PARTIAL SUBSTITUTION OF MURIATE OF POTASH BY COMMON SALT FOR CASSAVA (*Manihot esculenta* Crantz) IN OXISOLS OF KERALA

By

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DECLARATION

I hereby declare that this thesis entitled **"Partial substitution of muriate of potash by common salt for cassava (*Manihot esculenta* Crantz) in oxisols of Kerala"** 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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CONTENTS

Page No

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Abbreviations used in this Thesis

BR	Bulking rate
CD	- Critical Difference at 1%
CEC	Cation exchange capacity
CGR	Crop Growth Rate
CS	Common salt
EC	Electrical conductivity
HCN	Hydro cyanic acid
LAI	Leaf Area Index
MAP	Months after planting
MOP	Muriate of potash
NRA	Nitrate Reductase Activity
RWC	Relative water content
UI	Utilisation index
WHC	Water holding capacity
ha^{-1}	Per hectare
%	Per cent

INTRODUCTION

INTRODUCTION

Potassium was first recognised as an essential element for plant growth by Home in 1762. The importance and essentiality of this univalent cation in plant kingdom has been acclaimed ever since. It is the most abundant cation in the tissues of higher plants making up about 1.7 to 2.7 per cent of the drymatter of normal leaves (Evans and Sorger 1966).

With the awareness of the importance of K in plant growth grew the demand for its increased supply. The fact that India depends entirely on other countries for its requirements of potash fertilizers made this fertilizer nutrient all the more expensive. As a result of the recent decontrol of fertilizers and subsequent escalation in fertilizer prices, farmers were compelled to reduce the use of K fertilizers causing an imbalance in the use of N, P and K. Reduction in K consumption was reported from various states and on an average 34.6 percent reduction in use of K fertilizers was reported on all India basis and 45 percent reduction in consumption was reported from Kerala (Mahatvaraj 1993).

Cassava (*Manihot esculenta* Crantz.) is an important tuber crop of the tropics widely cultivated in several countries of S. America, Africa and S.E. Asia. The root tubers form an important source of food in these regions. It is estimated that about 70 million people world wide obtain more than 500 calories a day from cassava (Beeching *et al.* 1994). In some African countries cassava contributes up to 50 per cent of the dietary energy (Cock 1985). Cassava leaves are rich sources of protein and are consumed as food in some parts of Africa It has got several industrial uses It has been estimated that 65 per cent production is used for human consumption 25 per cent for industrial uses mostly as starch (6%) or animal feed (19%) and 10 per cent is lost as waste (Beeching *et al* 1994)

Out of the total area of 1 58 lakh hectares under cassava in India 1 418 lakh hectares fall in Kerala (Farm guide 1994) accounting for 89 7 per cent of the country s total production In Kerala ten per cent of the total food crops area is under cassava which is the most popular subsidiary food crop in the state

There is a view that Na can partially substitute the K requirement in some plants El Sheikh *et al* (1976) reported favourable response of sugar beet to Na application The exact mechanism of replacement of K by Na is not clearly understood Some scientists suggest that Na can substitute all the non specific functions of K sparing K for its specific functions Some workers are of the view that K is replaceable in the osmotic functions only Still all of them agree that K can be partially substituted

Hence this work was undertaken with the following objectives

1) To find out whether or not it is possible to substitute Na for K as nutrient in cassava

2) If substitution is possible to determine the most desirable level of substitution

3) To understand the mechanism of replacement to the extent possible

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Potassium is the only univalent cation generally recognised to be indispensable for growth of all plants Sodium has been considered essential only for the halophytes But beneficial effects of sodium on growth of many plants have been noted in media high or low in K (Truog *et al* 1953) Tubers in general respond to Na substitution to a greater degree as compared to other crops (Larson and Pierre 1953 Elsheikh and Ulrich 1970) The beneficial effect of Na has been explained as a sparing action on K through redistribution of K from places of abundance to those of deficiency This explanation is not complete when a large amount of Na added to a low K medium increases growth above that in a high K medium with no Na addition Several comparable experiments dealing with this question have been carried out From these experiments however only limited conclusions can be drawn with respect to the extent of replacement because in most cases only K alone or Na alone were compared with each other An exhaustive survey of the literature on the effects of K and Na on various plant growth and yield parameters of different crops is attempted in this chapter

2.1 Plant height

A number of workers have reported increase in plant height with increased application of K Pillai (1967) obtained significant increase in height with K and Ca application in cassava Increase in height with K application have been recorded by Rajanna *et al* (1987a) in potato and

Ashokan *et al* (1988) and Jimenez (1990) in cassava But contradictory to the above observation reduction in height was observed by Pushpadas and Aiyer (1976) in cassava Gupta *et al* (1992) in potato Ray *et al* (1993) in banana and Singh *et al* (1993) in potato

Increased salinity was found to reduce plant height in many of the plants (Gill and Dutt 1982 Mangal *et al* 1986 Roth 1989 Malini and Khader 1989 Dhindwal *et al* 1992 Mangal *et al* 1993 and Valia *et al* 1993)

2.2 Number of leaves

N and K_2O application increased number of leaves per plant in cassava (Ashokan *et al* 1988) But no significant effect on number of leaves could be obtained by Pushpadas and Aiyer (1975) in cassava Rajanna *et al* (1987) and Singh *et al* (1993) in potato and Ray *et al* (1993) in banana

Gupta and Srivastava (1989) while studying the effect of salt stress on morpho physiological parameters in wheat reported reduction in leaf number with salt stress This reduction was more pronounced in the wheat variety Kalyansona than Kharchia 65 which could maintain its leaf number on mother shoot even under NaCl stress Yang *et al* (1990) found that increasing concentration of NaCl in the irrigation water significantly reduced the number of green leaves per plant in sorghum

Reduction in number of leaves with increasing concentration of NaCl was also reported by Ibrahim *et al* (1991) and Mangal *et al* (1993) in potato and Valia *et al* (1993) in passion fruit

Prema *et al* (1987) observed increased number of leaves in coconut palm when 50% K was substituted with Na

2.3 Leaf area

Significant increase in leaf area in mustard (*Brassica juncea* L) was observed with application of N and K (Kurla *et al* 1992) LAI and LAD gradually increased in sweet potato cultivars upto 90 days with enhanced K levels (Chakrabarthy *et al* (1993) Contrary to this Singh *et al* (1993) reported that increase in the level of K had no significant effect on leaf area per plant in potato Corroborative reports have been made by White (1993) in rye plants

Maliwal and Paliwal (1979) found that the length and width of leaves of carrot and radish decreased with increase in salinity of the growth medium and more so in radish above an EC value of 6 mmhos/cm Confirmatory observations were obtained by Kayani and Rahman (1988) in maize Yaseen *et al* (1989) in barley Gupta and Srivastava (1989) in wheat and Malini and Khader (1989) in tube rose The whole plant response to NaCl was studied in *Sorghum bicolor* and *Sorghum halepense* by Yang *et al* (1990) and they showed that leaf area was reduced by increasing concentration of NaCl in the growth medium

Similar results have been reported by Pezeshki and Pan (1990) in rice Ibrahim *et al* (1991) in coleus Brugnoli and Lauteri (1991) in *Gossypium hirsutum* and Valia *et al* (1993) in passion fruit

2.4 Drymatter production

It is generally known that K fertilizers improve vegetative growth and thereby drymatter accumulation in plants. In cassava also similar results have been obtained by Pushpadas and Aiyer (1976). Again in 1977 Ashokan and Sreedharan found that drymatter production in cassava (variety H97) was maximum at 112.5 kg level of K_2O. But in 1989 Salim while studying the effects of NaCl salinity on growth and ionic relations of *Phaseolus vulgaris* L. observed that the plant growth was reduced more by higher concentrations of KCl than equal concentrations of NaCl. In mustard both Na and K significantly improved the drymatter accumulation in experiments conducted by Kuila *et al.* (1992).

In potato when application of K upto 80 kg ha^{-1} enhanced the drymatter production, still higher levels decreased it (Sharma and Ezekiel 1993). But Singh et al (1993a) and Singh *et al.* (1993b) reported higher dry matter production in soybean and wheat respectively with increasing K application.

Contradictory reports have emerged world wide on the effect of Na in drymatter production of plants. *Atriplex vesicaria* in cultures which had received Na made about four times as much growth as the plants in cultures with all other nutrients except Na. The dry weight production increased asymptotically with application of Na (Brownell 1964). In agreement with this the dry weight yields went up with Na supply in *Anabaena cylindrica* (Brownell and Nicholas 1967). In castor, sunflower and flax plants also dry matter increased upto 40 me/l NaCl level in trials conducted by Heikal *et al.* (1980). According to Indira (1978) Cassava plant growth was retarded beyond 2000 ppm Na in the growth medium.

Differential behaviour was observed in different cultures of potato (Morpurgo and Rodriguez 1987) on dry matter production under salinity Among the different cultivars tested only shoot fresh weight increased in cv Desire

Abd-Qadar (1988) opined that varieties of rice differed in shoot weight under sodicity stress In majority of the cases the effect of sodicity was more pronounced in grain yield compared to shoot dry weight But reduction in total drymatter yield has been reported from various parts of the world (Kayum and Rahman 1988 in maize Al Saadi *et al* 1988 in grape vine Campos *et al* 1989 in rice Pessarakli *et al* 1989 in sweet corn and Gupta and Srivastava 1989 in wheat) Moderate concentration of NaCl (0 5 1%) stimulated growth and induced phyllocoid production in both shoot segments and plantlets in *Asparagus officinalis* (Mills 1989) Plant dryweight was also not reduced in tomato plants under low K stress when replaced with Na But at toxic levels of Na reduction in plant dry weight was observed (Figdore *et al* 1989) Abdullah and Ahmad (1990) observed reduction in shoot growth in potato with increase in salinity Eventhough Brugnoli and Lauteri (1991) reported that in *Phaseolus vulgaris* plant growth was decreased by salinity Kharazian *et al* (1991) found that addition of Ca at all levels of NaCl increased shoot and root dry weight In barley seedlings Dhindwal *et al* (1992) obtained stimulation of growth at low levels of salinity But in Indian mustard a progressive decrease in plant growth was observed with increase in salinity (Garg *et al* 1993)

Na applied to sand cultures in the absence of potash enhanced the growth of the seven crops tested (cotton oats wheat sugarbeets vetch

Austrian winterpeas and turnips) by an average of 53% It was observed that the beneficial effect of sodium on plant growth decreased as the potash level of the nutrient media increased, but not in direct proportion to it (Holt and Volk 1945) Na addition along with all other nutrients into a culture medium increased plant growth than when Na or K alone was given in the medium in sugar beet plants (El Sheikh *et al* 1967) Mozafar *et al*, (1970) found that plants of *Atriplex halimus* L grew much better in saline media containing equal parts of NaCl and KCl The fresh weight of plants increased when equal parts of NaCl and KCl were given Similar observations have been reported by Yoshida and Castaneda (1969) in rice Ohta *et al*, (1988) in *Amaranthus tricolor* Jain *et al* (1988) in brinjal Figdore *et al* (1989) in tomato Matoh and Murata (1990) in *Panium coloratum* Von Chan Do (1990) in maize and Ali Qadar (1992) in *Atriplex amnicola*

2.5 Number of stomata

Eventhough the stomatal frequency is more or less a genetic trait studies have shown that alterations can be made by soil factors

Application of K increased the stomatal number per unit leaf area in a green house experiment with alfalfa conducted by Cooper *et al* (1967)

Salinity is reported to decrease stomatal number in general Sarada devi and Rao (1978) reported that the stomatal frequency and index of the NaCl treated safflower plants were lower than that of the control But Dwivedi *et al* (1982) could not obtain any conclusive results in this aspect At 90 ESP the stomatal number in some grasses decreased in some it remained unchanged, but in some it increased over that of normal Shaddad *et al* (1988) and Kayani and Rahman (1988) in maize reported reduced number of stomata with increased salinity

Increase in number of stomata with increased salinity has also been reported by Valia *et al* (1993) in passion fruit

2.6 Chlorophyll content

The univalent cations exert a pronounced influence on the chlorophyll content of plants

Forster (1976) observed that chlorophyll concentration in the flag leaf of spring wheat increased with the application of K A linear increase in chlorophyll concentration with increased application of K was noticed in alfalfa by Collins and Duke (1981) Patil *et al* (1987) reported that enhanced potash supply had a positive relationship with chlorophyll content in tobacco Contrary to the above observations Vortruba and Kase (1979) found that increased rates of K application decreased the chlorophyll concentration in spring barley in a green house trial

Total chlorophyll content in many plants was found to increase as a result of NaCl addition (Parasher and Varma 1987 Sinelnikova *et al* 1988 Motsan *et al* 1988 and Radi *et al* 1989) But negative response has been reported by many scientists (Pandey and Saxena 1987 Ashral 1989 Onkware 1990 Legaz *et al* 1993 and Valia *et al* 1993) Kharazian *et al* (1991) found that addition of Ca to all levels of NaCl corrected the depressive effect and enhanced the chlorophyll content in

Phaseolus vulgaris However Gupta and Srivastava (1989) could not obtain any change in chlorophyll content due to salt treatment Ando and Ouguchi (1990) opined that the chlorophyll content increased because Na takes part in chlorophyll synthesis Low levels (0 5%) of salinity stimulated production of chlorophyll in potato (Abdullah and Ahmad 1990) and in barley seedlings [Dhindwal *et al* 1992]

Ohta *et al* (1987) found that the chlorophyll content per unit leaf area increased markedly in leaves of *Amaranthus tricolor* L plants when Na was added to the nutrient culture medium

2.7 Relative water content (RWC)

The special function of K in water economy of the higher plants is well known This effect of K is atleast partially caused by influencing the stomatal movement (Peaslee and Moss 1966) In cowpea seedlings the RWC was found to be high in K enriched plants (Sastry 1982) Blanchet *et al* (1969) and Brag (1972) observed that increasing K levels lowered the transpiration rate and improved the water use efficiency of plants

It has been noted by several workers that some plants become more turgid and resist wilting better when supplied with sodium The water content of leaves was increased by salinity in salt affected quandong (*Santalum acuminatum*) in trials conducted by Walker (1989) Ashraf (1989) and Wignarajah (1990) also made similar observations in *Vigna* *mungo* and *Phaseolus vulgaris* respectively But treatment difference could not be observed by Ziska *et al* (1989) in *Prunus salicina* under saline conditions Maintenance of leaf water status under saline conditions resulted partly from increased stomatal closure causing a reduction in leaf transpiration rate Low levels of salinity were found to increase the leaf water potential in barley seedlings (Dhindwal *et al* 1992) The leaf water content was either maintained or increased with salt treatment in experiments by Legaz *et al* (1993) But in barley plants at ear emergence and grain filling stages a decreasing trend in leaf water potential due to soil salinity has been reported by Dutt (1988) However in his experiments the more tolerant variety DL 223 recorded a lesser decrease in leaf water potential than varieties K 141 and Ratna Reports by Nejad (1988) Onkware (1990) and Flowers *et al* (1991) also proved that leaf water concentration is negatively correlated with Na concentration

When KCl and NaCl were given in equal concentrations Lindhauer *et al* (1990) found that the drop in leaf osmotic potential was less in sugar beet plants

2 7 1 Enzyme activity

A large number of enzymes catalyzing a wide variety of reactions are activated by certain univalent cations

Evans and Sorger (1966) pointed out that the activities of some fifty different important enzymes known to participate in a variety of metabolic processes were either completely dependent upon or were stimulated by K or other univalent cations They concluded that a large number of apparently unrelated types of enzyme catalyzed reactions were activated by K^+ or other univalent cations and those enzymes activated by K^+ also were usually activated by Rb^+ and NH_4^+ but were activated little by Na^+ and not at all by Li^+. According to them the few enzymes (associated with halophytes) that were activated primarily by Na were not functional in the presence of K.

They further proposed that K^+ and similar univalent cations induced specific conformations of enzyme proteins that are necessary for catalytic activity. Nitsos and Evans (1969) provided definitive information on the role of K^+ in the starch synthetase reaction.

Eventhough the effect of Na on enzyme activity has not been studied as elaborately as K except in halophytes, the available reports point to the fact that Na can replace K in some of the effects. Evans and Wildes (1971) found that addition of 0.05 M NaCl produced small but reproducible results when substituted for KCl as an activator of starch synthetase.

It was observed by Reddy and Vora (1985) that the activity of RNase and protease was improved in presence of salinity. Guerrier (1988) reported that the phosphorylase activity was increased in the presence of NaCl in the germination medium. Influence of NaCl on some biochemical aspects of two sorghum varieties (Giza 10 salt tolerant and IS4087 salt sensitive) was studied by Khan *et al.* (1989). Seeds were germinated in solutions containing 50, 100 or 150 me NaCl/l at 25°C. Increasing salt concentration decreased amylase and protease activity particularly in IS4087.

Abdullah and Ahmad (1990) found that the starch synthetase activity was reduced only to a lesser extent by increase in salinity in potato

In enzymatic studies usually only single salts of K and Na are compared But different ratios of K/Na in the activation of ATPase from sugarbeet roots were tried by Hansson and Kylin (1969) They found that the highest activity of the ATPase was not obtained by K or Na alone but at certain combinations of K and Na While searching for ATPases dependent upon the Na K ratio in leaves of *Avicennia* Kylin and Gee (1970) presented evidence that such enzyme activities were present and were dependent upon the ionic strength of the assay medium They obtained peak activities at more than one combination of K and Na Lindberg (1976) suggested that in the absence of K^+ Na^+ acts as an uncompetitive modifier raising the apparent Km and Vmax for Mg ATP and Na^+ and K^+ together stimulate the ATPase activity in a synergistic manner

2.7.2 Nitrate Reductase Activity

Sinha (1978) observed higher NR activity during the initial stages of water stress and soon after recovery from stress with K application Enhanced NR activity with K application has also been reported by Frost *et al* (1978) in wheat seedlings

As against this Rao and Gnanam (1990) reported that eventhough NR acting in sorghum leaves was inhibited both by NaCl and KCl the inhibition was greater when the enzyme extract was incubated with KCl

There are several reports that addition of Na to the culture medium depresses the activity of NR [Brownell and Nicholas 1968 Lal and Bhardwaj (1987) Pandey and Srivastava (1989) Abdullah and Ahmad

(1990) and Jayakumar *et al* (1992)] Evidences of positive response to Na addition has also been reported by various scientists (Joshi 1987 Reddy 1987 and Sudhakar and Veeranjaneyulu 1988]

2.8 Yield and Yield components

2 8 1 Number of tubers

Natarajan (1975) observed maximum number of tubers in cassava variety H 165 at 50 kg level of K

Number of tubers was not influenced by K beyond 75 kg/ha for the variety H 97 in trials conducted by Ashokan and Sreedharan (1977) Increase in number of tubers in cassava with enhanced rates of K fertilizers have been reported later by Ashokan *et al* (1988) and Jimenez (1990) Gupta (1992) reported significant rise in total number of tubers in potato variety 'Kufri Bahar' with application of N and K

However no significant effect of K was noticed by Singh *et al* (1993) in the same crop

Abdullah and Ahmad (1990) while studying the effect of pre and post kinetin treatments on salt tolerance of different potato cultivars reported that salinity reduced the number of tubers per plant Kinetin reduced the adverse effects Evaluation of potato cultivars for salinity tolerance by Mangal *et al* , (1993) revealed that the number of tubers per plant was decreased significantly only when soil salinity exceeded 6 0 dSm^{-1} Hocking (1993) and Dua and Sharma (1993) found that salinity reduced the number of grains per head in sorghum and number of pods per plant in *Pisum sativum* respectively

2 8 2 Length and Girth of tubers

Length of tuber was not significantly influenced by K application in cassava variety H 97 But maximum girth of tubers was observed at 112 5 kg level of K (Ashokan and Sreedharan 1977) Later in 1988 Ashokan *et al* found that length of tuber was improved by combined application of N and K_2O application

A comparison of the growth observations of carrot and radish by Maliwal and Paliwal (1979) revealed that the growth of the taproot was adversely influenced by salinity But in a study with four graminoid facultative alkali halophytes viz , *Desmostachya bipinnata*, *Sporobolus marginatus* *Bracharia mutica* and *Panicum antidotale* Dwivedi *et al* (1982) could not obtain any conclusive results The thickness of roots in some grasses decreased whereas in others it remained unchanged or sometimes increased over that of normal

Significant reduction in root length of jamun (*Syzygium cuminii* Skeels) was noticed by Patil and Patil (1983) with increase in ESP Depressive effect of ESP started from twelve but the most striking effect was seen at 48 and 60 ESP levels Reduction in rootlength from an ESP of 12 onwards was also recorded by Valia *et al* (1993) in passion fruit

2 8 3 Tuber yield

A scan through the various works reported revealed that K has a definite role in boosting up yields especially in tuber crops As early in 1955 Malavolta *et al* reported that in the absence of K the weight of roots decreased while that of shoot increased. Mohankumar *et al* (1975) Rajendran *et al* (1975) and Pushpadas and Aiyer (1975) separately tested the efficiency of K in enhancing tuber yield in cassava and reported that enhanced rates of K application augmented yield of cassava tubers A linear yield increase due to application of N P and K was observed in colocasia by Pillai (1975) Ashokan and Sreedharan (1977) reported a progressive increase in tuber yield upto 112 5 kg level of K_2O beyond which there was a significant reduction Yield increase with increased rates of K application has also been reported by Nair *et al* (1980) Ashokan and Nair (1982) Aiyer and Prabhakumari (1983) Nair and Mohankumar (1984) Nair and Aiyer (1985) Jimenez (1990) Howeler and Cadavid (1990) Sugito and Guritno (1991) in cassava Gupta (1992) Sharma and Ezekiel (1993) and Singh *et al* (1993) in potato But Rajanna *et al* (1987) could not get any significant yield difference with increased levels of K_2O in potato Hedge *et al* (1986) and Chakrabarthy *et al* (1993) could get increased yield in sweet potato Ashokan *et al* (1984) noted a quadratic response to K application in sweet potato tubers

A reduction in yield was generally noticed with increased concentration of Na in the growth medium Maliwal and Paliwal (1979) observed that the tap root yield of carrot and radish regularly decreased with increase in salt concentration However, carrot appeared to be slightly more salt tolerant than radish

The effects of salinity on plant growth and tuberization in cassava was studied by Indira (1978) The results suggested that the plants were subjected to toxicity from 2000 ppm onwards resulting in retardation of plant growth and tuber initiation

An inverse relationship of tuber yield with Na was also noticed by Abdullah and Ahmad (1990) and Mangal *et al* (1993) in potato In various other crops a yield reduction with increased Na concentration in the rooting medium has been recorded by Mangal *et al* (1986) in coriander and fennel Qadar (1988) in *Atriplex amnicola* Rahim (1988) in spring wheat Alam *et al* (1989) in tomato Hocking (1993) in sorghum and Garg *et al* (1993) in Indian mustard

A significant increase in yield by Na application has also been reported by several workers Holt and Volk (1945) reported an increase in boll yield of cotton with application of Na Storage root weights of sugarbeet plants low in K were significantly increased as the Na supply was increased in the culture medium (Sayre and Shafer 1944 Sayre and Vittum, 1949, Crowther and Garner 1951 and El Sheikh *et al* 1967)

The response of red beets sugar beets, rutabagas carrots celery corn barley oats alfalfa and potatoes to additions of Na in nutrient solutions was investigated in hydropronics and field tests by Truog *et al* (1953) The yield of beets rutabagas carrots and celery were notably increased by addition of Na but corn alfalfa and potatoes responded only slightly barley and oats were intermediate in response

In the trials conducted by Truog *et al* (1953) the highest yields for red beets carrots rutabagas celery barley and oats were obtained when Na and K were supplied together in the rooting medium as fertilizers In table beets Larson and Pierre (1953) and in oats Cope *et al* (1953) also obtained the same results Cooper *et al* (1953) found that 30 lbs of K_2O along with 10 lbs of Na_2O produced the highest yield in cotton The storage root weight of plants in sugar beets high in K increased significantly with an increase of Na supply in trials conducted by El Sheikh *et al* (1967) Similar observations were made by Draycott *et al* (1970) In coconut also it was reported from Kerala by Prema *et al* (1987) that an increase of 104 15% in yield was obtained when 50% K was substituted with Na

2 8 4 Cooking quality

In cassava variety H 97 application of K at the highest level of 150 kg/ha had resulted in an appreciable increase in cooking quality (Ashokan and Sreedharan, 1977)

In agreement to the above finding Nair *et al* (1980) reported that treatments without potash or half the normal quantity were in general bitter to taste

2.9 Quality attributes

It is widely recognised that K can improve the quality of crop produces An extensive amount of literature on this aspect is available But some works on Na fertilization in addition or in place of K reveal that quality is also adversely affected or improved by Na

2 9.1 Starch

K is thought to play a definite role in starch biosynthesis K if deficient in the plant soluble carbohydrates and reducing sugars accumulate starch and glycogen synthesis are impaired

Pushpadas and Aiyer (1975) studied the quality aspects of cassava and reported that application of K increased the starch content of tubers Pillai (1975) also obtained the same result in colocasia But only a slight increase in starch content could be observed in cassava by Nair *et al* (1980) with enhanced levels of K application

Nair and Mohan Kumar (1984) could not get any significant increase in strach by NPK application

But Rajanna *et al* (1987) got significant increase in starch content in potato According to Mohankumar *et al* (1990) increasing levels of K, Ca and Mg tended to increase the starch in cassava tubers Combined application of N and K raised the starch content upto 27% (Sugito and Guritno, 1991)

The value of sodium in plant nutrition has been widely disputed and its beneficial effects upon crops are not well understood However root crops seem to be benefitted by Na (Truog *et al* 1953) But in an experiment by Nair *et al* (1980), the starch content of cassava tuber was not affected by different levels of NaCl

In *Triticum aestivum* L Parasher and Varma (1987) found that salinity at 6 mmhos/cm increased the soluble carbohydrate contents in leaves especially in flag leaf In a study conducted by Shaddad *et al* (1988) on the alleviation of the adverse effects of salinity on nitrogen fertilization found that the carbohydrate contents were variable under different salinity treatments

The studies by Fougere *et al* (1991) proved that 0 15 M NaCl treatment increased the total carbohydrates in *Medicago sativa* L A reduction in carbohydrate content was noticed by Radi *et al* (1989) in maize

2 9.2 Protein content

Recent refinements in both physiological and biochemical investigations have provided an opportunity for considerable insight into the role of univalent cations in the protein synthesizing mechanism

Considerable nutritional evidence indicates that K deficiency in several different kinds of organisms results in impaired protein synthesis

Pillai (1975) showed that in the case of colocasia the protein content gave a positive response to added K Rajanna *et al* (1987) and Sharma and Ezekiel (1993) also agreed that K augmented the crude protein content in potato tubers But contrary to the above results Pushpadas and Aiyer (1975) reported that the application of K decreased crude protein content in cassava tubers Later a gradual reduction in the crude protein content of tubers of cassava variety H97 with increased levels of K was reported by Ashokan and Sreedharan in 1977

Various workers suggest that eventhough Na cannot wholly replace in its role in enzyme activation low concentrations of Na is found to stimulate the protein synthesis

Experimental evidence in this aspect have been provided by Reddy and Vera (1985) In their studies 0 2% salinity slightly increased the leaf protein content of bajra leaves at all stages compared to that of controls Joshi (1987) also reported that the total N and protein content in *Cajanus cajan* increased under NaCl salinity while these decreased under Na_2SO_4 salinity Abdullah and Ahmad (1990) found an increase in total protein of potato plant at 0 5% salinity but decreased at 1%

Accumulation of amino acids due to salinity have been reported by Lal and Bhardwaj (1987) in field pea, Parasher and Varma (1987) in wheat and kidney bean plant and Jayakumar *et al* (1992) in sunflower

Nowakowski (1971) studied the replaceability of K by Na in Italian ryegrass and observed increase in protein nitrogen by addition of Na and K together Joham and Amin (1965) also made similar observation in cotton plants

2 9 3 HCN content

Cyanogenesis has been extensively studied in many plants because of the possible toxic effect of this deadly poison on mammals

The effect of K application on the genesis and distribution of HCN content in cassava plant and tubers have been a focal theme of study till date but no conclusive result have been emerged

As early as 1954 Bolhuis suggested that drought and K deficiency increased the linamarin content of cassava tubers Kurien *et al* (1975) opined that application of K alone or in combination with N and P reduced the cyanogenic glucosides in cassava tubers This was in conformity with the finding of Pushpadas and Aiyer (1975) Ashokan and

Sreedharan (1977) and Nair *et al* (1980) Mohankumar *et al* (1970) reported that increasing levels of K Ca and Mg tended to decrease the HCN content of tubers

But Ashokan *et al* , (1988) found no significant effect on the HCN content of tubers in cassava at different levels of potassium supply

Only little information is available on the effect of Na on the HCN content of tubers Nair *et al* (1980) studied the effect of different levels of NaCl on the HCN content of cassava tubers and reported that NaCl had no particular influence on the HCN content Leonova and Cherepenya (1989) studied the free and bound CN in barley grown in saline medium and observed that the free CN level decreased at high NaCl concentration in the medium

2.9.4 Amino acids

In the synthesis utilisation or accumulation of aminoacids the univalent cations are thought to play an important role

It was shown by Evans and Wildes (1971) that the protein synthesis was blocked by the deficiency of K whereby aminoacids accumulate

Nguyen *et al* (1972) demonstrated that application of K fertilisers diminished total free aminoacids in lucerne The enhanced potash increased the rate of utilisation of these aminoacids in protein formation thereby preventing their accumulation Similar observations were reported by Vaithilingam (1975)

The influence of low substrate Na levels upon the free aminoacid content of cotton leaves was examined by Plunneke and Joham (1972) According to them level of substrate Na had a great effect upon several free aminoacids particularly asparagine, methionine and argininosuccinic acid Rao and Rao (1979) also made a similar report in groundnut leaves While studying the effect of salinity on protein metabolism in Bajra leaves Reddy and Vora (1985) observed a considerable increase in free amino acid content and simultaneous enhancement in protease activity under saline conditions and suggested that the accumulation of free aminoacids might be due to hydrolysis of protein by the enzyme protease

Accumulation of free aminoacids with increasing levels of salinity has been reported by Lal and Bhardwaj (1987) in field pea Dubey and Rani (1989) in rice Sharma *et al* (1990) in roots of alfalfa

But contrary to the above results a decreasing content of amino acids with increasing salinity has also been reported by several workers Salama and Basset (1987) found a decrease in the seedling protein and amino acid with increasing salinity in wheat and kidney bean plants Khan *et al* (1989) also observed a similar trend in sorghum However instances have been noticed where change in salinity levels had no influence on the aminoacid content (Reddy 1987 and Yang *et al* 1990)

Total, Reducing and Non-reducing sugars

K and Na have been reported to have some important roles in determining the total and types of sugars in different plant species

Nair and Mohankumar (1984) reported that N P and K had no significant effect on sugar content in sweet potato A decrease in sugar content with increasing levels of N and K has been obtained by Ashokan *et al*, (1984) Sheela *et al*, (1991) observed an increase in sugars and non-reducing sugars in banana with increased levles of K_2O Reducing sugar increased upto 500 g K_2O Sharma and Ezekiel (1993) reported that potato varieties differed in their response to K application In cv Kufri Badshah, the total sugar content decreased and in all others increased with K application

Guerrier (1988) reported an increase in the sugar content of the seedlings with increase in NaCl in the germination medium Increased sugar content of the fruit juice of tomato with increased levels of salinity has been reported by Adam and Ho in 1989 Chandler *et al*, (1989) found that sugars and sucrose content of sugar beet increased slightly in direct proportion with Na concentration Abdullah and Ahmad (1990) also made a similar observation in potato But Khan *et al*, (1989) opined that the reducing and non-reducing sugar contents of sorghum declined with salinity Studies on the effects of salt stress on the carbohydrate composition of alfalfa by Fougere *et al*, (1991) showed that salt stress did enhance the total carbohydrate content in nodules and roots of alfalfa Sucrose remained the predominant carbohydrate and accounted for 37% at least of the carbohydrate pool in nodules and upto 70% in the roots

There are evidences to suggest that application of Na and K together caused changes in the composition and total content of sugars in plants

Total sucrose content increased in the storage roots with application of Na and K in sugar beet plants (El Sheikh *et al* 1967) Effects of Na and K on the contents of soluble carbohydrates in rye grass was studied by Nowakowski in 1971. He found that the lower rate of N (40 ppm) K and Na decreased reducing sugars and increased sucrose content but had little effect on the fructosan content of ryegrass. At higher N levels (160 ppm) combined application of Na and K increased the sugar content and produced more fructosan than K alone.

