POTASSIUM UTILIZATION IN CASSAVA (*Manihot utilissima* Pohl.) AS INFLUENCED BY NEEM CAKE - UREA BLEND

By

MANORAMA THAMPATTI K. C.

THESIS

submitted in partial fulfilment of

the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1985

DECLARATION

I hereby declare that this thesis entitled "Potassium utilization in cassava (Manihot utilissima Pohl.) as influenced by neem cake - urea blend" 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.

K C Manorama

Vellanikkara,
June, 1985.

MANORAMA THAMPATTI, K.C.

Dr. (Mrs.) P. Padmaja,
Professor, Project Coordinator
(Soils & Agronomy),
College of Horticulture,
Vellanikkara.

CERTIFICATE

Certified that this thesis entitled "Potassium utilisation in cassava (*Manihot utilissima* Pohl.) as influenced by neem cake - urea blend" is a record of research work done independently by Smt. Manorama Thampatti, K.C. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship, or associateship to her.

Dr. (Mrs.) P. PADMAJA
CHAIRMAN
ADVISORY COMMITTEE

Vellanikkara,
June, 1985.

Approved by:

Chairman

Dr. (Mrs.) P. PADMAJA

Members

1. Dr. A.I. Jose

2. Sri. T.F. Kuriakose

3. Sri. V.K.G. Unnithan

ACKNOWLEDGEMENT

I wish to place on record my heartfelt gratitude and obligation to Dr. (Mrs.) P. Padmaja, Professor, Project Coordinator (Soils and Agronomy), Chairman of my advisory committee, for suggesting the problem and for her versatile guidance, valuable suggestions and deep interest, that she has bestowed on me throughout the course of investigation as well as in the preparation of manuscript.

I owe my sincere thanks to Dr. A.I. Jose, Professor and Head, Department of Soil Science and Agricultural Chemistry, for his keen interest and constant help through out the course of investigation. No less has been the help, guidance and suggestions, I received during the conduct of experiment and preparation of manuscript from Sri. T.F. Kuriakose, Professor, Project Coordinator (Rice) and Sri. V.K.G. Unnithan, Associate Professor, Department of Agricultural Statistics.

I am specially thankful to Dr. C. Sreedharan, Professor and Head, Department of Agronomy for useful suggestions and encouragement during the course of the experiment.

My indebtness is also due to Dr. V.K. Venugopal, Associate Professor, Department of Soil Science and Agricultural Chemistry for the timely advice and help rendered at the various stages of my study.

I express my thanks to Sri. K.M. Sathianathan and Sri. C.S. Gopi for their unfailing encouragement and guidance during the period of study. Profound thanks are also due to each and every member of the Department of Soil Science and Agricultural Chemistry for their sincere help and co-operation for the proper conduct of the research work.

I acknowledge my sincere thanks to Professor T.P. George, Department of Agricultural Engineering and Dr. J. Thomas, Assistant Professor, Department of Agronomy for their warm and willing help.

I am greately thankful to Sri. K. Madhavan Nair, Associate Professor, Instrumentation for the help rendered during the period of study.

Thanks are also due to Dr. P.K. Gopalakrishnan, Associate Dean, College of Horticulture for providing the necessary facilities for completing the work.

My friends were of immense help to me at all stages of my research work with special thanks to Miss. Regi P. Mathews and Miss. Bridgit, T.K.

At this juncture, I remember my parents, uncle, auntie and my sister, who were offering me encouragement at every stage of my work.

The award of Research Fellowship by the Potash Research Institute of India, Haryana during the tenure of the study is gratefully acknowledged.

K.C. Manorama

MANORAMA THAMPATTI K.C.

CONTENTS

LIST OF TABLES

<u>Table No.</u>

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

The population explosion in recent years in the developing countries like India has thrown a challenge to agricultural scientists to grow more and more food, fuel and fibre. For the population in India which is likely to touch the figure of about a billion at the end of this century, the National Commission on Agriculture emphasized the need for producing annually 225 million tonnes of food grains by the year 2000 A.D. (Yadav, 1984).

Among the effective inputs for intensive and successful crop production, the fertilisers which play a vital role, especially those supplying the most beneficial single factor-nitrogen, the deficiency of which almost universally limits crop production have been one of the major concerns of soil scientists for many years.

The efficiency of nitrogen utilisation by most of the arable cereal crops seldom exceeds 50 per cent. For upland irrigated crops the utilisation of nitrogen generally varied from 50 - 60 per cent (Dhar, 1981). The tropical and sub tropical climate prevailing in the country aggravates the situation by enhancing denitrification and leaching losses of nitrogen.

Efficient nitrogen utilization is the key to the solution of the problems concerned with high crop production and, minimal pollution and energy conservation. There is considerable scope for increasing the recovery of fertiliser nitrogen according to agroclimatic conditions of the area and level of management. Considering the annual fertilizer consumption of 16 million tonnes by 2000 A.D. an increase of one per cent recovery of nitrogen will result in recovery of one to two lakh tonnes of the nutrient which will be equivalent to more than one million tonne of food grain (Yadav, 1984).

The recent energy crisis, the high cost of the nutrient nitrogen and its low recovery, warrant that research should be directed towards measuring the magnitude of losses of nitrogen and identifying causes and/or developing practices that will reduce losses and increase the efficiency.

Since nitrogen is a mobile nutrient it is lost from uncropped as well as cropped lands through several mechanisms like leaching, volatilization, surface run off, denitrification and microbial immobilisation. The use of slow release nitrogenous fertilisers and nitrification inhibitors, that reduce the activity of nitrogen in solution, were found to be effective in reducing these types of losses.

After the discovery of nitrification inhibitory property of N-serve (Goring, 1962a), several synthetic chemicals and indigenous materials were tested and screened for their nitrification inhibiting capacity. If the nitrification inhibitors are to be recommended for field application, they have to be cheap and abundantly available. The high cost and limitted availability of chemical inhibitors preclude their large scale use and the search for cheap, indigenous sources has become necessary.

Bains et al. (1971) made a break through in this line of research by revealing the nitrification inhibitory property of acetone extract of dried neem kernel and later the nitrification inhibitory capacity of non-edible oil cakes was identified. The oil seed crushing industry faces serious problems in handling and disposal of bulky non-edible oil cakes, which has low manurial value. Hence the progress of this industry largely depends on the utilisation of this product.

In well aerated uplands of Kerala, with its humid tropical climate, nitrification takes place fast, resulting the loss of major part of nitrogen in the heavy rainfall received. In a study, different non-edible oil cakes at different ratios of urea to neem cake were tested for their nitrification inhibitory property under upland Kerala conditions with cassava as the test crop and found that urea-neem cake blend at 5:3 ratio was the best (Sathianathan and Padmaja, 1983b).

Cassava occupies prime place in area and production among tuber crops in Kerala. It is cultivated in 2.70 lakh hectares of Kerala out of 3.46 lakh hectares in India. Since tropics are the places where population growth is highest and threat of large scale starvation is much severe, it has become a matter of urgency to improve the quantity and quality of these tuber crops, which comes second in popularity as a food crop.

Sathianathan and Padmaja (1983b) obtained an increase in tuber yield of cassava with poor quality tuber when urea-neem cake blend at 5:3 ratio was used. The reason attributed for poor quality was low potassium utilisation by the crop since potassium concentration was found to decrease in plant parts with the use of urea-neem cake blend. Potassium is essential to facilitate and regulate the growth and yield of cassava. Besides increasing the yield, potassium application considerably improves the quality of tubers.

Excellent response to potassium was observed in tropics due to the leaching loss of soil potassium by the heavy rainfall received. Increased availability of nitrogen undoubtly increased the need for potassium due to better crop uptake. Hence in the present study an attempt is made for the better utilisation of urea-neem cake blend as a slow release nitrogenous fertiliser either by changing the time of application of potassic fertiliser or by increasing the dose of potassium when applied together with urea-neem cake blend. Use of urea-neem cake blend helps in the efficient utilisation of urea - N during the monsoon season when the cassava crop is planted and maximum loss is expected.

Keeping the above facts in view the present investigation was taken up with the following objectives.

i) To study the effect of using urea-neem cake blend on availability of soil nitrogen and potassium at different stages of growth.

2) To investigate the influence of urea-neem cake blend on the uptake of nitrogen and potassium at major growth stages of cassava.

3) To evaluate the effect of changing the time and levels of application of potassium on its utilization, yield and quality of cassava when applied in conjunction with urea-neem cake blend.

4) To study the dynamics of NH_4^+ - N and K^+ ions in the soil profile when untreated urea or urea-neem cake blend and potassium either alone or in combination are applied to the surface 15 cm of soil.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Indian soils in general have low nitrogen content because of tropical and subtropical climate prevailing in the country. The first map of available nitrogen status of Indian soils was prepared by Ramamoorthy and Bajaj (1969), using organic carbon as the index of nitrogen availability, which was later on updated by Ghosh and Hassan (1980). Out of 365 districts, only 18 districts in hilly regions of India were found to be high in available nitrogen, 228 districts were low, and the rest, medium in status. In Kerala, particularly high temperature and rainfall cause rapid decomposition of soil organic matter and continuous loss of nitrogen reserve. Total nitrogen content of Kerala soils ranged from 0.02 to 0.10 per cent (Nambiar et al. 1966).

Data on the response of field crops to nitrogen were available from thousands of field experiments conducted in agricultural experiment stations and farmers fields under AICRIP projects and several crop improvement projects of ICAR. A critical analysis of the experimental results indicated that while nitrogen application is universally beneficial for all crops, the recovery of fertiliser nitrogen by different crops under different agroclimatic conditions vary considerably. Efficiency of fertiliser nitrogen applied to field showed considerable variation depending upon crop, climate and edaphic factors. It was 40 - 50 per cent for rice, 40 - 91 per cent for wheat, 25 - 88 per cent for maize and 59 per cent for sugarcane (Prasad and Thomas, 1981).

Martin and Skyring (1962) observed that the recovery of fertiliser nitrogen seldom exceeded 50 per cent and residual effect of succeeding crop in general was observed to the extent of 10 per cent only.

In uplands of tropics losses were more severe, as heavy rainfall at short intervals of time causes alternate wetting and drying condition which lead to greater nitrogen losses (Wijler and Delwiche, 1954; Prasad, 1966). The low recovery of nitrogen was variously attributed to volatilisation as ammonia, run-off and leaching losses of soluble nitrogen fractions, denitrification under flooded conditions, fixation as non-exchangeable ammonium and immobilisation by soil micro-organisms.

Broadbent and Stojanovic (1952) reported, though denitrification was common in submerged soil, was also likely to occur in localised anaerobic pockets in well drained upland soils also. The soils and areas worst affected by this process were those subjected to alternate submergence and drying (Patrick and Wyatt, 1964; Prasad and Lakhdivie, 1969; Rajale, 1970).

Various agronomic practices adapted to increase efficiency of nitrogenous fertilisers were incubation of urea with moist soil at 1:6 ratio for two to three days (Mahapatra, 1970) and split application synchronising with peak periods of nitrogen requirement of crops (Katyal and Pillai, 1975).

