tubers

Effect of potassium substitution with sodium at varying levels on the nutrient content of tubers are presented in Table 12

No profound influence was observed in the content of major nutrients with respect to treatments Fifty per cent substitution registered a maximum nitrogen content of 0 67 per cent

Table 12 Effect of potassium substitution by sodium on nutrient content of tubers (%)

Treatments	N	P	K	Na
100% K basal	0 62	0 063	1 08	0 15
87 5% K + 12 5% Na as basal	0 62	0 066	0 88	0 20
75% K + 25% Na as basal	0 66	0 065	0 96	0 24
50% K + 50% Na as basal	0 67	0 066	1 00	0 26
25% K + 75% Na as basal	0 58	0 069	0 89	0 30
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	0 56	0 066	0 99	0 27
SE	0 041	0 0104	0 0904	0 038
CD	NS	NS	NS	0 116

Maximum phosphorus content of 0 069 per cent was registered by 75 per cent substitution and maximum potassium content of 1 08 by no substitution

But the content of sodium differed significantly All levels of substitution registered higher sodium content compared to no substitution with a maximum at 75 per cent substitution Zero 12 5 25 and 50 per cent levels registered similar content of sodium Eventhough the effect of these treatments was not significant treatment receiving no sodium recorded the minimum value

Sources of nutrients had no influence on the nutrient content of tubers

4 7 Uptake of Nutrients

The effect of treatments on uptake of nutrients are presented in Table 13

Regarding the uptake of nitrogen maximum uptake was recorded by 50 per cent substitution which behaved similarly with 25 per cent substitution But the effect due to 12 5 25 and 50 per cent substitution as bicarbonate was on par

Fifty percent substitution registered the maximum phosphorus uptake which was on par with 12 5 and 25 per cent sub stitution and significantly superior to 0 and 75 per cent substitution

Table 13 Effect of potassium substitution by sodium on uptake of nutrients (kg ha^{-1}) at harvest

Treatments	N	P	K	Na
100% K basal	216 98	21 98	246 45	58 35
87 5% K + 12 5% Na as basal	246 35	25 78	243 95	89 08
75% K + 25% Na as basal	260 18	26 35	258 95	109 98
50% K + 50% Na as basal	278 45	28 18	261 38	127 30
25% K + 75% Na as basal	210 38	24 25	188 13	103 13
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	236 53	24 50	247 25	108 48
SE	9 971	1 293	12 022	4 873
CD	30 049	3 896	36 230	14 686

Regarding the uptake of potassium also 50 per cent substitution registered maximum uptake which was on par with 0 12 5 and 25 per cent substitution and significantly superior to 75 per cent substitution Fifty per cent substitution registered maximum sodium uptake which was significantly superior to all other treatments

Sources of nutrients had a significant influence on the uptake of nitrogen and sodium Fifty per cent substitution as KCl and NaCl registered more uptake compared to 50 per cent substitution as bicarbonates

4 8 Soil properties

The soil properties like soil reaction water holding capacity available potassium and sodium and mean weight diameter as influenced by treatments are presented in Table 14

Soil reaction water holding capacity and available potassium and sodium were not significantly influenced by different degrees of substitution Treatments registered a significant effect on mean weight diameter Seventy five per cent substitution recorded significantly superior mean weight diameter than 0 and 12 5 per cent substitution But the effect was on par with 25 and 50 per cent substitution

Sources of nutrients had no influence on the various soil properties

Table 14 Effect of potassium substitution by sodium on soil properties at harvest

Treatments	pH	WHC (%)	Mean weight diameter	Available k kg ha^{1}	Available Na kg ha^{1}
100% K basal	4 38	21 39	1 13	81 78	23 25
87 5% K + 12 5% Na as basal	4 58	21 90	1 13	95 20	25 50
75% K + 25% Na as basal	4 58	22 21	1 15	96 88	27 45
50% K + 50% Na as basal	4 65	22 79	1 18	93 23	29 95
25% K + 75% Na as basal	5 00	23 27	1 23	73 65	31 10
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	4 68	22 25	1 20	85 98	28 55
SE	0 304	1 003	0 031	9 296	3 532
CD	NS	NS	0 093	NS	NS

4 9 Agronomic Efficiency

The data on agronomic efficiency are presented in Table 15

Regarding nitrogen and phosphorus 50 per cent substitution recorded maximum agronomic efficiency which was on par with 12 5 and 25 per cent substitution Agronomic efficiency of nitrogen and phosphorus registered same effect at 0 and 75 per cent substitution but were significantly inferior to 12 5 25 and 50 per cent substitution Sources of nutrients registered a profound influence on the efficiency of nitrogen and phosphorus Fifty per cent substitution as KCl and NaCl recorded maximum efficiency than 50 per cent substitution as bicarbonates

But regarding the agronomic efficiency of potassium 75 per cent substitution was most efficient and was significantly superior to all other treatments Efficiency of 12 5 and 25 per cent substitution was similar while 25 per cent substitution was significantly superior to no substitution The effect due to 0 and 12 5 per cent substitution was on par

Unlike potassium the agronomic efficiency of sodium was least in 75 per cent substitution Maximum agronomic efficiency was registered by 12 5 per cent substitution