2.10 Uptake of nutrients

The uptake mechanisms differ drastically with ionic affinities and selectivities of the species. Cation composition, specifically K, Na, Ca and Mg of plant species and plant organs depends upon the processes of absorption, transport and accumulation, which in turn is related to each species and composition of the growing medium.

The effect of K application on the uptake of nutrients was studied by Pushpadas *et al.*, (1975) in cassava. According to them K application decreased the N content of tissues of Cassava petioles. Further in 1976 they reported that in cassava when the K content of the tissue of petiole increased with application of K, the N and P content decreased.

K uptake in potato was found to increase with increased rates of its application (Shukla and Singh, 1976, Rajanna *et al.* 1987). Uebel (1992) reported that potatoes and sugarbeet had high average K removal rates responding to K fertilisers. Increase in K uptake with enhanced K application has been reported by various other scientists (Singh 1973, Singh *et al.*, 1993b and Prasad 1993).

Studies in *Zea mays*, *Glycine max*, *Citrus jambhiri* and *Persea americana* by Huffaker and Wallace (1959) showed that a low K level stimulated Na absorption and a high K level decreased it. But contrary to this no significant effect on Na was noted by Spiers (1993) in the leaves of black berry with enhanced K uptake.

Application of K was found to decrease the absorption of Ca and Mg in cassava by Mohankumar *et al.*, (1990). Razmjoo and Kaneko (1993) also observed a reduction in Ca and Mg contents in ryegrass with enhanced K application. Spiers (1993) reported a decrease in Mg content in blackberry with increase in K application but no effect on Ca content.

Spiers (1993) also observed a decrease in the Zn content with enhanced uptake of K in the leaves of blackberry but no influence was seen in the case of Cu, Fe and Mn.

Eventhough the available reports on the effect of Na on the uptake of nutrients are controversial, there is every reason to believe that this univalent ion has some influence on the absorption and translocation of nutrient elements.

In a study by Heikal (1980) with castor, sunflower and flax it was found that the N content increased upto 40 me/l NaCl but decreased at higher levels. Analysis of nitrogen fractions of the root and shoot of field pea after 15 days of soil salinization by Lal and Bhardwaj (1987) has revealed that contents of NO_3 and NH^+_4 nitrogen were increased in salt fed plants while the contents of total and protein N were lowered. Parasher and Varma (1987) reported that with increase in salinity N uptake decreased in wheat. Soil salinization upto 10 mmhos/cm was found to improve the N content of plants (Pandey and Saxena 1987). Increase in N content has also been reported by Pongskul *et al.*, (1988) and Pessarakli *et al.* (1989).

Ohta *et al*, (1988) found that application of Na^+ at a concentration of 0 5 mM significantly improved the NO_3 uptake capacities of *Amaranthus tricolor* L seedlings

Heikal *et al* (1980) found that the P content in castor, sunflower and flax increased with increase in salinity upto 40 me/l NaCl but decreased at higher levels But Parasher and Varma reported in 1987 that with increase in salinity the P uptake decreased The specific effect of NaCl on the uptake rate of NO_3 and ortho phosphate P was studied by Silberbush and Asher (1989) The reduction in ion influx was noticed for NO_3 while phosphate influx was not affected by NaCl

NaCl and Na_2SO_4 have got differential influence on the K content of salt stressed peanut plants (Chavan and Karadge, 1980) Heikal *et al* (1980) reported an increase in K content upto 40 me/l NaCl and a decrease thereafter Lal and Bhardwaj (1987) reported a decrease in K uptake with salinity

A decrease in K uptake with increase in salinity has also been reported by Parasher and Varma (1987) in wheat, Pandey and Saxena (1987) in different plants, Sharma (1988) in wheat, Patil *et al*, (1989) in safflower, Alam *et al*, (1989) in tomato, Mills (1989) in Asparagus and Walker (1989) in quandong Abdulla and Ahmad (1990) reported that 0 5% salinity increased the K content in potato and 1% level decreased it Watad *et al*, (1991) also reported similarly

Heikal (1980), in a study conducted in castor sunflower and flax found that the contents of Ca and Mg increased upto 40 me/l NaCl but decreased at higher levels Dhindwal *et al*, (1992) observed that low levels of salinity stimulated the uptake of Ca and Mg in studies conducted with barley seedlings

Ohta *et al*, (1988) found that NO_3 uptake was stimulated by 0 5 mM of NaCl added to the culture medium containing KCl

In 1948 Andrews, studying the relation of sodium to availability of phosphorus, reported that sodium fertilizer added to soils of low or high available K status increased yields of cotton by improving and maintaining the availabiltiy of soil phosphate

When Na^+ and K^+ were present in equivalent concentration the rate of absoprtion of K^+ in barley increased (Rains and Epstein 1967) and the total rate of absorption of K^+ and Na^+ mainly reflected the absorption characteristics of Na^+ Hiatt (1969) reported that equal absorption of K^+ and Na^+ occurred at a K Na ratio of approximately 0 5 which implied a slight preference for K^+ over Na^+ in this concentration range in barley roots

When the plants of *Atriplex amnicola* were given NaCl+KCl it retained most of the Cl in roots while Na^+ and K^+ were translocated more to the shoot (Qadar, 1992)

Effect of Cl on plant growth

Ollagnier and Ochs (1971) reported that coconut and oil palm benefitted from application of muriate of potash and the benefit was due to Cl rather than K

Terry (1977) observed a reduction in plant growth in the absence of Cl Manciot *et al* , (1979) reported that Cl has a specific role in the nutrition and yield of oil palm and coconut Nair (1981) reported favourable response in oil palm to the addition of Cl

Contrary to the above findings Syvertsen *et al* (1988) reported that treatment with 20 ml m^{3} Cl lowered LAI of all citrus trees by more than 50% Sharma *et al* , (1990) reported that in pot trials predominance of Cl and SO_4 types of salinity reduced the chlorophyll carbohydrate starch and protein content of leaves in 2 chickpea cultivars Decrease in plant dry wieght and increased defoliation due to a high chloride content has been reported by Banuls and Primo millo (1992) in Citrus

2.11 Soil available nutrients

Bhargava *et al* , (1992) while studying the dynamics of added potassium in a red soil under banana plantation, reported that K application at rates of 0 2, 0 4 or 0 8 kg K_2O/plant increased both readily and potentially available forms of K in the soil Application of 0 2 kg K_2O/ plant increased the sum of watersoluble and exchangeable K

Singh *et al* , (1993) studied K-Na exchange equilibria at 15°C and 25°C in three dominant soils of Chambal Command and reported a higher preference of Na to K by these soils In a five year experiment with Sorghum Wheat cropping system, Rao *et al* (1993) found a decrease in subsurface soil K when K was not added Addition of optimum amount of K resulted in decrease of available K by 18 kg ha^{1} whereas high rate raised it by 146 kg ha^{1}

Bal and Dutt (1987) reported that with increase in soil salinity Na and Cl excretion increased gradually but in cases of K Ca and Mg there was not much increase over control Bajwa *et al* , (1993) found that leaching with saline waters resulted in the release of exchangeable K and hence increased its concentration in the effluent samples Such trends were particularly more pronounced in sandy loam soil

Prema *et al* , (1987) reported that total N, available P Na and Cl exchangeable Ca and Mg did not differ due to the influence of Na and K treatments in the soil

MATERIALS AND METHODS

MATERIALS AND METHODS

Field experiments to evaluate the possibility of substitution of MOP by common salt were carried out for two consecutive seasons of 1992-93 and 1993 94 at the Instructional Farm College of Agriculture Vellayani The details of the experimental site season and weather conditions materials used and methods adopted are presented in this chapter

3.1 Experimental site

3.1.1 Location

The Instructional Farm, Vellayani is located at 8° 30 N latitude and 76° 54' E longitude and at 29 m above MSL

3.1.2 Soil

The soil of the experimental site comes under the order Oxisol The soil belongs to the family of Loamy skeletal Kaolinitic Isohyperthermic Haplustox

The physical and chemical characteristics of the soil where the experiment was conducted are given in table 1

3.2 Season

The experiments were conducted during the main cassava planting season of May to March in 1992 93 and 1993 94

3.3 Weather conditions

The mean annual rainfall of the location was 1858 mm The mean annual maximum and minimum temperatures were 30 37 and 23 02°C respectively Monthly distribution of rainfall and temperature prevailed during the cropping period in both the years are depicted in Fig 1 and 2

3.4 Materials

3 4 1 Planting material and variety

The planting material of the cassava variety M 4 (Malayan 4) was obtained from the Central Tuber Crops Research Institute Sreekaryam M_4 is a semi branching cultivar introduced from Malaysia Due to its superior cooking quality it is a very popular culinary variety widely cultivated in Kerala It is a long duration variety of ten months duration

3 4.2 Fertilizers

Fertilizers and manures used for the experiment were analysed and presented in Table 2 Cattle manure was applied @ 12 5 t/ha N and P2O5 were applied as per the recommendations of Package of Practices K was applied as per treatment Woodash was applied @ 200 kg/ha to suubstitute for 25 kg/ha K

3.5 Methods

3 5 1 Design and layout of the experiment

Design		Randomised Block Design
Variety	-	M 4
Replication	-	4
Treatments	-	7
Plot size	-	5 25m x 4 5m
Net plot	-	3 75m x 3m
Spacing		75cm x 75cm

Treatments

1 T_1 Full recommended dose (100%) of K as MOP

2 T_2 75% K as MOP + 25% K replaced by Na of common salt

3 T_3 - 50% K as MOP + 50% K replaced by Na of common salt

4 T_4 25% K as MOP + 75% K replaced by Na of common salt

5 T_5 100% K replaced by Na of common salt

6 T_6 50% K as Wood ash + 50% K replaced by Na of common salt

7 T_7 50% K as $KHCO_3$ + 50% K replaced by Na of $NaHCO_3$

The layout plan of the experiment is presented in Fig 3

3.6 Biometric observations

The following biometric observations of the plants under different treatments were recorded at two months intervals A plant was selected from each plot and observations were taken from that plant

3.6 1 Plant height

Height of the stem was measured from the base of the sprout to the terminal bud

3.6.2 Number of functional leaves per plant

The total number of functional leaves in the plant at the sampling time was counted

3 6.3 Leaf Area Index

The leaf area was measured using the Leaf Area Meter (I I COR

Model 3100 Area Meter) and the leaf area index was calculated by the following formula developed by Watson (1947)

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

3 6.4 Root volume at 2 MAP

Volume of the roots at 2 MAP was measured by water displacement method

3.6 5 Number of tubers

The tubers from the observational plant were separated and counted

3.6.6 Length of tubers

Length of all the tubers were measured and the average taken

3.6 7 Girth of tubers

Girth measurements were recorded from the middle and end portions of the tubers and the average was calculated

3.6.8 Tuber yield

After carefully pulling out the plants from the soil the tubers were separated, cleaned and the fresh weight recorded

3.6 9 Cooking quality

The cooking quality of tuber was assessed by a taste panel (Prema *et al* 1975) on a discrete scale with five points The best taste was assessed as sweet and was allotted a score of 4 The other scores in decreasing order of taste were powdery sweet (3) starchy (2) bitter (1) and watery bitter (o) Texture was also recorded to determine the overall acceptability

3.6.10 Shelf life of tubers

Fifteen tubers from each treatment were harvested carefully without any damage Both ends were dipped in paraffin wax These were kept in separate cardboard boxes in slightly moist soil (20% Field Moisture Capacity) One sample each from all the boxes was drawn on the 5th 8th 10th 11th, 12th 13th and 15th day and tested for the cooking quality

The samples which didnot show evidence of deterioration were kept still further, examining the tubers on every 3rd day In the second year also a similar experiment was carried out to confirm the results of the first experiment

3.7 Physiological parameters

The following physiological measurements were also made from the uprooted plant

3.7 1 Number of stomata

Peels were taken from the abaxial side of the third leaf Number of stomata per microscopic field was counted from five different positions in peel and average taken (Sampson, 1961)

3 7 2 Size of stomata

The length and width of five different stomata from each peel were taken with an ocular micrometer and the average calculated

3.7.3 Chlorophyll content

Chlorophyll content was determined by the colorimeteric method as described by Arnon (1949)

3 7 4 Cuticle (wax coating) thickness

The thickness of the cuticle from five different positions in a section was measured using the ocular micrometer and the average value taken

3.7.5 Size of epidermal cell

The size was measured using the ocular micro meter from five different positions in a section and the average was found out

3.7.6 Silica deposit

The epidermal cells were examined under microscope for silica deposit as per the method of Hashiosuzuki (1935)

3.7 7 Tissue turgidity (Relative water content)

Relative water content was determined by the method proposed by Weatherley (1950) which was modified by Slatyer and Barrs (1965)

$$\text{RWC} = \frac{\text{Fresh weight} \quad \text{dryweight}}{\text{Turgid weight - dryweight}} \times 100$$

3.7.8 Nitrate reductase Activity

NR activity of third leaf was determined at 6 months after planting The method suggested by Nason and Evans (1955) was followed

3.8 Growth analysis

3 8 1 Drymatter production and distribution

At each sampling one plant from each plot was carefully pulled out and separated out into stem leaves petioles and roots Fresh weight of each part was recorded and subsamples were taken for estimating the dryweight The subsamples were dried in oven at [illegible]°C to constant dry weight Then the dry weight of each plant part was computed and recorded

3.8.2 Net Assimilation Rate

The procedure given by Watson (1958) was followed for calculating NAR This was expressed as g m^{-2} day^{-1}

$$\text{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e LA_2 - \log_e LA_1}{LA_2 - LA_1} \quad \text{where}$$

LA_2 and LA_1 are the leaf areas at t_2 and t_1 and W_2 and W_1 are the dry weights at t_2 and t_1

3.8 3 Crop Growth Rate (CGR)

CGR was calculated by the formula of Watson (1958) and expressed as $g m^{-2} day^{-1}$

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \quad \text{where}$$

W_2 and W_1 are the crop dry weight per unit area at the two time units t_2 and t_1

3.8.4 Tuber Bulking Rate (BR)

BR is expressed as $g\ day^{-1}\ plant^{-1}$ (dry weight)

$$BR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \quad \text{where}$$

W_2 = Dry weight of tuber at time t_2
W_1 = Dry weight of tuber at time t_1

3 8 5 Utilisation Index

The ratio of root weight to top weight was calculated for each treatment

3.9 Chemical analysis

3 9 1 Plant analysis

Leaf petiole stem and root/tuber samples were separately analysed for the contents of N P K Na Ca and Mg at two month intervals and for Cl at harvest time

Nitrogen was estimated by modified Kjeldhal method after digestion with H_2SO_4 (Jackson 1973) Determination of other elements were done after digestion with HNO_3 $HClO_4$ H_2SO_4 mixture (Piper 1966) Phosphorus was estimated by the Vanadomolybdic yellow colour method in a Klett Summerson photoelectric colorimeter (Jackson 1973) Na and K were estimated using the Systronics Flame photometer and Ca and Mg were estimated by an Atomic Absorption Spectrophotometer (Perkin Elmer PE 3030) Cl was estimated titrimetrically after digestion (Humphries 1979)

3 9 2 Uptake of nutrients

Uptake of N P K Na Ca and Mg was calculated from their contents in the plant parts multiplied by the respective dry weights

3 9 3 Fresh tuber analysis

Tubers were collected fresh from the plots and analysed for various quality parameters The parameters studied and the analytical methods followed are given in Table 3

3 9 4 Soil analysis

Soil samples from each plots were analysed for pH organic carbon EC available P available K Na Ca Mg and Cl

Soil physical properties like water holding capacity and water stable aggregates were also determined The procedures followed are given in Table 4

3.10 Statistical analysis

Statistical methods of analysis such as analysis of variance correlation regression and path analysis were carried out to find out the relationship between variables and to draw definite conclusions

Table 1 Physical and chemical properties of the soil of the experimental site

1	Mechanical composition	
	Sand (%)	79 80
	Silt (%)	11 60
	Clay (%)	8 10
2	Texture	Sandy loam
3	pH	4 54
4	EC (dSm ^{1})	<0 02
5	CEC (cmol kg ^{1})	3 20
6	WHC (%)	45 60
7	Organic carbon (%)	0 61
8	Available N (kg ha ^{1})	114 00
9	Available P (kg ha ^{1})	16 10
10	Available K (kg ha ^{1})	70 50
11	Available Na (kg ha ^{1})	68 00
12	Exchangeable Ca (ppm)	28 60
13	Exchangeable Mg (ppm)	10 10

Table 2 Analysis of fertilizers and manures used in the experiment

Fertilizer/Manure	Composition
Urea	46% N
Mussoorie Rock Phosphate	20 4% P
Muriate of Potash	60% K
Common salt	39 3% Na
Wood ash	12 4% K
Cowdung	0 5%N 0 32%P 0 5%K
Potassium bicarbonate (LR)	39% K
Sodium bicarbonate (LR)	27 38% Na

Table 3 Analytical methods followed in tuber quality studies

Sl No	Parameters Studied	Method followed	Reference
1	Starch content	Titrimetry	Chopra & Kanwar (1976)
2	Total sugars	Titrimetry	Chopra & Kanwar (1976)
3	Reducing sugars	Titrimetry	Chopra & Kanwar (1976)
4	Sucrose content	Difference method	Chopra & Kanwar (1976)
5	Amylose in starch	Colorimetry	McCready & Hassid (1943)
6	Amylopectin	Fractionation of starch	McCready & Hassid (1943)
7	Hydrocyanic acid content	Colorimetry	Indira & Sinha (1969)
8	Total phenols	Colorimetry	Folin & Ciocalteu (1927)
9	Total amino acids	Colorimetry	Spies (1957)
10	Free amino acids	Colorimetry	Draper (1976)
11	Crude protein content	% N x 6 25	Chopra & Kanwar (1976)
12	Crude fibre content	Ashing and weight loss	Chopra & Kanwar (1976)
13	Viscosity	Viscometer	ISI 1960
14	Gelatinisation temperature	Thermometer	MacMasters (1964)
15	Starch synthesizing enzymes		
	a Phosphorylase activity	Colorimetry	Fe[illegible]ld et al (197[illegible])
	b Q enzyme activity	Colorimerty	Fe[illegible]ld et al (197[illegible])

Table 4 Analytical methods followed in soil analysis

Characteristics studied	Method of estimation	Instrument used	Reference
pH	Direct reading	pH meter	Jackson (1973)
Organic carbon	Wilkley Black Rapid Titration	Titration	Jackson (1973)
Available P	Molybdenum blue method	Klett Summerson photo electric colorimeter	Jackson (1973)
Available K	Direct reading	Flame photometer	Jackson (1973)
Available Na	Direct reading	Flame photometer	Jackson (1973)
Available Ca (Exchangeable)	Direct reading	Atomic absorption spectro photometer	Jackson (1973)
Available Mg (Exchangeable)	Direct reading	Atomic absorption spectro photometer	Jackson (1973)
Cl	Silver nitrate precipitation	Titration	Iswaran (1980)
Water holding capacity	Keen Rackzowski method	Keen Rackzowski Box	Iswaran (1980)
Water stable aggregates	Yoder method	Yoder wet sieving machine	Black (1965)

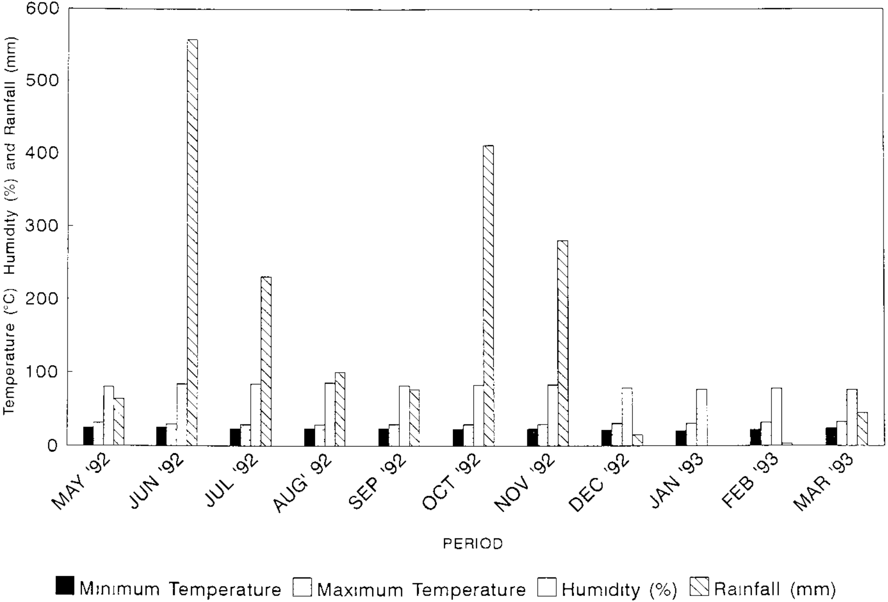


Fig. 1. Meteorological observations from May 1992 to March 1993

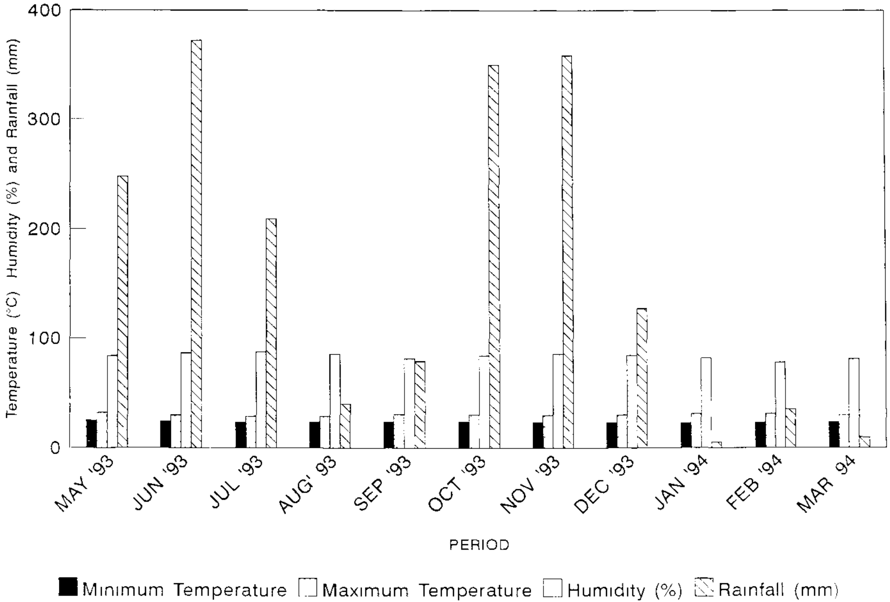
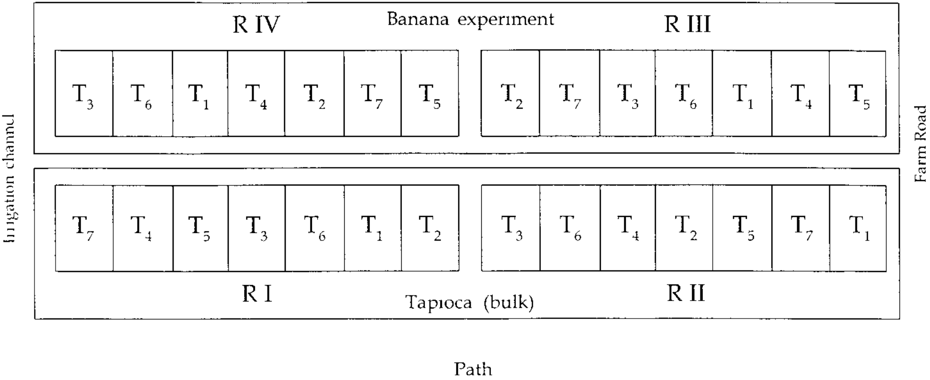


Fig. 2. Meteorological observations from May 1993 to March 1994

Fig. 3. Lay out plan of the experiment



RESULTS

RESULTS

Muriate of potash is the sole source of K used extensively. This is being imported in India. Hence a search for other indigenous cheap sources to substitute the costly MOP for potash loving crops like cassava became an area of high priority research. Such a study was conducted in the College of Agriculture during the period from 1991 to 1994 using M4 variety of cassava as test crop. The possibility and extent of replacement of MOP with common salt in cassava the main substitute of rice in Kerala was the aim of the investigation. The results obtained in the study are presented in this chapter. Field experiments were conducted from 1992 to 1994 in the Instructional Farm attached to the College of Agriculture, Vellayani. The physical and chemical properties of the soil of the experimental site are given in Table 1. The results presented in Tables 5-51 are mean values of four replications.

4.1 Growth Characteristics

4.1.1 Plant height

The mean plant height of treatment plants at different stages of growth is presented in Table 5. Plant height did not vary significantly at any of the growth stages. T_3 (50% MOP + 50% CS) recorded the highest value during the most of the growth stages. Reduction in plant height was observed at still higher substitution.

Table 5 Height of plant (cm) at different growth stages

Treatments	Plant height (cm)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	52.50	114.50	146.50	176.50	177.00
T_2) 75% MOP + 25% CS	37.25	117.00	167.75	180.50	192.00
T_3) 50% MOP + 50% CS	53.75	115.5	189.75	189.00	188.25
T_4) 25% MOP + 75% CS	48.00	103.50	126.50	192.30	182.00
T_5) 100% CS	42.50	105.00	109.00	163.00	154.25
T_6) 50% Woodash + 50%CS	42.75	108.25	137.00	187.30	160.00
T_7) 50% $KHCO_3$ + 50%$NaHCO_3$	41.00	104.25	147.00	138.30	139.00
CD	NS	NS	NS	NS	NS

4.1.2 Leaf characteristics

4.1.2.1 Number of functional leaves

Table 6 presents the data on number of functional leaves at different growth stages. There was no significant difference among treatments in the production of leaves upto 4 MAP. At 6 MAP the treatments were significantly different from one another. The treatment which received 50% MOP and 50% CS recorded the highest number of leaves. The lowest number was for the treatment which received full CS

At 8 MAP and harvest also the difference among treatments was not statistically significant. During most of the growth stages T_3 (50% MOP + 50% CS) retained comparatively higher number of leaves on the plant.

Table 6 Number of functional leaves at different growth stages

Treatments	Number of leaves				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	32	105	107	49	118
T_2) 75% MOP + 25% CS	28	107	84	46	82
T_3) 50% MOP + 50% CS	37	105	132	61	98
T_4) 25% MOP + 75% CS	31	63	59	60	76
T_5) 100% CS	29	71	36	41	78
T_6) 50% Woodash + 50%CS	36	68	91	40	111
T_7) 50% $KHCO_3$ + 50%$NaHCO_3$	25	53	86	41	68
CD	NS	NS	39 744	NS	NS

4 1 2 2 Weight of leaf lamina

Weight of leaf lamina (Table 7) was significantly different at tuber initiation (2 MAP) and at tuber filling stage (6 MAP) Maximum weight of leaf lamina was recorded by T_3 (50% CS + 50% MOP)

At all other stages treatment difference was not significant

Table 7 Weight of leaf lamina at different growth stages

Treatments	Weight of leaf lamina (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	18 97	20 70	26 25	10 15	14 44
T_2) 75% MOP + 25% CS	8 77	24 15	17 50	8 76	10 94
T_3) 50% MOP + 50% CS	20 91	31 48	38 94	8 58	11 38
T_4) 25% MOP + 75% CS	17 05	20 27	19 34	12 25	9 65
T_5) 100% CS	13 94	23 72	12 90	7 35	9 19
T_6) 50% Woodash + 50% CS	12 22	45 28	36 75	10 50	13 56
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	8 90	28 45	23 19	12 35	10 50
CD	7 302	NS	14 417	NS	NS

4.1.2.3 Weight of petiole

The treatments differed significantly at all stages except at 4MAP and harvest stages (Table 8). At tuber initiation and tuber filling stages the same trend as in weight of leaf lamina was seen followed with T_3 recording maximum weight.

Table 8. Weight of petiole at different growth stages

Treatments	Weight of petiole (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	1.82	3.71	5.12	1.81	1.48
T_2) 75% MOP + 25% CS	0.84	3.22	2.67	1.61	1.17
T_3) 50% MOP + 50% CS	2.01	3.84	5.55	1.98	1.38
T_4) 25% MOP + 75% CS	1.64	2.23	2.13	1.98	1.04
T_5) 100% CS	1.34	2.72	1.46	1.81	1.24
T_6) 50% Woodash + 50% CS	1.18	6.44	3.84	1.74	1.49
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	0.85	3.47	2.23	2.28	1.36
CD	0.701	NS	2.184	0.438	NS

Table 9. Leaf Area Index of the plants at different growth stages as affected by treatments

Treatments	Leaf Area Index				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	1.598	2.240	1.675	0.224	0.314
T_2) 75% MOP + 25% CS	0.984	2.111	1.354	0.227	0.233
T_3) 50% MOP + 50% CS	1.803	2.292	1.856	0.425	0.348
T_4) 25% MOP + 75% CS	1.314	1.452	0.848	0.336	0.243
T_5) 100% CS	1.290	1.640	0.348	0.126	0.152
T_6) 50% Woodash + 50% CS	1.100	1.576	1.268	0.506	0.332
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	0.756	1.398	1.033	0.289	0.217
CD	NS	NS	0.698	0.233	0.202

4.1.2.4 Leaf Area Index

The LAI as per Table 9 clearly followed the trend as that of the number of leaves in the early growth stage upto 6th month. At all stages of growth except at 8 MAP the treatment 50% MOP + 50% CS registered the maximum LAI. With increasing substitution of MOP by CS a general reduction in LAI was seen. At 2 MAP and 4 MAP the full CS treatment recorded the lowest LAI. At 8 MAP the treatment T_6 was found to register the largest leaf area.

After 6 MAP there was a drastic reduction in the LAI in all the treatments.