Use of slow release coated nitrogenous fertilizers like sulphur, plastic, shellac (Rajale, 1970; Prasad, 1979; 1981; Thomas and Prasad, 1982), rockphosphate and gypsum coated ureas (Arumozhiselvum, 1985) or use of inherently low solubility compounds such as IBDU, CDU etc. (Hamamoto, 1966) were found to increase nitrogen use efficiency in different soils and crops.

Foliar application of nitrogen in dry lands (Bhaumik, 1966) and submerged rice fields (Singh, 1974) was also found efficient for increasing nitrogen use efficiency.

2.1 Use of nitrification inhibitors

Goring's work using chemical inhibitor, N-serve (1962 (a) and (b)) triggered the idea of using nitrification inhibitors for increased nitrogen use efficiency and finally led to the development of fertilisers blended with compounds having nitrification inhibitory property.

In India the research on the use of nitrification inhibitors for higher nitrogen use efficiency was started by Prasad et al. (1966) and further work in this line has clearly brought out that these compounds can be advantageously be used in submerged, well drained or partially drained soils.

Apart from N-serve, various chemicals like AM Didin, ATC, Thiourea, ST, Furano compounds, Terrazole derivatives etc. (Prasad et al., 1971) also showed nitrification inhibitory property.

2.1.1 Non-edible oil cakes as nitrification inhibitors

High cost and limited availability of chemical nitrification inhibitors preclude their large scale use. Hence the easily available, low cost indigenous materials had been extensively tested for their nitrification inhibitory property (Bains et al., 1971). Swaminathan (1979) stressed the urgency, to find out new uses for the non-edible oil cakes that have accumulated, as a result of increased oil extraction which even remains as a threat to the progress of oil industry. He also stated that the fertiliser industry should take advantage of the properties of these oil cakes for increasing the return from urea application by preparing urea-oil cake blend .

Non-edible oil cakes particularly karanja, neem, maroti and mahua have been used as a manure since long. Their manurial value and slow rate of nitrification were described by Yashwant et al. (1933) and Khan (1952).

Sahrawat (1982) compared alcohol extracts of karanja and neem cakes with karanjin and found that treatment of urea with the extracts at the rate of 30 per cent of fertiliser nitrogen basis was comparable to pure karanjin applied at the rate of 5 and 10 per cent.

Sathianathan and Padmaja (1983a) showed that urea mixed with non-edible oil cakes, viz., neem, mahua, maroti, rubber and karanja at 5:1, 5:2 and 5:3 ratios possess nitrification inhibitory property at varying degrees. According to them the descending order of inhibitory capacity of different cakes was found as neem > mahua > maroti > rubber > and karanja. They also found that narrowing the ratio of urea to oil cakes increased inhibition capacity of all oil cakes except that of maroti cake which showed maximum inhibition at 5:2 ratio.

2.1.2 Nitrification inhibitory property of neem cake and neem oil

The pioneering work of Bains et al. (1971) made a break through in this search and showed that acetone extract of neem seed cake was on par with the proven synthetic nitrification inhibitors under field conditions. He ascribed the inhibitory property to the presence of acrid alkaloids.

Patil (1972) reported that neem oil contained two fractions, namely a bitter and an odourscent compound which possessed the inhibitory property. He also observed that when the concentration of neem oil was increased from 1.5 to 12 per cent by weight of fertilizer there was a corresponding decrease in nitrification rate.

100 kg nitrogen supplied as urea coated with neem cake produced crop yields equivalent to that of 200 kg nitrogen as urea alone in rice (Anjaniyasharma, 1972).

Application of urea - neem cake mixture in 3:1 ratio on emergence of potato seedlings increased the efficiency of urea for tuber yield (Sharma and Grewal, 1978). Sathianathan (1982) observed an increase in tuber yield of cassava due to mixing of urea with neem cake at 5:3 ratio in a red loam soil.

Enhanced crop yields through the use of neem cake were also obtained in sorghum (Anon, 1972); wheat (Wasink, 1974); sugarcane (Ketkar, 1978); and cotton (Shivraj and Iruthayaraj, 1980).

2.1.3 Stage of inhibition in the mineralisation of urea

Selective inhibition of *Nitrosomonas sp*. by neem cake was observed by Mishra et al. (1975). Nair and Sharma (1976) also made a similar observation in a pot culture experiment using maize as the test crop. They found that activity of *Nitrosomonas sp*. was at its peak on the 22nd day and that of *Nitrobactor sp*. on 42nd day of fertilizer application.

Sathianathan and Padmaja (1983a) observed that NO_2^- - N accumulation during the period of incubation was negligible indicating that inhibition of nitrification took place at the NH_4^+ - N oxidation step mediated mainly by *Nitrosomonas* sp. and *Nitrosococcus* sp. and not at nirite oxidation step.

2.1.4 Period of retention of NH_4^+ - N in soil

Reddy and Prasad (1975) found neem cake was effective in retarding nitrification of urea for two weeks. In moist aerobic condition NH_4^+ - N showed an increase during initial stages, which dropped down sharply in 20 days and then gradually upto 70 days of incubation in a laterite soil. NO_3^- - N content was found to increase with time (Siddappa and Sarkunam, 1979).

Subbiah (1979) and Subbiah and Kothandaraman (1980) observed that blending of urea with neem cake significantly increased NH_4^+ - N on 10th day which gradually declined by 30th day due to its conversion to NO_3^- - N in rice soils.

Thomas and Prasad (1982) found that after three weeks of incubation nitrification rate was 63 per cent, 46 per cent, 29 per cent and 12 per cent for N - serve coated urea, neem cake coated urea - Alchemi (15%), neem coated urea - IARI (20%) and neem mixed urea - IARI (20%) respectively. NO_3^- - N content was very low upto two weeks and thereafter increased sharply. NO_2^- - N was detected only after one week and was highest in urea alone treatment.

Urea - neem cake blend at 5:3 ratio recorded maximum accumulation of NH_4^+ - N on 12th day in a red loam upland soil and then showed a faster decrease accompanied by an increase in NO_3^- - N content (Sathianathan and Padmaja, 1983a).

Thomas and Prasad (1983) reported that the inhibition of nitrification of urea by neem cake was maximum by the end of the first week in alluvial and black cotton soils and by the end of second week in laterite and acid sulphate soils.

2.1.5 Effect of nitrification inhibitors on uptake and utilisation of nutrients

When nitrification inhibitors are used, there is every chance for a temporary preponderance of NH_4^+ - N over NO_3^- - N in soil. Higher ratio of NH_4^+ - N to NO_3^- - N may affect plant metabolism and plant composition by differential absorption of cations and anions.

Jurkowska and Wojcichowicz (1976) observed that nitrification inhibitors like N-serve, DCD and O-nitroaniline applied at 5 ppm or 25 ppm, decreased calcium, magnesium, manganese and zinc while it increased nitrogen, phosphorus and molybdenum concentration in Oats plants grown on neutral soils. But these inhibitors were not found to have any significant influence on uptake of potassium and copper. Contrary to the above observation Bosewell (1977) did not find any significant influence of N-serve on levels of phosphorus, potassium, calcium, manganese, iron and zinc in maize tissues.

Application of N-serve along with ammonium nitrate, ammonium sulphate and urea to winter wheat resulted in a lower concentration of potassium, calcium and magnesium (Mathers et al., 1982). Pill and Sparks (1982) obtained an increased concentration of potassium and ammonium in tomato shoots cv. Marglobe due to N-serve application.

Subbiah et al. (1979A) found that neem cake blended - urea increased nitrogen and phosphorus uptake and reduced potassium uptake in rice. Similarly neem cake treated ammonium sulphate and urea stimulated the uptake of nitrogen and phosphorus, but decreased the uptake of potassium in ragi (Subbiah et al., 1982).

Mixing of non-edible oil cakes like neem, mahua, maroti, rubber and karanja with urea resulted in a lower concentration of potassium in different plant parts of cassava (Sathianathan, 1982) grown on a red loam soil.

2.2 Importance of nitrogen and potassium on growth and yield of cassava

A rainfed crop of cassava under favourable conditions could yield a fresh root yield of 30 tonnes per hectare. In order to obtain this yield, cassava removed 180-200 kg nitrogen, 15-22 kg phosphorus and 140-160 kg potassium per hectare from soil (Anon, 1983).

High nitrogen rates tended to increase the weight of stems and leaves, total dry weight of plants, top to root ratio and plant height (Krochmal and Samuels, 1970; Cheo-Samut, 1974). However Acosta and Pinto (1978) did not find any relation between plant height and number of roots per plant.

According to Fox et al. (1975) top growth responded more strongly to nitrogen application and roots only moderately. In support of this finding Ratnanakul (1976) observed that nitrogen above 50 kg ha^{-1} increased the fresh weight of stems but not that of roots.

The reasons for poor yield of cassava per unit area was attributed to disproportionate use of potassium when compared to other major nutrients (Kanwar, 1974).

Malavolta et al. (1955) in their studies on mineral nutrition of cassava opined that in the absence of potassium the weight of roots decreased whereas that of shoots increased. Contrary to the above observation Pushpadas and Aiyer (1976) observed that there was no effect of potassium on weight of shoots at harvest.

Several workers observed that the most economic dose of potassium for high yielding varieties of cassava was 100 kg ha^{-1} (Mandal et al.,1970; Mohankumar and Hrishi, 1973; Rajendran et al., 1976; Nair et al., 1980).

Asokan and Sreedharan (1978) observed a reduction in potassium utilisation index above 75 kg K_2O ha^{-1} in cassava variety H-97 though total drymatter production increased with potassium.

Asokan and Nair (1982) in their studies concluded that soils having medium to high available nitrogen and potassium the cassava variety M_4 may not require more than 50 kg N and 50 kg K_2O per hectare for obtaining maximum tuber yield.

2.3 Influence of increased availability of nitrogen on potassium uptake in tuber crops

Application of nitrogen along with potassium was necessary for increasing the uptake of potassium in cassava variety H-97 (Mohankumar and Nair, 1969). Kumar et al. (1971) found an increased potassium demand existed at higher nitrogen levels. Rajendran et al. (1976) observed that increased nitrogen and potassium supply increased potassium uptake and the uptake of potassium was positively correlated with rate of nitrogen application for cassava variety H-97 in acid laterite soils. Muthuswamy (1978) also observed an increase in potassium uptake due to nitrogen and potassium fertilization in cassava Varieties, Burma and H-165. Increased nitrogen supply to cassava (M_4) increased potassium uptake, though a lower concentration was observed in different plant parts due to higher dry matter production (Sathianathan and Padmaja, 1983b).

2.4 Effect of increased rate of potassium on nitrogen and potassium uptake in tuber crops

Jacoby (1965) reported the large requirement of cassava, for soil nutrients particularly potassium. Wicke (1968) and Steinck (1974) observed that increased rate of potassium application improved potassium uptake and efficiency of nitrogen utilization.

Kumar et al. (1971) found that the tuber yield of cassava increased progressively with application of potash upto 100 kg ha^{-1} for improved varieties, beyond which it decreased and the optimum level was found to be 103 kg ha^{-1}. According to Rajendran et al. (1976) and Nair et al. (1980) also the most optimum dose of potash was 100 kg ha^{-1} and further application resulted in luxury consumption.