Table 15 Effect of potassium substitution by sodium on agronomic efficiency

Treatments	N	P	K	Na
100% K basal	147 04	220 55	147 04	
87 5% K + 12 5% Na as basal	150 23	225 35	171 76	2048 64
75% K + 25% Na as basal	155 17	232 75	206 89	1057 96
50% K + 50% Na as basal	168 30	252 45	336 60	573 75
25% K + 75% Na as basal	127 40	191 10	509 60	289 55
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	147 00	220 50	294 00	501 14
SE	6 593	9 889	12 594	57 932
CD	19 868	29 803	37 954	178 521

Sources of nutrients did not manifest any influence on the efficiency of potassium and sodium

4 10 Physiological efficiency

The effect of potassium substitution with sodium at varying degrees on physiological efficiency are presented in Table 16

Physiological efficiency with respect to nitrogen potassium and sodium did not differ significantly No substitution recorded maximum physiological efficiency for nitrogen and sodium whereas for potassium 75 per cent substitution recorded maximum physiological efficiency

With regard to phosphorus 100 per cent K recorded maximum physiological efficiency which was on par with 50 per cent substitution and significantly superior to 12 5 25 and 75 per cent substitution

Sources of nutrients failed to show any significant influence on the physiological efficiency of nutrients

4 11 Recovery Fraction

The data on recovery fraction are presented in Table

Recovery fraction of nitrogen was maximum with 50 per cent substitution which was on par with 25 per cent substitution

Table 16 Effect of potassium substitution by sodium on physiological efficiency

Treatments	N	P	K	Na
100% K basal	51 08	506 14	44 76	190 67
87 5% K + 12 5% Na as basal	45 69	436 52	46 19	126 49
75% K + 25% Na as basal	44 85	441 90	44 97	105 88
50% K + 50% Na as basal	45 59	450 75	50 23	99 74
25% K + 75% Na as basal	44 43	438 91	51 18	93 35
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	47 34	453 06	44 75	102 75
SE	2 236	20 354	2 724	6 315
CD	NS	61 341	NS	NS

Table 17 Effect of potassium substitution by sodium on recovery fraction

Treatments	N	P	K	Na
100% K basal	2 89	0 44	3 28	
87 5% K + 12 5% Na as basal	3 29	0 51	3 72	16 2
75% K + 25% Na as basal	3 47	0 53	4 61	10 0
50% K + 50% Na as basal	3 71	0 57	6 97	5 79
25% K + 75% Na as basal	2 81	0 43	10 03	3 13
50% K as potassium bicarbonate + 50% Na as sodium bicarbonate	3 15	0 49	6 59	4 93
SE	1 323	0 021	0 382	0 452
CD	0 399	0 062	1 152	1 394

and was significantly superior to an other treatments 12 5 and 25 per cent substitution behaved similarly

Regarding the recovery fraction of phosphorus 50 per cent substitution registered maximum recovery fraction which was on par with 12 5 and 25 per cent substitution and significantly superior to 0 and 75 per cent substitution

Nitrogen and phosphorus recovery differed significantly with respect to sources Fifty per cent substitution as KCl and NaCl registered maximum recovery compared to 50 per cent substitution as bicarbonates

Maximum potassium recovery was for 75 per cent substitution which was significantly superior to all other treatments and minimum was for no substitution whereas maximum sodium recovery was for 12 5 per cent substitution which was significantly superior to all other treatments and minimum was for 75 per cent substitution Potassium and sodium recovery were not significantly influenced by sources of nutrients

4 12 Economics

The economic analysis presented in Table 18 brings out that 50 per cent substitution as KCl and NaCl registered maximum benefit cost ratio of 4 33 and maximum net income of Rs 29119 50 which were on par with 12 5 and 25 per cent substitution

Table 18 Effect of potassıum sodium substıtution on the economics of sweet potato cultivatıon

Treatments	Benefıt cost ratıo	Net returns per rupee ınvested	Net ıncome Rs ha^{1}
100% K basal	3 68	2 68	24082 50
87 5% K + 12 5% Na as basal	3 78	2 78	24862 50
75% K + 25% Na as basal	3 93	2 93	26031 50
50% K + 50% Na as basal	4 33	3 33	29119 50
25% K + 75% Na as basal	3 33	2 33	20034 00
50% K as potassıum bicarbonate + 50% Na as sodium bicarbonate	1 44	0 43	9941 00
SE	0 155	0 155	1483 405
CD	0 468	0 467	4470 522

Maximum net returns per rupee invested of 3 33 was for 50 per cent substitution which was on par with 25 per cent substitution and significantly superior to all other treatments The same treatment was found economically more viable than the existing Package of Practices Recommendations The economic viability registered by 12 5 and 25 per cent substitution was similar to the existing Package of Practices Recommendations ie no substitution

4 13 Simple correlation coefficient between yield and other parameters

Simple correlation coefficient was worked between yield and various growth yield and quality parameters and nutrient use efficiencies of different fertilizers The results are presented in Table 19

Among the growth parameters maximum correlation was observed for vine length Among the yield contributing parameters number of tubers was highly correlated with yield About 11 per cent correlation was worked out between yield and K content of tubers Among quality aspects highest correlation was seen between yield and sugar content of tubers Considering the uptake of nutrients N uptake registered maximum correlation Agronomic efficiency as well as recovery fraction of nitrogen and agronomic efficiency of phosphorus registered significantly higher correlation coefficients

Table 19 Values of simple correlation coefficient between yield and other parameters