4.1.2.5 Chlorophyll content of leaves

The chlorophyll content of different treatments at different stages is presented in Table 10. At 4 MAP, 8 MAP and harvest stage there was significant variation among treatments. In all the treatments except T_6 and T_7 the chlorophyll content decreased after 6 month stage. In general there was an increase in chlorophyll content with NaCl substitution.

At 2 MAP the treatment T_1 (full potash) and T_3 (50% MOP + 50% CS) registered lower values than the other treatments. At 8MAP and harvest the highest value was exhibited by T_7 (50% $KHCO_3$ + 50% Na HCO_3). In all the growth stages except 2 MAP, T_1 (full potash) recorded the lowest content of chlorophyll.

4.1.2 Number of somata

As evident from the Table 11, there was significant variation in the number of stomata with Na application except at 4 MAP. There was an increase in the stomatal frequency with Na substitution. Highest frequency was observed in T_5 (full CS) at all stages. T_3 (50% CS + 50% MOP) and T_7 (50% $KHCO_3$ + 50% $NaHCO_3$) recorded almost same frequency of stomata per unit area at all major growth stages.

Table 10 Chlorophyll content of leaves at different growth stages

Treatments	Chlorophyll content of leaves (ppm)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	1.999	2.337	2.472	2.235	2.218
T_2) 75% MOP + 25% CS	2.111	2.990	2.541	2.305	2.301
T_3) 50% MOP + 50% CS	1.960	2.493	2.814	2.739	2.720
T_4) 25% MOP + 75% CS	2.103	3.256	2.874	2.789	2.759
T_5) 100% CS	2.321	2.689	2.634	2.485	2.412
T_6) 50% Woodash + 50% CS	2.325	2.676	2.723	2.836	2.807
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	2.078	2.336	2.702	2.841	2.818
CD	NS	0.326	NS	0.147	0.118

Table 11 Effect of NaCl substitution on number of stomata

Treatments	Number of stomata/microscopic field				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	25	39	30	30	30
T_2) 75% MOP + 25% CS	26	34	28	28	28
T_3) 50% MOP + 50% CS	21	37	36	31	31
T_4) 25% MOP + 75% CS	32	42	30	27	28
T_5) 100% CS	30	42	37	35	34
T_6) 50% Woodash + 50% CS	32	29	35	34	34
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	33	39	32	31	31
CD	1.604	NS	4.960	2.944	2.941

4.1.2.7 Size of stomata

This parameter showed significant variation with treatments (Table 12). At early growth stage (2 MAP) T_1 (full potash) recorded the largest size of stomata but showed drastic reduction with growth. The stomata from T_6 (Woodash + CS) were apparent with the largest size. This difference became prominent from 4 MAP onwards.

Table 12. Effect of NaCl substitution on size of stomata

Treatments	Size of stomata (area) (μm^2)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	396	224	178	176	160
T_2) 75% MOP + 25% CS	277	197	210	210	192
T_3) 50% MOP + 50% CS	215	155	191	200	168
T_4) 25% MOP + 75% CS	236	178	261	197	165
T_5) 100% CS	238	181	202	209	172
T_6) 50% Woodash + 50%CS	260	400	322	287	252
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	336	135	201	186	168
CD	69.221	32.206	63.658	42.489	38.131

4.1.2.8 Cuticle (Wax coating) thickness

Table 13 shows the values obtained in the above parameter in the different treatments. Cuticle (Wax coating) thickness did not vary significantly due to different treatments. During all the stages of growth except 6 MAP the full potash treatment (T_1) recorded the highest values. The treatments T_6 and T_7 consistently recorded lower values from 6 MAP onwards.

Table 13. Effect of NaCl substitution on cuticle thickness

Treatments	Cuticle (wax coating) thickness (µm)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	3.25	3.00	2.50	3.00	3.00
T_2) 75% MOP + 25% CS	2.75	2.00	2.75	2.75	2.75
T_3) 50% MOP + 50% CS	3.00	2.00	2.00	2.50	2.50
T_4) 25% MOP + 75% CS	3.00	2.00	2.50	2.50	2.50
T_5) 100% CS	2.00	2.25	2.75	2.50	2.50
T_6) 50% Woodash + 50% CS	2.25	2.00	2.25	[illegible]	[illegible]
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	3.00	3.00	2.00	2.25	2.25
CD	NS	NS	NS	NS	NS

4.1.2.9 Size of epidermal cell

Except at 2 MAP at all the other stages there was no significant variation in this parameter (Table 14). At all the stages the full potash treatment recorded the largest size of epidermal cells and 75% CS treatment (T_4) registered the smallest size. Since there was no statistically significant variation all the treatments were on a par as far as this parameter is concerned.

Table 14. Size of epidermal cell of leaves as affected by different treatments

Treatments	Size of epidermal cell (µm)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	7.50	7.00	7.00	7.00	7.00
T_2) 75% MOP + 25% CS	7.25	7.00	7.00	6.75	7.00
T_3) 50% MOP + 50% CS	6.75	5.50	6.00	6.75	6.75
T_4) 25% MOP + 75% CS	5.00	5.50	6.50	6.50	6.50
T_5) 100% CS	5.50	5.50	7.00	7.00	7.00
T_6) 50% Woodash + 50% CS	5.25	5.50	7.00	7.00	7.00
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	7.00	6.75	7.00	7.00	7.00
CD	1.560	NS	NS	NS	NS

4.1.2.10 Relative Water Content (RWC) of leaf tissues

RWC recorded at different growth stages is presented in Table 15. RWC reduced with growth in all the treatments.

Table 15. Relative water content of leaf tissues as affected by NaCl substitution

Treatments	Relative water content (%)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	73.05	70.01	62.17	54.84	55.00
T_2) 75% MOP + 25% CS	69.12	72.40	72.10	53.55	53.50
T_3) 50% MOP + 50% CS	74.48	71.28	70.25	60.40	62.55
T_4) 25% MCP + 75% CS	71.87	70.72	69.85	56.20	52.70
T_5) 100% CS	68.61	63.71	72.17	65.30	64.50
T_6) 50% Woodash + 50% CS	66.96	74.54	65.12	47.47	56.30
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	65.64	71.53	63.55	72.50	62.50
CD	NS	NS	NS	7.489	8.012

4.1.3 Weight of stem at different stages

Weight of stem (Table 16) did not vary significantly except at 2MAP The treatment which was given 50% MOP and 50% CS (T_3) had the highest weight at this stage followed by full MOP (T1) treatment At 6 MAP and 8 MAP also the treatment T_3 recorded the maximum weight

Table 16 Weight of stem at different growth stages as affected by treatments

Treatments	Weight of stem (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	69 45	138 89	375 00	418 05	479 16
T_2) 75% MOP + 25% CS	41 67	219 45	286 81	438 88	573 61
T_3) 50% MOP + 50% CS	77 50	170 84	456 94	451 11	434 72
T_4) 25% MOP + 75% CS	55 83	123 61	244 44	361 11	425 00
T_5) 100% CS	41 81	184 03	181 95	300 00	258 33
T_6) 50% Woodash + 50% CS	52 64	191 67	363 88	329 17	277 78
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	51 11	139 58	268 05	315 28	277 78
CD	13 352	NS	NS	NS	NS

4 1.4 Root characteristics

4 1 4 1 Number of roots/tubers

Efficiency of the various treatments in the production of roots/tubers is given in Table 17 In the early stages upto 6 MAP there was no significant variation in production of roots but at the later stages there was significant difference among the treatments From the tuber initiation stage till harvest the treatment T_3 (50% MOP + 50% CS) produced and maintained the maximum number of roots and tubers At all the growth stages except 2 MAP the treatment T_5 (full CS) produced the lowest number of roots and tubers

Table 17 Effect of NaCl substitution on number of roots/tubers

Treatments	Number of roots /tubers				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	26 00	9 00	9 75	9 75	9 50
T_2) 75% MOP + 25% CS	20 00	8 00	7 00	7 75	7 00
T_3) 50% MOP + 50% CS	30 00	10 00	10 00	12 25	13 00
T_4) 25% MCP + 75% CS	22 00	7 00	10 00	8 00	7 00
T_5) 100% CS	21 00	7 00	7 00	7 50	6 50
T_6) 50% Woodash + 50% CS	22 00	8 00	7 50	8 25	8 00
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	17 00	7 00	8 25	9 50	8 00
CD	NS	NS	NS	2 037	3 389

4 1 4 2 Root volume

Root volume recorded at 2MAP is given in Table 18 There was notable difference in the root volume at 2MAP The treatment T_3 (50% MOP + 50% CS) registered the highest root volume and this was significantly higher than all other treatments T_7 (50% $KHCO_3$ + 50% $NaHCO_3$) recorded the lowest volume

Table 18 Root Volume at 2 MAP as affected by different treatments

Treatment		Root volume (cc)
T_1)	100% MOP	47 75
T_2)	75% MOP + 25% CS	24 00
T_3)	50% MOP + 50% CS	76 25
T_4)	25% MCP + 75% CS	36 25
T_5)	100% CS	15 00
T_6)	50% Woodash + 50% CS	17 50
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	11 25
	CD	21 323

4 1 4 3 Weight of root/tuber

The weight of root/tuber at initial growth stages followed the same trend as that of root volume (Table 19)

Table 19 Weight of root/tuber as affected by different treatments

Treatments	Weight of root/tuber (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	22 95	431 33	681 75	919 75	931 50
T_2) 75% MOP + 25% CS	8 55	428 98	523 00	678 33	855 00
T_3) 50% MOP + 50% CS	35 36	428 35	705 90	932 10	1066 00
T_4) 25% MOP + 75% CS	16 39	407 45	758 35	809 10	754 00
T_5) 100% CS	6 56	446 40	554 40	769 65	468 00
T_6) 50% Woodash + 50% CS	7 84	548 80	812 18	770 60	565 50
T_7) 50% $KHCO_3$ + 50%$NaHCO_3$	5 20	327 94	681 86	737 56	631 13
CD	10 519	NS	203 177	184 51	331 992

At 6MAP T_6 recorded the highest tuber weight which was on a par with all the other treatments except T_5 and T_4. At 8MAP T_3 recorded the highest tuber weight which was on a par with all the treatments except T_2 and T_7. At the harvest stage T_3 recorded the highest tuber weight in the first experiment which was on a par with all the other treatmentsexcept T_5 (100 per cent substituion of K by Na).

4.1.5 Total biomass accumulation during different stages

Total biomass accumulation of different treatments from 2MAP upto harvest is presented in Table 20. There was significant variation among treatments at all stages. At 2MAP T_3 recorded the highest total biomass which was on a par with T_1. All the other treatments recorded lower values at this stage. At 8 MAP and Harvest stages also T_3 recorded the highest biomass. T_3 was on a par with T_1, T_2, T_3 and T_4 ie complete K and substitution of K upto 75 per cent by Na.

At 4MAP and 6 MAP the ash + CS treatment (T_6) was found to give the highest weight. During most of the major growth stages the treatment which received full CS recorded the lowest weight. In general there was an increase in total weight of plant with NaCl substitution upto 50% and thereafter a decrease with higher levels of substitution at all growth stages.

4.1.6 Crop Growth Rate (CGR)

Table 21 indicates the CGR at different growth stages. Significant difference in CGR could be noticed at all stages. CGR (planting to harvest) was highest in 50% CS+50% MOP treatment. The lowest rate was observed in T_5 (full CS).

Table 20 Effect of NaCl substitution on weight of plants

Treatments	Weight of plant (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	113 18	594 63	1088 12	1354 76	1426 58
T_2) 75% MOP + 25% CS	59 83	675 80	804 98	1127 58	1440 98
T_3) 50% MOP + 50% CS	135 78	634 49	1207 33	1393 77	1513 48
T_4) 25% MOP + 75% CS	90 90	553 56	1024 26	1184 44	1189 66
T_5) 100% CS	63 65	663 63	750 58	1078 81	736 76
T_6) 50% Woodash + 50% CS	74 12	792 19	1216 65	1112 00	858 33
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	66 06	499 45	975 34	1067 47	892 96
CD	25 452	244 016	323 318	252 168	480 467

Table 21 Crop Growth Rate (CGR) as affected by different treatments

Treatment	CGR upto 2 MAP	CGR 2 MAP 4 MAP	CGR 4MAP 6MAP	CGR 6MAP 8MAP	CGR 8MAP Harvest	CGR Planting Harvest
T_1) 100% MOP	1.89	8.03	8.23	4.44	1.26	5.28
T_2) 75% MOP + 25% CS	2.00	10.27	3.09	5.37	5.22	5.34
T_3) 50% MOP + 50% CS	2.26	8.31	9.54	3.11	2.04	5.61
T_4) 25% MOP + 75% CS	1.52	7.71	7.85	3.60	2.42	4.41
T_5) 100% CS	1.06	9.98	1.46	3.78	0.18	2.73
T_6) 50% Woodash + 50% CS	1.23	11.97	8.81	2.28	0.13	3.18
T_7) 50% $KHCO_3$ + 50% NaHCO	1.10	7.22	7.93	3.27	0.00	3.31
CD	0.425	4.136	6.292	5.156	3.728	1.780

Table 22 Length and girth of tubers at different growth stages as affected by treatments

Treatment		4MAP		6MAP		8MAP		Harvest	
		Length	Girth	Length	Girth	Length	Girth	Length	Girth
T_1)	100% MOP	25 10	6 28	28 70	9 38	26 15	9 00	34	10 85
T_2)	75% MOP + 25% CS	27 28	6 25	27 05	9 48	23 30	9 33	29 50	11 28
T_3)	50% MOP + 50% CS	24 50	6 60	26 15	8 68	26 85	9 73	33 75	11 03
T_4)	25% MCP + 75% CS	22 15	5 97	27 65	8 28	25 27	9 25	25 75	9 80
T_5)	100% CS	25 38	7 17	26 20	7 05	22 85	10 20	24 75	8 52
T_6)	50% Woodash + 50% CS	26 80	6 68	31 48	8 92	27 33	10 55	36 25	13 70
T)	50% $KHCO_3$ + 50% NaHCO	29 73	7 10	27 63	8 68	23 20	8 63	27 00	1 77
	CD	NS	NS	NS	0 901	NS	1 028	5 596	0 720

4.2 Yield parameters

4.2.1 Length of tubers

Length of tubers (Table 22) varied significantly only at the harvest stage. However T_6 (woodash + CS) produced the longest tubers in most of the growth stages.

4.2.2 Girth of tubers

Average girth of tubers obtained in various treatments at different growth stages are presented in Table 22. This parameter showed significant variation among treatments from 6 MAP onwards. At 8 MAP and harvest T_6 (Woodash + 50% CS) registered the highest values.

4.2.3 Tuber yield

First year 1992-1993

Significant treatment effect could be observed in tuber yield during the first year (Table 23) of the experiment. Highest yield was recorded by the treatment in which 50% MOP and 50% CS (T_3) were given. T_5 registered the lowest yield.

Second year 1993-1994

Significant difference in tuber yield could be observed in the second year also (Table 23). Here also T_3 registered the highest weight of tubers and T_5 the lowest. In the second year the yield observed in T_1 (100% MOP) and T_5 (100% CS) were almost similar. In all other treatments where both the nutrients were supplied the tuber yield was more than when single nutrient alone was supplied.

Pooled mean yield

Table 23 shows the pooled mean yield of tubers from the two experiments T$_3$ was superior to all others and was significantly different from others

Table 23 Tuber yield in the first year and second year as affected by NaCl substitution

Treatment	Tuber yield (tons/ha) I year (1992 93)	Tuber yield (tons/ha) II year (1993 94)	Pooled mean
T$_1$) 100% MOP	21 91	16 70	19 30
T$_2$) 75% MOP + 25% CS	19 05	20 30	19 70
T$_3$) 50% MOP + 50% CS	26 04	24 50	25 30
T$_4$) 25% MOP + 75% CS	18 42	17 90	18 20
T$_5$) 100% CS	11 43	15 30	13 40
T$_6$) 50% Woodash + 50% CS	13 81	18 30	16 10
T$_7$) 50% $KHCO_3$ + 50% $NaHCO_3$	16 19	17 80	17 00
CD (0 05)	7 873	6 558	3 443

4.2.4 Bulking Rate (BR)

Bulking Rate day ^{1} is presented in Table 24 There was significant difference between treatments at all stages A significantly higher BR was registered by T_3 (50% MOP + 50% CS) at 2 MAP Tuber formation was started in T_3 alone at 2MAP The lowest BR was exhibited by T_5 (full CS) During 2 4 months stage, the rate was significantly higher for T_6 where ash in combination with commonsalt was applied When the period from planting to harvest was considered the rate was highest in T_3 but was on a par with T_1 (full potash) T_2 (75% potash) and T_4 (25% potash)

Table 24 Bulking rate of the plants at different stages as affected by different treatments

Treatment	BR up up to 2MAP (g day ^{1})	BR 2MAP 4MAP (g day ^{1})	BR Planting Harvest (g day ^{1})
T_1) 100% MOP	0 71	12 60	6 39
T_2) 75% MOP + 25% CS	0 25	12 29	5 55
T_3) 50% MOP + 50% CS	1 14	12 59	7 60
T_4) 25% MCP + 75% CS	0 47	11 24	5 37
T_5) 100% CS	0 17	11 45	3 33
T_6) 50% Woodash + 50% CS	0 27	18 40	4 03
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	0 18	10 87	4 72
CD	0 330	4 961	2 298

4.2 5 Utilisation Index (UI)

The table 25 reveals that the UI is affected by different treatments The treatments varied significantly in the UI T_3 (50% CS + 50% MOP) registered the highest UI and T_2 (25% MOP) the lowest

Table 25 Utilisation index as affected by treatments

Treatment		Utilization index
T_1)	100% MOP	2 02
T_2)	75% MOP + 25% CS	1 45
T_3)	50% MOP + 50% CS	2 40
T_4)	25% MOP + 75% CS	1 85
T_5)	100% CS	1 99
T_6)	50% Woodash + 50% CS	1 91
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	2 29
	CD	0 922

4.3 Quality of tubers

4 3 1 Cooking quality

Table 26 presents scores obtained for different treatments

Table 26 Cooking quality of tuber as affected by NaCl substitution

Treatment		Score obtained for sweetness	Texture	Overall acceptability
T_1)	100% MOP	3	soft [illegible]	good
T_2)	75% MOP + 25% CS	2 8	powdery	not satisfactory
T_3)	50% MOP + 50% CS	3	soft [illegible]	good
T_4)	25% MCP + 75% CS	3 4	slightly hard	not satisfactory
T_5)	100% CS	4	hard	not satisfactory
T_6)	50% Woodash + 50% CS	2 8	powdery	not satisfactory
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	3 4	slightly hard	not satisfactory

The maximum score of 4 (sweet) was obtained by the tubers from the treatment which received full CS But when cooked this became hard Next highest score was recorded by the treatments T_4 (25% MOP + 75% CS) and T_7 (50% $KHCO_3$ + 50% $NaHCO_3$) T_6 (50% woodash + 50% CS) recorded the lowest score

Upto 50% substitution by CS, texture was good and comparable with that of T_1 but at higher substitutions the tubers were sweeter but became hard when cooked

4.3.2 Starch and Sugars

Table 27 illustrates the average content of starch starch fractions and sugar fractions obtained as a result of NaCl substitution

Table 27 Effect of NaCl substitution on the starch and sugar content of tubers

Treatment		Starch content %	Amylose in starch %	Amylopectin in starch %	Total sugars %	Reducing sugars %	Sucrose content %
T_1)	100% MOP	28.90	29.15	51.60	1.74	1.39	0.36
T_2)	75% MOP + 25% CS	28.33	28.38	52.18	2.06	1.45	0.61
T_3)	50% MOP + 50% CS	28.95	29.59	51.88	2.27	1.35	0.92
T_4)	25% MOP + 75% CS	27.55	27.06	51.37	2.31	1.02	1.29
T_5)	100% CS	27.15	27.61	52.77	2.60	1.49	1.12
T_6)	50% Woodash + 50% CS	26.75	27.94	52.90	2.39	1.40	0.99
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	28.45	28.71	50.12	2.25	1.15	1.13
	CD (0.05%)	NS	0.896	0.148	0.182	0.099	0.154

Starch content did not show any significant variation as a result of substitution The highest content was shown by T_3 (50% MOP + 50% CS) and the lowest by T_6 (50% woodash + 50% CS)

Starch fractions (amylose and amyto pectin) showed significant variation due to treatment effect Amylose was significantly higher in full CS treatment (T_5) whereas amylopectin was highest in T_6 (50% wood ash + 50% CS)

Significant differences were observed in total sugars reducing sugars and sucrose content of fresh tubers under different treatments Total sugar content was lowest in the tubers of full potash treatment With increasing levels of substitution with CS, the content of total sugars increased and the value was highest in the treatment where full substitution of MOP by CS was effected Reducing sugar content was also highest in T_5 (full CS)

Sucrose content was found to increase with Na application upto 75% substitution of K by Na (T_4)

4.3.3 Proteins and aminoacids

Crude protein content (Table 28) varied significantly as a result of Na substitution The highest content was observed in the treatment T_6 (50% wood ash + 50% CS)

There was significant variation in the total and free amino acid content of various treatments Total amino acids content increased with increase in Na substitution upto 75% but free amino acid content increased with all levels of substitution Total and Free aminoacids were found to be highest in T_6

Table 28 Effect of NaCl substitution on the proteincontent and amino acid content of tubers

Treatment	Crude Protein content %	Total amino acid (% leucine equivalent)	Free amino acids (ppm leucine equivalent)
T_1) 100% MOP	2 56	11 32	31 18
T_2) 75% MOP + 25% CS	1 80	12 32	31 12
T_3) 50% MOP + 50% CS	2 06	12 22	33 38
T_4) 25% MCP + 75% CS	2 33	17 69	35 00
T_5) 100% CS	1 92	12 11	71 16
T_6) 50% Woodash + 50% CS	3 21	29 45	85 96
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	3 15	12 23	45 20
CD	0 261	5 166	18 312

4.3.4 Hydrocyanic acid content (HCN content)

There was significant variation among treatments in HCN content of fresh tubers (Table 29) The treatment T_5 (full CS) registered the highest and T_3 (50% MOP + 50% CS) the lowest values The treatment with 75% MOP + 25% CS or vice versa recorded almost equal HCN content in fresh tubers

Table 29 Hydrocyanic acid content of tubers as affected by different treatments

Treatment		HCN content (µg/g)
T_1)	100% MOP	7 35
T_2)	75% MOP + 25% CS	8 00
T_3)	50% MOP + 50% CS	6 75
T_4)	25% MOP + 75% CS	8 40
T_5)	100% CS	17 10
T_6)	50% Woodash + 50% CS	8 55
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	9 15
	CD	5 010

4.3 5 Total phenols

The treatments differed significantly in total phenol content Total phenol content increased as a result of Na substitution With 75% substitution the highest value was obtained (Table 30)

4 3 6 Crude fibre

There was significant difference in the crude fibre content (Table 31) The wood ash + CS (T_6) treatment registered the highest content of crude fibre in tuber

Table 30. Total phenols in the flesh of tubers as affected by treatments

Treatment		Total phenols (ppm catechol equivalent)
T_1)	100% MOP	7.79
T_2)	75% MOP + 25% CS	7.88
T_3)	50% MOP + 50% CS	7.81
T_4)	25% MOP + 75% CS	8.09
T_5)	100% CS	7.21
T_6)	50% Woodash + 50% CS	8.06
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	7.28
	CD	0.523

Table 31. Effect of NaCl substitution on the crude fibre of tubers

Treatment		Crude fibre content (%)
T_1)	100% MOP	2.53
T_2)	75% MOP + 25% CS	2.84
T_3)	50% MOP + 50% CS	2.64
T_4)	25% MOP + 75% CS	2.78
T_5)	100% CS	2.58
T_6)	50% Woodash + 50% CS	3.55
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	2.53
	CD	0.161

4 3.7 Viscosity of the starch solution

The viscosity of the starch solution from the different treatments was found to vary (Table 32) The starch solution from T_4 (75% Na substitution) was the most viscous followed by T_6 (wood ash + CS) The lowest value was exhibited by T_5 (full CS)

Table 32 Viscosity of starch solution as affected by NaCl substitution

Treatment		Viscosity (NS m 2)
T_1)	100% MOP	10 23
T_2)	75% MOP + 25% CS	10 48
T_3)	50% MOP + 50% CS	10 22
T_4)	25% MOP + 75% CS	10 70
T_5)	100% CS	9 90
T_6)	50% Woodash+50% CS	10 55
T_7)	50% $KHCO_3$+ 50% $NaHCO_3$	10 11
	CD	0 340

Table 33 Mineral content of tubers from different treatments

Treatment		N %	P %	K %	Na %	Ca %	Mg %
T_1)	100% MOP	0 41	0 08	0 40	0 020	0 03	0 037
T_2)	75% MOP + 25% CS	0 29	0 09	0 58	0 020	0 01	0 043
T_3)	50% MOP + 50% CS	0 27	0 09	0 55	0 020	0 03	0 041
T_4)	25% MOP + 75% CS	0 37	0 08	0 26	0 018	0 04	0 032
T_5)	100% CS	0 31	0 07	0 38	0 030	0 02	0 041
T_6)	50% Woodash + 50% CS	0 51	0 08	0 36	0 020	0 01	0 042
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	0 52	0 08	0 30	0 020	0 01	0 039
	CD	0 041	NS	0 048	0 002	0 003	0 001

4.3.8 Mineral content of tubers

The mineral content of tubers from different plots is presented in Table 33 Tubers from plots which were treated with 50% MOP and 50% CS generally registered higher mineral content except N

4 3 9 Shelf life of tubers (Keeping quality of tubers)

From a preliminary study conducted in shelf life of tubers it was observed that the tubers from all other treatments except T_1 and T_3 perished and could not be used for cooking by 6th day when stored in moist soil Tubers from T_1 and T_3, therefore were subject for detailed study n both the experiments Tubers from T_1 could be kept for 12 days without deterioration and tubers from T_3 could be stored upto 35th day without affecting cooking quality

The total phenols and HCN content of the rind and flesh of tubers from T_3 and T_4 were analysed and presented in Table 34 In T_3 the total phenols and HCN content were more in rind whereas in tubers from T_1 they were more in flesh

4.4 Enzyme activity

4 4 1 Starch synthesising enzymes activity

Significant difference was noticed among treatments in the activity of phosphorylase and Q enzyme (Table 35)

The maximum phosphorylase activity was shown by the treatment T_3 (50% MOP + 50% CS) and Q enzyme activity by T_6

Table 34 HCN content and total phenols in the rind and flesh of tubers from different treatments

		HCN µg/g			Total phenols ppm catechol equivalent		
		10th day after harvest	12th day after harvest	15th day after harvest	10th day after harvest	12th day after harvest	15th day after harvest
T_1	Rind	19 1	20 3	25 5	8 57	9 03	13 81
	Flesh	17 5	18 2	19 3	14 08	16 34	25 41
T_3	Rind	18 6	21 6	20 8	27 45	32 13	26 63
	Flesh	9 6	10 8	11 8	8 04	8 16	7 13

Table 35 Activity of starch synthesising enzymes as affected by NaCl substitution

Treatment	Phosphorylase acivity (units)	Q enzyme activity (%Δ660)
T_1) 100% MOP	10 10	0 099
T_2) 75% MOP + 25% CS	10 38	0 101
T_3) 50% MOP + 50% CS	11 63	0 101
T_4) 25% MCP + 75% CS	9 63	0 101
T_5) 100% CS	6 08	0 095
T_6) 50% Woodash + 50% CS	5 38	0 108
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	7 70	0 098
C D	1 047	0 004

4.4.2 Nitrate Reductase Activity (NRA)

NRA at 6MAP as affected by different treatments is given in Table 36

There was no significant variation in NRA at 6 MAP due to substitution with Na The highest activity was recorded by the 50% CS + 50% MOP treatment (T_3)

Table 36 Nitrate Reductase Activity (at 6MAP) as affected by NaCl substitution

Treatment		Nitrate Reductase Activity $NO_2\ g^{-1}h^{-1}$
T_1)	100% MOP	0 00290
T_2)	75% MOP + 25% CS	0 00298
T_3)	50% MOP + 50% CS	0 00305
T_4)	25% MCP + 75% CS	0 0029
T_5)	100% CS	0 00285
T_6)	50% Woodash + 50% CS	0 00285
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	0 00290
	CD	NS

4.5 Uptake of nutrients as affected by Na and K

4.5.1 Nitrogen

Uptake of nitrogen at different growth stages is given in Table 37 In all the treatments, the N uptake followed a definite pattern Upto 6 months in all the treatments the uptake showed an increasing trend and thereafter a decrease The decline in uptake was more conspicuous in T_3 than the other treatments At 2 MAP 6 MAP and harvest stage there was significant variation among treatments in N uptake At 2 MAP and 6 MAP the 50% CS + 50% MOP treatment recorded the highest uptake of N But at harvest stage the treatment T_1 (full potash) showed the highest uptake

Table 37 Nitrogen uptake as affected by different treatments

Treatment		Nitrogen (kg ha ^{1})				
		2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	17 08	33 90	77 36	59 73	60 94
T_2)	75% MOP + 25% CS	11 13	48 89	58 81	54 60	45 74
T_3)	50% MOP + 50% CS	18 85	42 30	102 42	49 65	37 01
T_4)	25% MOP + 75% CS	14 95	37 39	69 25	50 53	34 93
T_5)	100% CS	10 20	43 32	66 48	53 58	23 97
T_6)	50% Woodash + 50%CS	8 86	57 10	89 36	54 04	30 50
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	11 20	33 18	77 25	49 54	36 93
	CD	4 162	NS	22 39	NS	28 399

4.5.2 Phosphorus

As clear from the table 38, the P uptake also increased upto 6MAP and thereafter decreased Treatment differences were significant only at 2MAP During most of the growth stages, the highest uptake was shown by T_3 (50% CS + 50% MOP) and the lowest by T_5 (full CS)

4.5.3 Potassium

K uptake (Table 39) was also found to increase upto 6MAP and decrease thereafter Except at 4 and 6 MAP at all other stages there was significant variation among treatments in K uptake At all stages the highest uptake was shown by T_3 (50% CS + 50% MOP) At later stages of growth, Na substitution above 50% or substitution with alternate sources (T_6 and T_7) did not favour K uptake

4.5.4 Sodium

Na uptake (Table 40) also showed the same pattern as that of K Upto 6 months, the uptake was in an ascending order and after that in a descending order Only at 2 MAP, Na uptake varied significantly between treatments The uptake by T_3 at 2 MAP was significantly higher than all other treatments Na uptake by T_1 which received no Na was generally higher than other treatments receiving Na, especially at later stages of growth

Table 38 Phosphorus uptake as affected by different treatments

Treatment		Phosphorus (kg ha 1)				
		2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	1 92	4 36	8 87	8 65	6 27
T_2)	75% MOP + 25% CS	0 61	5 47	7 29	6 32	6 61
T_3)	50% MOP + 50% CS	1 82	5 19	11 14	9 55	7 02
T_4)	25% MOP + 75% CS	1 11	4 65	8 70	7 77	5 00
T_5)	100% CS	0 65	4 84	6 60	7 53	3 09
T_6)	50% Woodash + 50%CS	0 71	5 80	10 40	6 62	4 03
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	0 92	3 75	8 14	7 15	4 36
	CD	0 361	NS	NS	NS	NS