Response to nitrogen was not observed in the absence of potassium or vice versa (Anon, 1977).

2.5 Effect of higher levels of potassium on uptake of other nutrients in tuber crops

Uptake of nutrients particularly the cations were seriously influenced by potassium fertilization in crops. Wicke (1968) reported that heavy dressings of potassium decreased the uptake of magnesium, manganese and sodium while it did not affect nitrogen, phosphorus and copper uptake in potato and sugarbeet.

Potassium-magnesium interaction had been studied in detail by several workers and a lower uptake of magnesium in plants due to the abundance of available potassium in soil was observed (Walsh and Donhoe, 1945; Prince et al., 1947). Similar observation was made by Hovland and Caldwell (1960) in potato and sugarbeet.

Higher rates of NPK reduced total drymatter production in cassava due to calcium and magnesium deficiency (Ngongi, 1976). Contrary to the above observation, Anon (1977) did not find any effect of high rates of potassium on calcium content of the plant but induced magnesium deficiency in cassava, variety Llanera.

Muthuswamy (1978) did not find any significant influence on concentration of iron, manganese, zinc and copper due to nitrogen and potash application in cassava varieties, Burma and H-165, though their uptake increased.

2.6 Time of application and uptake of potassium in relation to yield

Mandal et al. (1970) observed that split application of potassium, half as basal and other half two months after planting was better than its application in two splits, half as basal and other half one month after planting.

Asokan and Sreedharan (1978) reported that the response at lower rate of K_2O (75 kg ha^{-1}) was better in three splits, at basal, two months and three months after planting, but at higher rate (150 kg ha^{-1}) in two splits, half as basal and other at two month in cassava variety H-97.

Application of nitrogen and potassic fertilisers 15, 60 and 90 days after planting gave higher tuber yields in cassava (M_4 and H_{2304}) as reported by Asokan and Nair (1982) in acid laterite soil. However Correa et al. (1981) could not observe any favourable influence in the time of nitrogen and potassium application on yield.

2.7 Index plant parts in cassava

Thomas (1937) found that whole plant analysis will not give any indication of the nutritional status of plants due to heterogenous nature of tissues involved. Cours et al. (1961) suggested the use of phylloderm tissue of main stem in cassava for detecting the nutrient status. Fox et al. (1975) showed that nutrient composition of fourth and fifth fully expanded leaves at the age of four to five months could be better related to tuber yield.

Incremental levels of applied nitrogen reflected more in leaf lamina, where highest concentration was observed (Kanapathy, 1974). Muthuswamy (1978) reported that leaf blades collected from fully opened leaves from the top at five month stage of the crop showed significant correlation with tuber yield. But according to Okeke et al. (1979) blade nitrogen at three month stage was well correlated with plant dry weight at three month stage of the crop and tuber yield at 12 month stage.

Howeler et al. (1982) observed that the youngest fully expanded leaf can be taken as index leaf for boron, copper, manganese and zinc. Kang (1984) considered, leaf blades from fully matured leaves sampled at six months after planting as the best index part for potassium and magnesium.

Petioles from the middle one-third of the total leaves collected, four and half months after planting would serve as the best indicator for nitrogen, phosphorus potassium and calcium (Pushpadas et al., 1975). Ngongi (1976) suggested that petiole of the fifth opened leaf from the top was the most reliable tissue for detecting the potassium status of the plant in relation to soil applied potassium. Okeke et al. (1979) also observed a linear response for applied potassium in petioles at three month stage of the crop.

2.8 Effect of nitrogen and potassium on growth and dry matter production of cassava

Forno (1977) observed that low nitrogen levels restrict height of plants. Contrary to the above statement, Pillai (1967) and Acosta and Pinto (1978) did not find any significant influence on plant height by nitrogen fertilisation. According to Sathianathan (1982) the level of nitrogen though did not influence the height of plants in initial stages of growth, a favourable trend was observed in the later stages of growth.

Natarajan (1975) obtained significantly higher plant height at 150 kg ha^{-1} level of potassium when compared to lower levels. A beneficial effect of potassium on plant height was reported by Ngongi (1976).

Incremental doses of nitrogen had resulted in an increased leaf production and the shedding of leaves was also observed to be proportional to the number of leaves produced (Prabhakar et al., 1979; Ramanujam and Indira, 1979; Sathianathan, 1982).

Pillai (1967) observed a decrease in number of leaves produced at higher levels of potassium (200 kg K_2O ha^{-1}) where as Natarajan (1975) found an increase in leaf number at 150 kg K_2O ha^{-1}.

Increasing nitrogen supply had a favourable influence on tuber number (Deques, 1967; Vijayan and Aiyer, 1969; Pillai and George, 1978; Ramanujam and

Indira, 1979; Sathianathan, 1982), while potassium contributed towards tuber size (Degues, 1967; Pillai, 1967; Muthuswamy, 1978). But Maglhaes (1980) could not find any effect on root number and weight due to potassium application.

High nitrogen rate increased top weight, total dry weight and top to root ratio (Krochmal and Samuels, 1970; Cheo-Samut, 1974). Pillai and George (1978) found that drymatter content increased with increasing nitrogen, phosphorus, potassium and calcium. Wholey (1980) and Sathianathan (1982) also observed that higher levels of nitrogen significantly and positively influenced total dry matter production.

2.9 Effect of nitrogen and potassium on tuber yield of cassava

Significant response to nitrogen application had been observed in cassava in different soil and climatic conditions (Chanda, 1958; Pillai, 1967). Obigbesan and Fayemi (1976) obtained the maximum tuber yield in improved varieties with 120 kg N ha^{-1}. From the results of field trials from CTCRI, the most economic level of nitrogen was suggested to be 80 kg ha^{-1} for hybrids and 40 kg ha^{-1} for local variety M_4 (Mohankumar and Mandal, 1977).

Mohankumar and Nair (1969) observed a progressive increase in tuber yield upto 150 kg K_2O ha^{-1} for cassava variety H-97, while Asokan and Sreedharan (1977) reported an increase in yield from 24 to 39.1 tonnes ha^{-1} due to the increased application of K_2O from 37.5 to 112.5 kg ha^{-1}.

Chan and Lee (1982) recorded highest tuber yield for cassava cv. Black twig on an Orthoxic Tropudult Oxisol soil at 180 kg K_2O ha^{-1} within a range of 0 to 300 kg K_2O ha^{-1}.

2.10 Effect of nitrogen and potassium on quality of tubers

Pillai (1967) showed that nitrogen along with phosphorus and potassium significantly contributed to dry matter percentage and starch content of tubers.

According to Vijayan and Aiyer (1969) and Thampan (1979), balanced NPK supply was critical which decided the quality of tubers.

Increased nitrogen supply reduced starch content (Malavolta et al., 1955; Vijayan and Aiyer, 1969) and Cooking quality (Prema et al., 1975) but increased crude protein and hydrocyanic acid content of tubers (Bruijn, 1971; Prabhakar et al., 1979).

Increased potassium supply enhanced starch content, cooking quality and reduced crude protein and hydrocyanic acid content of tubers (Natarajan, 1975; Asokan and Sreedharan, 1977; 1978; Pillai and George, 1978; Muthuswamy and Rao, 1981; Sathianathan, 1982).

2.11 Tuber yield and nitrogen accumulation with nitrification inhibitors

Information on experiments in cassava with nitrification inhibitors are meagre, except some trials carried out at Thailand. The results showed that there was no significant increase in yield of cassava with slow release nitrogen fertilisers or nitrification inhibitors. But good yield was obtained in sandy loam soils with low organic matter and sufficient phosphorus and potassium (Anon, 1965).

Nopamorndee et al. (1967) used IBDU, ureaform compounds, crotonylidene diurea and guanylurea phosphate salt (12-18-16) as slow release nitrogen sources for cassava but the increased yield obtained was non significant over urea alone.

Though the use of urea-neem cake blend increased nitrogen uptake over untreated urea through out the growth period of cassava, significant increase in nitrogen concentration of tubers was observed only in initial stages of growth (Sathianathan and Padmaja, 1983b).

Hendrickson et al. (1978) found application of nitrification inhibitors reduced both total yield of tubers and proportion of marketable tubers due to their smaller size.

2.12 Dynamics of nitrogen and potassium in the soil profile consequent to application of fertilizers containing them

Downward movement of fertilizers and cations in soil with rainfall or irrigation leading to resultant specific depletion of these ions from root zone is a problem in agriculture. Ghosh (1976) stated that when ionisable salts were added as such or in solution to water saturated soil, the movement of ion pairs of salts were almost instantaneously affected by interaction with soil colloids involving adsorption, exchange, fixation and similar reactions. Presence of other ions, pH value, porosity and compaction of soils were some of the factors likely to influence vertical movement of cations in solution. In general cations moved through soil at all moisture levels but the movement decreased with decline in soil moisture.

Black (1969) reported that maximum nitrogen content occurred in surface layers and distribution with depth differed among soils and also depended on the accumulation of organic matter. Bulk of nitrogen was found in the surface 50 cm of the profile in most of the soils. Sowden et al. (1978) showed fixed ammonium was related to clay content and increased with depth in the profile in sandy soils. Aomine (1951) and Pathak and Srivastava (1963) reported that ammonium fixation was higher in subsoils than in surface soils. Sah and Pasricha (1984) also observed that 22 to 87 per cent of total nitrogen was present as fixed ammonium and higher per cent of latter was observed at lower depths in some soils of Punjab.

2.12.1 Mineralisation of urea

In soil soon after application urea undergoes hydrolysis and later nitrification. About 57 - 82 per cent of added urea nitrogen was hydrolysed within one day of incubation in fine soils. Maximum NH_4^+ - N was noted on the third day of incubation and NO_2^- - N was detected upto seven days. Major portion of the loss of urea nitrogen occurred immediately after addition and within one day of incubation in saline, non-saline, heavy and light soils (Shankhyan and Shukla, 1978).

Patrick and Wyatt (1964) reported the significance of concurrent ammonium oxidation and nitrate reduction in soil that was wet but not submerged. A marked reduction in nitrate accumulation below a suction of 0.50 bar and an increase in ammonium between a suction of 0.05 and zero bar were observed. Mineralisation at zero bar was equal or greater than that of 0.50 bar.

More and Varade (1982) observed about 65 per cent of applied urea nitrogen hydrolysed within two to four days at soil moisture potentials of -0.33, -0.50 and -25 bar in a Vertisol soil.

2.12.2 Potassium dynamics

Black (1969) reported that with increasing depth total potassium in soil remained more or less same or increased in soils of uniform parent material. A deficit in upper part was observed due to weathering and leaching. But in some cases higher potassium content was observed in surface soil due to the transporting action of plants. Kadrekar (1977) observed an increase in total potassium with depth in lateritic, non lateritic and black calcareous soils derived from basalt and a soil derived from mixed rocks. HCl soluble potassium and fixed potassium increased with depth in non-lateritic and soil derived from mixed rocks, while slightly decreased in other two.

Bosewell and Anderson (1968) also found an accumulation of potassium ions in 30 to 60 cm layer in a fallow soil due to higher clay content in this band.