Sl No	Characters correlated	Correlation coefficient
1	Yield x Length of vine (115 DAP)	0 3340
2	Yield x Number of branches (115 DAP)	0 0886
3	Yield x LAI	0 1990
4	Yield x Number of tubers per plant	0 1763
5	Yield x Length of tuber	0 0866
6	Yield x Girth of tuber	0 0877
7	Yield x N content of tuber	0 0293
8	Yield x P content of tuber	0 0215
9	Yield x K content of tuber	0 1098
10	Yield x Na content of tuber	0 0141
11	Yield x Starch content of tuber	0 0085
12	Yield x Protein content of tuber	0 0291
13	Yield x Total sugar content of tuber	0 1107
14	Yield x TBR (30 60 DAP)	0 1489
15	Yield x TBR (60 115 DAP)	0 0831
16	Yield x CGR (30 75 DAP)	0 0520
17	Yield x CGR (75 115 DAP)	0 01122
18	Yield x Dry weight of leaves	0 2274
19	Yield x Dry weight of stem	0 1525
20	Yield x Dry weight of tubers	0 1233
21	Yield x N uptake	0 5433
22	Yield x P uptake	0 2919
23	Yield x K uptake	0 4551
24	Yield x Na uptake	0 1611
25	Yield x Physiological efficiency of N	0 0669
26	Yield x Physiological efficiency of P	0 0496
27	Yield x Physiological efficiency of K	0 0056
28	Yield x Physiological efficiency of Na	0 0023
29	Yield x Agronomic efficiency of N	1 0000
30	Yield x Agronomic efficiency of P	0 9999
31	Yield x Agronomic efficiency of K	0 0489
32	Yield x Recov y fraction of N	0 5471
33	Yield x Recovery fraction of K	0 0465

DISCUSSION

5 DISCUSSION

The investigation entitled Partial substitution of potassium with sodium in sweet potato was taken up to study the effect of replacing potassium with sodium in varying levels in sweet potato

Any technology to replace potassium which is exclusively an imported fertilizer will definitely help to save much of our foreign exchange Sodium is reported to replace potassium in varying degrees in different plant functions The extent of replacement of potassium by sodium depends decidedly upon the plant species In this study it is envisaged to assess the extent of replacement of potassium by sodium in sweet potato The results of this study is discussed below under the following categories

5 1 Effect of replacing potassium with sodium in different degrees on the growth and yield of sweet potato

Effect of varying degrees of substitution of potassium by sodium on the growth and yield attributes of sweet potato was studied The results showed that 50 per cent substitution registered maximum yield of 12 62 t ha ^{1} which is 14 4 per cent more than the yield realised under no substitution ie T_1 (Fig 3 and Plate 1) Thus it was observed that combined application of potassium with sodium in 50 50 ratio is better than applying potassium alone Olson (1947) reported that in cotton the

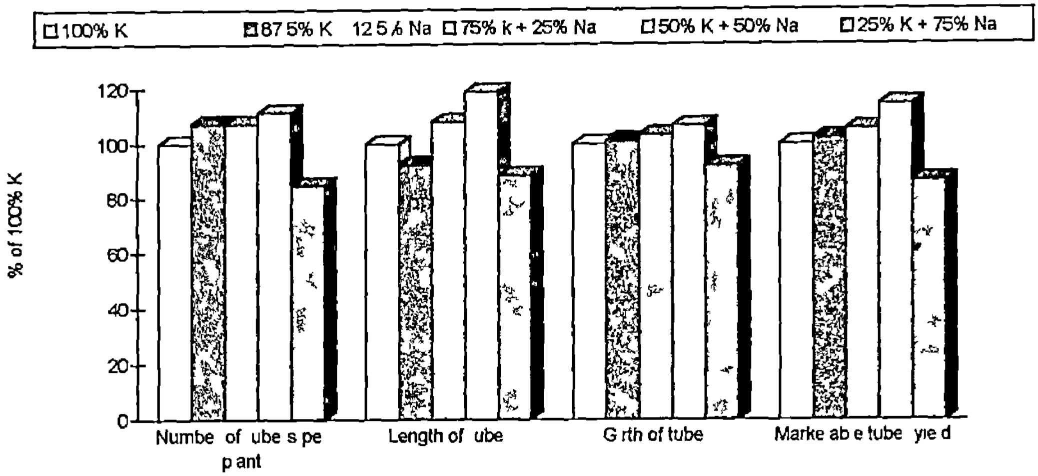

Fig 3 Effect of potassium substitution with sodium on yield and yield attributes

Effect of substitution of potassium with sodium on the tuber yield of sweet potato

0 per cent substitution

50 per cent substitution

highest yield was obtained when 32 lbs each of K and Na were used together than application of K alone

Better performance of this treatment may be attributed to its beneficial effect on the various growth and yield parameters (Fig 4) Results further showed that a maximum length of vine ie 17 68 per cent more than the length of vine observed under no substitution at harvest was obtained at this level of substitution Length of vine at harvest is correlated with yield with a correlation coefficient of 0 33 Khanna and Balaguru (1981) reported that the height of wheat plants increased significantly with an increase in the levels of Na with a maximum height of 18 1 cm at 5 0 mM l^{-1} each of K and Na Better branching ie 7 14 per cent more than that realised under 0 per cent substitution at harvest was also observed at this level of substitution This showed a correlation coefficient of 0 09 with yield This better vine length and branching has resulted in the production of more number of leaves which is quite evident from the better values of LAI ie 27 12 per cent more than LAI obtained under 0 per cent substitution manifested to this additional treatment LAI at harvest stage is correlated with yield with a correlation coefficient of 0 20 Prema *et al* (1992) observed that coconut palms receiving 50 per cent substitution of KCI by NaCl retained maximum number of leaves Sayre (1949) observed that sodium increased significantly the