Table 39 Potassium uptake (kg ha[1]) as affected by different treatments

Treatment	Potassium (kg ha[1])				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	12 44	11 03	46 66	35 35	28 45
T_2) 75% MOP + 25% CS	4 40	18 25	38 00	35 77	38 53
T_3) 50% MOP + 50% CS	12 14	16 49	48 36	37 54	38 76
T_4) 25% MOP + 75% CS	6 44	10 05	29 76	24 33	14 13
T_5) 100% CS	4 06	11 88	18 58	21 96	14 57
T_6) 50% Woodash + 50%CS	3 84	23 34	46 56	31 49	15 95
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	2 79	10 54	30 56	20 82	14 37
CD	2 438	NS	NS	10 188	17 501

Table 40 Sodium uptake as affected by different treatments

Treatment		Sodium (kg ha^{-1})				
		2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	0 48	2 17	2 76	2 70	1 45
T_2)	75% MOP + 25% CS	0 24	2 47	1 96	1 81	1 42
T_3)	50% MOP + 50% CS	1 00	1 68	2 75	2 38	1 65
T_4)	25% MOP + 75% CS	0 63	1 49	3 87	2 92	1 14
T_5)	100% CS	0 62	2 11	2 56	2 40	1 09
T_6)	50% Woodash + 50%CS	0 45	1 94	3 69	2 03	0 98
T_7)	50% $KHCO_3$ + 50%$NaHCO_3$	0 34	1 75	2 82	1 99	1 04
	CD	0 292	NS	NS	NS	NS

4.5.5 Calcium

The treatment differences (Table 41) were significant at all stages except at 4 MAP At 2MAP the maximum uptake was by T_1 (full potash) but on a par with T_3 (50% CS) At the tuber filling stage T_3 recorded the highest uptake which was significantly superior to all others Higher degrees of substitution than 50% were found to lessen the uptake of Ca The treatment T_7 ($NaHCO_3$ + $KHCO_3$) had the lowest uptake at all growth stages

4.5.6 Magnesium

Effect of treatments on the Mg uptake is presented in Table 42 Upto 6 MAP the Mg uptake showed an increasing trend But at harvest this was reduced to almost half the values obtained at 8MAP Except at 4 MAP at all other stages the treatment differences were statistically significant The highest uptake at harvest was by T_3 (50% CS + 50% MOP) and the lowest by T_5 (full CS) treatment

4.6

4.6.1 Soil pH

Table 43 shows the changes in pH of the experimental plots with the application of treatments pH differences in the plots were not significant in the initial growth stages At 4 MAP a gradual increase in pH was observed with 75% and 100% substitution of Na

Table 41 Calcium uptake as affected by different treatments

Treatment	Calcium (kg ha ^{1})				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	0 53	4 63	4 41	6 51	6 41
T_2) 75% MOP + 25% CS	0 24	5 23	13 28	5 60	5 00
T_3) 50% MOP + 50% CS	0 51	4 40	17 23	5 80	5 32
T_4) 25% MOP + 75% CS	0 32	2 48	5 06	2 33	3 80
T_5) 100% CS	0 24	4 96	1 59	2 11	2 62
T_6) 50% Woodash + 50%CS	0 22	5 65	5 48	3 13	1 99
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	0 21	3 92	2 74	1 10	1 46
CD	0 113	NS	2 264	1 633	1 961

Table 42 Magnesium uptake (kg ha ^{1}) as affected by different treatments

Treatment		Magnesium (kg ha ^{1})				
		2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	1 59	5 26	9 38	9 46	4 58
T_2)	75% MOP + 25% CS	0 57	5 40	7 94	13 46	5 29
T_3)	50% MOP + 50% CS	1 34	5 40	18 39	9 04	5 91
T_4)	25% MOP + 75% CS	1 02	5 16	7 23	6 25	4 21
T_5)	100% CS	0 71	4 81	4 05	5 92	2 93
T_6)	50% Woodash + 50%CS	0 63	6 75	11 86	6 60	3 32
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	0 38	5 82	11 02	7 08	3 37
	CD	0 311	NS	3 276	2 218	1 670

Table 43 Soil pH as affected by NaCl substitution

Treatment		pH					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	4 35	4 68	4 98	4 93	4 90	5 08
T_2)	75% MOP + 25% CS	4 40	4 45	4 79	5 18	5 00	5 19
T_3)	50% MOP + 50% CS	4 45	4 50	5 09	5 11	5 00	5 14
T_4)	25% MOP + 75% CS	4 60	4 60	5 23	5 06	5 00	5 19
T_5)	100% CS	4 65	4 78	5 34	5 08	5 04	5 25
T_6)	50% Woodash + 50% CS	4 68	4 70	4 90	4 93	4 90	5 10
T_7)	50% $KHCO_3$+ 50% $NaHCO_3$	4 68	4 63	4 98	5 16	5 00	5 26
	CD	NS	NS	0 084	0 050	0 060	0 071

4.6.2 Water Holding Capacity (WHC)

The WHC of the plots (Table 44) differed significantly with the application of treatments At 2 MAP in all the sodium treated plots the WHC increased and in the full potash treated plot it decreased when compared to initial values At 6 MAP all the treatments except T_5 (100% CS) were on a par

4.6.3 Organic carbon

The organic carbon status (Table 45) differed significantly due to treatments at all stages Initially the plots were having medium status of organic carbon

A significant increase in T_6 (wood ash treatment) was observed at 2 MAP At 4 MAP, a sharp decrease was noticed in all the plots But at 6 MAP it again increased in all the treatments At harvest stage, the highest value was recorded by T_6 (wood ash) and lowest by T_1 (full potash)

4.6.4 Available phosphorus

The initial P status of the experimental site was low Treatments differed significantly in the available P content (Table 46) Initially at 2 MAP, there was a sharp rise in the available P status in all the plots with the application of phosphatic fertilizer After 6 months stage there was a gradual decline in all the treatments At harvest all the treatments above 50% substitution with Na and substitution with alternate sources generally registered lower values of available P in soil T_2 (25% Na) had the highest content of available P in soil at harvest

Table 44 Water holding capacity of soil as affected by NaCl substitution

Treatment		WHC %					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	47 00	28 59	37 54	44 31	29 85	39 66
T_2)	75% MOP + 25% CS	46 40	50 00	38 48	45 42	34 65	40 35
T_3)	50% MOP + 50% CS	44 40	47 88	39 83	44 23	31 29	37 66
T_4)	25% MOP + 75% CS	45 90	37 42	40 66	43 09	29 24	35 41
T_5)	100% CS	43 70	45 19	36 14	32 77	27 81	40 93
T_6)	50% Woodash + 50% CS	46 00	47 53	43 75	44 55	31 63	43 14
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	46 40	48 21	44 43	44 30	32 72	40 98
	CD	NS	2 792	2 642	3 065	2 116	1 574

Table 45 Soil organic carbon as affected by NaCl substitution

Treatments		Organic Carbon					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	0 65	0 94	0 65	0 62	0 57	0 64
T_2)	75% MOP + 25% CS	0 68	0 97	0 56	0 78	0 70	0 78
T_3)	50% MOP + 50% CS	0 67	0 95	0 53	0 80	0 52	0 66
T_4)	25% MOP + 75% CS	0 70	0 90	0 51	0 66	0 75	0 77
T_5)	100% CS	0 61	0 80	0 50	0 89	0 82	0 91
T_6)	50% Woodash + 50% CS	0 72	1 25	0 48	0 88	0 81	0 92
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	0 71	0 72	0 60	0 90	0 85	0 87
	CD	NS	0 135	0 065	0 092	0 059	0 069

Table 46 Available P as affected by treatments

Treatments		Available P (kg/ha ^{1})					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	14 6	27 38	27 92	36 8	33 68	33 12
T_2)	75% MOP + 25% CS	14 4	26 08	25 60	33 0	34 08	33 36
T_3)	50% MOP + 50% CS	16 1	28 08	27 44	33 8	31 76	28 00
T_4)	25% MOP + 75% CS	16 2	24 96	26 90	36 6	34 16	26 32
T_5)	100% CS	16 8	25 37	30 24	32 6	36 48	18 56
T_6)	50% Woodash + 50%CS	17 8	20 00	25 20	36 1	31 44	19 52
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	17 0	23 12	24 96	24 5	22 64	27 36
	CD	1 286	1 687	1 737	1 756	2 541	2 840

4.6.5 Available potassium

Changes in available potassium with the application of different treatments are presented in Table 47 At 2 MAP there was an increase in available K status of soils in all the treatments except T_5 (full Na) The variation among treatments was significant in all the stages of growth Towards the later stages of growth in all the Na treated plots, the available K status decreased The full CS treated plots registered the lowest value and the full MOP treated plots, the highest value But even at the highest content of K in T_1 the status was low in soil

4.6.6 Available sodium

There was significant difference among treatments in the available Na status of soil at all stages (Table 48) There was an increase in the available Na content with the application of treatments at 2 MAP At 2 MAP, the treatment T_2 (25% Na) registered the highest and T_1 (full potash) the lowest values At 4 MAP there was a decrease in the content in all the treatments except T_5 (full CS) where it continued to rise At 6 MAP the status was lower than at 4 MAP in all the plots At 8 MAP, the status was slightly improved in all the treatments but at harvest it again came down After the crop, at harvest a status lower than the initial was recorded from all the plots

4.6 7 Cation - Anion ratio (C-A ratio)

C-A ratio (K + Na to Cl ratio) in soil (Table 49) was found to increase level and then decrease during the different stages of growth

Table 47 Available K as affected by treatments

Treatments		Available K (kg/ha [1])					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	89 40	92 30	128 70	113 30	108 90	111 10
T_2)	75% MOP + 25% CS	67 70	108 35	138 60	127 60	119 90	105 60
T_3)	50% MOP + 50% CS	81 20	110 95	103 95	70 95	94 05	90 00
T_4)	25% MOP + 75% CS	73 20	84 15	90 75	76 45	68 75	67 10
T_5)	100% CS	73 20	44 00	70 95	45 65	52 25	59 95
T_6)	50% Woodash + 50% CS	59 60	81 40	106 15	95 15	61 45	86 90
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	55 30	97 90	79 20	67 10	67 65	66 50
	CD	NS	19 641	21 756	12 674	9 597	9 744

Table 48 Available Na of soil as affected by NaCl substitution

Treatments		Available Na (kg/ha ^{1})					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	64 90	72 05	46 20	25 30	23 10	22 55
T_2)	75% MOP + 25% CS	85 80	104 50	64 90	26 95	36 30	30 25
T_3)	50% MOP + 50% CS	71 50	72 05	48 40	38 50	41 25	31 35
T_4)	25% MOP + 75% CS	62 20	85 80	53 90	41 25	42 90	36 85
T_5)	100% CS	61 60	78 10	91 30	63 25	79 20	48 40
T_6)	50% Woodash + 50% CS	57 20	65 45	70 40	63 80	50 05	24 75
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	74 10	80 85	63 80	56 10	46 20	35 20
	CD	NS	19 272	4 872	7 377	10 576	5 005

Table 49 Cation (Na + K) - anion (Cl) ratio of soil as affected by NaCl substitution

Treatments		C-A ratio					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	1 89	2 01	2 14	1 70	1 62	1 64
T_2)	75% MOP + 25% CS	1 88	2 61	2 49	1 89	1 91	1 66
T_3)	50% MOP + 50% CS	1 87	2 24	1 87	1 34	1 66	1 48
T_4)	25% MOP + 75% CS	1 66	2 08	1 77	1 44	1 37	1 27
T_5)	100% CS	1 65	1 50	1 99	1 33	1 61	1 33
T_6)	50% Woodash + 50% CS	1 43	1 80	2 16	1 95	1 37	1 37
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	1 59	2 19	1 75	1 51	1 40	1 25
	CD	0 380	0 290	0 302	0 163	0 130	0 138

This ratio was varying significantly among treatments at all stages Except at 6 MAP, at all other stages, the highest C-A ratio was shown by T_2 (75% MOP) The treatments T_1 (full potash) and T_2 (75% MOP) maintained comparatively higher values than the other treatments at all stages

4.6.8 Available calcium

Changes in available calcium (Table 50) was significant from 4 MAP onwards Upto 4 MAP the available Ca status in all the plots increased irrespective of treatments At 6 MAP in T_1 (full K) T_2 (75% K), T_5 (full Na) and in T_7 ($KHCO_3$ + $NaHCO_3$) the status kept on increasing At 8 MAP and harvest, the highest available Ca status was seen in T_7 ($KHCO_3$ + Na HCO_3)

4.6.9 Available Magnesium

At all stages of growth the difference in available magnesium status was statistically significant (Table 51) At 2 MAP, in all the plots the status increased At 6 MAP and 8 MAP the available status increased than at 4MAP in all the treatments At harvest the status in T_5 (full CS) T_6 (wood ash + CS) and T_4 (25% K) decreased and in all others it increased

Correlation between the various factors :

1 The relationship between yield and uptake of nutrients at harvest Table 52)

Yield of tubers was positively and significantly related to the uptake of N, P, K, Na, Ca and Mg These correlations were significant at 1% level A significant positive correlation ($r = 0\ 8728^{**}$) was obtained between uptake of K and Na No significant correlation was obtained between Cl uptake and yield

Table 50 Available Ca of soils as affected by treatments

Treatments		Available Ca (ppm)					
		Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1)	100% MOP	25 75	32 25	31 00	52 25	53 75	60 75
T_2)	75% MOP + 25% CS	29 00	34 50	45 75	66 50	61 25	61 00
T_3)	50% MOP + 50% CS	26 25	40 50	69 50	48 25	45 50	53 00
T_4)	25% MOP + 75% CS	31 75	37 75	51 00	38 75	43 00	51 25
T_5)	100% CS	29 75	36 50	38 50	57 00	52 50	48 25
T_6)	50% Woodash + 50% CS	30 25	36 75	37 75	36 00	61 25	56 00
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	28 75	38 00	38 50	67 25	65 50	68 25
	CD	NS	NS	12 367	8 994	10 647	7 568

Table 51 Available Mg of soils as affected by treatments

Treatments	Available Mg (ppm)					
	Initial	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	9 96	12 36	10 11	32 80	21 25	25 81
T_2) 75% MOP + 25% CS	10 45	12 80	16 59	18 45	25 49	25 55
T_3) 50% MOP + 50% CS	9 96	15 08	22 39	17 74	18 01	19 94
T_4) 25% MOP + 75% CS	10 10	12 59	15 06	26 56	28 05	26 60
T_5) 100% CS	9 92	12 23	11 74	13 25	20 14	13 40
T_6) 50% Woodash + 50% CS	9 91	12 24	10 13	11 93	30 43	24 48
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	10 10	13 04	11 99	23 05	16 30	37 19
CD	NS	1 672	1 953	3 541	6 458	4 209

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Table 52 Correlation coefficient between uptake of nutrients at harvest and yield

Uptake at harvest	N	P	K	Na	Ca	Mg	Cl	Yield
N	1 000							
P	0 5425**	1 000						
K	0 2101	0 8314	1 000					
Na	0 4685*	0 8770**	0 8728**	1 000				
Ca	0 5646**	0 8221**	0 6856**	0 7759**	1 000			
Mg	0 5766**	0 9567**	0 7863**	0 8620**	0 8306**	1 000		
Cl	0 0917	0 1013	0 2150	0 2492	0 3899*	0 1905	1 000	
Yield	0 5625**	0 9370**	0 7321**	0 8838**	0 7596**	0 8983**	0 0696	1 000

* Significant at 0 05 level

** Significant at 0 01 level

2 Relationship between various growth parameters and yield (Table 53)

Yield at harvest was positively and significantly correlated to the root weight, root volume and BR at 2 MAP The relationship between yield and CGR upto 2 MAP was positive and significant at 5% level A better relationship was observed between yield and CGR form 6 to 8 months which coincide with the tuber filling stage

Number of stomata and size of stomata registered a negative non significant relationship with yield The phosphorylase activity was significantly and positively ($r = 0\ 4767^{*}$) correlated with yield

3 Yield and leaf concentration of different nutrients at various stages (Table 54)

The leaf concentration of N at 8 MAP and harvest were significantly correlated with yield P and K concentration at harvest bear significant (at 5% level) positive correlation with yield Na concentration at 6 months stage was positively and significantly correlated with yield ($r = 0\ 5985^{**}$) There was no significant correlation between yield and Ca concentration in the leaf at different stages Mg at 6 month stage was positively related to yield ($r = 0\ 4869^{*}$)

4 Enzyme activity, HCN content and tuber quality parameters (Table 55)

Starch content of tubers had a negative relationship with the HCN content Phosphorylase activity was positively and significantly correlated to the starch content and negatively and significantly related to the total sugars, free amino acids and crude protein of tubers

Table 53 Correlation coefficeint between various growth parameters and yield

	Root wt (2MAP)	Root vol (2MAP)	BR (2MAP)	CGR (2MAP)	CGR (8MAP harvest)	Phosphorylase activity	No of stomata	Size of stomata	Yield
Root weight at 2MAP	1 000								
Root vol at 2MAP	0 9882**	1 000							
Bulking rate rate 2MAP	0 9974**	0 9859**	1 000						
Crop Growth rate 2MAP	0 9377**	0 9217**	0 9381**	1 000					
Crop Growth rate 8MAP harvest	0 0838	0 0884	0 0778	0 0755	1 000				
Phosphorylase activity	0 5876**	0 6460**	0 5818 *	0 4727*	0 3133	1 000			
No of stomata	0 2106	0 2367	0 1872	0 1707	0 3943*	0 5080	1 000		
Size of Stomata	0 2701	0 2727	0 2479	0 2916	0 0691	0 3596	0 2716	1 000	
Yield	0 5252**	0 5071**	0 5374**	0 4604*	0 6499**	0 4767	0 2132	0 2583	1 000

* Significant at 5% level

* Si nificant at 1% level

Table 54 Correlation coefficients between the leaf concentration of elements at different sampling intervals and yield

	2MAP	4MAP	6MAP	8MAP	Harvest
N	0 3356	0 0953	0 2551	0 4496*	0 4067*
P	0 2675	0 2083	0 2875	0 0045	0 4155*
K	0 4276*	0 1206	0 6408**	0 3659	0 4223**
Na	0 0818	0 0577	0 5985**	-0 1077	0 2956
Ca	0 0871	0 0136	0 0139	0 1490	0 3712
Mg	0 1689	0 1693	0 4869*	0 0523	0 0116

* Significant at 5% level

** Significant at 1% level

Table 55 Relationship between various tuber quality parameters

	Starch	Total sugars	Reducing sugars	Total amino acids	Free amino acids	Crude protein	Amylo pectin
HCN	0 5500**	0 3655	0 2175	0 0758	0 2622	0 2337	0 2831
Phosphorylase activity	0 5170**	0 5495**	0 1225	-0 2518	-0 4899**	0 5379**	0 0411
Q enzyme acivity	0 1303	0 0481	0 1730	0 6243**	0 5387**	0 1615	0 4916**

** Significant at 1% level

Q enzyme activity had a strong positive and significant correlation with total and free amino acids and amylo pectin of starch

5 Relationship between the tuber components and nutrient concentration in leaf and tuber at harvest (Table 56)

Of the major components starch was correlated significantly and positively only to the NL Total sugars had significant negative correlations with NL and PL and significant positive correlations with NaT and CaL Reducing sugars was significantly and positively related to KT NaT MgT and ClT Sucrose had negative significant correlations with KT Amylose in starch was positively and significantly correlated with NaT CaL MgT and ClT HCN was negatively correlated to KL and positively and significantly correlated to NaT and CaL Total phenols had positive significant relation with KL Free amino acids and KL were negatively correlated and free amino acids and NaT were positively correlated Crude protein was found to bear significant positive relation with NT and MgL This was negatively and significantly correlated to the KT CaT ClT and ClL

6 Inter correlations between nutrients at harvest time (Table 57)

K content in tuber was negatively and significantly correlated to the NT Na in tuber was positively and significantly related to the Ca in leaf NT was positively and significantly correlated to the MgL and negatively and significantly correlated to the ClL and ClT Na and Cl in leaf were inter correlated positively Na in tuber was significantly and positively correlated to ClL and ClT Ca in tuber was negatively and significantly correlated to the MgL and MgT and positively and significantly related to ClL and ClT

Table 56 Correlatıon coeffıcıents between the tuber qualıty parameters and nutrıent concentratıon ın leaf (L) and tuber (T)

	NL	NT	PL	PT	KL	KT	NaL	NaT	CaL	CaT	MgL	MgT	ClL	ClT
Starch	0 4729	0 1649	0 2784	0 1962	0 2214	0 1918	0 2914	0 3243	0 2630	0 0197	0 2443	0 0391	0 1752	0 0213
Total Sugars	0 4004	0 0656	0 3905	0 1186	0 2834	0 2417	0 1940	0 4598	0 4485	0 0767	0 1977	0 1900	0 1650	0 0164
Reduc ng Sugars	0 0404	0 3438	0 0837	0 0529	0 2190	0 4595	0 2396	0 5498	0 3144	0 3053	0 3722	0 7428	0 3215	0 5169*
Sucrose	0 3170	0 1508	0 2870	0 0924	0 1264	0 4704	0 2906	0 0995	0 2189	0 2264	0 0719	0 2425	0 0695	0 2876
Amylose	0 3422	0 3649	0 0883	0 2434	0 5314	0 1493	0 0161	0 7865	0 7559	0 0283	0 1517	0 4334	0 3522	0 6940*
Amy opect n	0 3672	0 0700	0 0786	0 2660	0 2285	0 3403	0 0086	0 3099	0 4423	0 1707	0 5387	0 3043	0 1544	0 0546
HCN	0 2053	0 2336	0 1150	0 2680	0 5125	0 2208	0 2262	0 5639	0 6121	0 2334	0 1791	0 1500	0 3617	0 2698
Tota phenols	0 1333	0 0385	0 3441	0 3622	0 7045	0 2776	0 3869	0 4678	0 4555	0 1435	0 2996	0 1704	0 1103	0 2444
Tota am no ac ds	0 6565	0 2101	0 1804	0 0876	0 1275	0 1642	0 2134	0 1535	0 2214	0 1375	0 3520	0 1805	0 0670	0 2539
Free am no ac ds	0 3386	0 2814	0 1410	0 3284	0 3912	0 0664	0 3129	0 4278	0 2201	0 3613	0 0573	0 3904	0 1696	0 1418
C ude prot en	0 1750	0 9999	0 1900	0 0738	0 0833	0 4861	0 3120	0 2845	0 2920	0 3997	0 6268	0 1118	0 7274	0 4538

S gn f cant at 5° evel
S gn f cant at 1 eve

Table 57 Correlation coefficients between nutrient concentrations in leaf (L) and tuber (T) at harvest time

	N(L) 1	N(T) 2	P(L) 3	P(T) 4	K(L) 5	K(T) 6	Na(L) 7	Na(T) 8	Ca(L) 9	Ca(T) 10	Mg(L) 11	Mg(T) 12	Cl(L) 13	Cl(T) 14
N (leaf)	1 000													
2 N (Tuber)	0 1737	1 000												
3 P (leaf)	0 3907	0 1923	1 000											
4 P (Tuber)	0 0497	0 0740	0 3142	1 000										
5 K (leaf)	0 0356	0 0827	0 1725	0 2398	1 000									
6 K (Tuber)	0 0470	0 4874	0 0356	0 3021	0 3873	1 000								
7 Na (leaf)	0 1539	0 3128	0 0587	0 1394	0 1678	0 1386	1 000							
8 Na (Tuber)	0 0630	0 2846	0 3457	0 2835	0 3831	0 1893	0 1064	1 000						
9 Ca (leaf)	0 2098	0 2907	0 2148	0 4846	0 4180	0 1912	0 2673	0 8208	1 000					
10 Ca (Tuber)	0 4564	0 3986	0 0408	0 1316	0 1392	0 2680	0 4619	0 0224	0 3150	1 000				
11 Mg (leaf)	0 0584	0 6266	0 2244	0 2210	0 0274	0 2494	0 4643	0 2576	0 3521	0 4217	1 000			
12 Mg (Tuber)	0 2841	0 1119	0 0085	0 2737	0 2328	0 3911	0 3086	0 3669	0 0524	0 5849	0 0355	1 000		
13 Cl (leaf)	0 0836	0 7272	0 1706	0 2205	0 0253	0 2783	0 5777	0 4183	0 5485	0 4346	0 8084	0 0145	1 000	
14 Cl (Tuber	0 6160	0 4525	0 1141	0 1983	0 4102	0 1613	0 2614	0 5757	0 6350	0 3844	0 4729	0 1771	0 4947	1 000

S gn f cant at 5% level
S gn f cant at 1 % evel

7 Soil available nutrients and yield (Table 58)

Yield was positively and significantly related to available K content and C A ratio in soil Available K was significantly and negatively correlated to the available Na in soil Available Ca and available Mg were inter related ($r = 0\ 6507^{**}$)

Path coefficient analysis

1 Yield and the growth components

Path coefficient analysis to trace the most contributing characters on yield was done and results presented in table 59 and 60

It is evident from the table 60 that the maximum direct effect was via the drymatter of roots at 2^{nd} month The high positive correlation of drymatter of roots at 2^{nd} month to the yield was mainly due to the positive direct effect of the same and positive indirect effect via LAI and dry weight of leaves The maximum positive indirect effect was through the root volume at 2 MAP Root volume through it indirect effects on the dry weight of roots N uptake Ca uptake LAI and Dry weight of leaves contributed significantly to the yield The number of leaves influenced the yield mainly thorough the indirect effects of LAI dryweight of roots and the uptake of nutrients The P uptake at 4 MAP had a direct positive influence on yield whereas N uptake at 4 MAP had a negative influence on yield

Table 58 Relationship between soil available nutrirents and yield

	OC	Avail P	Avail K	Avail Na	Avail Ca	Avail Mg	WHC	Yield
Organic Carbon	1 000							
Avail P	0 6887**	1 000						
Avail K	0 5265**	0 6116**	1 000					
Avail Na	0 4402*	0 4739*	0 7227**	1 000				
Avail Ca	0 0715	0 3763*	0 2891	0 3704	1 000			
Avail Mg	0 0313	0 3732	0 0190	0 3038	0 6507**	1 000		
WHC	0 5279**	0 2999	0 0975	0 0994	0 2323	0 0088	1 000	
Yield	0 5939*	0 3293	0 4285*	0 3135	0 2016	0 0527	0 3986*	1 000

Significant at 5% level
Significant at 1% level

Table 59 Path Coefficient analysis (Y = Yield)

	No of leaves (4MAP) X	LAI (4MAP) X_2	Dry wt of leaves (4MAP) X_3	Dry wt of root (2MAP) X_4	Root volume (2MAP) X_5	N up take (4MAP) X_6	P up take (4MAP) X_7	K up take (4MAP) X_8	Na up take (4MAP) X_9	Ca up take (4MAP) X_{10}	Mg up take (4MAP) X_{11}	Plant height (4MAP) X_{12}
X	**0 0628**	0 3712	0 0143	0 7829	0 7250	0 1691	0 2279	0 0700	0 0637	0 0831	0 0010	0 1102
X_2	0 0506	**0 4615**	0 1672	0 5929	0 5216	0 5786	0 5563	0 1266	0 0917	0 1894	0 0585	0 1102
X_3	0 0021	0 1819	**0 4243**	0 1812	0 1929	1 2505	1 2035	0 3004	0 0981	0 3231	0 1391	0 0642
X_4	0 0232	0 1288	0 0362	**2 1245**	1 8432	0 2232	0 0653	0 0148	0 0278	0 0474	0 0153	0 0338
X_5	0 0244	0 1288	0 0438	2 0945	**1 8696**	0 1789	0 0016	0 0154	0 0206	0 0398	0 0127	0 0376
X_6	0 0073	0 1825	0 3627	0 3242	0 2286	**1 4629**	1 4778	0 3402	0 1413	0 3730	0 1429	0 0809
X_7	0 0092	0 1654	0 3291	0 0894	0 0019	1 3952	**1 5517**	0 3136	0 1441	0 3450	3 1371	0 0802
X_8	0 0108	0 1433	0 3126	0 0769	0 0705	1 2209	1 1939	**0 4076**	0 1066	0 3052	0 1062	0 0873
X_9	0 0210	0 2224	0 2187	0 3102	0 2023	1 0863	1 1750	0 2283	**0 1903**	0 3431	0 1122	0 0882
X_{10}	0 0125	0 2089	0 3277	0 2405	0 1780	1 3043	1 2797	0 2974	0 1561	**0 4183**	0 1356	0 0911
X_{11}	0 0004	0 1646	0 3601	0 1978	0 1445	1 2750	1 2977	0 2641	0 1302	0 3461	**0 1639**	0 0724
X_{12}	0 0385	0 2825	0 1513	0 3992	0 3909	0 6571	0 6918	0 1976	0 0932	0 2118	0 0660	**0 1800**

Table 60 Path Coefficient Analysis (Y=Yield)

Variable	Direct effect	Total indirect effect		Maximum indirect effect		Total correlation coefficient
		+	−	+	−	
X_1	-0 0628	1 5167	-1 1017	0 7829	-0 7250	0 3522
X_2	0 4615	1 4260	1 6176	0 5929	-0 5786	0 2700
X_3	0 4243	2 1159	-1 8211	1 2035	-1 2505	-0 1294
X_4	2 1245	0 4356	2 0234	0 2232	1 8432	0 5367
X_5	-1 8696	2 4874	-0 1107	2 0945	-0 0376	0 5071
X_6	-1 4629	2 5133	-1 1481	1 4778	-0 3730	0 0974
X_7	1 5517	0 7602	-2 2480	0 3136	-1 3932	0 0639
X_8	0 4076	1 6205	2 0137	1 1939	-1 2209	0 0144
X_9	0 1903	1 9402	2 0675	1 1750	1 0863	0 0629
X_{10}	0 4183	2 2557	1 9761	1 2797	1 3043	0 1388
X_{11}	0 1639	2 0011	2 2518	1 2977	1 2750	0 0867
X_{12}	0 1800	1 7303	1 4496	0 6918	0 6571	0 1006

2. Relative Water Content (RWC) and the physiological parameters

Path coefficient analysis to determine the most influencing factor on RWC has shown that the cuticle thickness had the maximum direct effect on RWC, (Table 61 and 62) Size of epidermal cell also had a direct influence on RWC

REGRESSION

Regressions between the various quality parameters of tuber and the nutrient concentration in different plant parts have been worked out and they are presented in Appendices I to 7 The variables were amenable to linear relationships

Na and Cl in tuber had a significant relation with reducing sugars (Appendix II) the equations being Y = 0 83 + 23 25 x in the case of Na and Y = 1 05 + 0 87 x in the case of Cl

The coefficient of determination values were 0 3013 and 0 2672 respectively pointing out that the contribution was 30% and 26% in the above cases Mg in tuber also had a positive significant relationship with reducing sugars and the regression equation in this case was Y = 0 03 + 33 02 X and the R^2 value was 0 5518 indicating that there was 55% contribution from this factor

Na in tuber and Cl in tuber were also significantly and positively correlated with the amylose in starch (Appendix III) The equations obtained were Y = 22 98 + 282 14 x for NaT and Y = 25 81 + 9 84 x for