Hanway et al. (1962) stated that sub soils were always low in exchangeable potassium after analysing 48 profiles at North-Central U.S. Riversat (1974) also observed a rapid decrease in exchangeable potassium from surface, till a depth of 50 cm and it varied according to topographic site. Contrary to this Sparks et al. (1983) observed an increased exchangeable potassium in A_2 and B_{2t} horisons in Dothan soils due to leaching of potassium to clayey subsoil horisons.

In calcareous sandy soils bulk of potassic fertiliser was retained in 0 - 10 cm layer and only 4 - 6 per cent of it was found in 10 - 15 cm layer (Kozak, 1973). Best and Drover (1979) found loss of potassium by leaching in columns packed with soils rich in exchangeable magnesium was negligible. Downward movement of potassium was accelerated by increasing the amount of potassium applied or leachate water. Prasad et al. (1981) observed considerable movement of potassium in sandy and sandy loam soil. About 75 per cent of applied potassium moved more than 40 cm depth, whereas in loamy soil about 80 per cent of potassium remained within 4 top 15 cm.

Swarup et al. (1984) reported that most of applied potassium was retained within top 10 cm of the columns packed with forest soil (Terra Fusca Rendzina) under steady state saturated flow condition at the rate of 1 cm day^{-1}. A negative salt balance was observed at the end of the experiment (80 days).

The potassium moving downwards through soil in solution equilibrated continuously with exchangeable cations in the soil and its downward passage was delayed. The extent of delay may be perceived to increase with cation exchange capacity of soil (Allison et al., 1959).

2.12.3 NH_4^+ - K^+ interaction in soil leading to their fixation and plant availability

The fixation and availability of potassium and ammonium are some what interdependant and prior fixation of K^+ or NH_4^+ has a depressing effect on subsequent fixation of other, since the ionic diameters of both are very close and mechanism of lattice fixation of two ions are similar (Stanford and Pierre, 1947; Hanway et al., 1957; Raju and Mukhopadhyay, 1973).

Kardos (1964) stated that considerable amount of added K^+ and NH_4^+ ions undergo fixation depending upon the nature of clay size fraction present in the soil.

The two cations were fixed in nearly equivalent proportions when applied individually but NH_4^+ was fixed preferentially over K^+ when added together to soils rich in illite and montmorillonite clay minerals (Nielson, 1972). A similar observation was made by Raju and Mukhopadhyay (1973) in red loam soils. They also observed that NH_4^+ fixation was lesser when ammonium sulphate and potassium chloride were added simultaneously than that when applied individually.

Kar et al. (1975) found 25 to 40 per cent and 20 to 28 per cent of added K^+ were fixed in the absence and presence of NH_4^+ when added together to an illite dominant acid soil of West Bengal. Of the added K^+ 46 to 59 per cent remained in water soluble form, more being in presence of NH_4^+.

Equilibration of soil with NH_4^+ before addition of K^+ was found superior to addition of K^+ before NH_4^+, or both together as basal dose, since it increased both dry matter production and uptake of nutrients in rice (Singh and Sinha, 1975).

Welch and Scott (1961) observed that maize absorbed 21.8, 16.4, 11.6, 4.96 and 0.12 mg of non-exchangeable K^+ when 0, 10, 25, 50 and 100 mg NH_4^+ were added to moist soil before cropping. But the blocking effect was short lived as NH_4^+ was quickly nitrified.

Raju and Mukhopadhyay (1975) reported that maximum fixation of NH_4^+ ion occurred when addition of NH_4^+ preceeded K^+ addition, and least when K^+ ions was added 10 days before NH_4^+ application, irrespective of concentration in the presence of previously adsorbed cations (Ca^{2+}, Na^+ or Ba^{2+} equivalent to 30 per cent of CEC)

Contrary to the observations made before by other workers Singh and Singh (1979) observed that simultaneous application of both NH_4^+ and K^+ resulted in more fixation of K^+ than when K^+ was applied prior to NH_4^+. Beauchamp (1982) also made a similar observation in Brookston soil series of Ontario.

Bhide and Motiramani (1964) observed application of increasing rates of ammonium sulphate proportionately reduced available potassium in the soil.

Senguptha et al. (1971) showed that addition of superphosphate and diammonium phosphate together with potassium chloride before applying ammonium sulphate significantly decreased NH_4^+ fixation in slightly alkaline soil, while it was only slightly decreased in acidic alluvial soil.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present work was taken up as a continuation of the post graduate project on "Increasing nitrogen use efficiency in upland soils" carried out at the College of Agriculture, Vellayani. Non-edible oilcake - urea blended materials were found to inhibit nitrification at varying degrees, thus reducing leaching and run-off losses of nitrogen. This was found to be specially useful for cassava crop since planting and fertiliser application of the crop coincide with early period of south-west monsoon. Neem cake was found to be the best among different oil cakes tried for increasing nitrogen availability which was evident from both soil analysis and nitrogen uptake at early stages of crop Growth. Uptake of nitrogen at three month stage from urea-neem cake blend was almost double than that from untreated urea. Though urea-neem cake blend recorded an increase of 16.27 per cent in tuber yield over untreated urea, the treatment differences were not statistically significant. Nitrogen - potassium imbalance in the crop was evident, since urea-neem cake blend showed low root to shoot ratio with low quality tubers.

The present work was undertaken to take advantage of the higher nitrogen utilization by the urea-neem cake blend treatment by some manipulation of the potassic fertiliser treatment.

The study comprises of two parts

A) A field experiment to investigate whether the increased nitrogen use efficiency of urea-neem cake blend treatment can be utilised for better tuber production in cassava either by adjusting time of application or increasing the level of potassic fertiliser.

B) A soil column experiment to study the dynamics of ammonium and potassium in soil profiles when surface soil is given differential treatments, under natural conditions during south-west monsoon period. The study also intended to have quantitative estimation of ammonium and potassium in different depths of soil as well as the leaching loss of potassium, since movement beyond the root-zone is likely to affect the crop adversely.

3.1 <u>Field experiment</u>

A field experiment was laid out to study how best the efficiency of urea-neem cake blend for nitrification inhibition can be utilised for increasing tuber production in cassava.

3.1.1 Experimental site

The experiment was laid out in the Agriculture Research Station, Mannuthy. Soil belongs to sandy clay loam texture of order Alfisol.

3.1.2 Season

The crop was grown from July 1983 to April 1984. Weather conditions during the entire cropping season were recorded from meteorological observatory of the District Agricultural Farm, Mannuthy and presented as daily averages in Appendix-I and Fig.6.

3.1.3 Planting material

The introduced exotic variety from Malaya, Malayan-4 (M_4) was used for the study. Mature stem harvested and preserved in shade in the previous season were cut to get setts of 15-20 cm length, from middle portion of the stems.

3.1.4 Fertilisers

Urea, superphosphate and muriate of potash were used as the source of N, P and K. The fertilisers contained 46.01, 15.64 and 54.25 per cent of N, P_2O_5 and K_2O respectively.

3.1.5 Neem cake

The neem cake used for the experiment was analysed for N, P, K and oil content and were found to be 3.28, 0.69, 1.01 and 4.70 per cent respectively. Adjustments in the amount of urea was made, considering the nitrogen content of neem cake so that nitrogen supply by urea-neem cake blend was in accordance with the treatments fixed.

The neem cake purchased from local market of Trichur was finely powdered, and mixed with urea granules, twelve hours prior to soil application.

3.1.6 Treatments

1) T_1 - 50 kg N as untreated urea + 50 kg K_2O as muriate of potash per hectare in two equal splits, half as basal and other half two months after planting (Package recommendation of KAU for cassava var. M_4).

2) T_2 - 50 kg N as urea-neem cake blend at 5:3 ratio and 50 kg K_2O as muriate of potash, half as basal dressing and the other half two months after planting.

3) T_3 - 50 kg N as urea-neem cake blend at 5:3 ratio, half as basal and other half two months after planting and 50 kg K_2O as muriate of potash, half one month after planting and other half three months after planting.

4) T_4 - 50 kg N as urea-neem cake blend as basal dressing and 50 kg K_2O as muriate of potash, half one month after planting and other half two months after planting.

5) T_5 - 50 kg N as urea-neem cake blend and 75 kg K_2O as muriate of potash in two equal splits, one as basal and other half two months after planting.

6) T_6 - 50 kg N as urea-neem cake blend and 100 kg K_2O as muriate of potash in two equal splits, half as basal and other half two months after planting.

Note: P_2O_5 at the rate of 50 kg ha^{-1} was applied uniformly to all treatments.

3.1.7 <u>Layout</u> (Fig.1)

Design - Randomised block design

Replication - Four

Plot size: Gross : 6 m x 4.5 m (48 plants)

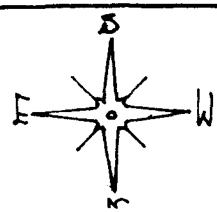
Net : 4.5 m x 3 m (24 plants)

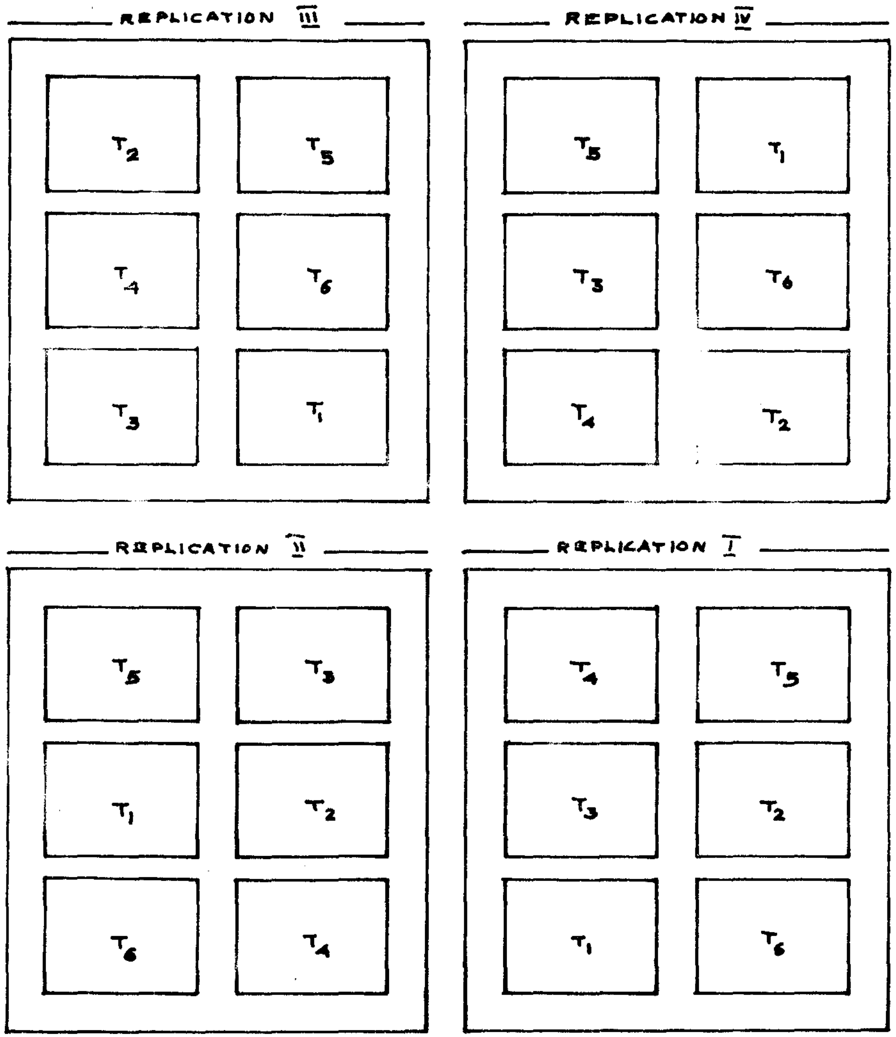
Spacing 75 cm x 75 cm

Total number of plots - 24.