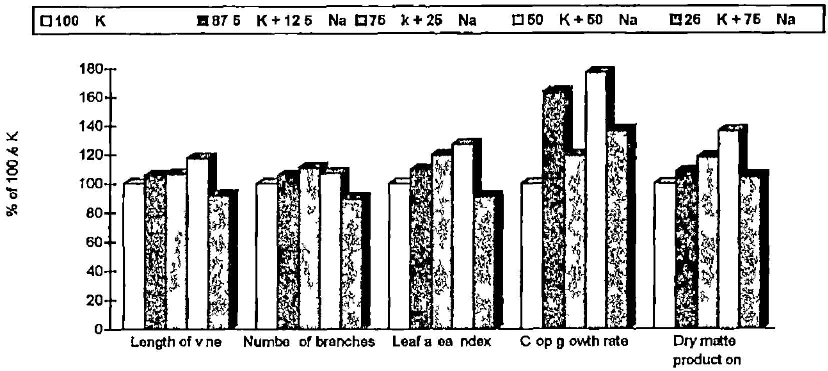

Fig 4 Effect of potassium substitution by sodium on the growth characters of sweet potato at harvest

total yield and value of red beets Sodium also had a marked effect on colour and vigour of the foliage All these might have helped in tapping of more solar radiation which helped to increase the photosynthetic efficiency as seen from a comparatively better CGR values of 76 67 per cent more than CGR values realised under 0 per cent substitution at later growth stages at this level of substitution on 50 50 ratio During the initial stages also 40 91 per cent more CGR value was obtained than that under 0 per cent substitution This stage since corresponds to the critical stages like tuber initiation bulking and development stages of the crop higher CGR might have helped in the better source sink relationship

Sodium is reported to substitute potassium in different functions Considering the comparable and better performance of substituted treatments it is assumed that besides potassium, sodium also participates in various activities mediated by potassium like activating chloroplast enzymes and ATPase Peiris and Ranasingha (1993) reported an increase in total chlorophyll and chlorophyll a content in rice due to NaCl application Ando and Oguchi (1990) suggested that sodium takes part in chlorophyll synthesis in sodium requiring C_4 plants These results showed favourable influence of sodium on chlorophyll synthesis in both C_3 and C_4 plants

All these positive influences affected the yield contributing characters like tuber number per plant (11 5 per cent more than that realised under 0 per cent substitution) length of tuber (18 82 per cent more than that obtained under 0 per cent substitution) girth of tuber (6 42 per cent more than that obtained under 0 per cent substitution) Even though the differences were not significant the significance was lost only by marginal differences especially in the length and girth of tubers All these cumulatively resulted in a better yield The less insect attack found in sodium treated plants also might have played a role in making the treatment superior

In addition to this higher physiological and agronomic efficiency at this level of substitution revealed a better utilization of nutrients within the plant A better recovery fraction responds to a minimum loss of nutrients There was more uptake of nutrients in combination of potassium and sodium than in potassium alone Therefore some additional growth response could be expected from this additional treatment

Sodium can replace potassium to a large extent in the functions of potassium within vacuole because this function is non specific This replacement within the vacuole make potassium available for specific functions within the cell or for retranslocation Eventhough the activating effect of sodium in enzymes is generally small compared to potassium at least in some plant species sodium is able to activate enzyme system remarkably In this case the ratio of K Na is of special importance A pre requisite for this replacing function is the high membrane permeability for sodium From the high mobility of sodium within the plant it may be concluded that in sweet potato the pre requisite may be fulfilled

According to Garman (1947) sodium performs some of the normal functions of potassium when potassium is low such as in maintaining ionic balance relationships necessary for physiological processes Sodium also influences osmotic pressure turgidity and transpiration or it may function actively in the overall ionic balance and buffer capacity relationships within the protoplasm It may be active in facilitating the assimilation of carbon dioxide and in regulating the permeability of cell wall Cooper (1949) reported that plants like sweet potato cotton and mustard are able to use relatively large quantities of sodium in their growth processes Besides because of the replacement of a high proportion of potassium there was an additional stimulating effect of sodium on the growth of plant species

The fact that 50 per cent substitution of KCI by NaCl not only increased the yield but the increase was significant is of high practical significance Tl uptake of nitrogen phos phorus potassium and sodi ʼas found to be higher when the cations were supplied in ı ratio The uptake of nitrogen phosphorus potassium and sodium at 50 per cent substitution showed respectively 28 83 per cent 28 2 per cent 6 06 per cent and 118 16 per cent respective increase than that realised under 0 per cent substitution Nitrogen uptake showed maximum corre lation with yield ie a correlation coefficient of 0 54 Phosphorus potassium and sodium uptake were correlated with yield with correlation coefficient of 0 29 0 45 and 0 16 respectively