Table 61 Path Coefficient Analysis (y = RWC)

	No of stomata	Size of stomata	Cuticle thickness	Size of epidermal cell
No of stomata	**-0.3519**	-0 0161	0 0183	0 0028
Size of stomata	0 1487	**0.0381**	-0 0261	0 0157
Cuticle thicken	0 0565	-0 0087	**0.1139**	0 0433
Size of epidermal cell	0 0119	-0 0072	0 0589	**0.0836**

Table 62 Path Coefficient Analysis (Y= RWC)

Variable	Direct effect	Total indirect effect		Maximum indirect effect		Total Correlation coefficient
		+	–	+	–	
Number of stomata	-0 3519	0 0183	-0 0189	0 0183	0 0161	-0 3525
Size of Stomata	0 0381	0 1487	0 0418	0 1487	0 0261	0 1449
Cutide thickness	0 1139	0 0433	-0 0652	0 0433	0 0565	0 0919
Size of epidermal cell	0 0836	0 0708	0 0072	0 0589	0 0072	0 1473

ClT The R^2 values were 0 6185 and 0 4816 These values suggested that the contribution to the amylose content was 62% from NaT and 48% from ClT

The HCN content of tuber and K in leaf were negatively correlated (Appendix IV) The regression equation showing this relationship is Y = 26 95 27 37 x and the R^2 is 0 2626 From this it is inferred that there was only 26% contribution from KL

The relation between total phenols and K in leaf is given by the equation Y = 5 68 + 3 29 x (R^2 = 0 4962) This shows that the contribution from KL is about 50% (Appendix IV)

Final yield could be predicted from KL at 6 MAP and NaL at 6 MAP (Appendix VII) by equations

Y = 2 00 + 16 50 x for KL

Y = -26 11 + 732 84 x for NaL

DISCUSSION

DISCUSSION

Sodium is thought to be essential only for halophytes But there are reports that this monovalent cation can substitute K in certain functions in some plants (Truog *et al* 1953 El Sheikh *et al* 1967 Draycott *et al* 1970) An investigation was carried out in the College of Agriculture Vellayani to study the feasibility of substitution of K by Na in a potash loving crop like cassava

Elaborate field experiments were conducted for two consecutive years in the Oxisols of the Instructional Farm College of Agriculture Vellayani using the cassava variety M_4 The soil of the experimental site was acidic in reaction medium in organic carbon status and low in available P and K The location enjoys a humid tropical climate with an average annual rainfall of 1858 mm Growth and yield characters were measured quality parameters of the tuber were tested, culinary properties and nutritive qualities of the tubers were evaluated keeping quality was studied and came out with results which are discussed below

Growth and growth characters

Measurements in plant height did not show any significant difference in any of the growth stages Number of leaves taken also showed that the treatments were on a par except at 6 MAP This points out that K has no specific role in these growth characters Pushpadas and Aiyer (1976) have reported that K had no effect on plant height or number of leaves in cassava Singh *et al* (1993) made similar observations in potato

Ray *et al* (1993) found that K application had little influence on the rate of leaf production in banana but its role in extending the longevity of the leaves can not be denied Number of leaves retained by full potassium treatment was higher in this experiment also (Table No 6) The Leaf Area Index (LAI) (Table 9 and Fig 4) on the other hand differed significantly from the tuber bulking stage upto harvest stage The treatment where 50% K was substituted by Na of common salt manifested maximum LAI in all the growth stages A high LAI is desirable because the effective area for photosynthesis is decided by this parameter Since cassava exhibits a phasic growth pattern (Williams and Ghazali 1969) in which the development of leaf canopy precedes tuber growth a high LAI predetermines a high tuber yield

Investigations made at different agro climatic regions have shown that LAI had a significant influence on the CGR of cassava (Ghosh *et al* 1988)

It was observed that the chlorophyll content increased with increased substitution of K by Na upto 75% and there after declined When 100% K was substituted the chlorophyll content even though less was more than when 100% K was given When the total amount of chlorophyll is taken into account it is maximum in plots where 50% K was substituted with CS when the weight of leaf is taken in to account From this it is reasonable to think that NaCl favours chlorophyll synthesis Either by way of activating enzymes involved in the synthesis of chlorophyll or its precursors or by directly participating in its biosynthesis Na plays a role in augmenting the chlorophyll concentration in leaves

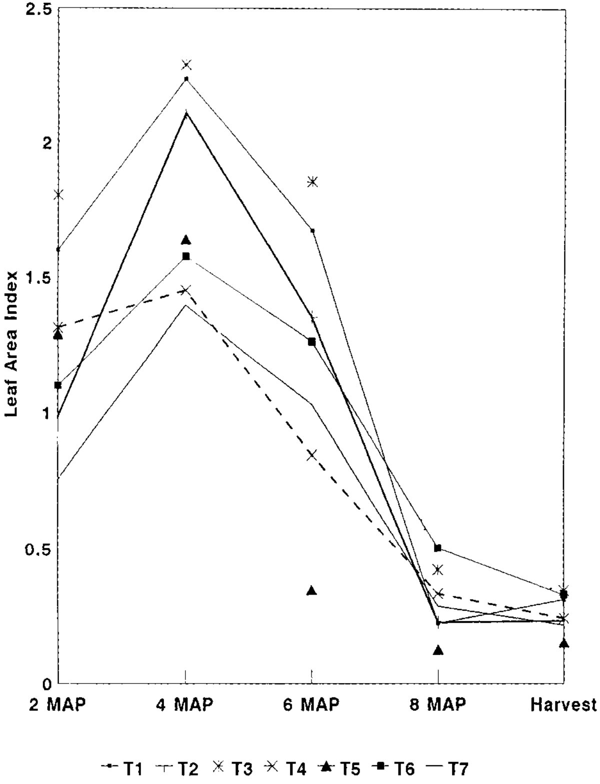


Fig. 4. Leaf Area Index as affected by substitution of K by Na.

Ando and Oguchi (1990) studied the possible role of Na in chlorophyll biosyntheis of Na requiring C_4 plants and concluded that Na takes part in chlorophyll synthesis after 5-amino laevulinic acid synthesis in these plants

Cassava being classified as an intermediate between C_3 and C_4 plants Na might have a role in stimulating chlorophyll synthesis in this crop also

The number of stomata generally increased with Na substitution Similar observation has been reported by Kemal Ur Rahim (1988) in spring wheat

The size of stomata multiplied by the number gives the total area covered by stomata When K alone was given it was too low If the area occupied by stomata is low it may interfere with the easy CO_2 exchange and photosynthetic efficiency When Na alone was given it may be too high to increase the transpiration rate So a definite ratio of K and Na in the nutrition of cassava may probably result in optimum CO_2 exchange and transpiration rate Gorham *et al* (1985) reported that reduction of transpiration rate is a characteristic response to salinity The change in stomatal resistance parallels exactly a change in stomatal frequency and changes in stomatal frequency are in fact a consequence of the increase in succulence However ions delivered per unit area or per unit volume of leaf will be reduced probably as a consequence of the reduced stomatal frequency

The relative water content (RWC) generally decreased with age The treatments T_3 T_5 and T_7 succeeded to maintain a high status of RWC

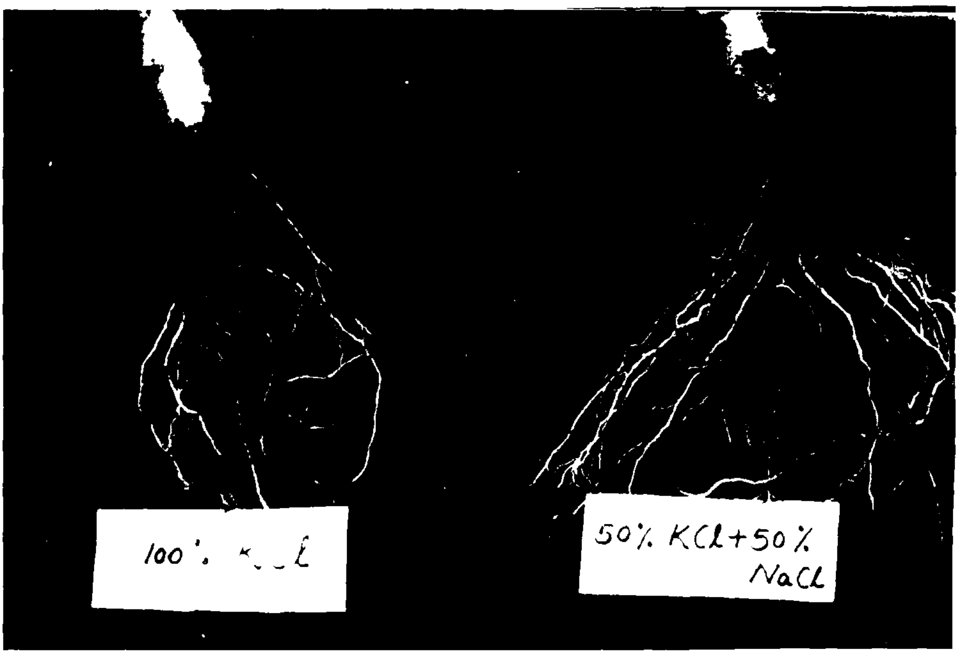


PLATE 1 Stimulation of root growth under 50% KCl + 50% NaCl treatment in comparison to 100% KCl treatment

upto the harvest stage In T_2 and T_4 the RWC was relatively very low Cuticle thickness and epidermal thickness (except at 2 MAP) did not vary significantly at any stage But it could be noticed that these were maximum when full K was given While the cuticle does not normally form a complete barrier to the movement of ions and water there is almost no information concerning how cuticular permeability varies in plants in relation to salt stress Ziska and Hutmacher (1989) opined that maintenance of leaf water status under saline conditions resulted partly from increased stomata closure with a subsequent reduction in leaf transpiration rate Dhindwal *et al* (1992) also reported that low levels of salinity stimulated plant growth and increased leaf water potential Na and Cl ions accumulate mainly in the vacuole rather than the cytoplasm (Greenwav and Munns 1980) with their accumulation therefore being conducive to osmotic adjustment and turgor maintenance

The weight of plant including tuber was significantly different at all stages of growth Here also the treatment where 50% K was substituted with Na of common salt excelled all other treatments It was found that total drymatter production and growth rates of shoot and root tuber followed the pattern of change as LAI (Table 20) suggesting that drymatter production and tuber yield are largely limited by LAI

When Na^+ and K^+ as chloride salts were present in equal concentrations plants showed much better growth than when K^+ alone was given Here it can be assumed that a biochemical interaction must have existed between Na^+ and K^+ and Cl accounting for the observed higher growth of cassava plants

Oertli (1968a and 1968b) while studying the kinetics of salt transport into vacuoles of expanding plant cells under saline conditions presented evidence that there exists an optimum external salt concentration at which the rate of cell elongation is rapid than at low or high salinity levels. He predicted that salts taken up faster from equivalent solutions to stimulate growth by fulfilling the requirement at a faster rate. In addition Cl is reported to have a role in the rate of cell multiplication in leaves (Terry 1977). The growth curve (Fig. 5) of cassava plants showed that cassava growth was stimulated by equimolar concentration of K and Na as chloride. Another explanation that can be given to this phenomenon is that the Na^+ added in this treatment might have partly substituted the K^+ requirement of cassava plants. When salt concentrations in the protoplasm of the cell increase, some of the K ions present in the vacuoles may be substituted by Na ions in the protoplasm, making K more available for specific functions. Mainly the plant species decide the degree of replacement of K^+ by Na^+ (Harmer and Benne 1945 and Harmer *et al.* 1953).

Larson and Pierre (1953) reported that more the translocation of Na to the shoot, better its capacity to replace K in its functions.

Table 6.3 Content of K and Na in different plant parts

	Root/tuber		Shoot	
	K	Na	K	Na
T_1	0.40	0.020	1.28	0.056
T_2	0.58	0.020	1.46	0.059
T_3	0.55	0.020	1.37	0.071
T_4	0.26	0.018	1.41	0.076
T_5	0.38	0.030	1.18	0.071
T_6	0.36	0.020	1.17	0.066
T_7	0.30	0.020	1.17	0.070

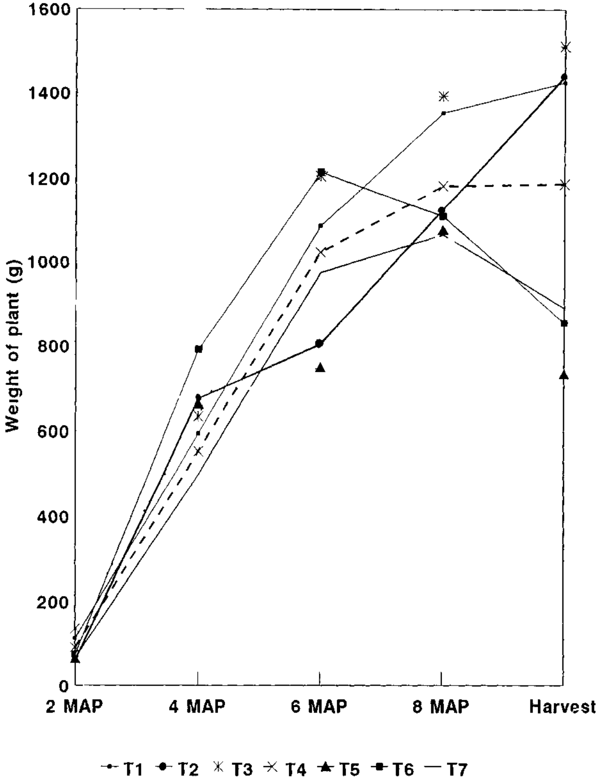


Fig. 5. Growth curve of cassava plants as affected by Na substitution

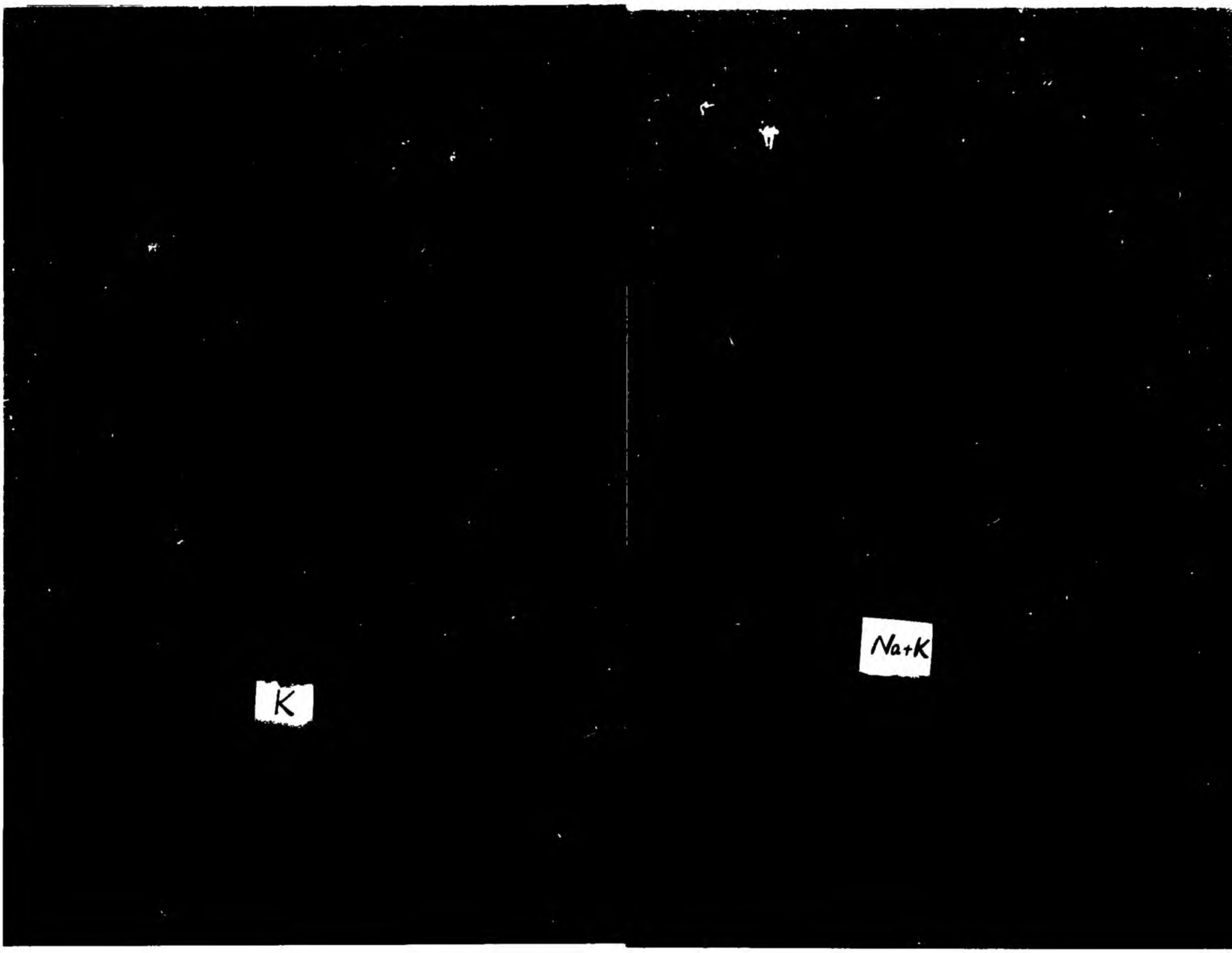


PLATE 2 Ph
wh

As is evident from the table 63 in cassava Na is readily translocated into the shoot from root and is able to replace K in its functions in the cells The results of Harmer and Benne (1945) and others were summarised schematically by Lehr (1953) in Fig 6 Accordingly cassava can be grouped in class B of this scheme where a better growth is obtained with addition of Na^+

It is known that plant growth is the result of interrelated utilization of different elements concerned in nutrition Accordingly the concept of cation balance presents a situation where the addition of an element may cause positive or negative growth effects depending on the relative concentrations of other elements A certain cation balance could be beneficial for the growth of plants either by increasing the activity of enzymes or direct or indirect role as a nutrient Fifty per cent substitution of K by Na may be beneficial, since K and to a lesser extent Na have been reported to activate many enzyme systems (Evans and Sorger 1966)

Ohta *et al* 1987 found that growth increase of the Na deficient *Amaranthus tricolor* seedlings occurred within 24 hours of the addition of sodium salt in solution culture experiments The reason they have attributed for this was that the rates of oxygen evolution in the leaf discs were found to increase within 24 hours of receiving the sodium treatment Accordingly the improvement of the growth was intrinsically correlated with the stimulation of photosynthesis by sodium application Moreover chlorophyll production was found directly related to Na nutrition in the present experiment (Table 10)

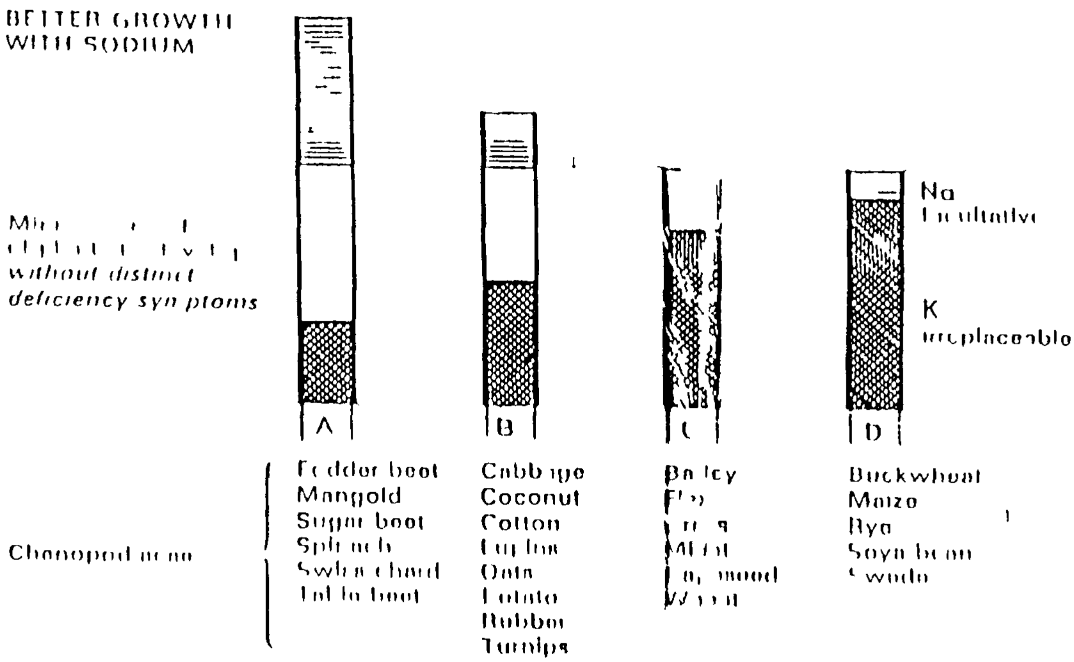


Fig 6 Lehr's Tentative scheme of classification of crops

Eventhough the maximum beneficial effect was obtained ... Na + 50%K the 75% Na and 100% Na depressed ... plants. It is presumed that the K-Na balance might have been upset at substitution above 50 per cent. The increase ... growing medium has been reported to decrease the growth of plants to various degrees (Nair and Ramaiah 1956 Gupta and Srivastava 19.. Campos et al. 1969 and Pessarakli et al. 1989). The ... transport ... limited ... delivery to ... maturing tissues ... detrimental effects on growth ... had the effect on patterns of distribution and elements of redistribution of mineral nutrients (Table 37, 38 and 39).

Considering all the above factors the overall beneficial effect of fifty per cent substitution of K by Na in the manuring schedule of cassava can be ascribed as a combination of sodium, potassium and additional quantity of chloride supplied.

Yield and yield components

It is evident from Table .. that 50% substitution of K on ... of potash by Na or common salt produced maximum ... The same treatment produced maximum number and ... of ... the initial growth stages (Fig. ..). Treatments 5 and 7 ... since these are also 50% substitution treatments. When Na and K were given at equimolar concentrations there was a stimulation in the production of roots and tubers. The stimulation of root growth ... has been reported by Marcum (1990) in Bermuda grass and Manila grass. Garner (1952) and Tinker (1965) also reported an additional response of sugar beet plants to Na in the production of roots/tubers even in the

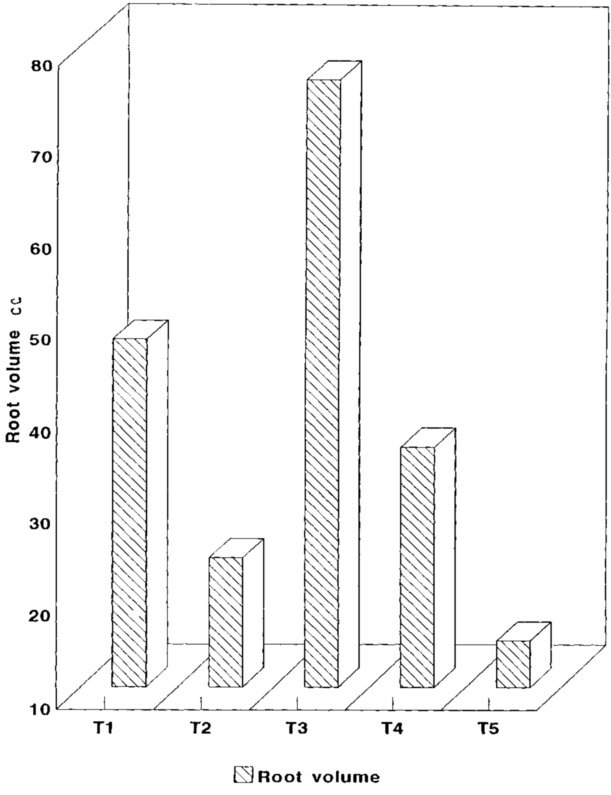


Fig. 7. Root volume at 2 MAP as affected by different treatments

presence of large amounts of K The present results are in agreement with the above finding When K and Na were given in equimolar concentrations it stimulated root growth in the initial stages causing more nutrient absorption in the early growth stages itself As a result tuber formation started in this particular treatment earlier than the other treatments

Maximum tuber yield was also reported by the same treatment (Fig 8) It is evidently due to the larger number of tubers produced by the plants under the treatment (Table 17) without affecting length and girth of tubers

The root volume at 2 MAP which differed significantly among treatments reflected well in the final yield Tuber formation was started even before the second month of planting in the case of the 50K 50 Na (as CS) treatment

In cassava tuber can be defined as an organ which has lost its polarity in growth (Indira and Kurian 1977) For the development of a tuber it is essential that the polarity of root growth changes from longitudinal to radial This is accomplished in cassava through the vascular secondary growth which ensures growth in thickness of roots (Indira and Sinha 1970) Therefore the initiation of secondary growth in roots seems to be an important factor in tuber differentiation in cassava This explains the importance of the high root volume and early initiation of secondary growth found in the 50% Na (NaCl) substituted treatment The number of storage roots and mean tuber weight are the yield components in cassava which essentially determine the sink capacity Hence the capacity to produce more storage roots by the 50% NaCl treatment helped it to produce maximum tuber weight at the harvest stage Kamalam *et al* (1977) observed that the number of tubers contributed the maximum positive direct effect to the tuber yield in sweet potato