FIG: 1 LAYOUT PLAN

SCALE X AXIS 1 cm = 2 M
Y AXIS 1 cm = 2 M





TREATMENTS

T_1 - 50 kg N AS UREA + 50 kg K_2O AS MURIATE OF POTASH (½ BASAL + ½ 2 MONTHS AFTER PLANTING)

T_2 - 50 kg N AS UREA - NEEM CAKE BLEND + 50 kg K_2O AS MURIATE OF POTASH. (½ BASAL + ½ 2 MONTHS AFTER PLANTING)

T_3 - 50 kg N AS UREA - NEEM CAKE BLEND (½ BASAL + ½ 2 MONTHS AFTER PLANTING) + 50 kg K_2O AS MURIATE OF POTASH (½ 1 MONTH + ½ 3 MONTHS AFTER PLANTING)

T_4 - 50 kg N AS UREA-NEEM CAKE BLEND (FULL BASAL) + 50 kg K_2O AS MURIATE OF POTASH (½ 1 MONTH ½ 2 MONTHS AFTER PLANTING)

T_5 - 50 kg N AS UREA - NEEM CAKE BLEND + 75 kg K_2O AS MURIATE OF POTASH. (½ BASAL + ½ 2 MONTHS AFTER PLANTING)

T_6 - 50 kg N AS UREA - NEEM CAKE BLEND + 100 kg K_2O AS MURIATE OF POTASH (½ BASAL + ½ 2 MONTHS AFTER PLANTING)

3.1.8 Field culture

The cultural practices recommended in the package of practices (1982) prepared by Kerala Agricultural University were followed.

1) Land preparation

The experimental area was ploughed twice and was divided into four blocks. Plots of size 6 m x 4.5 m were laid out, separated by bunds of about 50 cm width and 25 cm height. The plots were dug, the soil was mixed throughly, levelled and mounds of 45 cm height were taken in lines, 75 cm apart on either way.

2) Planting

Planting was done on 8th July 1983. Three noded setts were planted vertically on the centre of the mounds, inserting the tip 4 cm below.

3) Fertilizer application

N and K were given, according to the treatments fixed and all plots received a uniform basal dose of 50 kg P_2O_5 ha^{-1}. To ensure uniformity of application measured amounts of all the fertilizers were applied in bands taken around the middle of each mound.

4) After cultivation

Sprouting of setts was satisfactory. Gap filling was done ten days after planting. Weeding and earthing up operations were given twice, at an interval of two months in the initial stages of growth. Plant protection measures were not found necessary.

3.1.9 Periodic soil analysis

Soil samples were analysed for available nitrogen and available potassium before and twentyfour hours after fertiliser application, and at monthly intervals till harvest.

3.1.10 Biometric observations

1) Height, girth of main stem and number of leaves

Five plants in the net plots were selected at random from each plot for taking biometric observations. Averages of the observations were recorded.

The number of fully opened leaves, girth at a uniform height of 30 cm from the ground level and height of tallest stem of each plant measured from the base of first sprout from planted sett to the top of unopened bud, were recorded at six month and harvest stages of the crop.

2) Dry weight of plant and uptake of nutrients

One representative plant of each plot from the net area was uprooted at three month, six month and harvest stages of the crop. From each plant, the laminae, petioles, stem and tubers were separated and weighed. Representative samples from each of the plant parts were taken, wiped with damp cloth to remove adhering dust particles and were dried in air-oven at 80°C ± 5 till constant weights were recorded. From the dry weight of the sample the total plant dry weight was computed. Dried samples were powdered and analysed for chemical constituents.

Uptake of nutrients were computed from the dry weight and nutrient concentration in the different plant parts. The total plant uptake was then worked out.

3) Tuber length and girth

Length and girth of tubers of five representative plants were measured after harvesting the crop and average worked out.

4) Number of tubers per plant

Total number of tubers of representative plants of each net plot were recorded, and average per plant worked out.

5) <u>Tuber yield</u>

After the harvest of the crop, fresh weight of tubers from five representative plants were recorded after removing the adhereing soil particles and yield per plot was worked out.

6) <u>Root to shoot dry weight ratio</u>

After harvest, root to shoot ratio on dry weight basis was worked out for all treatments in each replication.

7) <u>Quality attributes</u>

Hydrocyanic acid content of the flesh of tuber was estimated on the same day of harvest. Drymatter content of tuber was determined by taking uniform quantity of tuber, chopped into different pieces and dried to constant weight in an air-oven at 105°C. The weight of drymatter obtained was expressed as percentage on the fresh weight of tuber.

Dried flesh was powdered and analysed for starch, and crude protein content.

3.2 Soil column experiment

The soil column study was undertaken to investigate the influence of urea-neem cake blend on ammonium potassium dynamics in the soil columns and the leaching loss of potassium within a period of one month of application.

Pits of 60 cm depth were dug in the experimental area at Mannuthy in four locations and soil samples were collected separately from every 15 cm depth. Bulk density for each depth zone was determined by taking four random samples. Samples from different locations of each depth were thoroughly mixed and air dried under shade.

PVC pipes of 65 cm length and 6 cm internal diameter chosen for the study were washed with 1 N hydrochloric acid and then with tap water and finally with distilled water. The tubes were closed at one end by tying muslin cloths and above these filter papers were placed.

Soil required to fill each 15 cm depth of column was weighed taking into consideration the volume of the tube and bulk density of soil under field conditions. The columns were packed with the soil by tamping small constant increments with steel plunger upto 60 cm height from bottom of the tubes, and top 5 cm was left free.

The following treatments were applied to the top 15 cm of the soil.

1. T_1 - Control
2. T_2 - 100 ppm N as untreated urea
3. T_3 - 100 ppm K as muriate of potash
4. T_4 - 100 ppm N as urea-neem cake blend at 5:3 ratio
5. T_5 - 100 ppm N as untreated urea + 100 ppm K as muriate of potash
6. T_6 - 100 ppm N urea-neem cake blend at 5:3 ratio + 100 ppm K as muriate of potash.

Fertilisers according to the treatments were weighed on the basis of the whole soil weight in the columns and throughly mixed with the top 15 cm soil. While weighing urea-neem cake blend the nitrogen content of neem cake was also accounted. Muslin cloths were laid at the soil surface to avoid direct raindrop impact and consequent soil loss.

The filled soil columns were installed in open field with the help of bamboo poles. Beneath the columns, plastic containers of suitable size were fitted to collect the leachate water and the joints were sealed with cellophane to prevent the escape and entry of water. Enough number of replications were kept so that duplicate samples were removed at weekly intervals for one month. Weather parameters during the experimental period were collected from District Agricultural Farm and presented in Appendix-II and Fig. 1.

Initial soil samples were drawn eight hours after filling the columns, and at weekly intervals for one month. At the end of each week two columns were removed and cut into 15 cm sections. Soil from each section was removed, mixed throughly and immediately extracted for ammonical nitrogen and exchangeable potassium. The collected leachate was also analysed for potassium.

Subtractions were made for ammonium and potassium present in rainwater from all estimate fractions.

3.3 Analytical procedures

3.3.1 Methods used for soil analysis

1 Physical properties

a) Particle size distribution

Mechanical analysis of the soil was carried out by the Robinson's international pipette method, after oxidation of organic matter with 6 per cent H_2O_2 as described by Piper (1950). Soil was classified into textural group using I.S.S.S. system.

b) Single value constants

Single value constants like particle density, bulk density, per cent pore space, field capacity and maximum water holding capacity of the soil for field experiment were determined using keen Raczkowski brass cup measurements (Piper, 1950).

3.3.1.2 Electrochemical properties

a) Soil reaction

The pH of soil water suspension at 1:2.5 soil water ratio was determined using ELICO pH meter with glass and calomel electrodes (Hesse, 1971).

b) Electrical conductivity

Electrical conductivity of the saturation extract was determined as described by Hesse (1971).

3.3.1.3 Chemical properties

a) Organic carbon

Organic carbon was estimated by rapid titration method (Walkly and Black, 1952).

b) Total nutrients

The soil was digested with nitric and perchloric acid and made upto a constant volume (Hesse, 1971).

Total phosphorus, sodium, calcium, magnesium, iron and manganese were estimated from the above extract.

Total phosphorus was estimated by the Vanadomolybdate yellow colour method (Jackson, 1968).

Total sodium was determined using a EEL Flame photometer. Total calcium, magnesium, iron and manganese were estimated using an Atomic absorption spectrophotometer at wavelengths 422.7 nm, 285.2 nm, 248.3 nm and 279.5 nm respectively in air-acetylene flame.

c) Available nitrogen

Available nitrogen in the soil was determined by the alkaline permanganate method, described by Subbiah and Asija (1956).

d) Available phosphorus

Available phosphorus in the soil was extracted in Bray No.1 dilute acid flouride solution (0.03 N NH_4F and 0.025 N HCl) (Bray and Kurtz, 1945) and estimated by colorimetric determination of phosphorus in the extract by chlorostannous reduced molybdophosphoric blue colour method in hydrochloric acid system (Jackson, 1958).

e) Cation exchange capacity

The cation exchange capacity of the soil was determined by leaching the soil with neutral normal ammonium acetate solution and estimating the NH_4^+ - N adsorbed, by distillation using MgO (Peech et al., 1947).

f) Exchangeable cations

Ammonium acetate extract of soil was treated with aquaregia, evaporated to dryness and dissolved in 0.1N HCl. From the extract sodium was determined flame photometrically (Jackson, 1958) and calcium and magnesium by versenate titration method (Cheng and Bray, 1951).

g) Available iron and manganese

Available iron and manganese were extracted with DTPA extractant (Lindsay and Norvell, 1978) and read in an Atomic absorption spectrophotometer.

3.3.1.4 Forms of nitrogen

a) Total nitrogen

Total nitrogen was determined by the macro-Kjeldahl method (Jackson, 1958).

b) Exchangeable Ammoniacal nitrogen

Soil samples were extracted with 2M KCl and ammoniacal nitrogen was estimated by micro-Kjeldahl distillation method as described by Keeny and Nelson (1982).

c) Nitrate nitrogen

Nitrate nitrogen was estimated by the phenol disulphonic yellow colour method as described by Jackson (1958) and the colour intensity was read at 420 nm using a photo-electric colorimeter.

3.3.1.5 Forms of potassium

1) Total potassium

Total potassium was estimated in nitric-perchloric acid digest (Hesse, 1971).

2) Fixed potassium

Fixed potassium was extracted with boiling 1.0 N nitric acid (Wood and Turk, 1941).