All these have resulted in the production of more photosynthetic surface at all growth stages of the crop which finally contributed to better production of source and the higher tuber bulking rate Better source sink relationship was observed in plants receiving 12 5 and 25 per cent substitution over no substitution These levels of substitution showed higher length of vine branching LAI tuber number and girth of tubers than that at 0 per cent substitution Yield increased by 2 18 per cent and 5 53 per cent respectively over 0 per cent substitution This better development of source and sink finally reflected in better biomass production These levels of substitution showed better dry matter production of leaves stem and tuber Thus 12 5 and 25 per cent substitution was also better than no substitution

The poor performance of crop that received 75 per cent substitution shows the inability of sodium to substitute potassium beyond a particular threshold level Cooper et al (1953) observed that there was no significant increase in yield of seed cotton from application of more than 30 lbs of K per acre in combination with NaCl In the present study also response to sodium was not seen when the K Na ratio decreased below one

But the performance of 50 per cent substitution as bicarbonates compared with 75 per cent substitution was better This again emphasises the importance of the balance between K and Na as nutrient for sweet potato It is well known that rather than the absolute quantity of nutrient the ratios play a major role even though interaction between plant nutrients are often overlooked inspite of their considerable influence on plant growth

This role of sodium ie its importance as a substitute for potassium is of much importance since the cost of NaCl is less compared to KCl

5 2 Effect of sources of nutrient

Effect of chlorine on sweet potato is well clear from the poor performance of plants that received K and Na as bicarbonates compared to those that received the nutrients as chlorides (Fig 5 and Plate 2) This may be due to the favourable effect of chlorine and unfavourable effect of bicarbonate

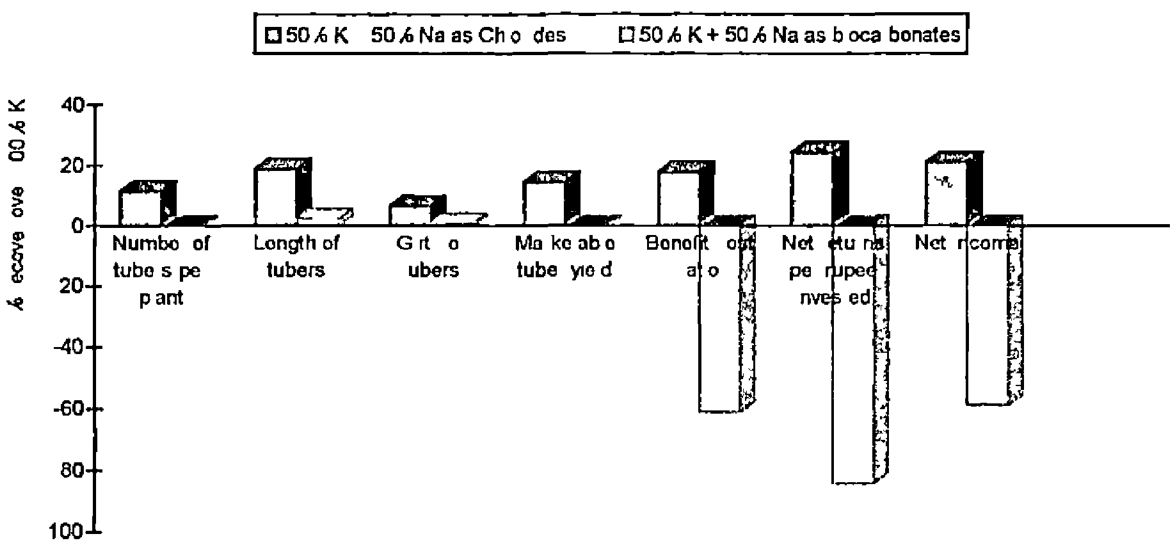

Fig 5 Effect of sources of nutrients on yield yield attributes and economics

Effect of sources of nutrient on tuber yield of sweet potato

50 per cent substitution as chlorides

50 per cent substitution as bicarbonates

Literature pertaining to the response of tuber crops to different sources of sodium is scanty The need of supplemental chlorine in plant nutrition has been documented by research world wide and has resulted in both higher crop yield and disease suppression in various crops (Potash and Phosphate Institute 1993)

Bicarbonate salts had an inhibitory effect on cytochrome oxidase activity in plant extracts Extracts from the bicarbonate treated plant had markedly reduced cytochrome oxidase activity compared to the chloride treated plants (Miller et al 1959) Rediske and Biddulph (1953) observed that bicarbonate was associated with a decrease in uptake of tracer mineral nutrients Porter and Thorne (1955) reported that increased bicarbonate concentration decreased growth and chlorophyll content of bean and tomato plants Large amounts of bicarbonate in leaves also inactivated the iron in plants

5 3 Effect on quality

The quality parameters studied in the experiment were texture appearance taste colour starch protein and total sugar As seen from the results higher contents of sugar starch and protein were recorded when the cations were applied in 50 50 ratio The total sugar starch and protein content were 3 53 per cent 3 45 per cent and 8 83 per cent respectively more than that observed under 0 per cent substitution In addition better appearance taste and colour were in this additional treatment

It is probable that in higher plants there may be an enzyme system or at least isoenzymes which shows their highest activity in an ionic environment of both K and Na and not of K alone

Hale (1948) reported that in sugarbeet sugar yield was increased by the application of sodium Truog (1950) observed that application of sodium to sugarbeet increased the sugar content by 20 per cent and also improved the quality of celery