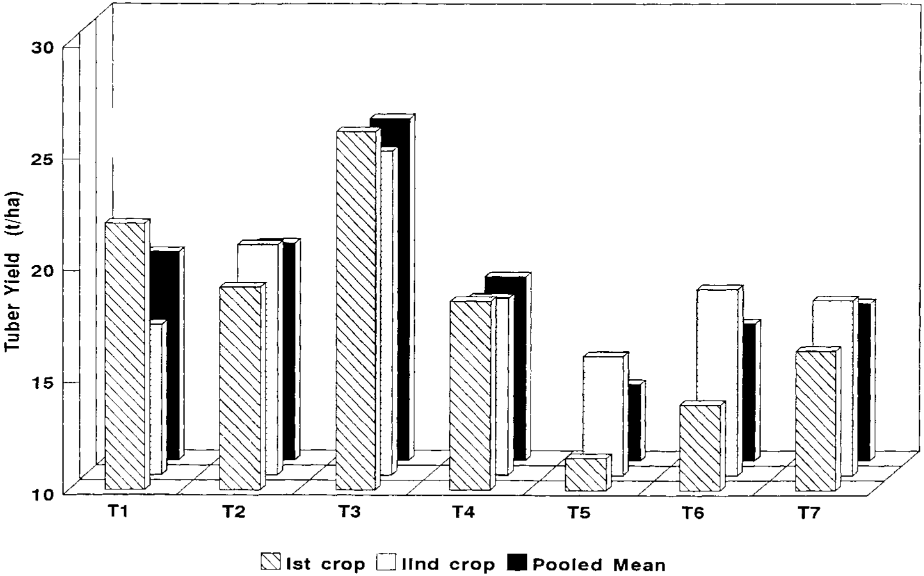


Fig. 8. Tuber yield as affected by Na substitution

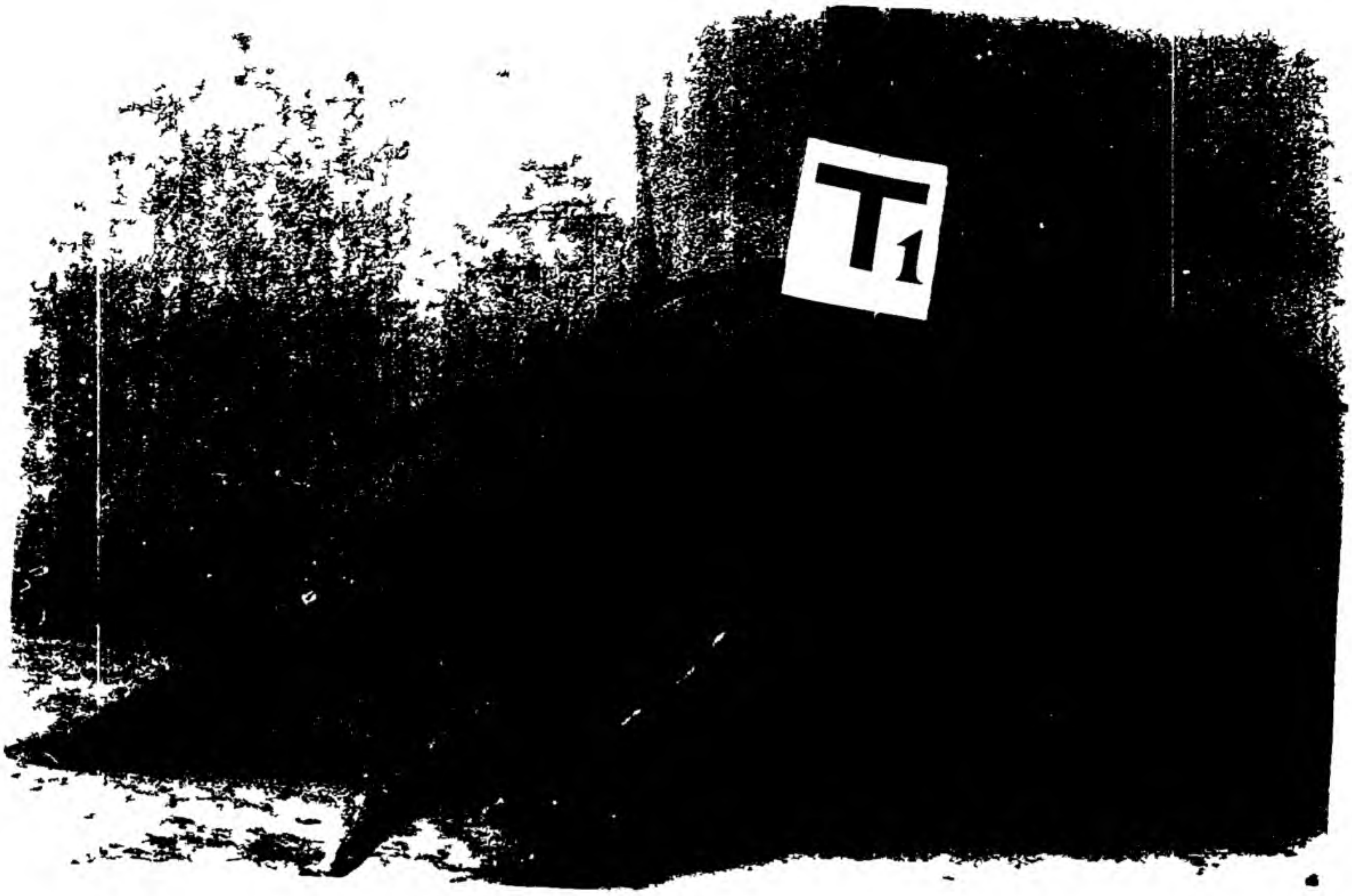


PLATE 3 Tubers from treatment T_1 at harvest

PLATE 4 Tubers from treatment T_2 at harvest

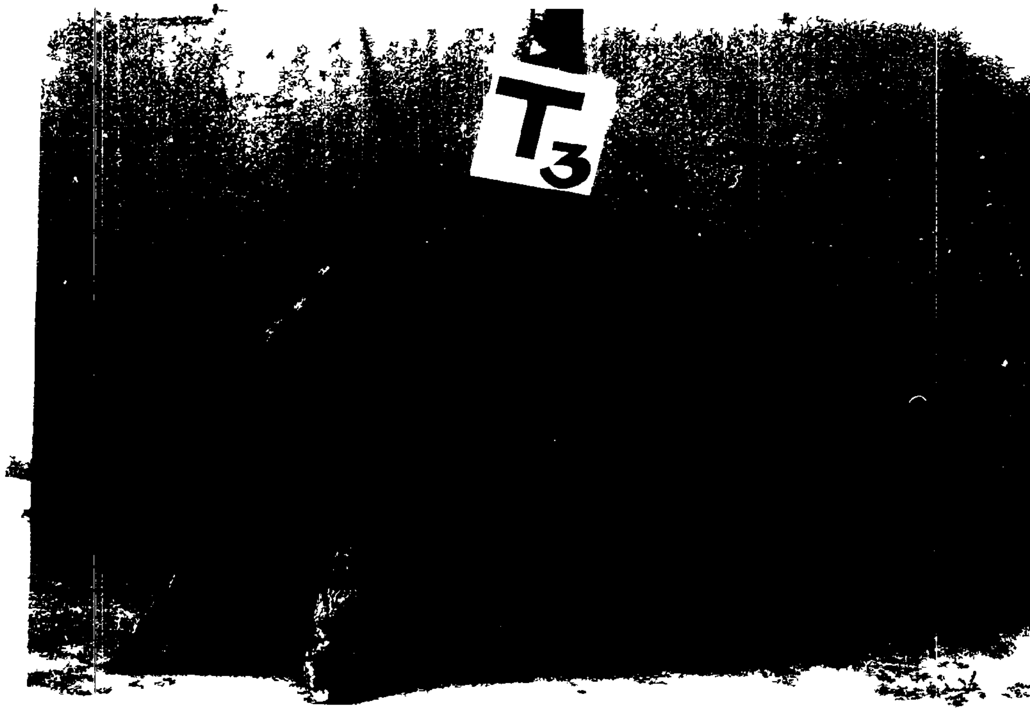


PLATE 5 Tubers from treatment T_3 at harvest

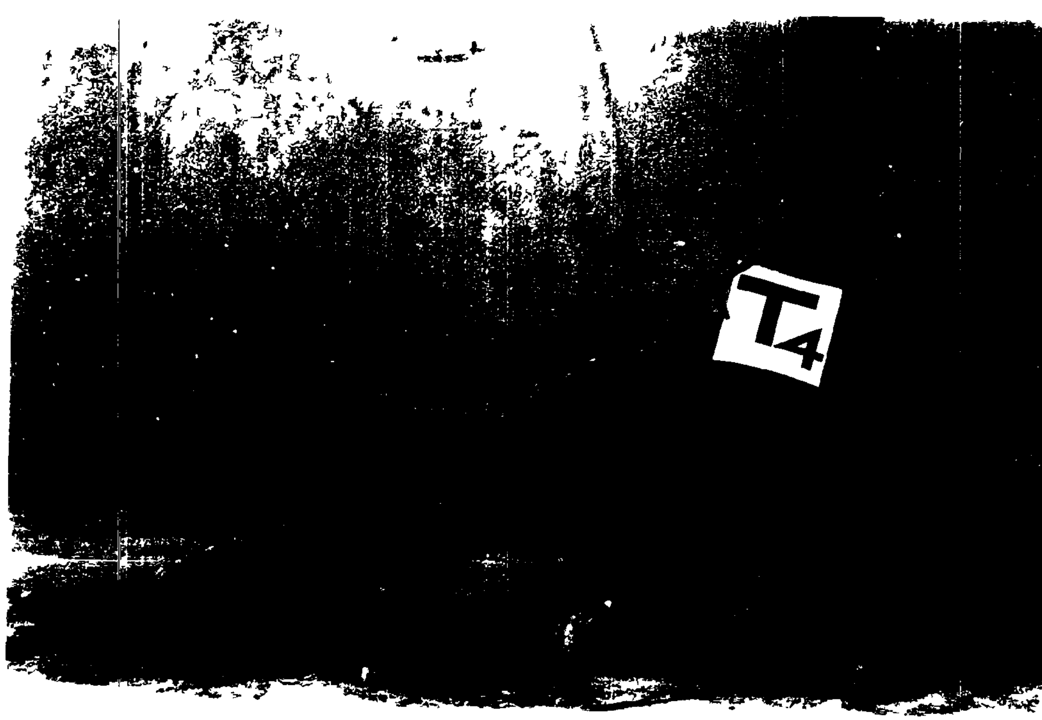


PLATE 6 Tubers from treatment T_4 at harvest

PLATE 7 Tuber from treatment T_5 at harvest

PLATE 8 Tuber from treatment T_6 at harvest

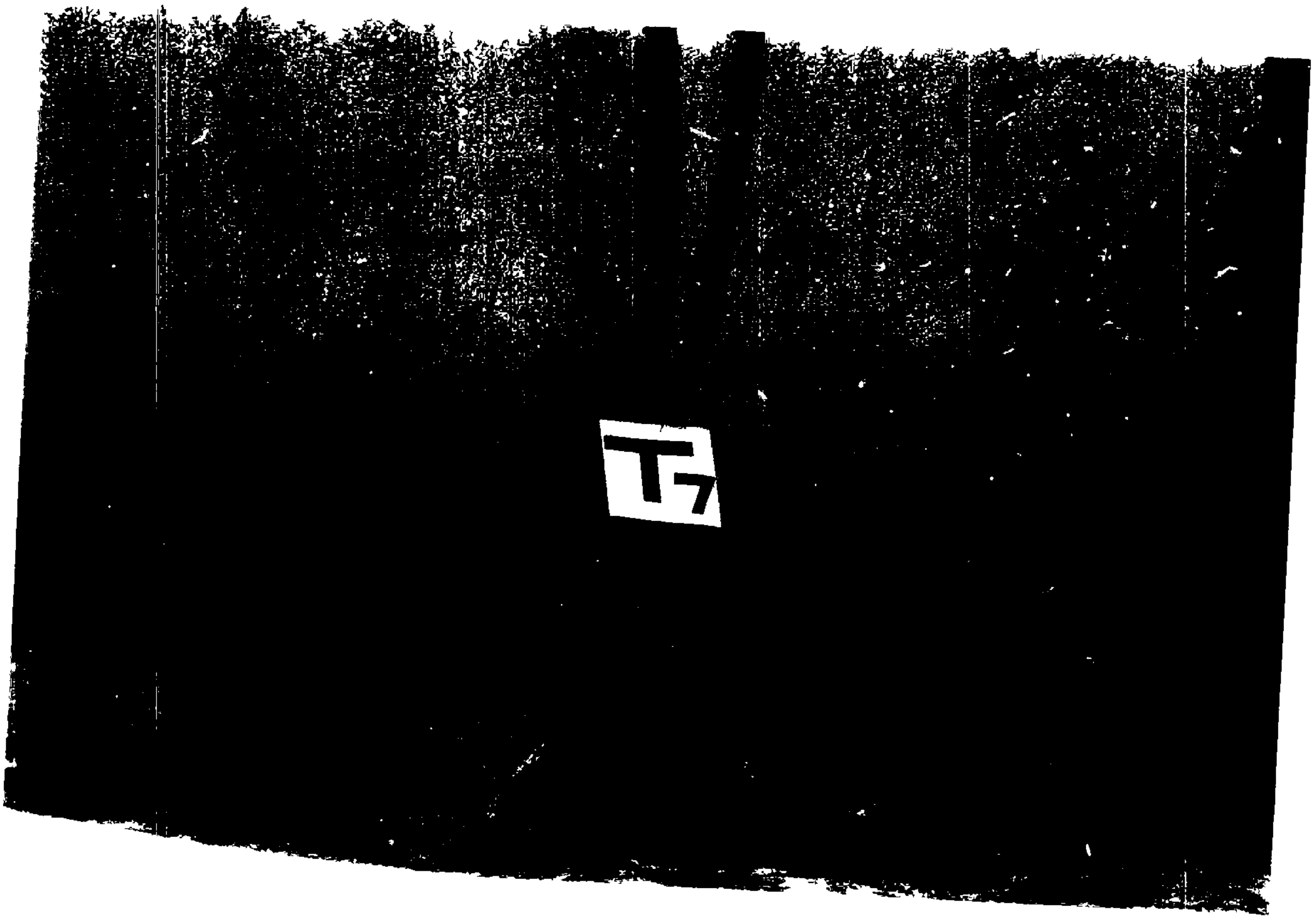


PLATE 9 Tubers from treatment T_7 at harvest

Proportionate decrease in the number volume and weight of roots were observed with increase in substitution above 50 per cent This may be due to the direct depressing effect of salinity on the growth of cassava plants The relationship between the total root dry weight and maximum photosynthetic rate (Williams 1972) indicates that root demand for assimilates increase photosynthetic activity In the present study substitution above 50 per cent resulted either in the deficiency of K or in the direct injury of NaCl leading to hastened senescence of leaves and thereby a reduction in the photosynthetic activity With advancing age of cassava plant number of leaves retained on the plant reduced drastically in treatments above 50 per cent substitution of K by Na (Table 6) of leaves of plants under treatments Contrary to the above observation Indira (1978) could obtain significant retardation in tuber initiation in cassava only from 2000 ppm NaCl onwards

The length and girth of tubers recorded varied significantly at harvest stage The maximum length and girth of tubers was observed in the treatment in which 50% K was substituted by Na of CS and 50% K by wood ash But this could not reflect in the final tuber yield since the number of tubers was less in this case The least girth and length was observed in 100% CS substituted plots This may be due to the injurious effect of NaCl Maliwal (1975) also reported decrease in length and girth of tubers of carrot and radish with increase in salt concentration

The stimulation of growth obtained by equal concentration of Na and K at 50% substitution especially in the early stages (Table 21) was manifested in the root yield The top growth is predisposing to tuber yields the ultimate yield depending on the inherent harvest index In the present experiment tuber weight followed the pattern of plant weight (Fig 9)

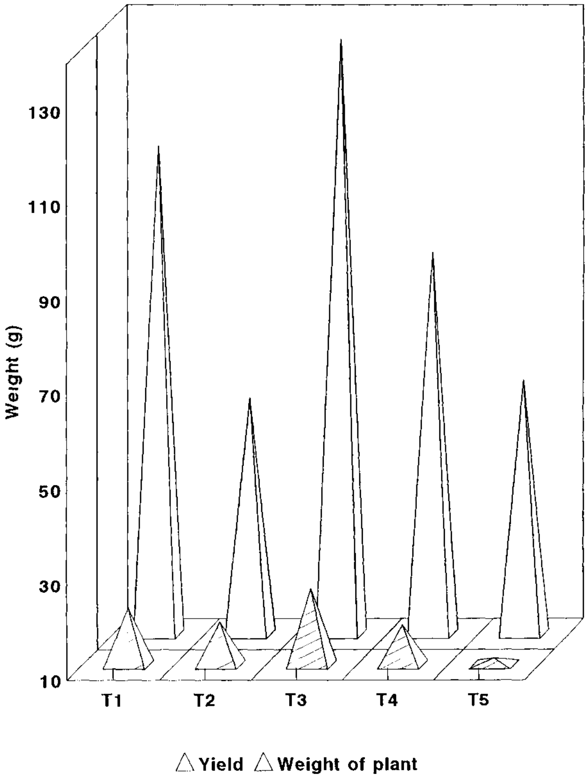


Fig. 9. Effect of Na substitution on tuber and plant weight

A high yielder would have a high photosynthetic capacity and a partitioning priority in favour of the storage tubers (Okeke *et al* 1979) It would appear that the key to high yield is the efficiency of partitioning of photosynthates to the sink sites Hence the better growth obtained in the early stages in the case of 50% substitution of Na by K attributes to the better yield obtained and the poor yield obtained in 100% substitution of Na is explained by the poor partitioning efficiency T_3 recorded maximum single tuber weight in most of the growth stages Rekha *et al* (1991) also found that single tuber weight contributed maximum direct effect to tuber yield The BR and yield followed the same pattern as is clear from Fig 10

In the trials conducted by Truog *et al* (1953) the highest yields for red beets carrots rutabagas celery barley and oats were obtained when Na and K were supplied together in the rooting medium as fertilizers Prema *et al* (1987) also obtained highest yield in coconut when Na and K were supplied in equal quantity Rice plants also yielded better under mild salinity when the soil available K status was less (Yoshida and Castaneda 1969)

Soil availability of Ca as well as Mg increased especially in the early stages on introducing NaCl in manuring schedule to substitute 50 per cent of K is evident in table 19 and 50

The better yield obtained in the above treatment may be attributed to the proper cationic balance maintained by way of a proper ratio of monovalent (K Na) and divalent cations (Ca Mg) which helped in carrying out in a better way the physiological and metabolic functions of the plant

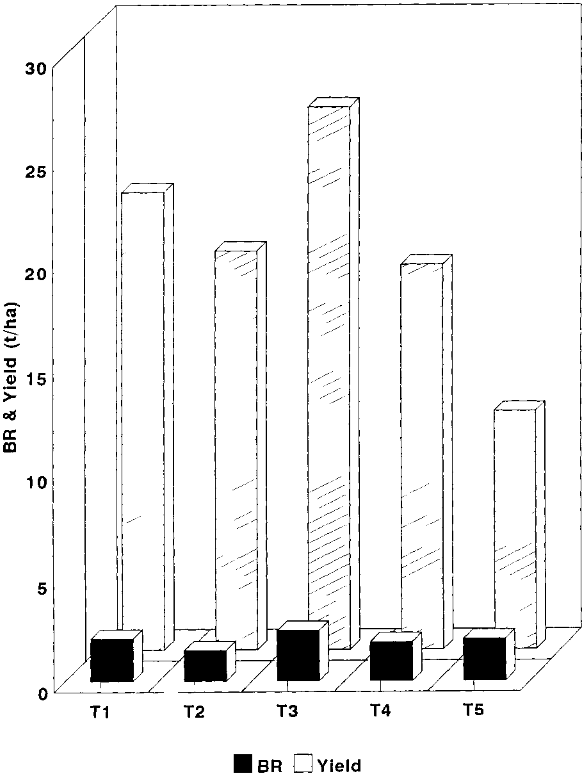


Fig. 10. Relationship between BR and Yield

leading to higher growth and yield Increased availability of Ca and Mg in Oxisols is very much essential for crop growth Mg being an integral part of chlorophyll will definitely increase the photosynthetic efficiency and Ca being essential for cell multiplication increase tuber formation

Tuber quality parameters

The various quality parameters assessed showed variation among treatments which reflected the effects of these treatments on tuber quality

The most important aspect as far as quality is concerned is the cooking quality The maximum score of 4 (sweet) was obtained for the 100% NaCl treatment This can be expected because this treatment contained the maximum amount of total and reducing sugars (Table 27) But for cassava this is not relished because it becomes hard and slimy when cooked So even though the taste is sweet this cannot be appreciated for culinary purpose in cassava

The cooking quality of tubers from 75% NaCl plots and 50% $KHCO_3$ + 50% $NaHCO_3$ plots was poor because they also became hard and slimy when cooked The ash treatment T_6 and 25% NaCl substituted treatment T_2 were found to be starchy So for edible purpose the most relished taste was of the tubers from 100% KCl (T_1) and 50% K as MOP + 50% Na as CS (T_3) plots They were starchy as well as sweet to taste with a score of 3 The overall acceptability of these tubers was good The similar score obtained in both these treatments justifies the view that the cost of 50% KCl can be saved without any bad effect on cooking quality

Eventhough there was no statistically significant variation in the starch content of tubers from different treatments substitution above 50% was found to decrease the starch content (Table 27) This throws light into the fact that eventhough it is thought that K is essential for starch synthesis Na can be substituted at least upto 50% of K in this role The assay of starch synthesising enzymes activity described in this chapter also supports this view (Table 35) Evans and Sorger, (1966) opined that no specific enzyme involved directly in the synthesis of polysaccharides has been shown to require K^+ But in the present experiment complete deficiency of K (Full NaCl plots) was found to decrease the starch content This is expected because as suggested by Evans and Sorger (1966) when K^+ is deficient in the plant starch content decreases This may be an indirect effect of an insufficient energy supply This possibility could be predicted because K^+ has been reported necessary for glycolysis oxidative phosphorylation photophosphorylation and for the synthesis of adenine

Espie *et al* (1988) while studying the relationship between photosynthesis and Na^+ in the cyanobacterium *Synechococcus* reported that a complex relationship existed between the two and proved there were distinct effects of Na on photosynthesis The activity of enzymes involved in starch synthesis in this experiment also suggest the same (Fig 11) From this it seems logical to expect that the interaction of enzyme proteins with univalent cations having different ionic radii degrees of hydration charge and density would result in different conformations of protein cation complexes thereby modifying their effects From the above results it can be assumed that Na might have been able to modify the effect in favour of K to some extent

Lind berg (1976) from kinetic investigations of transport Na KAT Pases proposed several models for activation by Na^+ and K^+ Studies of animal tissue thus suggest two alternative mechanisms

a Multiple interacting sites with each cation binding at different specific sites

b a class of cation sites which alternatively bind Na^+ and K^+ according to changing affinities

It is interesting to note that the changes in the total sugar content was dependent on the Na content in the plant The highest quantity of total sugars was found in the 100% NaCl treatment Sucrose content also increased upto 75% substitution and then declined (Fig 12) Hence in the treatment which was considered the best (ie 50% KCl 50% NaCl) the sucrose content and reducing sugars were in a balanced position Increasing both leaf and photosynthetic activity could provide more sugar translocation to the roots there by accounting in part at least for the increase in the sucrose per cent observed Conversion of sucrose to starch is mediated through a series of intermediary metabolities like Glucose 1 phosphate UDP glucose etc in the cytosol and amyloplast with the utilization of enzymes starch synthetase and phosphorylase (Sinhar *et al* 1989) Therefore a possible explanation for the high content of sucrose observed is that it is the sugar of translocation and the rate of translocation to the tuber exceeded conversion of sucrose to starch (Pressey 1969) and among various sugars sucrose is of prime importance for the biosynthesis of starch

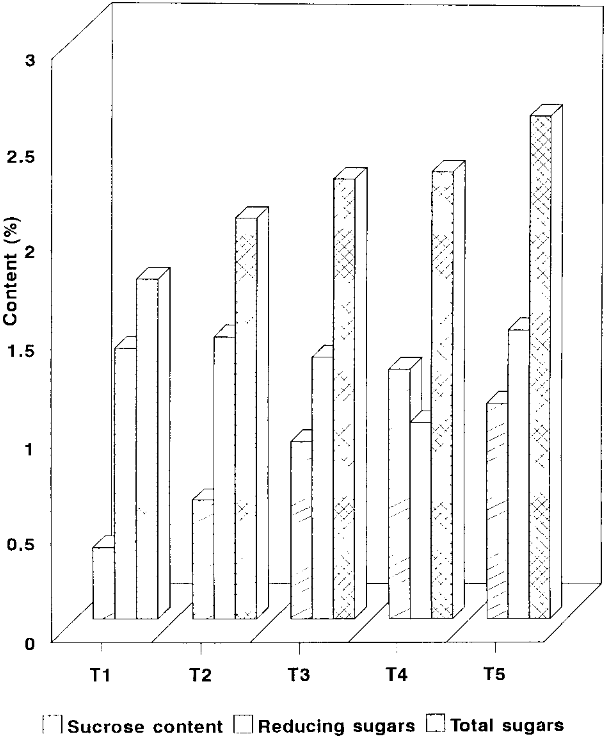


Fig. 12. Total sugars, Reducing sugar and sucrose content of tubers from various treatments

The increased sucrose content might have been produced by the plant for enhanced osmotic adjustment in the cells Lerner (1985) has reported that sucrose and 2M glycerol could protect the activity of enzymes in a saline environment producing changes in the conformation of enzymes thereby modifying its stability

The crude protein content was highest in KCl treated plot A decrease was observed with NaCl substitution Pessarakli *et al* (1989) also observed a decrease in total crude protein and protein N content with increase in salinity Parasher and Varma (1987) also observed similar results in wheat

K is evidently required during initiation of protein synthesis (Flowers 1985) In mature cells some times Na^+ may substitute for K^+ which is evidenced by its low concentration but in meristemic zones higher K concentrations are seen The content to which Na may substitute for K in protein synthesis remains to be fully explored

In the series of steps involved in protein synthesis K is required for the synthesis of effective ribosomes some of the aminoacyl t RNAs and the peptide bond synthesis by the peptidyl transferase reaction So a high protein content observed in KCl plots stands justified

The important limiting factor as far as quality of tuber is concerned is the hydrocyanic acid content The two cyanogenic glucosides linamarin and lotaustralin which are present in all parts of the cassava plant are hydrolysed by an endogenous B-glucosidase linamarase forming cyanide which is toxic (Nambisan and Sundaresan 1990) The results from table

29 and Fig 13 indicate that HCN content was maximum in full NaCl plants whereas the least was found in T_3 (50% K 50% Na as chloride plants The high content of reducing sugar found in full NaCl plots might have been used for production of cyanoglucosides The reduced activity of starch synthesising enzymes also might have contributed for the higher HCN content at the higher rate of application of NaCl Results obtained by Nambisan and Sundaresan (1990) showed that accumulation of cyanoglucosides is initiated in the root tissue even before tuberisation occurs Decline in the level is observed during the active tuber bulking phase as the drymatter increases If conditions favour further growth and drymatter accumulation after this period further decrease in cyanide levels in tuber would be obtained In the present experiment also a decrease in HCN content was seen in 50% K 50% Na (as chloride) treatment The growth curve (Fig 5) shows that drymatter accumulation in this case continued even after 8 months Conditions which promote active bulking and drymatter accumulation in tubers tend to reduce cyanide potential (Nambisan and Sundaresan 1990) This may also contribute low cyanide content in 50% KCl 50% NaCl plots and high cyanide content in full NaCl plots Leonova and Cherepenya (1989) also observed an increase in cyanide content with increased salinity

Mohankumar *et al* (1990) reported that increasing levels of K Ca and Mg tended to decrease the HCN content of tubers Increased levels of Ca Mg and also K in the 50% K 50% Na (as chloride) plants lends support to this view

The total and free amino acids determined in this experiment showed wide variation between treatments (Fig 14) The ash treatment registered

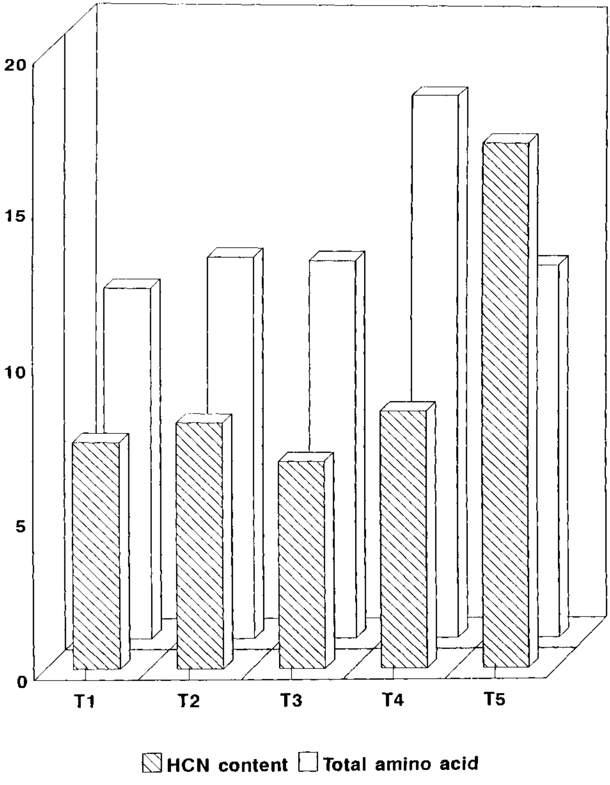


Fig. 13. Relationship between HCN content and total amino acids

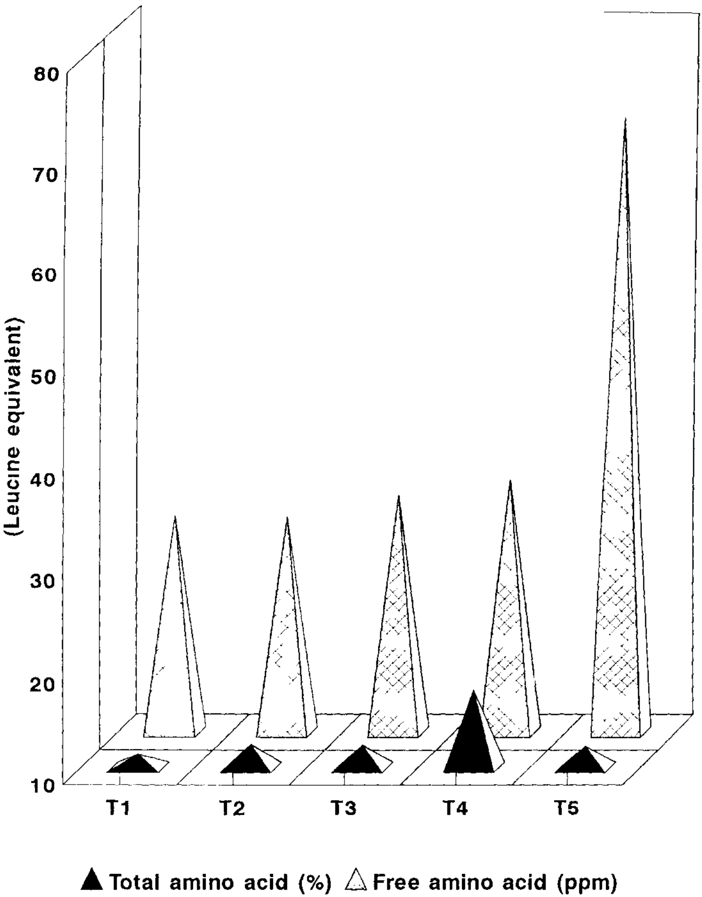


Fig. 14. Relationship between Total and Free amino acid of tubers from various treatments

the highest content of total as well as free amino acids Since the free amino acids were also maximum it is inferred that these were not fully utilized for protein formation Amino acid production was also favoured by 25% KCl and 75% NaCl and viceversa But the free amino acids were more in treatments with higher levels of substitution It was shown by Evans and Wildes (1971) that the protein synthesis was blocked in the absence of K whereby amino acids accumulate The enhanced application of potash increased the rate of utilisation of these aminoacids in protein synthesis thereby preventing their accumulation Considerable increase in free amino acid content was noticed by Reddy and Vora (1985) in bajra leaf with a simultaneous enhancement in protease activity and decrease in protein content under saline conditions They explained that the accumulation of free aminoacids may be partially due to hydrolysis of protein by the enzyme protease

The keeping quality of the tubers was also studied The tubers from 50% K 50% Na (as chloride) treated plots did not deteriorate for 35 days when stored in moist soil while the tubers from full KCl treated plots perished by 13th day (Plate 10 11) Higher quantity of phenols and hydrocyanic acid were observed in the rind of the tuber of the former treatment and probably this might have prevented the entry of pathogens causing the rotting of tuber (Table 34) on storage

The results thus confirm that the substitution of 50% of the recommended dose of potassium can be made with much cheaper common salt without any adverse effect on the quality but with an increase in tuber yield of cassava

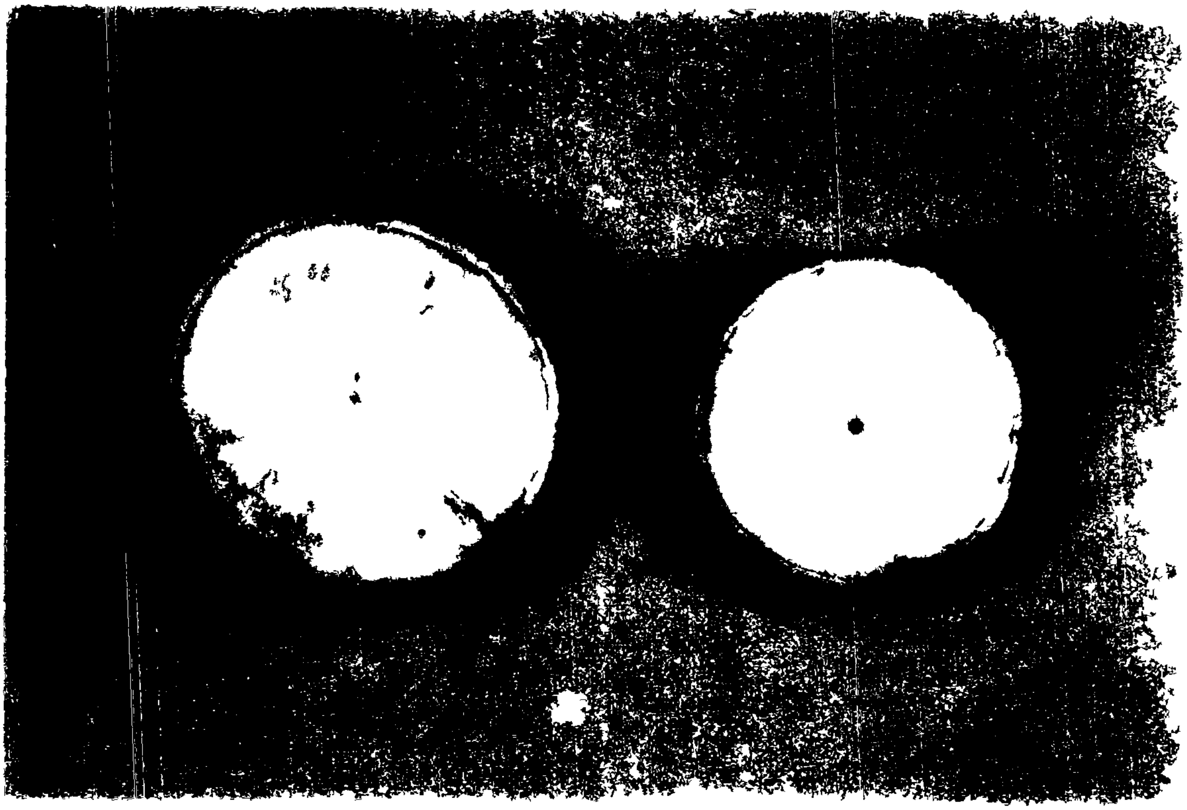


PLATE 10   C ic   tion of tubers from I_1 and I_3 on 6^{th} day of st ing

Uptake of nutrients

In the early stages of growth T_2 to T_4 and T_7 where Na is partially substituted for K generally favoured absorption of N But in the case of full KCl treatment the uptake was steady at all growth stages, indicating that N absorption continued till harvest From the results obtained (Table 64 and Figs 15 to 19) it is clear that the top weight of plants in this treatment is comparatively higher Hence a major part of N taken up is utilised for the vegetative growth rather than tuber growth

Table 64 Weight of aerial parts as affected by different treatments

Treatments	Weight of aerial parts (g)				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	90 23	163 3	406 37	435 01	495 08
T_2) 75% MOP + 25% CS	51 28	246 82	281 98	449 25	585 98
T_3) 50% MOP + 50% CS	100 42	206 14	501 43	461 67	447 48
T_4) 25% MOP + 75% CS	74 51	146 11	265 91	375 34	435 66
T_5) 100% CS	57 09	217 23	196 18	309 16	268 76
T_6) 50% Wood ash + 50% CS	66 86	243 39	404 47	341 40	292 83
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	60 86	171 51	293 48	329 91	261 83