3) Exchangeable potassium

Ammonium acetate extract of the soil was treated with aquaregia, evaporated to dryness, and dissolved in 0.1N HCl acid. This was used for estimating the exchangeable potassium.

4) Water soluble potassium

Water soluble potassium was estimated in saturation extract of soil (Jackson, 1958).

Potassium content in different extracts were determined using SSL Flame photometer.

3.3.2 Methods for plant analysis

1) Nitrogen

Nitrogen in the plant samples was estimated by the semi-micro-Kjeldahl method as described by Jackson (1958).

2) Other nutrients

Plant parts were digested with nitric-perchloric acid mixture as described by Wilde et al. (1972) and phosphorus, potassium, calcium and magnesium were estimated.

Phosphorus was estimated by vanadomolybdate yellow colour method (Jackson, 1958).

Potassium was determined flame photometrically (Jackson, 1958) and calcium and magnesium by versanate titration method (Cheng and Bray, 1951).

3) Starch content of tubers

Starch content of the edible portion was determined by titration of the sugar solution using ferricyanide ion in alkaline solution, using methylene blue as indicator (Aminoff et al., 1970).

4) Crude protein

Dried flesh of tuber was analysed for total nitrogen by micro-Kjeldahl method (Jackson, 1958) and crude protein content was computed by multiplying with factor 6.25.

5) Hydrocyanic acid content

HCN content of the fresh tuber was determined immediately after harvest by the following method suggested by Indira and Sinha (1969).

The HCN released on acidulation of homogenised sample was absorbed in a picrate paper, which was later eluted with distilled water and the colour read at 540 nm. The result was expressed as microgram of HCN per gram of fresh tuber flesh.

3.4 Analysis of neem cake and fertilizers used

Nitrogen, phosphorus and potassium contents of neem cake were estimated as described by Jackson (1958). The oil content of the cake was estimated using soxhlet apparatus. Standard analytical procedures were used for the estimation of N, P and K in fertilizers.

3.5 Statistical analysis

The results obtained were statistically analysed as described by Snedecor and Cochran (1967). Some of the relevant correlations were also worked out.

RESULTS

RESULTS

This chapter deals with results of the investigation carried out, which include a field experiment to study the feasibility of utilisation of nitrification inhibitory property of neem cake without affecting the utilisation of other nutrients particularly potassium. As per package of practices recommendations of Kerala Agricultural University for cassava, nitrogenous and potassic fertilizers are applied together, both at the time of planting as well as at top dressing. An attempt is made in this field experiment to achieve full benefit from urea-neem cake blend either by adjusting the time of application of potassic fertilizer or by increasing its rate of application.

Available nitrogen and available potassium of soil under different treatments were analysed at monthly intervals to study the effect of treatments on plant availability of these nutrients.

Plant analysis were done at major growth stages of the crop, such as tuber formation, filling and harvest stages. Nutrient concentration in different plant parts and dry matter production at major growth stages were also recorded and uptake computed.

A soil column study was also conducted to investigate the dynamics of nitrogen and potassium in the profile where treatments were given to surface 15 cm of soil and kept under natural condition in the South West monsoon season.

4.1 Analysis of soil

Physical, electrochemical and chemical characteristics of soil are presented in Table 1a, b and c. Soil belongs to the order Alfisol. Analysis of particle size distribution indicated that it contained 28.83% coarse sand, 34.28% fine sand, 12.99% silt and 21.83% clay. The soil belongs to sandy clay loam textural class as per I.S.S.S. system of soil classification. Absolute and apparent specific gravity of soil were 2.16 and 1.29 respectively. Porosity percentage was found to be 40.30. Maximum water holding and field moisture capacity were 27.70 and 21.11 per cent respectively.

Soil was found to be slightly acidic in reaction with a pH of 5.10. Electrical conductivity of the saturation extract of soil was 0.40 mmho cm^{-1} and cation

Table 1. Characteristics of the soil

a) Physical characteristics

Sl. No.	Particulars	
1	Particle size distribution (%)	
	Coarse sand	28.83
	Fine sand	34.28
	Silt	12.99
	Clay	21.83
	Textural class	Sandy clay loam
2	Absolute specific gravity	2.16
3	Apparent specific gravity	1.29
4	Porosity (%)	40.30
5	Field moisture capacity (%)	21.11
6	Maximum water holding capacity (%)	27.70
b)	Electrochemical characteristics	
1	Soil reaction (pH)	5.10
2	Electrical conductivity of saturation extract (mmho cm^{-1})	0.40
3	Cation exchange capacity (me 100 g $soil^{-1}$)	7.12
c)	Chemical characteristics	
1	Organic carbon (%)	0.93
2	Total nutrients (%)	
	a) Phosphorus	0.03
	b) Calcium	0.12

(Contd.)

Table 1. (Contd.)

Sl. No.	Particulars	
	c) Magnesium	0.12
	d) Iron	2.80
	e) Manganese	0.08
	f) Sodium	0.04
3	Available nutrients (kg ha^{-1})	
	a) Nitrogen	573.30
	b) Phosphorus	55.00
	c) Calcium	805.00
	d) Magnesium	200.00
	e) Iron	26.00
	f) Manganese (ppm)	79.14
	g) Sodium	200.00
4	Forms of Nitrogen	
	a) Total nitrogen (%)	0.05
	b) Ammoniacal nitrogen (ppm)	70.00
	c) Nitrate nitrogen (ppm)	5.50
5	Forms of potassium (kg ha^{-1})	
	a) Water soluble potassium	6.90
	b) Exchangeable potassium	480.00
	c) Fixed potassium	1040.00
	d) Total potassium	5400.00

exchange capacity was 7 me 100 g soil^{-1}. Chemical analysis of soil indicated that organic matter content was very high (1.42%). Total nitrogen, phosphorus, potassium, calcium and magnesium were 0.05, 0.03, 0.27, 0.12 and 0.12 per cent, respectively. Total iron and manganese were 2.80% and 0.08% respectively. Available nitrogen, phosphorus, potassium, calcium and magnesium were 573.30, 55.00, 480.00, 805.00 and 200.00 kg ha^{-1} respectively. Available iron and manganese were 26.00 and 79.14 ppm respectively.

4.2 Field experiment

The results of analysis of soil and plant samples, biometrical observations made on cassava crop at major growth stages, uptake of nutrients, tuber yield and quality attributes are presented here under.

4.2.1 Available nitrogen and available potassium in soil during the crop growth

Table 2 and 3 present the mean values of available nitrogen and available potassium status of soil under different treatments at monthly intervals. Analysis of variance table for the data is given as Appendices III and IV.

4.2.1.1 Available nitrogen

The treatments which have received urea-neem cake

Table 2. Soil available nitrogen at monthly intervals after fertiliser application (Mean values in kg ha^{-1})

Treat-ments	24 hours	1 month	2 months	3 months	4 months	5 months	6 months	7 months	8 months
T_1	718.00	316.50	316.55	180.17	292.10	294.10	227.94	252.77	247.59
T_2	774.22	334.65	302.75	186.25	332.48	290.40	256.31	327.46	325.19
T_3	769.50	317.15	274.25	206.32	317.94	322.99	224.11	345.29	346.19
T_4	1331.50	366.58	282.50	182.09	333.94	272.31	274.20	245.64	296.78
T_5	724.65	326.10	257.05	238.68	303.59	290.45	267.04	316.33	312.69
T_6	738.05	290.15	318.85	226.44	322.47	288.41	242.01	199.83	199.83
CD	158.89	37.63	46.83	35.77	NS	NS	NS	39.52	35.66
SEm ±	52.73	12.49	15.54	11.87	12.98	21.30	46.20	13.12	11.83

blend recorded higher values for available nitrogen when compared to untreated urea treatment. Application of urea-neem cake blend as single basal dose (T_4) showed significantly higher available nitrogen status at 24 hours and one month after fertilizer application.

The available nitrogen content of soil was almost half at one month after fertiliser application when compared to initial level and was only one-fourth in the treatment that has received entire quantity of nitrogen at the time of planting as urea-neem cake blend.

In general available nitrogen content of soil decreased with crop growth. T_5 which has received 75 kg K_2O ha^{-1} in two equal splits recorded significantly lower available nitrogen when compared to others at two months after planting.

Most of the treatments recorded lowest available nitrogen status at three months after planting. Among the treatments, T_5 and T_6 which have received 75 and 100 kg K_2O ha^{-1}, recorded significantly higher values for this parameter than T_1, T_2 and T_4. T_3 which has received first dose of potassium one month after planting recorded a comparatively higher available nitrogen status than those treatments receiving potassium at the same rate.

Treatment differences were not significant at fourth, fifth and sixth month after planting. But the treatment influences were significant after seventh and eighth month. During this stage highest available nitrogen status was recorded by T_3. The treatments T_2, T_3 and T_5 were significantly superior to T_1 which has received nutrients as per package of practices recommendation.

4.2.1.2 Available potassium

Different treatments significantly influenced available potassium status of soil, twentyfour hours after basal application of fertilizers and upto six months after planting except at second and fourth month. Neem cake blending of urea significantly reduced soil available potassium. With increasing levels of potassium, soil availability of the nutrient also showed a corresponding increase. Highest level of potassium recorded maximum value till harvest except at fifth and sixth month. Treatments T_3 and T_4 which have not received the basal dose of potassic fertilizer recorded minimum quantity of plant available form of this nutrient at the first and the second sampling.

Soil available potassium showed significant differences among the between treatments. Maximum available potassium was

Table 3. Soil available potassium at monthly intervals after fertilizer application (Mean values in kg ha^{-1})

Treatments	24 hours	1 month	2 months	3 months	4 months	5 months	6 months	7 months	8 months
T_1	1622.82	728.48	628.85	438.94	439.12	492.71	475.20	461.49	374.39
T_2	1167.21	655.07	624.71	450.26	428.22	510.96	408.79	491.63	390.13
T_3	562.43	517.03	603.65	306.32	515.17	713.27	613.20	548.66	452.43
T_4	589.04	529.71	606.03	427.72	486.58	531.60	449.68	543.60	395.24
T_5	1854.45	821.91	627.19	462.39	504.11	539.24	592.75	537.70	431.73
T_6	2868.93	1134.44	624.65	520.04	563.89	563.89	597.84	595.01	457.72
CD	465.89	258.45	NS	68.44	NS	124.09	87.82	NS	NS
SEm ±	154.59	85.76	16.96	22.71	42.04	41.18	29.14	50.77	22.71

registered by T_6 which has received 100 kg K_2O ha^{-1}. Untreated urea treatment (T_1) recorded a higher value when compared to urea-neem cake blend treatment (T_2).

Treatment differences were not significant at the second month of planting. Treatments T_3 and T_4 which have received initial dose of potassium one month after planting showed comparatively lower available potassium at this stage.

During the third month T_6 was significantly superior to all other treatments except T_5. T_3 recorded the lowest potassium availability and differed significantly from all others.

At the fourth month T_2 recorded the lowest value. Among the treatments, T_3 followed T_6, but the differences were nonsignificant.

Available potassium status of the soil increased during the fifth month and decreased thereafter. Treatment differences were significant, with T_3 recording the highest value followed by T_6 and T_5. During fifth month stage T_3 was significantly superior to other treatments. At six month stage also the same trend was followed, but T_3 was on par with T_6 and T_5.