5 4 Effect on nutrient content and uptake

Results showed that those plants that received 50 per cent substitution of KCl by NaCl showed better nutrient content and uptake over the plants that received full dose of KCl

Data on N content as influenced by treatments ie 8 06 per cent more than that obtained under 0 per cent substitution showed a higher content as well as uptake of N in plants that received the combined application of KCl and NaCl than plants supplied with KCl only This may be due to potash neutrioperiodism Ammonium and potassium have almost the same ionic radii and ionic properties These ions are reported to compete with each other on ion exchange sites on soil colloidal surface and on root absorption sites The entire quantity of K when applied as basal along with entire quantity of P and half the recommended dose of N the simultaneous application of K and

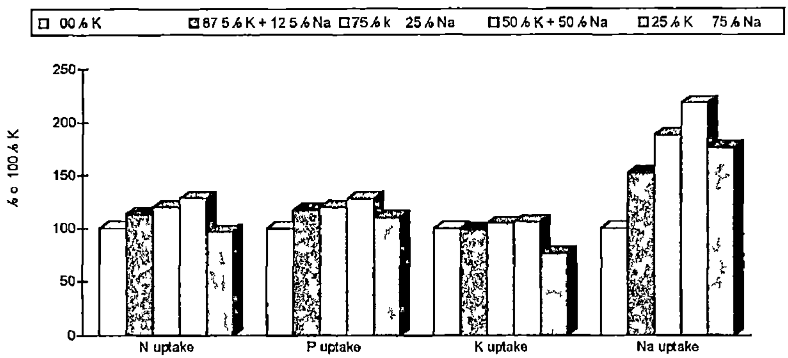

Fig 6 Effect of potassium substitution by sodium on the nutrient uptake of sweet potato

N might have affected N metabolism Similar results was reported by Shehna (1981) In plants receiving 50 per cent KCl + 50 per cent NaCl only half the quantity of K is applied as basal along with N

A lower content of K was observed in plants supplied with Na showing the antagonistic effect between sodium and potassium Potassium content ranged from 1 08 per cent in 0 per cent substitution where as all the other treatments recorded a K content of 1 per cent and below 1 per cent Antagonism between K and Na was reported by Barrant (1975)

Regarding the Na content a maximum of 0 3 per cent was registered in 75 per cent substitution and only about half was observed in no substitution This higher content of Na in sodium substituted plants is due to the direct effect of Na

In general uptake of N P K and Na differed significantly with treatments The N P K and Na uptake corresponding to T_1 (no substitution) and T_4 (50 per cent substitution) were 216 98 kg ha ^{1} and 278 45 kg ha ^{1} for N 21 98 kg ha ^{1} and 28 18 kg ha ^{1} for P 246 48 kg ha ^{1} and 261 38 kg ha^{-1} for K and 58 35 kg ha ^{1} and 127 3 kg ha ^{1} for Na respectively This gradation in nutrient uptake clearly reflects the positive influence of 50 per cent substituted treatments

Jordan and Lewis (1953) observed that increasing the rate of sodium salts increased both available soil and fertilizer phosphate According to Andrews (1948) the value of sodium is attributed to its efficiency as a plant nutrient its ability to partially substitute for potash in the plant its tendency to reduce the leaching of potash and its ability to maintain and improve the availability of soil phosphate Nowakowski (1971) reported that Na can replace K to a higher extent in nitrate translocation Brownell and Nicholas (1967) reported the beneficial role of Na in increasing N fixation by alleniating nitrate toxicity

It was also found that the uptake of nutrients in Na substituted plants to the extent of 12 5 and 25 per cent was better than no substitution

5 5 Effect on soil properties

Treatments failed to give any significant difference in soil properties like pH EC and WHC The pH range varied between 4 4 to 5 0 and water holding capacity between 21 39 per cent and 23 27 per cent EC of all treatments was less than 0 05 So the results of the study showed that pH WHC and even the EC were not adversely affected by Na application Prema et al (1992) reported that application of Na had no adverse effect on pH EC and CEC of the soil Similar report was also earlier made by Prema et al (1987)

Even the available status of K and Na did not differ significantly between the treatments Available K ranged between 73 65 and 96 88 kg ha ^{1} and available Na ranged between 23 28 and 31 10 kg ha ^{1} This may be due to luxury consumption of K and the leaching loss of Na which have resulted in more or less comparable values in the status of these two nutrients in all the treatments According to Tisdale et al (1990) high concentration of sodium was toxic to some plants and the associated high pH can create deficiencies of the micronutrient cations High sodium affected soils become almost impervious to water and air But these adverse effects were not seen in this experiment Since the result of this study is based on the data realised from an investigation conducted only for one season to draw an effective conclusion the study has to be repeated especially for assessing the effect of Na on soil properties

5 6 Effect on economics

Perusal of data on economic analysis showed that 50 per cent substitution recorded maximum benefit cost ratio of 4 33 This higher benefit cost ratio is due to better returns realised from this treatment Combined application of KCl and NaCl on

50 50 ratio registered a net income of Rs 29119 50 and net returns per rupee invested of 3 33 which was higher than those obtained from other treatments Compared to 0 per cent substitution this additional treatment recorded 24 25 per cent increase in net returns per rupee invested and 20 92 per cent increase in net income Cost of cultivation for this treatment was also less due to low cost of NaCl compared to KCl