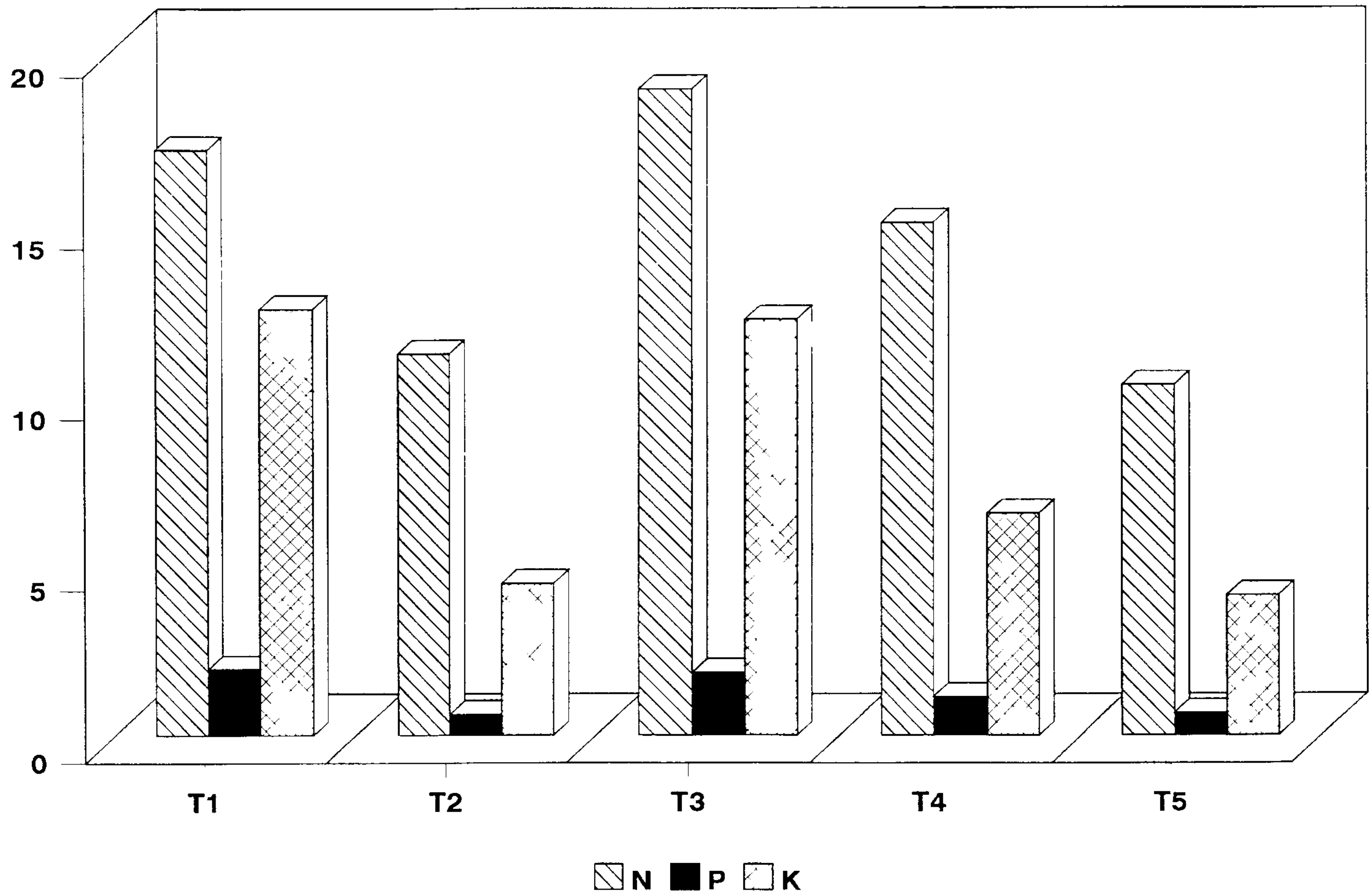


Fig. 15. Uptake at 2 MAP N, P and K

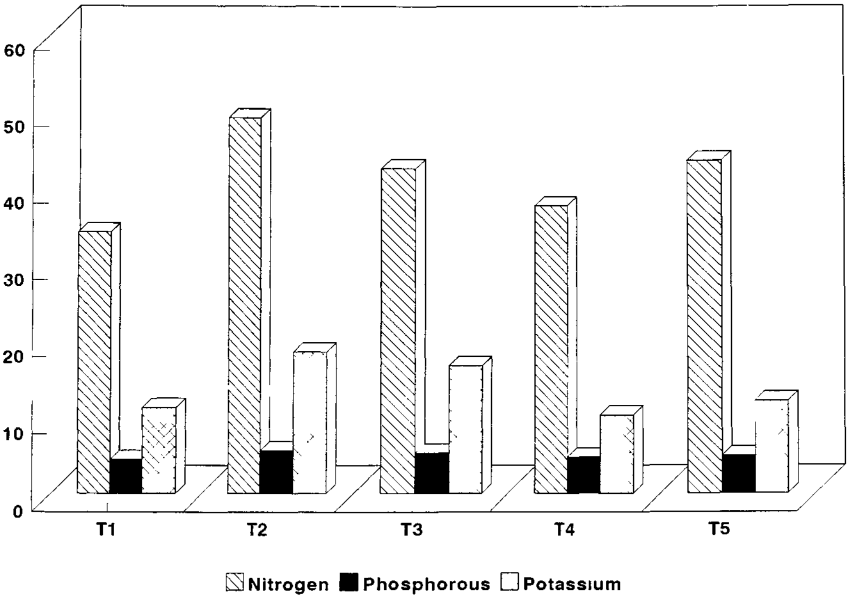


Fig. 16. Uptake at 4 MAP N, P and K

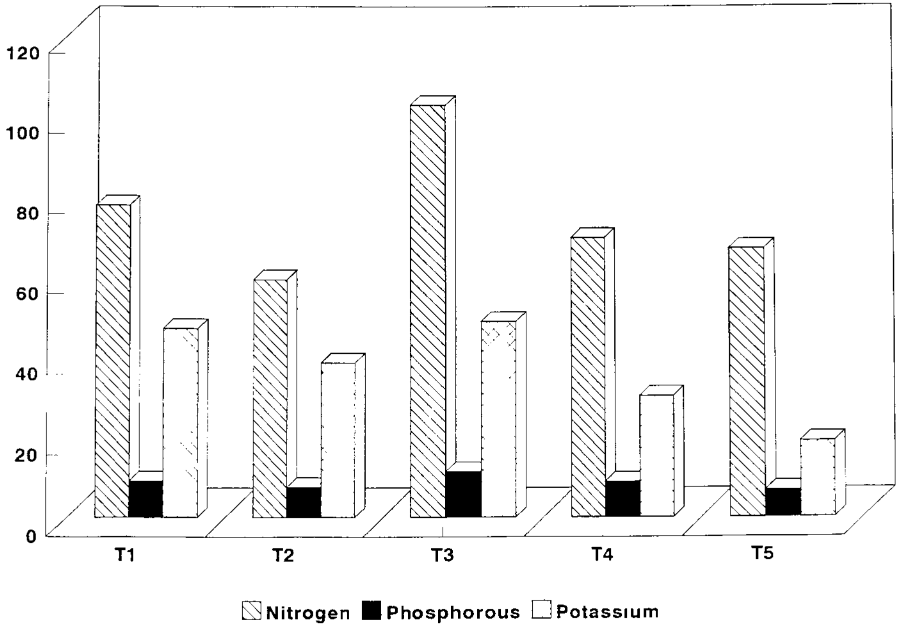


Fig. 17. Uptake at 6 MAP N, P and K

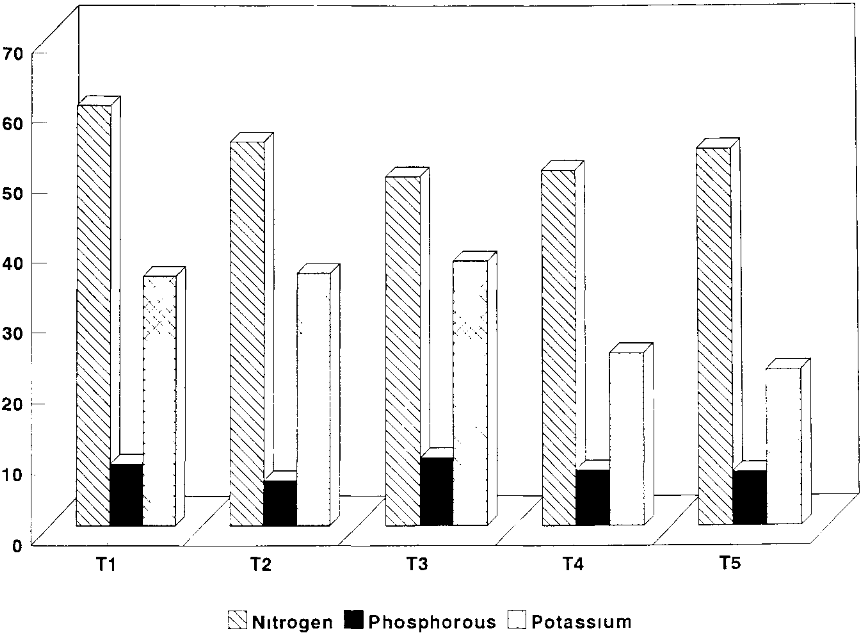


Fig. 18. Uptake at 8 MAP N, P and K

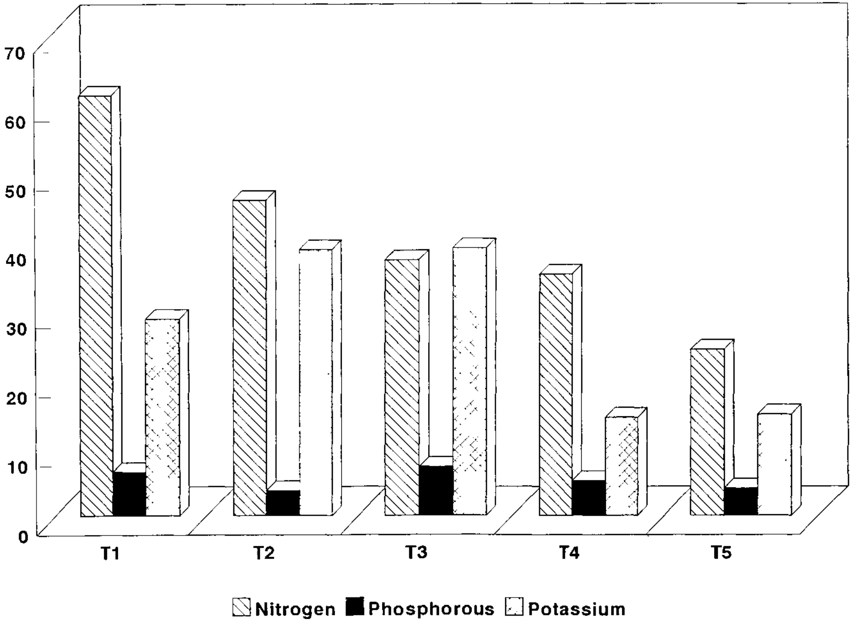


Fig. 19. Uptake at Harvest N, P and K

In the 6^{th} month the N uptake was highest in 50% K 50 Na (as chloride) treatment The NR activity was found maximum for this treatment at this stage Hence a higher rate of assimilation of N is expected at this stage During this period as expected the vegetative growth and leaf production were also maximum for this treatment (Table 64) After the 6^{th} month stage the reduction in N uptake in this treatment may be due to the higher rate of leaf fall compared to full KCl treatment

An enhanced uptake of P was observed in the 50 K 50 Na (T_3) treatment At harvest stage also maximum uptake was recorded in this treatment This can be expected since P is required in all energy involving anabolic reactions in the plant tissues P is a constituent in energy yielding compounds Above 50% substitution was not found to favour P uptake

The absorption translocation and accumulation of K and Na differed drastically Out of the 2 mechanisms of alkali cation transport mechanism II which is operative at comparatively higher concentrations which favour Na uptake was found to take place upto 6 months stage when K was substituted upto 75% by Na Hence compared to K Na was more absorbed in the early stages

After the six months stage the mechanism I which occurs at low concentrations became operative with a preferential uptake of K All treatments except T_4 (75% CS) and full NaCl (T_5) distributed the absorbed K in different plant parts almost in definite proportions (Fig 20) This means that T_4 and T_5 plants absorbed K indiscriminately and could not use it for anabolic purposes

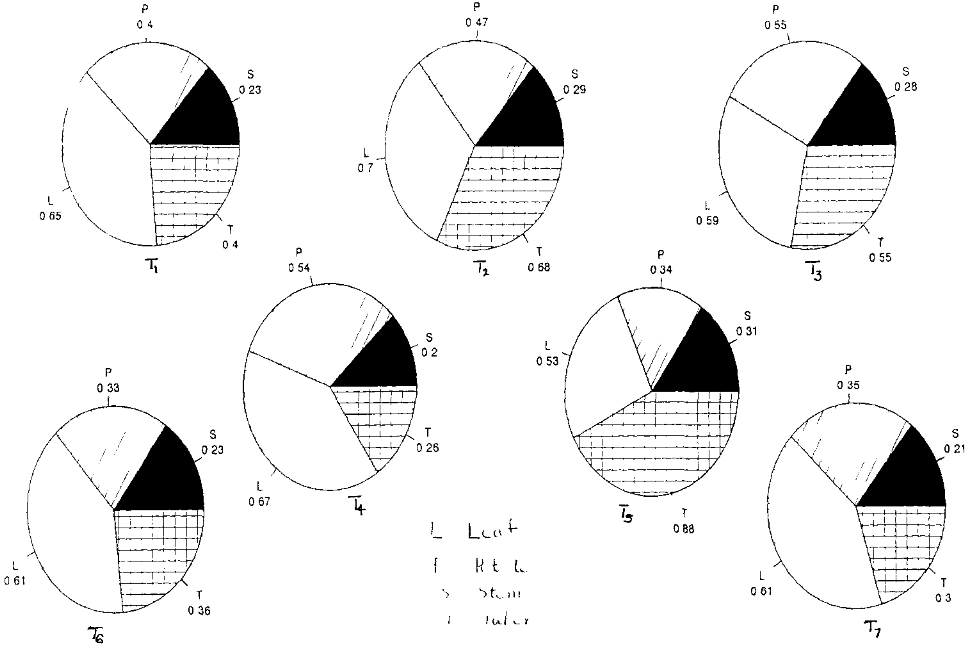


Fig. 20. Effect of Na substitution on K distribution at harvest

A stimulation in K uptake was noticed generally upto 50% substitution of K by Na. But maximum uptake was noticed in 50% K 50 Na (as chloride) treatment. An increased K uptake when Na was also supplied as fertilizer has been reported by Russell (1945) and Abd-Elrahem *et al* (1991). Rains and Epstein (1966) in their studies in barley found that when Na^+ and K^+ were present in equivalent concentrations the rate of absorption of K^+ was higher than when K alone was given. Watad *et al* (1991) suggested that the enhancement in K uptake is due to electrophoretic flux.

Table 65 shows that the absorbed Na was readily translocated to the aerial parts. The absorbed Na did not face any hindrance in translocation towards the shoots. During the tuber initiation stage major portion of Na was utilised or accumulated in the roots (Table 65). But during the later stages a ready translocation to the top parts resulted.

Table 65 Content of sodium in leaf, petiole stem and tuber of cassava at 2 months after planting

Treatments	L	P	S	T
T_1) 100% MOP	0.063	0.075	0.060	0.133
T_2) 75% MOP + 25% CS	0.073	0.099	0.043	0.213
T_3) 50% MOP + 50% CS	0.083	0.097	0.123	0.180
T_4) 25% MOP + 75% CS	0.073	0.093	0.097	0.260
T_5) 100% CS	0.078	0.083	0.078	0.878
T_6) 50% Woodash + 50% CS	0.073	0.083	0.050	0.555
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	0.060	0.060	0.073	0.328

Fig 21 proves that the yield of tuber was more or less related to the Na uptake A scan through the data (Tables 50 and 51) reveals that soil availability of Ca and Mg and absorption were increased in the 50% K 50 Na (as chloride) treatment even from early stages of growth This treatment maintained high uptake of Ca and Mg upto the harvest stage (Figs 22 to 26) The lesser uptake seen in full KCl treated plants may be due to the antagonism existing between K and Ca as well as between K and Mg Such antagonistic reactions are well established (Pushpadas and Aiyer 1976 Mohankumar *et al* 1990)

A high uptake of Ca and Mg in T_3 (50 K 50 Na as chloride) plants may be due to a high requirement of these cations for various functions in the plant body Grieve and Maas (1988) suggested that the role of Ca could be to balance the increased levels of Cl in cells Improved growth with Ca addition under saline conditions has also been reported by Gorham *et al* (1985) and Banuls and Primomillo (1992)

It is interesting to note that the uptake of all alkali cations in the T_3 was more than the other treatments at all growth stages except 4 MAP (Table 66)

The chloride content was also determined at the harvest stage With increased degrees of substitution chloride uptake of the plant also increased (Table 67) but it was not reflected in tuber yield after 50 per cent substitution Even though the Cl uptake and yield did not show any significant relationship a definite concentration of Cl in leaf is required for optimum tuber yield It is presumed that the optimum chloride concentration is attained at 50% substitution

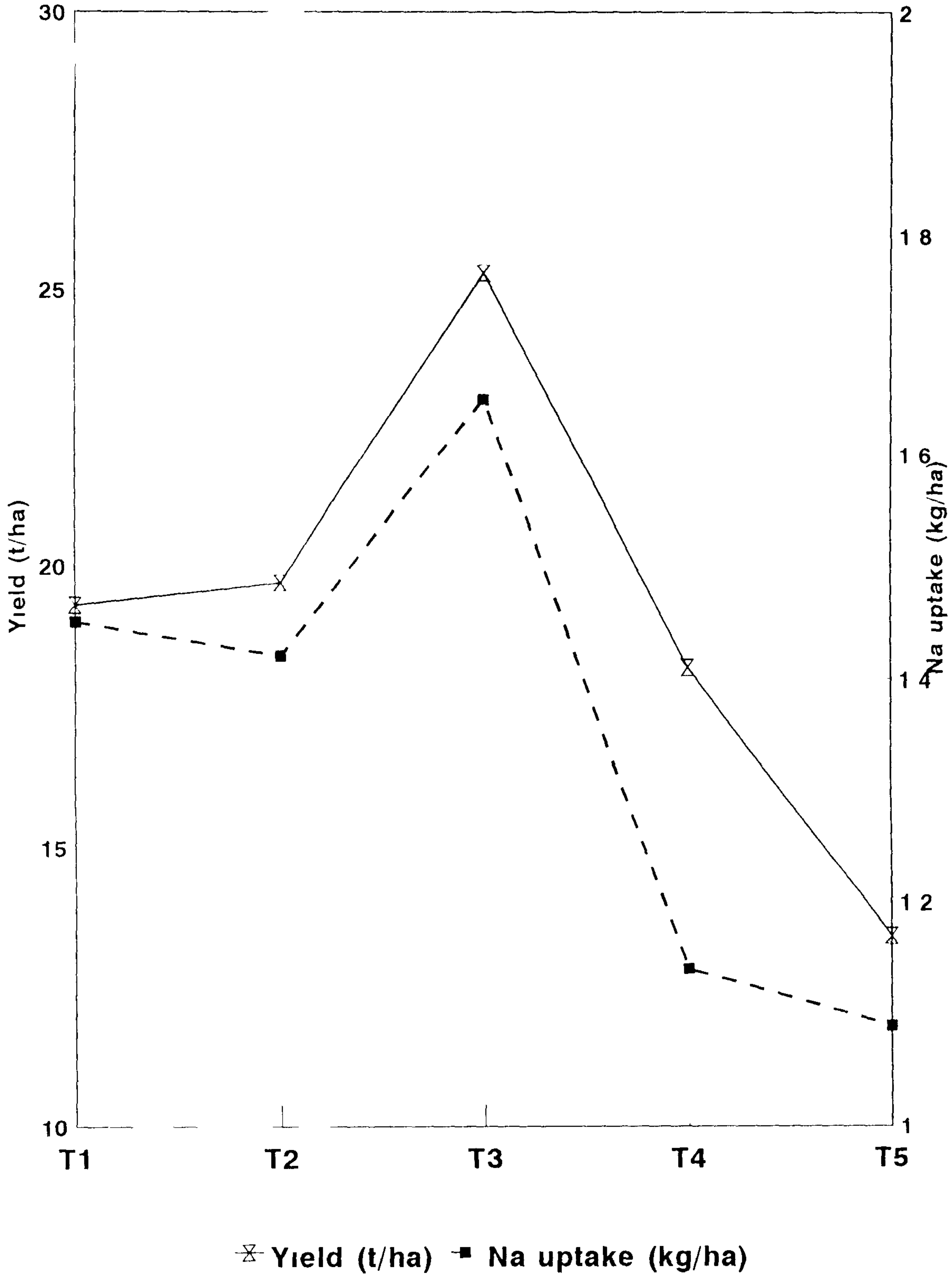


Fig. 21. Na uptake at harvest and yield

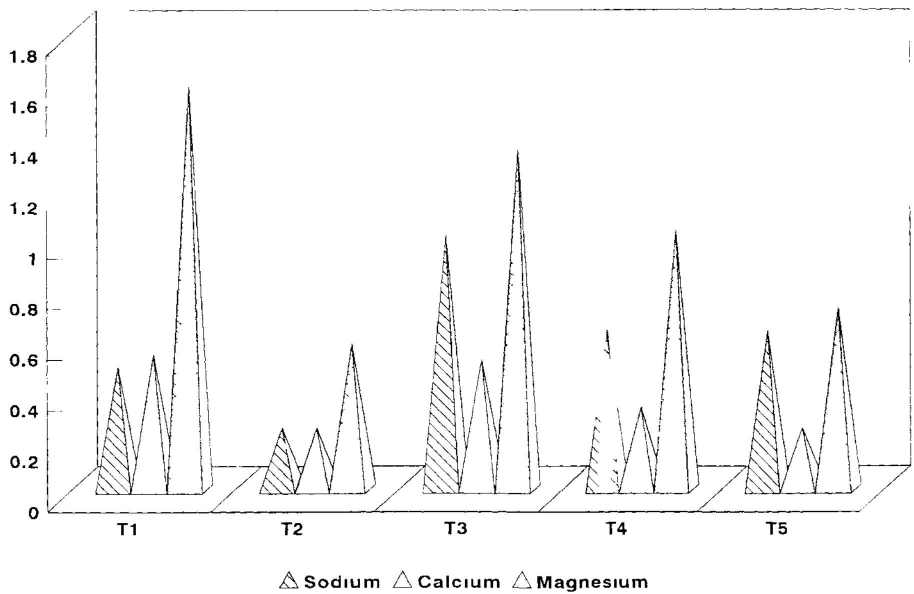


Fig. 22. Uptake at 2 MAP Na, Ca and Mg

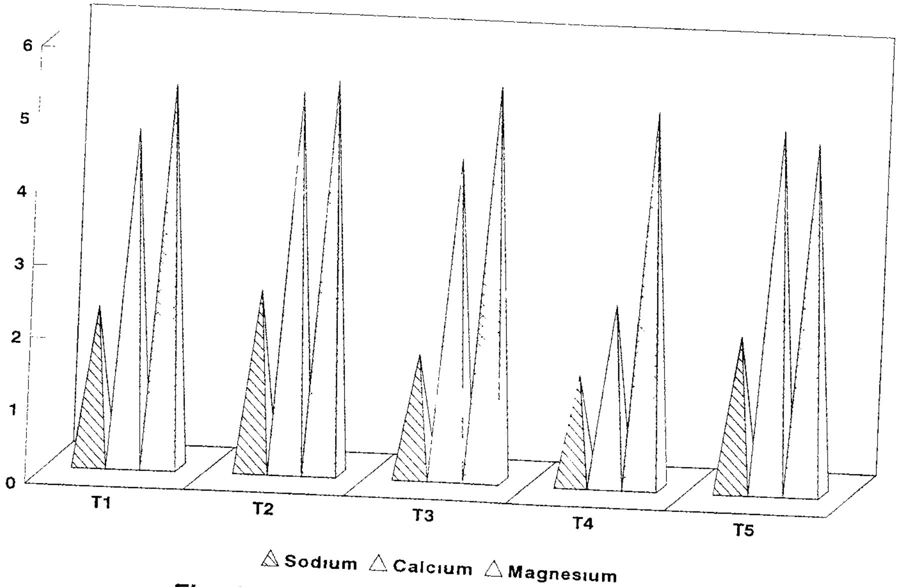


Fig. 23. Uptake at 4 MAP Na, Ca and Mg

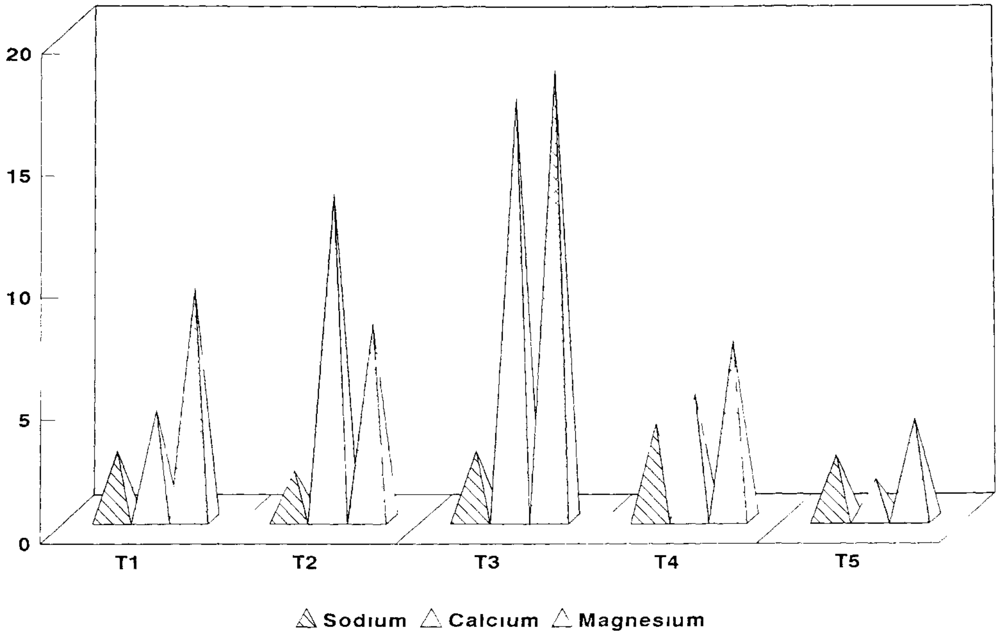
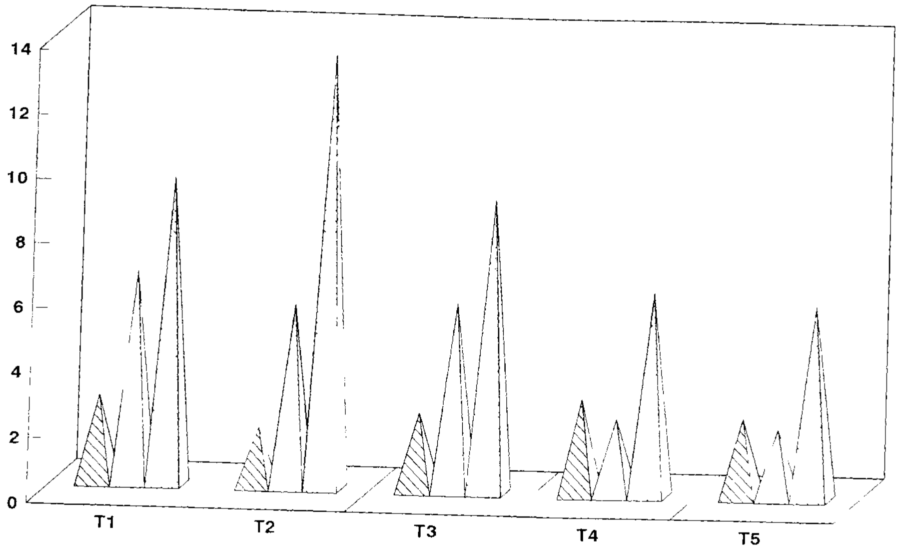


Fig. 24. Uptake at 6 MAP Na, Ca and Mg



Sodium Calcium Magnesium

Fig. 25. Uptake at 8 MAP Na, Ca and Mg

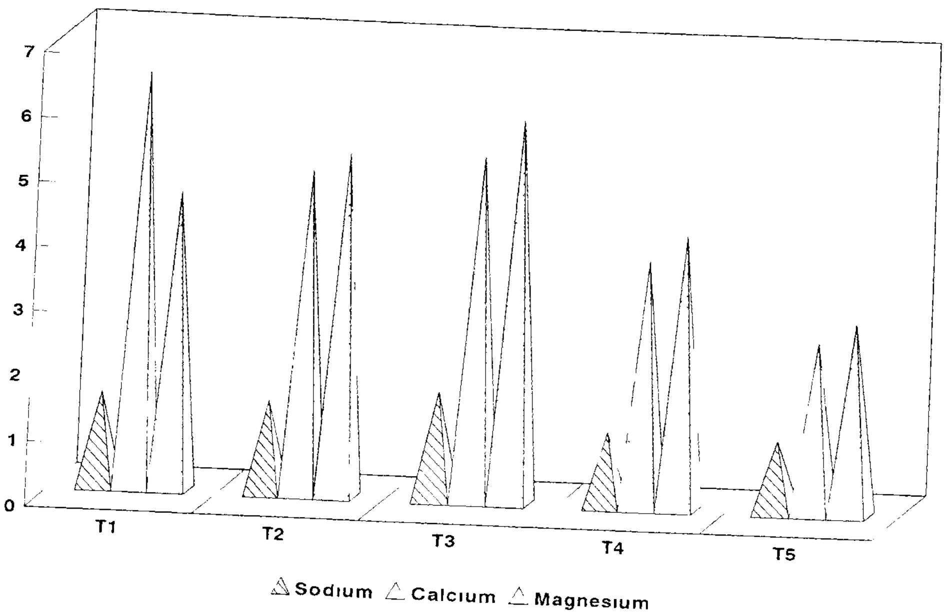


Fig. 26. Uptake at Harvest Na, Ca and Mg

Table 66 Uptake of alkali cations during different growth stages

Treatments	[illegible]				
	2 MAP	4 MAP	6 MAP	8 MAP	Harvest
T_1) 100% MOP	12 92	13 20	49 42	38 05	29 90
T_2) 75% MOP + 25% CS	4 64	20 72	39 96	37 58	39 95
T_3) 50% MOP + 50% CS	13 14	18 17	51 11	39 92	40 41
T_4) 25% MOP + 75% CS	7 07	11 54	33 63	27 25	15 27
T_5) 100% CS	4 68	13 99	21 14	24 36	15 66
T_6) 50% Wood ash + 50% CS	4 29	25 28	50 25	33 52	16 93
T_7) 50% $KHCO_3$ + 50% $NaHCO_3$	3 13	12 29	33 38	22 81	15 41