During seventh and eighth month of sampling the treatment differences were not significant. Among the treatments T_6 maintained maximum available potassium in soil followed by T_3.

4.2.2 Growth characters

Data on growth characters like plant height, girth and number of leaves per plant at six month and harvest stages of the crop, as influenced by the treatments are Presented in Table 4 and analysis of variance in Appendix V.

Plant height was significantly influenced by the treatments at six month stage of the crop. At the same level of potassic fertiliser T_1 was significantly superior to T_4 where the entire quantity of nitrogen was applied as single basal dose of urea-neem cake blend. Beyond 75 kg K_2O ha^{-1} a decreasing trend was noticed in plant height. The same trend was followed at the harvest stage also, but the treatment effects were non-significant.

Plant girth differences were not found to be significantly affected by treatments.

The number of leaves per plant was not significantly influenced by the treatments at six month stage, but was significant at harvest stage with T_4 recording the maximum.

Table 4. Growth characters at different stages of growth (Mean values)

Treatments	Plant height (cm)		Plant girth (cm)		Number of leaves	
	6 month	Harvest	6 month	Harvest	6 month	Harvest
T_1	2.31	2.46	6.91	7.18	30.50	17.00
T_2	2.25	2.45	6.68	7.45	31.75	21.00
T_3	2.15	2.31	6.69	7.00	27.75	17.75
T_4	1.91	2.14	6.62	7.25	34.50	21.25
T_5	2.42	2.49	6.70	7.40	32.00	19.50
T_6	2.17	2.36	7.13	7.72	31.75	16.00
CD	0.30	NS	NS	NS	NS	2.23
SEm ±	0.10	0.11	0.35	0.36	1.99	0.74

4.2.3 Dry matter production

Dry matter production at different growth stages of the crop and the respective root to shoot ratio are presented in Table 5 and analysis of variance in Appendix-VI.

4.2.3.1 Three month stage

At this stage of growth, treatment effects were significant for dry weight of shoot, root and whole plant weight, as well as for root to shoot ratio.

T_5 which has received 75 kg K_2O ha^{-1} recorded maximum shoot weight followed by T_3 where both first and second applications of potassic fertilizer were done one month after nitrogen application as urea-neem cake blend. T_5 and T_3 were on par with each other and T_5 was significantly superior to T_1, T_4 and T_6. T_4 and T_6 were significantly inferior to all other treatments.

Use of urea-neem cake blend (T_2) significantly increased dry weight of tuber at this stage. T_5 registered the maximum tuber weight while T_6 recorded a significantly lower value than T_5. T_4 recorded minimum tuber weight among different treatments tried.

Table 5. Drymatter production at different growth stages of the crop
(Mean values in g $plant^{-1}$)

Treat-ments	3 month stage				6 month stage				Harvest stage			
	Shoot weight	Root weight	Total dry weight	Root to shoot ratio	Shoot weight	Root weight	Total dry weight	Root to shoot ratio	Shoot weight	Root weight	Total dry weight	Root to shoot ratio
T_1	76.18	25.38	101.55	0.33	277.68	292.19	556.87	1.05	275.36	352.87	638.74	1.28
T_2	82.81	44.04	126.85	0.53	305.32	311.76	617.44	1.02	302.96	377.57	680.53	1.25
T_3	85.78	39.95	125.73	0.47	290.46	356.99	646.46	1.23	292.94	465.25	758.19	1.59
T_4	49.37	21.31	70.68	0.43	241.41	342.14	583.50	1.42	265.51	397.68	663.20	1.49
T_5	92.25	59.97	152.33	0.65	337.12	393.53	730.63	1.17	252.91	495.49	848.41	1.40
T_6	57.99	30.13	88.07	0.52	293.80	326.58	593.19	1.11	290.73	398.61	689.34	1.37
CD	12.92	17.76	13.93	0.14	50.77	NS	NS	0.23	NS	52.76	96.77	0.34
SEm ±	4.29	5.89	4.63	0.05	16.89	27.76	57.84	0.08	30.09	17.52	32.11	0.11

Total dry matter production followed the same trend as that of shoot and root weight.

With regard to the root to shoot ratio, T_5 recorded highest value which was on par with T_2 and T_6. T_1 receiving untreated urea recorded the lowest value.

4.2.3.2 <u>Six month stage</u>

At this stage of crop growth, treatment effects were significant only for shoot weight and root to shoot ratio. T_5 recorded the maximum shoot weight and was on par with treatments T_2, T_3 and T_6. The minimum shoot weight was registered by T_4.

T_4 recorded the maximum root to shoot ratio which was on par with T_3. T_2 which has received urea-neem cake blend at 50 kg K_2O ha^{-1} recorded the minimum.

4.2.3.3 <u>Harvest stage</u>

Root weight, total dry weight and root to shoot ratio were significantly different among treatments. Root weight of T_5 and T_3 were on par and significantly superior to all other treatments. Among the treatments, T_1 which has received untreated urea recorded the lowest value preceeded by T_2.

The total dry matter production was also maximum for T_5 which did not differ significantly from T_3. The root to shoot ratio of T_3 was highest followed by T_4 and T_5, with T_2 recording the lowest value.

4.2.4 Nutrient concentration in plant parts

Mean concentration of nitrogen, phosphorus and potassium in different plant parts, viz., leaf lamina, petiole, stem and tuber at different growth stages of the plant, as influenced by treatments are presented in Table 6 to 8 and their analysis of variance in Appendices VII to IX.

4.2.4.1 Nitrogen

Nitrogen content in lamina was significantly influenced by the treatments only in the initial stages of crop growth. Application of urea-neem cake blend in two splits, once at planting and another at two months after planting favourably influenced nitrogen content in leaf lamina at this stage. Changing the time of application and higher levels of potassium reduced it significantly. Application of the entire quantity of nitrogen in single basal dose (T_4) also reduced laminar nitrogen content.

Treatment differences were non-significant at six month and at harvest stages of the crop.

Table 6. Nitrogen concentration in plant parts at different growth stages
(Mean values in %)

Treatments	Lamina			Petiole			Stem			Tuber		
	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage
T_1	5.29	3.69	4.12	0.82	1.21	1.17	0.06	0.64	0.47	0.69	0.38	0.47
T_2	6.60	3.96	4.60	0.88	1.30	1.16	1.13	0.92	0.66	0.84	0.49	0.55
T_3	4.90	4.38	4.13	0.85	0.86	1.17	1.17	0.62	0.69	0.67	0.42	0.38
T_4	4.39	3.98	4.41	0.61	0.91	0.91	1.21	0.62	0.97	0.61	0.49	0.46
T_5	3.92	4.10	4.38	0.96	0.88	1.11	1.20	0.69	0.72	0.69	0.52	0.57
T_6	4.59	4.17	4.06	0.89	0.83	1.06	1.11	0.50	0.78	0.64	0.55	0.50
CD	0.61	NS	NS	0.06	0.21	0.16	NS	0.14	0.12	0.21	0.11	0.07
SEm ±	0.20	0.21	0.15	0.02	0.07	0.05	0.13	0.05	0.04	0.07	0.04	0.02

Nitrogen content in the petiole was significantly influenced by the treatments in all the three major growth stages of the crop. Increased rate of potassium supply and blending of urea with neem cake in general increased nitrogen concentration in petiole, while changing the time of application of potassium as well as application of entire quantity of urea-neem cake blend in single basal dose reduced it at three month stage of the crop. At six month stage of growth T_2 recorded the highest percentage of nitrogen. Almost the same trend was followed at harvest stage also. The nitrogen concentration in petiole showed an increasing trend by harvest stage.

Nitrogen content in stem did not show any significant difference at three month stage of the crop. At six month stage, T_2 recorded highest nitrogen percentage in stem and was found to be significantly superior to all other treatments.

At the three major growth stages of the crop, nitrogen content in tuber was significantly influenced by the treatments. Maximum nitrogen concentration at three month stage was observed in T_2 which was found to be significantly higher to T_4. At six month stage, increased levels of potassium increased nitrogen content of tuber and was on par with T_4 and T_2. Changing the time of application of potassic fertiliser as well as application of untreated urea reduced nitrogen content at this stage. T_5 recorded highest nitrogen percentage in tuber followed by T_2 at harvest stage of the crop. Changing the time of application of potassic fertiliser considerably reduced nitrogen concentration in tuber.

4.2.4.2 <u>Phosphorus</u>

Phosphorus concentration in lamina was not significantly influenced by the treatments at any of the growth stages. But the treatment differences were significant for phosphorus content in petiole and stem at three month and six month stages of the crop. In general petiole phosphorus content was higher at higher levels of potassium at these stages. In early stages of crop growth T_4 recorded maximum phosphorus percentage in stem. At six month stage T_5 recorded lowest stem phosphorus concentration.

At all major growth stages of the crop the phosphorus content of tuber did not show any significant difference among the treatments.

4.2.4.3 <u>Potassium</u>

Potassium content in leaf lamina was significantly influenced by the treatments only upto six month stage

Table 7. Phosphorus concentration in plant parts at different growth stages
(Mean values in %)

Treatments	Lamina			Petiole			Stem			Tuber		
	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage
T_1	0.31	0.19	0.26	0.34	0.07	0.20	0.34	0.13	0.12	0.16	0.07	0.12
T_2	0.31	0.19	0.30	0.31	0.07	0.20	0.38	0.14	0.12	0.17	0.08	0.13
T_3	0.36	0.21	0.36	0.36	0.10	0.20	0.36	0.14	0.13	0.16	0.07	0.12
T_4	0.33	0.23	0.31	0.32	0.13	0.14	0.45	0.13	0.15	0.16	0.08	0.12
T_5	0.32	0.19	0.29	0.48	0.09	0.14	0.39	0.09	0.12	0.18	0.07	0.13
T_6	0.34	0.18	0.26	0.46	0.08	0.13	0.40	0.12	0.13	0.17	0.08	0.10
CD	NS	NS	NS	0.06	0.03	NS	0.06	0.02	NS	NS	NS	NS
SEm ±	0.02	0.01	0.03	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.003	0.01

Table 8. Potassium concentration in plant parts at different growth stages
(Mean values in %)

Treatments	Lamina			Petiole			Stem			Tuber		
	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage	Three month stage	Six month stage	Harvest stage
T_1	1.95	1.14	1.05	1.83	0.83	1.66	1.81	0.83	0.74	1.25	0.83	1.06
T_2	1.82	1.44	1.22	1.79	0.80	1.08	1.51	0.76	0.86	1.28	0.79	1.03
T_3	1.76	1.30	1.19	1.90	0.76	1.12	1.33	0.64	0.72	1.16	0.86	0.88
T_4	1.53	1.29	1.07	1.89	0.87	0.83	2.14	0.57	0.58	1.07	0.76	0.93
T_5	1.83	1.23	1.14	2.06	0.88	0.84	1.98	0.83	0.81	1.23	0.92	1.05
T_6	1.94	1.22	1.12	2.06	1.00	0.87	1.72	0.81	0.83	1.17	0.88	0.94
CD	0.23	0.18	NS	NS	NS	0.27	0.45	0.14	0.15	NS	NS	0.11
SEm ±	0.08	0.06	0.09	0.13	0.06	0.09	0.15	0.05	0.05	0.06	0.05	0.04

of the crop. T_1 receiving untreated urea registered the maximum potassium concentration in the leaf lamina and was significantly higher to T_4, where the entire quantity of nitrogen was applied at the time of planting. All other treatments were on par with each other. T_2 showed maximum potassium content in the lamina at six month stage of the crop. Though not significant, almost the same trend was followed at the harvest stage also.