All levels of substitution except 75 per cent registered better returns than 0 per cent substitution which reveal the economic viability of these substituted treatments

Combined application of potassium bicarbonate and sodium bicarbonate registered poor returns compared to all treatments supplied with KCl and NaCl This is due to direct reflection of poor yield in bicarbonate treated plots and higher cost of bicarbonates compared to the cost of chlorides

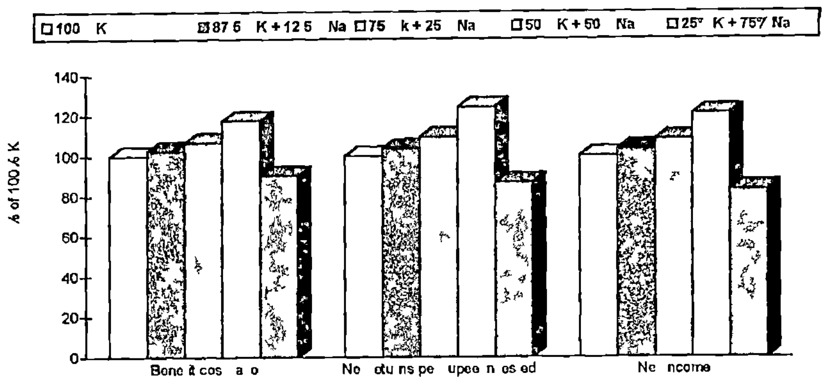

Fig 7 Economics of substitution of potassium by sodium on sweet potato

SUMMARY

6 SUMMARY

An experiment was conducted at Instructional Farm College of Agriculture Vellayani during May October 1994 to study the effect of partial substitution of potassium with sodium in sweetpotato The treatment consists of five levels of substitution ie 0 12 5 25 50 and 75 per cent Substitution was effected as potassium and sodium on equivalent basis The experiment was conducted on sweetpotato variety kanjangad The trial was laid out in Randomized Block Design The data generated were statistically analysed presented and discussed in the foregoing chapters The findings of this study are summarised below

Substitution of potassium with sodium to the extent of 50 per cent in the form of KCl and NaCl produced longest vine (111 25 cm) at harvest Branching was found to be maximum at 25 per cent substitution (11 67) Fifty per cent substitution of KCl by NaCl recorded a maximum LAI at all growth stages with a LAI of 3 75 at harvest

Yield attributes like the number of tubers per plant length and girth of tubers were found to be maximum when 50 per cent of K was substituted by Na in the form of KCl and NaCl Maximum marketable tuber yield (12 62 t ha^{1}) and vine yield (15 94 t ha^{1}) were recorded at 50 per cent substitution as KCl and NaCl

Tuber qualities like starch and protein was maximum (48 3 per cent and 4 19 per cent respectively) when 50 per cent of KCl was substituted by NaCl Whereas total sugar content was maximum (2 95 per cent) when 25 per cent of KCl was substituted by NaCl

The attributes used to assess the cooking quality were appearance taste colour and texture Appearance was found best (4 01) when 50 per cent of KCl was substituted by NaCl Whereas taste was best (3 38 per cent) at 25 per cent level of substitution Best colour (3 84) was obtained when 50 per cent of K was substituted by Na as bicarbonates Texture of tubers was best at 0 per cent level of substitution Pest incidence was minimum when 50 per cent of K was substituted by Na in the form of bicarbonates

Dry matter production of leaves stem and tuber were maximum (19 0g 25 25 g and 79 12 g respectively) at harvest when 50 per cent of K was substituted by Na as chloride

Physiological parameters like tuber bulking rate and crop growth rate was maximum (2 42 and 0.00053 respectively) when 50 per cent of K was substituted by Na as KCl and NaCl at harvest

Regarding the nutrient content of tubers N content was maximum (0 67 per cent) when 50 per cent K was substituted by Na as KCl and NaCl Content of P and Na was maximum (0 069 per cent and 0 30 per cent respectively) when 75 per cent of K was substituted by Na Maximum content of K (1 08 per cent) was observed at no substitution Maximum uptake of N P K and Na was observed at 50 per cent substitution ie 278 45 kg ha^{1} 28 18 kg ha^{1} 261 38 kg ha^{1} and 127 3 kg ha^{1} respectively

Available potassium content of soil increased from 81 78 kg ha^{1} to 96 88 kg ha^{1} when 25 per cent of K was substituted by Na whereas available sodium content was maximum (31 10 kg ha^{1}) when 75 per cent of K was substituted by Na pH and water holding capacity of soil was not affected by different levels of substitution

Agronomic efficiency for N and P was maximum when 50 per cent of K was substituted by Na as chlorides Where as that for K was maximum (509 60) when 75 per cent K was substituted by Na Maximum agronomic efficiency for Na was registered when 25 per cent of K was substituted by Na

Physiological efficiency was maximum for N P and Na (51 08 506 14 and 190 67 respectively) at 0 per cent substitution whereas for K it was maximum (51 18) at 75 per cent of substitution

Maximum recovery fraction for N and P (3 71 and 0 57 respectively) was observed when 50 per cent of K was substituted by Na as chlorides Seventy five per cent substitution of K by Na registered maximum recovery fraction (10 03) for K where as for Na it was maximum (16 2) when 12 5 per cent of K was substituted by Na