As suggested by Tisdale *et al* (1985) and Rathore and Manohar (1990) a leaf chloride concentration of 0 818% could in this crop be fixed as critical level for economic yield (Fig 27) In wheat, chloride content upto 0 4 % is needed in the whole plant at the boot to flowering stage for full yield potential of Cl responsive varieties The chloride content in $NaHCO_3$ $KHCO_3$ treatment was too low The yield in this case was also low Therefore from this it can be inferred that the enhanced growth and yield found in 50% K 50% Na (as chloride) treatment may be the cumulative effect of K Na and Cl ions,all being at optimum concentrations

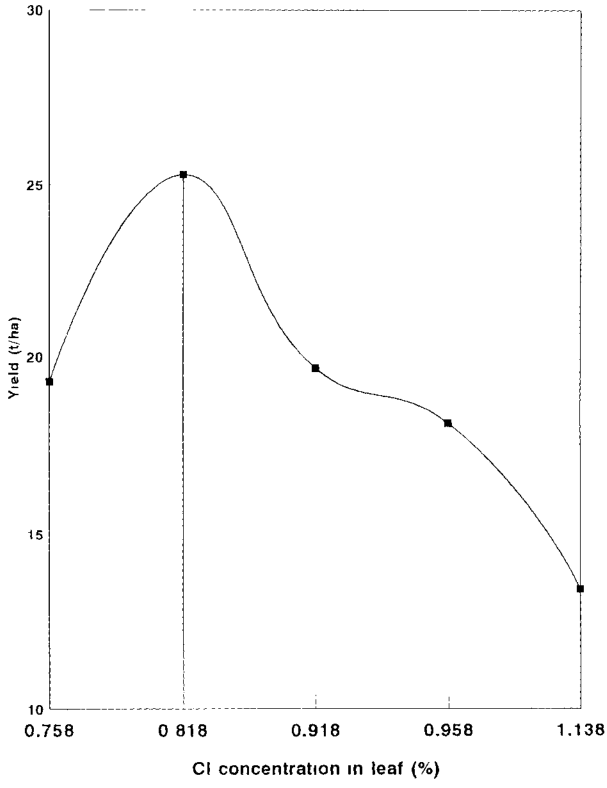


Fig. 27. Cl concentration in leaf for optimum yield

Table 67 Mean uptake of chloride at harvest

Treatment		Uptake of Cl kg ha^{-1}
T_1)	100% MOP	51 16
T_2)	75% MOP + 25% CS	52 15
T_3)	50% MOP + 50% CS	53 21
T_4)	25% MOP + 75% CS	54 29
T_5)	100% CS	68 32
T_6)	50% Woodash + 50% CS	43 28
T_7)	50% $KHCO_3$ + 50% $NaHCO_3$	24 84

Changes in physical and chemical properties of soil with NaCl substitution

The organic carbon (Table 45) and thereby the N status of the soil remained more or less same even after the crop though cattle manure at the rate of 12 5 t ha^{-1} was applied for the crop The available P and K status of all the experimental plots increased after the crop when compared to the initial (Fig 18) Jordan and Lewis (1953) reported that sodium salts added to soil increased the available phosphate in soil This conforms with the present finding Even in treatments where MOP is substituted by NaCl in different degrees K status was found to increase after the harvest of the crop The increased K availability (Fig 28) may be due to the release of K by Na from the colloidal exchange sites But the availability of sodium showed a decrease after the crop This could be attributed to crop removal or loss due to leaching consequent to the rainfall received during the crop growth period

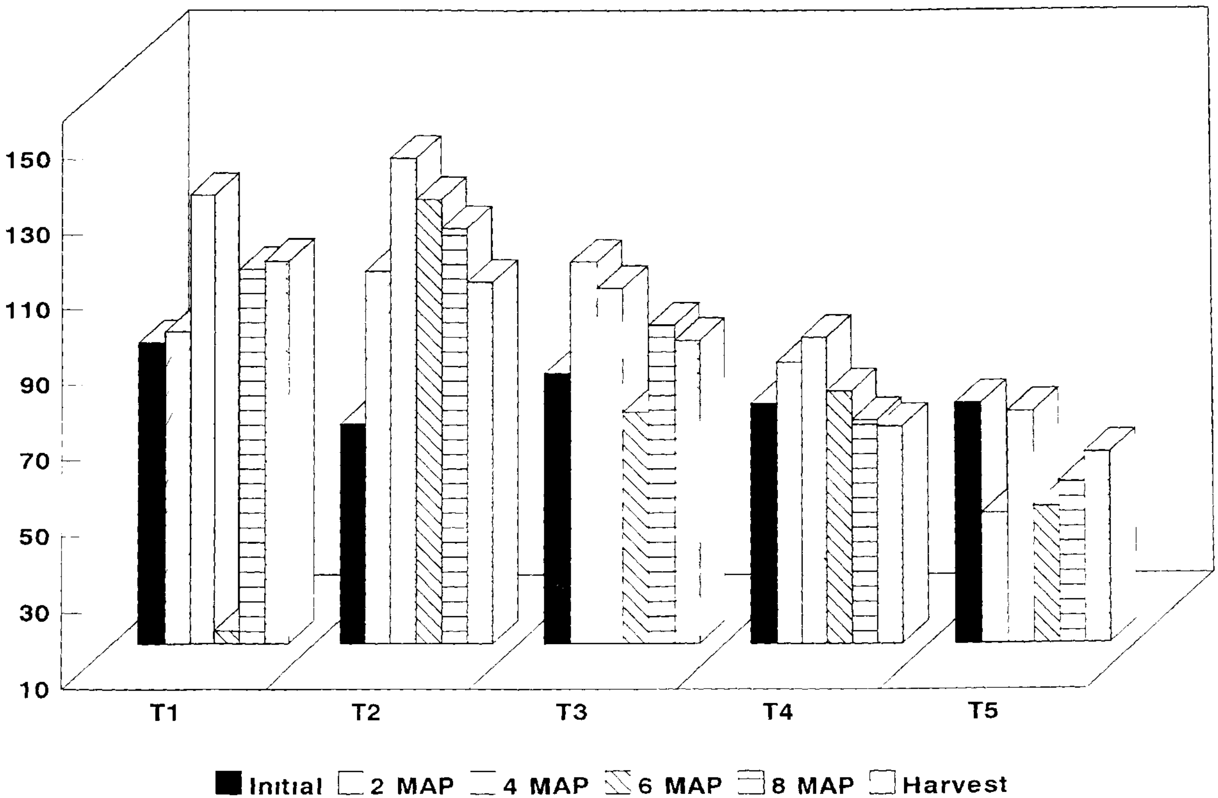


Fig. 28. Soil K from initial to harvest

Higher uptake of Na was observed in treatment receiving higher rate of application of NaCl (Table 40)

The availability of Ca and Mg status was almost doubled after the crop (Fig 26) This might have partly resulted from the fertilizer supply and from the exchange reactions in clay colloids The shed leaves might have released Ca and Mg to the soil since these are the cations found in large quantities in mature leaves Ca and Mg status was more in plots which received higher rate of NaCl probably due to the contribution of fallen leaves (Tables 50 and 51)

The ratio of monovalent to divalent cations decreased after the crop K and Na were taken up by the crop at a higher rate than Ca and Mg

Correlations between the various factors

Tuber yield was positively and significantly correlated with the root volume at 2 MAP and BR from 6 to 8 months The root volume at tuber initiation phase has a profound influence on the final yield (Indira and Sinha 1970)

CGR upto 2 MAP and from 6 to 8 months were significantly and positively correlated with yield This relationship between CGR and tuber yield has been reported earlier by Ghosh *et al* (1988)

Starch content of tubers had a negative relationship with the HCN content This is expected since more free sugar glucosides are required for HCN formation As the sugars are more converted to starch, the HCN synthesis becomes less The HCN content and free amino acid content were positively related

A significant positive correlation obtained between all the major nutrients and tuber yield stresses the importance of a proper balance of nutrients The correlation obtained between uptake of Na and yield is more than that obtained between uptake of K and yield From this it becomes clear that Na also has got influence in deciding the final tuber yield of cassava

Available K in soil was significantly and negatively correlated with the available Na in soil When the rate of NaCl increased, available K status decreased K released from exchange sites by Na might have been either absorbed by the crop or lost by leaching Increased uptake of K was observed in NaCl treated plots (Table 39)

SUMMARY

SUMMARY

An investigation was carried out in the College of Agriculture Vellayani from 1991 to 1994 to study the possibility and extent of substitution of K of the costly potash fertilizer muriate of potash, with the Na of the cheaper indigenous and easily available common salt in cassava cultivation Replicated trials were carried out in the oxisols of the Instructional Farm, College of Agriculture for two consecutive years with M_4 variety of cassava Substitution of K was tried at 4 levels viz 25,50, 75 and 100 per cent of the recommended dose Muriate of potash replaced by wood ash and a combination of $KHCO_3$ and $NaHCO_3$ (eliminating chlorine source) also were included as treatments

The salient results of the study are summarised below

1 The growth parameters like plant height did not show any significant variation as a result of substitution No significant difference could be observed in number of functional leaves also except at 6 MAP 100% K as MOP retained maximum number of leaves even at the harvest stage Higher vegetative growth at the later stages of growth might have reduced tuber yield in this treatment The Leaf Area Index (LAI) differed significantly from the tuber bulking stage upto harvest stage The treatment where 50% K was substituted by Na of common salt manifested maximum LAI in all the growth stages With increasing degree of substitution a general reduction in LAI was observed

2 An increase in chlorophyll content was resulted with NaCl substitution suggesting a possible role of Na in chlorophyll biosynthesis in this crop In all the growth stages except 2 MAP, T_1 (full potash) recorded the lowest content of chlorophyll

3 There was significant variation in the number of stomata with NaCl substitution except at 4 MAP There was an increase in th stomatal frequency with Na substitution

4 In the early stages of growth there was no significant variation in the number of roots/tubers, but at the later stages there was significant difference in this aspect between treatments

5 There was significant difference in the root volume and weight recorded at 2 MAP The treatment T_3 registered the highest values for these parameters and T_7, the lowest The higher root volume and weight obtained at 2 MAP in T_3 were well reflected in the tuber yield Tuber formation was started even before the second month of planting in the case of 50% K 50% Na (as CS) treatment

6 There was significant variation between treatments in biomass accumulation at all stages In general there was an increase in total weight of plant with NaCl substitution upto 50% and there after a decrease at higher levels in all growth stages When Na^+ and K^+ as chloride salts were present in equal concentrations plants showed much better growth than when K^+ alone was given

7 Significant treatment effect could be observed in tuber yield during both the years of the experiment T_3 registered the highest tuber yield and T_5 the lowest The stimulation of growth obtained by equal concentration of Na and K at 50% substitution was manifested in the tuber yield Pooled analysis clearly showed the superiority of T_3 over other treatments On an average, about 31 per cent increase in tuber yield could be obtained by 50% substitution of K of MOP by Na of CS

8 Bulking rate and tuber yield were closely correlated and 50 per cent substitution recorded maximum bulking rate at all the stages The treatments differed significantly in Utilisation Index, T_3 having the highest value

9 The cooking quality of the tubers from T_3 was as good as that of T_1 Upto 50% substitution by CS texture was good and comparable with that of T_1 but at higher substitutions the tubers were sweeter but became hard when cooked

10 The starch content did not show any significant variation as a result of substitution But substitution above 50 per cent was found to decrease the starch content

11 Significant differences were observed in total sugars reducing sugars and sucrose content of fresh tubers under different treatments Total sugar content was lowest in the tubers of full potash treatment With increasing levels of substitution the content of total sugars increased Sucrose content was found to increase

with Na application upto 75% substitution of K by Na Reducing sugar content was also highest in T_5 (full CS)

12 There was significant variation in the crude protein, total amino acid and free amino acid content of tubers Total and free amino acids were highest in T_6 With increase in degree of substitution free amino acid content increased, maximum being recorded at T_5 (100% substitution)

13 Significant variation in the hydrocyanic acid content of fresh tubers was observed T_5 registered the highest and T_3 the lowest values The high content of reducing sugar found in full NaCl plots might have been used for the production of cyanoglucosides

14 The treatments differed significantly in total phenol and crude fibre content Crude fibre was found to be maximum in T_6 where 50% potash was added as wood ash and 50% potash substituted by Na as NaCl

15 Tubers from T_3 (50% MOP + 50% CS) could be stored in moist soil (20% FMC) fresh upto 35th day, whereas tubers from T_1 (full potash) could stored only upto 12th day without deterioration Tubers from all other treatments perished by 6th day The total potash and HCN content were more in the rind of tubers from T_3 whereas they were more in the flesh of tubers from T_1 High HCN and phenol content in the rind of tuber might have prevented infection by pathogens leading to tuber deterioration

16 N uptake showed an increasing trend upto 6 months in all the treatments and thereafter a decrease The decline in uptake was more conspicuous in T_3 than in the other treatments In the sixth month the N uptake was highest in 50% K 50% Na (as chloride) treatment The NRA was found maximum for this treatment at this stage During this period as expected, the vegetative growth and leaf production were also maximum for this treatment

17 Treatment differences in the case of P uptake were significant only at 2 MAP During most of the growth stages the highest uptake was shown by T_3 and the lowest by T_5

18 In the early stages of growth Na uptake was comparatively more when K was substituted upto 75% by Na After the six months stage, there was a preferential uptake of K to Na A stimulation in K uptake was noticed generally upto 50% substitution of K by Na when compared to 100 per cent K

19 The treatment differences in the case of Ca and Mg uptake were significant at all stages except at 4 MAP Uptake of Ca and Mg was maximum in 50 K 50 Na (as Cl) treatment at all stages of growth

20 Soil organic carbon available P and available K differed significantly at all stages of sampling At harvest, all the treatments above 50% substitution with Na and substitution with alternate sources generally registered lower values of available P in soil Towards the later stages of growth in all the Na treated plots

available K status decreased Changes in available Mg were statistically significant at all stages of growth and that of Ca was significant from 4 MAP onwards

21 Yield of tubers was positively and significantly correlated to the uptake of N P K Na Ca and Mg A significant positive correlation was obtained between uptake of K and Na (r = 0 8728**)

22 Yield at harvest was positively and significantly correlated to the root weight root volume and bulking rate at 2 MAP

23 Path coefficient analysis to trace out the most contributing character on yield revealed that the maximum direct effect was via the drymatter of roots at 2nd month and the maximum positive indirect effect was through the root volume at 2 MAP

From the results it can concluded that in soils having low to medium status of K K of MOP can be substituted upto 50% by Na of common salt in cassava without affecting the quality of tubers Fifty per cent substitution was found to increase the yield significantly With 50% substitution by Na of CS the shelf life of tubers could be extended to more than a month

Future lines of work

1 It became obvious from this study that Na in some way is able to replace K for some of its functions inside the plant To understand whether K is replaceable in its specific functions also by Na needs detailed study

2 The contribution of Cl in helping Na to substitute for K should be separately assessed

3 Substitution studies should be taken up in other crops and in other soil types of the state, since the input costs can be saved substantially

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* Original not seen

APPENDICES

Appendix - I

1 Starch Content % (y)

Variable	Regression equation	r	R^2	t
Nitrogen in leaf x_1	$y = 17\ 31 + 2\ 93\ x_1$	0 4729	0 2236	2 737*
Phosphorus in leaf x_2	$y = 22\ 21 + 31\ 68\ x_2$	0 2784	0 0775	1 478
Potassium in leaf x_3	$y = 26\ 35 + 2\ 67\ x_3$	0 2214	0 0490	1 1575
K in petiole x_4	$y = 26\ 69 + 3\ 11\ x_4$	0 2739	0 0750	1 4522
Na in leaf x_5	$y = 29\ 65\quad 66\ 61\ x_5$	0 2914	0 0849	1 5531
Na in petiole x_6	$y = 26\ 80 + 51\ 24\ x_6$	0 3227	0 1041	1 7382
Ca in leaf x_7	$y = 27\ 62 + 1\ 06\ x_7$	0 3329	0 1108	1 8000
Mg in leaf x_8	$y = 27\ 10 + 3\ 61\ x_8$	0 2443	0 0597	1 2845

2 Total Surgars (y)

Variable	Regression equation	r	R^2	t
Nitrogen in leaf x_1	$y = 4\ 36\quad 0\ 58\ x_1$	0 4004	0 1603	2 228*
Phosphorus in leaf x_2	$y = 4\ 14\quad 10\ 44\ x_2$	0 3905	0 1525	2 163*
Na in tuber x_3	$y = 1\ 60 + 30\ 11\ x_3$	0 4598	0 2114	2 640*
Ca in leaf x_4	$y = 2\ 06 + 0\ 95\ x_4$	0 4485	0 2012	2 558*
Ca in stem x_5	$y = 2\ 71\quad 4\ 02\ x_5$	0 5598	0 3134	3 445**
Mg in petiole x_6	$y = 3\ 92\quad 4\ 21\ x_6$	0 7571	0 5731	5 908**
Mg in stem x_7	$y = 0\ 95 + 11\ 58\ x_7$	0 6517	0 4247	4 381**

Appendix - II

3 Reducing sugars (y)

Variable	Regression equation	r	R^2	t
Nitrogen in petiote x_1	$y = 1\ 05 + 0\ 18\ x_1$	0 5160	0 2662	3 071**
N in Stem x_2	$y = 1\ 54\quad 0\ 18\ x_2$	0 7022	0 4931	5 028**
K in tuber x_3	$y = 1\ 09 + 0\ 56\ x_3$	0 4595	0 2111	2 637*
Na in Tuber x_4	$y = 0\ 83 + 23\ 25\ x_4$	0 5490	0 3013	3 349*
Ca in Stem x_5	$y = 0\ 99 + 2\ 75\ x_5$	0 5910	0 3493	3 736**
Mg in tuber x_6	$y = 0\ 03 + 33\ 02\ x_6$	0 7428	0 5518	5 658**
Cl in stem x_7	$y = 0\ 99 + 0\ 38\ x_7$	0 4127	0 1703	2 310*
Cl in tuber x_8	$y = 1\ 05 + 0\ 87\ x_8$	0 5169	0 2672	3 079**

4 Sucrose content (y)

Variable	Regression equation	r	R^2	t
Nitrogen in petiole x_1	$y = 1\ 37\quad 0\ 30\ x_1$	0 4670	0 2181	2 693*
K in tuber x_2	$y = 1\ 34\quad 1\ 04\ x_2$	0 4704	0 2213	2 718*
Ca in Stem x_3	$y = 1\ 75\quad 6\ 95\ x_3$	0 8224	0 6763	7 370**
Mg in petiole x_4	$y = 2\ 97\quad 5\ 12\ x_4$	0 7818	0 6112	6 393**
Mg in stem x_5	$y = \quad 0\ 42 + 12\ 08\ x_5$	0 5778	0 3338	3 609**

Appendix - III

5 Amylose in starch (y)

Variable	Regression equation	r	R^2	t
N in stem x_1	y = 30 12 0 98 x_1	0 4493	0 2019	2 565*
K in leaf x_2	y = 34 06 8 25 x_2	0 5314	0 2824	3 198**
Na in tuber x_3	y = 22 98 +282 14 x_3	0 7865	0 6185	6 493**
Ca in leaf x_4	y = 27 38 + 8 74 x_4	0 7559	0 5714	5 887**
Mg in petiole x_5	y = 33 56 11 55 x_5	0 3788	0 1435	2 087*
Mg in tuber x_6	y = 22 53 +163 17 x_6	0 4334	0 1878	2 452*
Cl in stem x_7	y = 26 12 + 3 23 x_7	0 4119	0 1697	2 305*
Cl in tuber x_8	y = 25 81 + 9 84 x_8	0 6940	0 4816	4 915**

6 Amylopectin in starch (y)

Variable	Regression equation	r	R^2	t
N in petiole x_1	y = 49 87 + 1 11 x_1	0 6324	0 3999	4 163**
Ca in leaf x_2	y = 52 10 3 03 x_2	0 4423	0 1957	2 515*
Mg in leaf x_3	y = 52 09 + 6 08 x_3	0 5386	0 2901	3 260**
Mg in petiole x_4	y = 47 68 + 9 67 x_4	0 5344	0 2856	3 224*

Appendix - IV

7 HCN Content (y)

Variable	Regression equation	r	R^2	t
K in Leaf x_1	$y = 26\ 95 \quad 27\ 37\ x_1$	0 5125	0 2626	3 043**
Na in tuber x_2	$y = \quad 4\ 73 + 696\ 17\ x_2$	0 5639	0 3180	3 482**
Ca in leaf x_3	$y = 5\ 64 + 24\ 36\ x_3$	0 6121	0 3747	3 947**
Cl in petiole x_4	$y = 2\ 28 + 9\ 33\ x_4$	0 3761	0 1415	2 070*

8 Total Phenots (y)

Variable	Regression equation	r	R^2	t
N in petiole x_1	$y = 7\ 21 + 0\ 34\ x_1$	0 3866	0 1494	2 137*
K in leaf x_2	$y = 5\ 68 + 3\ 29\ x_2$	0 7044	0 4962	5 061**
Na in leaf x_3	$y = 6\ 88 + 34\ 27\ x_3$	0 3869	0 1497	2 140*
Na in tuber x_4	$y = 8\ 79 \quad 50\ 55\ x_4$	0 4678	0 2188	2 699*
Ca in leaf x_5	$y = 8\ 01 \quad 1\ 59\ x_5$	0 4555	0 2075	2 609*
Mg in petiole x_6	$y= 6\ 32 + 3\ 52\ x_6$	0 3835	0 1471	2 118*

Appendix - V

9 Free amino acids (y)

Variable	Regression equation	r	R^2	t
N in stem x_1	$y = 70\ 15 \quad 20\ 93\ x_1$	0 4693	0 2202	2 709*
K in leaf x_2	$y = 122\ 06 \quad 124\ 48\ x_2$	0 3912	0 1530	2 167*
K in petiole x_3	$y = 111\ 35 \quad 156\ 40\ x_3$	0 5225	0 2730	3 125**
Na in tuber x_4	$y = \ 21\ 60 + 3146\ 70\ x_4$	0 4278	0 1830	2 414*
Mg in tuber x_5	$y = \ 73\ 48 + 3013\ 90\ x_5$	0 3904	0 1524	2 162*

10. Crude Protein Content (y)

Variable	Regression equation	r	R^2	t
N in petiote x_1	$y = 3\ 69 \quad 0\ 86\ x_1$	0 6823	0 4655	4 759**
K in petiote x_2	$y = 3\ 71 \quad 3\ 09\ x_2$	0 4963	0 2463	2 915**
K in tuber x_3	$y = 3\ 26 \quad 2\ 15\ x_3$	0 4861	0 2363	2 836**
Ca in petiole x_4	$y = 2\ 81 \quad 1\ 12\ x_4$	0 6414	0 4114	4 263**
Ca in stem x_5	$y \quad 3\ 42 \quad 8\ 55\ x_5$	0 5084	0 2585	3 011**
Ca in tuber x_6	$y = 2\ 87 \quad 23\ 60\ x_6$	0 3997	0 1598	2 223*
Mg in leaf x_7	$y = 1\ 10 + 5\ 09\ x_7$	0 6268	0 3929	4 102**
Cl in leaf x_8	$y \quad 3\ 65 \quad 1\ 63\ x_8$	0 7274	0 5292	5 406**
Cl in petiole x_9	$y - 3\ 92 \quad 1\ 87\ x_9$	0 6058	0 3670	3 883**
Cl in stem x_{10}	$y - 4\ 26 \quad 2\ 14\ x_{10}$	0 6405	0 4102	4 252**
Cl in tuber x_{11}	$y = 3\ 26 \quad 2\ 75\ x_{11}$	0 4538	0 2059	2 596*

Appendix - VI

11 Phosphorylase activity (y)

Variable	Regression equation	r	R^2	t
N in leaf x_1	y = 9 55 + 4 99 x_1	0 3957	0 1565	2 197*
N in tuber x_2	y = 13 46 12 46 x_2	0 5378	0 2892	3 253**
K in petiole x_3	y = 2 06 + 15 58 x_3	0 6738	0 4540	4 649**
K in tuber x_4	y = 6 21 + 6 16 x_4	0 3755	0 1410	2 066*
Na in stem x_5	y = 11 05 131 75 x_5	-0 4381	0 1920	2 485*
Na in tuber x_6	y = 13 74 239 16 x_6	0 4208	0 1770	2 365*
Ca in petiole x_7	y = 7 48 + 3 23 x_7	0 4991	0 2491	2 937**
Ca in stem x_8	y = 5 09 + 30 05 x_8	0 4817	0 2320	2 803**
Ca in tuber x_9	y = 7 02 + 81 89 x_9	0 3739	0 1398	2 056*
Mg in petiole x_{10}	y = 0 92 + 23 99 x_{10}	0 4966	0 2466	2 917**

Appendix - VII

12 Yield (y)

Variable	Regression equation	r	R^2	t
NL 2MAP x_1	$y = 30\ 50\quad 2\ 15\ x_1$	0 3356	0 1126	1 816
NL 4MAP x_2	$y = 21\ 11\quad 0\ 76\ x_2$	0 0953	0 0091	0 488
NL 6MAP x_3	$y = 9\ 25 + 6\ 03\ x_3$	0 2551	0 0651	1 345
NL 8MAP x_4	$y = 64\ 04\quad 11\ 81\ x_4$	0 4496	0 2021	2 566*
NL Harvest x_5	$y = 37\ 82 + 15\ 30\ x_5$	0 4067	0 1654	2 269*
PL 2MAP x_6	$y = 0\ 77 + 41\ 16\ x_6$	0 2675	0 0715	1 415
PL 4MAP x_7	$y = 36\ 53\quad 52\ 86\ x_7$	-0 2083	0 0434	1 086
PL 6MAP x_8	$y = 47\ 22 + 206\ 26\ x_8$	0 2875	0 0826	1 531
PL 8MAP x_9	$y = 18\ 31\quad 0\ 62\ x_9$	0 0045	0 0002	0 023
PL Harvest x_{10}	$y = 34\ 52 + 287\ 31\ x_{10}$	0 4155	0 1727	2 329*
KL 2MAP x_{11}	$y = 6\ 51 + 11\ 22\ x_{11}$	0 4276	0 1829	2 412*
KL 4MAP x_{12}	$y = 20\ 71\quad 3\ 14\ x_{12}$	-0 1206	0 0145	0 619
KL 6MAP x_{13}	$y = 2\ 00 + 16\ 50 x_{13}$	0 6408	0 4106	4 256**
KL 8MAP x_{14}	$y = 19\ 96 + 54\ 12\ x_{14}$	0 3659	0 1339	2 005
KL Harvest x_{15}	$y = 1\ 12 + 30\ 97\ x_{15}$	0 4223	0 1783	2 375*

Variable	Regression equation	r	R^2	t
NaL 2MAP x_{16}	y = 13 49 + 64 77 x_{16}	0 0818	0 0067	0 418
NaL 4MAP x_{17}	y = 20 94 35 28 x_{17}	0 0577	0 0033	0 295
NaL 6MAP x_{18}	y = 26 11 +732 84 x_{18}	0 5985	0 3583	3 809**
NaL 8MAP x_{19}	y = 23 42 78 57 x_{19}	0 1077	0 0116	0 552
NaL Harvest x_{20}	y = 8 00 +410 66 x_{20}	0 2956	0 0874	1 578
CaL 2MAP x_{21}	y = 16 93 + 12 12 x_{21}	0 0871	0 0076	0 446
CaL 4MAP x_{22}	y = 18 58 1 41 x_{22}	0 0136	0 0002	0 069
CaL 6MAP x_{23}	y = 17 96 + 0 77 x_{23}	0 0139	0 0002	0 071
CaL 8MAP x_{19}	y = 17 06 + 0 87 x_{24}	0 1490	0 0222	0 768
CaL Harvest x_{25}	y = 21 71 20 28 x_{25}	0 3711	0 1378	2 038
MgL 2MAP x_{26}	y = 1 27 + 72 54 x_{26}	0 1689	0 0285	0 8737
MgL 4MAP x_{27}	y = 24 82 24 18 x_{27}	0 1693	0 0287	0 8758
MgL 6MAP x_{28}	y = 6 01 + 91 37 x_{18}	0 4869	0 2371	2 843**
MgL 8MAP x_{29}	y = 19 85 4 24 x_{19}	0 0523	0 0027	0 2669
MgL Harvest x_{30}	y = 17 86 + 1 05 x_{30}	0 0116	0 0001	0 0593

ABSTRACT

Field experiments were carried out in the College of Agriculture Vellayani during 1991 to 1994 to study the possibility and extent of substitution of K of Muriate of Potash with the Na of common salt in Cassava variety M_4 used as the test crop Substitution of K was tried at 4 levels viz 25, 50, 75 and 100 per cent of the recommended dose Muriate of potash, replaced by wood ash and a combination of $KHCO_3$ and $NaHCO_3$ (eliminating chlorine source) also were included in the experiment

Plant growth characteristics like plant height and number of leaves did not vary significantly as a result of substitution The maximum LAI was observed in the case of 50% K as MOP + 50% Na as CS treatment at all the growth stages An increase in chlorophyll content was observed with NaCl substitution In the early growth stages there was no significant variation in the production of roots, but at the later stages there was significant difference in this aspect The root volume at 2 MAP varied significantly between treatments In general, there was an increase in total weight of plant with NaCl substitution upto 50% and thereafter a decrease with higher levels of substitution, at all growth stages

Significant treatment difference could be observed in tuber yield in both the years of the experiment T_3 (50% MOP + 50% CS) registered the highest tuber yield and T_5 the lowest The bulking rate and Utilisation Index also differed significantly among treatments

The cooking quality of the tubers from T_3 was as good as that of T_1 Significant differences could be observed in total sugars, reducing sugars and sucrose content of fresh tubers under different treatments With increasing levels of substitution, the content of total sugars increased Sucrose content was found to increase with Na application upto 75% substitution of K by Na

Significant variation was observed in the crude protein, total amino acid and free amino acid content of tubers Hydrocyanic acid, total phenols and crude fibre also differed significantly between treatments The keeping quality studies revealed that tubers from T_3 could be stored fresh up to 35th day in moist soil, whereas tubers from T_1 could be stored only upto 12th day, without deterioration Enzyme studies revealed significant difference in the activity of starch synthesising enzymes, but NRA at 6 MAP was not affected by different treatments

The uptake of N was highest in T_1 and P and K in T_3 Na uptake by T_1 which received no Na was generally higher than other treatments receiving Na Ca and Mg uptake also difered significantly between treatments

Changes in soil organic carbon, available P, available K and available Mg were statistically significant between treatments but that of Ca was significant only from 4 MAP onwards

Yield of tubers was positively and significantly correlated to the uptake of N, P, K, Na, Ca and Mg Yield at harvest was positively and significantly correlated to the root weight and root volume and also to the bulking rate at 2 MAP

Path Coefficient Analysis revealed that the maximum direct effect on yield was contributed by the drymatter of roots at 2 MAP

From the results, it can be concluded that in soils having low to medium status of K, the K of MOP can be substituted up to 50% by Na of commonsalt in cassava without affecting the quality and quantity of tubers