Maximum benefit cost ratio net returns per rupee invested and net income was obtained when 50 per cent of K was substituted by Na as chlorides

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Future line of work

Results of the experiment showed that 50 per cent substitution of potassium by sodium produced an increase in yield and net income in sweet potato without any adverse effects on the soil properties But the results are based on the data realised from the investigation carried for one season So the work has to be repeated to draw an effective conclusion on the effect of sodium on soil properties Effect of substituting potassium with sodium on other crops also has to be tried

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* Originals not seen

APPENDICES

APPENDIX I

Weather data during the cropping season (weekly averages)
(from 7 5 1994 to 21 10 1994)

Standard week	Period From	Period To	Maximum temperature °C	Minimum temperature °C	Relative humidity (%)	Rain fall (mm)
19	07 05 94	13 05 94	28 2	26 1	84 2	
20	14 05 94	20 05 94	33 0	26 4	84 3	
21	21 05 94	27 05 94	31 3	24 1	87 4	23 8
22	28 05 94	03 06 94	29 9	23 0	91 6	20 9
23	04 06 94	10 06 94	29 4	23 6	87 8	15 2
24	11 06 94	17 06 94	29 9	23 2	90 5	07 8
25	18 06 94	24 06 94	30 0	24 8	83 3	0 4
26	25 06 94	01 07 94	30 3	24 2	77 0	0 3
27	02 07 94	08 07 94	29 6	23 6	81 8	1 1
28	09 07 94	15 07 94	29 7	23 7	88 8	7 3
29	16 07 94	22 07 94	29 2	22 9	82 6	10 6
30	23 07 94	29 07 94	29 8	23 5	83 2	10 0
31	30 07 94	05 08 94	27 9	22 6	89 2	29 0
32	06 08 94	12 08 94	29 5	24 0	87 9	0 7
33	13 08 94	19 08 94	29 9	23 7	83 7	1 7
34	20 08 94	26 08 94	29 8	23 6	77 4	1 7
35	27 08 94	02 09 94	29 2	23 7	84 5	6 8
36	03 09 94	09 09 94	29 3	23 8	91 7	5 0
37	10 09 94	16 09 94	30 4	25 1	86 9	
38	17 09 94	23 09 94	30 2	23 4	85 9	0 7
39	24 09 94	30 09 94	30 9	24 0	84 4	
40	01 10 94	07 10 94	28 0	23 7	96 9	24 4
41	08 10 94	14 10 94	30 5	22 9	83 6	1 6
42	15 10 94	21 10 94	29 5	23 3	82 0	16 1

Appendix II

Score card for the organoleptic evaluation of cooked sweetpotato

Name of the judge

Signature   Date

Quality attributes	Subdivisions of each attri butes	Score for each sub divided attributes	Score for different samples Code no of each samples 1	2	3	4	5	6	7	8
Appearance	Excellent	5								
	Good	4								
	Medium	3								
	Fair	2								
	Poor	1								
Taste	Excellent	5								
	Good	4								
	Medium	3								
	Fair	2								
	Poor	1								
Colour	Excellent	5								
	Good	4								
	Medium	3								
	Fair	2								
	Poor	1								
Texture	Excellent	5								
	Good	4								
	Medium	3								
	Fair	2								
	Poor	1								

APPENDIX III

Quantity of KCl and NaCl applied for sweet potato

Levels of substitution	KCl (kg ha $^{-1}$)	NaCl (Kg ha $^{-1}$)
0 per cent	125 00	
12 5 per cent	109 40	11 90
25 per cent	93 75	23 80
50 per cent	62 50	47 60
75 per cent	31 25	71 40

PARTIAL SUBSTITUTION OF POTASSIUM WITH SODIUM IN SWEET POTATO

By

JOGGY MARIAM GEORGE

ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF REQUIREMENT

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VELLAYANI THIRUVANANTHAPURAM

1995

ABSTRACT

An investigation was carried out at Instructional Farm College of Agriculture Vellayani to study the effect of substituting potassium with sodium in varying levels in sweet potato The levels of substitution consists of 0 12 5 25 50 and 75 per cent as potassium and sodium on equivalent basis The trial was laid out in RBD with four replications

Partial substitution of potassium with sodium to the extent of 50 per cent increased the growth attributes like length of vine number of branches plant ^{1} and LAI at all growth stages Physiological parameters like TBR and CGR were increased due to the combined application of potassium and sodium on 50 50 ratio

Marketable tuber yield and yield attributes like number of tubers plant ^{1} length of tuber and girth of tuber were increased by the combined application of both the cations

Combined application of potassium and sodium increased the quality attributes of tubers like starch protein and total sugar Cooking qualities was also found to be better when potassium and sodium were applied together Pest incidence was also reduced when both the cations were applied in 50 50 ratio

Combined application of K and Na produced maximum N P and Na content in tubers whereas K content was maximum at zero per cent substitution Uptake of nutrients (N P K and Na) were maximum at 50 per cent substitution

Soil properties like pH EC water holding capacity available potassium and sodium were not affected by treatments

Physiological efficiency of N P and Na were found to be maximum at 0 per cent substitution whereas that of K was maximum at 75 per cent substitution Agronomic efficiency and recovery fraction of N P K and Na was found to be increased in the presence of both cations

Fifty per cent substitution of potassium by sodium was more economic than the existing Package of Practices Recommendation