The higher levels of potassium maintained higher potassium content in petiole at three month and six month stages, but the treatment effects were non-significant. At harvest stage the treatment effects were significant, but higher levels of potassium showed a decrease at this stage. Untreated urea recorded significantly higher potassium percentage than all other treatments and T_4 recorded the minimum value. T_4, T_5 and T_6 were found to be on par with each other.

Potassium in the stem maintained significant difference in all the major the growth stages of the crop. T_4 recorded the highest potassium content in stem at three month stage and was on par with treatments receiving higher levels of potassium (T_5 and T_6) and untreated urea (T_1). T_3 recorded the lowest value at this stage. Unlike at three month stage, T_4 recorded minimum potassium content in stem at six month and harvest stages.

Tuber potassium concentration was significantly influenced only at harvest stage of the crop. Maximum potassium concentration was observed in T_1 which was on par with T_2 and T_5.

4.2.5 Uptake of nutrients by the plant

4.2.5.1 Three month stage

Table 9 summarises the data on the uptake of different nutrients by plant at three month stage and analysis of variance table are given in Appendix-X.

Urea-neem cake blend (T_2) significantly increased nitrogen uptake over untreated urea and was superior to all other treatments. T_4, where entire quantity of nitrogen was applied in single basal dose as urea-neem cake blend recorded lowest nitrogen uptake preceeded by T_6 (100 kg K_2O ha^{-1}).

In general uptake of phosphorus, potassium, calcium and magnesium were higher in T_5 and lower in T_4 and T_6.

4.2.5.2 Six month stage

Mean values of total nutrient uptake at six month

Table 9. Nutrient uptake at 3 month stage of the crop (Mean values in mg plant^{-1})

Treatments	N	P	K	Ca	Mg
T_1	2185.87	301.95	1843.68	951.85	316.90
T_2	3005.58	311.05	1849.26	957.41	320.45
T_3	2541.26	356.04	1837.83	1002.26	278.93
T_4	1264.89	244.31	1260.32	623.21	149.40
T_5	2617.13	463.19	2566.48	1219.00	326.01
T_6	1746.64	213.47	1452.64	865.44	176.74
CD	784.70	72.50	553.31	189.99	82.41
SEm ±	260.38	24.05	183.59	63.04	27.35

Table 10. Nutrient uptake at 6 month stage of the crop (Mean values in mg $plant^{-1}$)

Treatments	N	P	K	Ca	Mg
T_1	4423.30	582.79	4672.52	3725.42	810.75
T_2	5747.09	655.11	5061.30	3554.12	1125.20
T_3	5117.65	666.38	5758.06	3113.89	1201.68
T_4	5007.72	634.04	4372.15	3053.87	1176.62
T_5	6475.49	656.98	6671.20	3749.58	1546.28
T_6	4523.38	550.86	5309.68	3339.51	921.29
CD	NS	NS	1189.34	NS	421.01
SEm ±	573.699	50.14	394.65	379.03	139.69

stage of plant growth as influenced by the treatments are presented in Table 10 and analysis of variance table in Appendix-XI.

Uptake of nitrogen, phosphorus and calcium were not significantly influenced by treatments. But the trend of result indicated that maximum nitrogen uptake was recorded by T_5 followed by T_2, whereas maximum phosphorus uptake was in T_3 followed by T_5 and calcium in T_5 followed by T_1. At six month of planting minimum uptake of nitrogen was recorded by T_1.

Uptake of potassium as well as magnesium showed significant differences among the between treatments. T_5 recorded highest potassium uptake followed by T_3, which were on par with each other. Among the treatments T_4 recorded the lowest value of potassium uptake and was significantly inferior to T_3 which also received same level of potassium.

Magnesium uptake was also highest in T_5 followed by T_3 which were on par with each other. T_1 was significantly inferior to all treatments except T_2 and T_6.

4.2.5.3 Harvest stage

Mean values of total nutrient uptake at harvest stage of the crop as influenced by treatments are presented in

Table 11. Nutrient uptake at harvest stage of the crop (Mean values in mg $plant^{-1}$)

Treat-ments	N	P	K	Ca	Mg
T_1	3281.29	799.36	5909.03	2779.48	1200.26
T_2	3996.15	883.26	6431.54	3142.44	1060.80
T_3	3845.24	955.01	6494.12	3166.21	1353.58
T_4	4469.80	880.59	5228.92	3084.49	1049.18
T_5	5746.99	1088.90	8088.53	3381.28	1562.82
T_6	4560.76	806.75	6270.81	2952.79	1002.65
CD	531.07	154.81	1006.42	NS	281.06
SEm ±	176.22	51.37	333.95	211.83	93.26

Table 11 and analysis of variance table in Appendix-XII.

Uptake of all nutrients except calcium was significantly influenced by treatments. T_5 recorded maximum nitrogen uptake followed by T_6. The untreated urea (T_1) was significantly inferior to all other treatments. Phosphorus uptake was also maximum in T_5 which was on par with T_3. T_1 recorded the lowest value which was significantly inferior to T_5 and T_3.

Potassium uptake by the plant was highest in T_5 and showed a significant difference from others. The minimum uptake was recorded by T_4 which was on par with T_1.

T_5 recorded the maximum magnesium uptake, which did not differ significantly from T_3 alone. The treatments T_2, T_4 and T_6 were significantly inferior to T_3 and T_5 and the minimum uptake was observed in T_6.

4.2.6 Yield attributes and yield

Table 12 presents data on mean values of tuber number, tuber girth, tuber length and tuber yield. Analysis of variance table is presented in Appendix-XIII.

Table 12. Yield attributes and yield of harvest stage

Treat-ments	Tuber number	Tuber girth (cm)	Tuber length (cm)	Tuber yield (tonnes ha^{-1})
T_1	6.00	12.05	19.98	15.20
T_2	6.25	11.10	28.15	15.83
T_3	9.75	12.95	36.83	19.76
T_4	7.50	16.75	23.60	17.11
T_5	9.25	15.78	37.53	21.39
T_6	8.00	13.03	29.15	17.24
CD	2.33	1.06	4.34	2.16
SEm ±	0.77	0.35	1.44	0.71

4.2.6.1 Yield attributes

The treatment effects on tuber number showed significant difference. T_3 recorded maximum number of tubers per plant which was on par with T_5, T_4 and T_6. The untreated urea (T_1) recorded the minimum number.

Tuber girth was also significantly influenced by the treatments. T_4 recorded highest girth and was on par with T_5. The urea-neem cake blend treatment (T_2) showed lowest girth.

Maximum tuber length was recorded by T_5 which was on par with T_3 and significantly differed from others. The untreated urea recorded the minimum tuber length.

4.2.6.2 Tuber yield

Among the treatments, T_5 recorded highest tuber yield which was on par with T_3. The rest of the treatments were on par and differed significantly from T_3 and T_5. The untreated urea (T_1) recorded the lowest yield preceeded by urea-neem cake blend (T_2).

4.2.7 Quality of tubers

Table 13 presents mean concentration of dry matter, starch, crude protein and hydrocyanic acid content of

Table 13. Quality attributes of tuber at harvest stage

Treat-ments	Dry matter content of tubers (%)	Starch (%) (Oven dry basis)	Crude protein (%) (Oven dry basis)	HCN content (ppm)
T_1	40.58	77.29	2.95	40.63
T_2	40.61	70.31	3.45	97.50
T_3	40.23	74.09	2.35	72.88
T_4	39.90	71.22	2.84	180.63
T_5	40.59	78.18	3.56	138.50
T_6	39.38	72.68	3.14	103.13
CD	NS	2.78	0.45	17.25
SEm ±	0.92	0.92	0.15	5.72

tubers. Analysis of variance table for the data is presented in Appendix-XIV.

Neither blending of urea with neem cake nor changing time of application or levels of potassium significantly influenced drymatter content of tuber .

Starch content of tubers was significantly influenced by the treatments. The maximum starch content was observed in T_5 followed by T_1 which were on par with each other. Among the treatments T_2 and T_4 were significantly inferior to other treatments.

The treatment effects were significant for crude protein content and the maximum was recorded by T_5, which was on par with T_2 and T_6. The minimum was observed in T_3.

HCN content was significantly influenced by the treatments. T_4 recorded significantly higher HCN content followed by T_5. HCN content of treatments decreased in the order $T_4 > T_5 > T_6 > T_2 > T_3 > T_1$. All the treatments differed significantly among each other except T_2 and T_6.

4.3 Soil column experiment

Soil samples of different depths were analysed for ammoniacal nitrogen and exchangeable potassium at eight hours after fertilizer application and seven, fourteen, twentyone and twentyeight days after the installation of soil columns.

4.3.1 NH_4^+ - N concentration in soil at different periods

Mean concentration of NH_4^+ - N at different depths of soil during different periods of sampling is given in Table 14.

4.3.1.1 Eight hours after fertilizer application

Treatment without any fertilizer (T_1) represented the initial status of NH_4^+ - N in soil and was found to increase with depth. The treatments that received nitrogenous or potassic fertilizers recorded a higher level of NH_4^+ - N in the top 0-15 cm of the soil. Treatment where urea alone (T_2) was applied maintained a higher level of NH_4^+ - N than the treatment urea-neem cake blend (T_4). Simultaneous application of urea (T_5) or urea-neem cake blend (T_6) with muriate of potash resulted a higher concentration of NH_4^+ - N in soil than when these were applied

Table 14. Concentration of exchangeable NH_4^+ - N in different depths at weekly intervals (Mean values in ppm)

Time	Treatments / Depth (cm)	T_1	T_2	T_3	T_4	T_5	T_6
8 hours after fertilizer application	0-15	88.40	476.21	108.63	420.00	587.44	564.82
	15-30	129.50	126.50	127.80	129.00	126.10	128.21
	30-45	378.34	366.24	369.50	374.56	378.34	378.34
	45-60	418.00	419.40	418.21	420.65	416.64	418.22
7th day	0-15	82.43	606.61	120.51	708.43	377.53	440.71
	15-30	117.61	257.26	154.76	265.59	539.20	580.63
	30-45	221.33	333.78	205.63	168.44	372.44	363.36
	45-60	315.31	318.93	325.75	319.63	349.29	334.05
14th day	0-15	77.81	215.83	72.83	403.62	294.21	500.85
	15-30	64.78	228.31	51.93	421.68	302.52	401.02
	30-45	228.98	226.01	281.72	162.54	224.91	310.66
	45-60	360.07	475.88	390.00	211.37	331.63	238.30
21st day	0-15	65.85	154.31	63.14	261.17	167.45	294.99
	15-30	51.94	272.76	51.91	425.54	349.96	415.98
	30-45	137.25	136.62	239.15	253.76	208.37	415.75
	45-60	169.09	389.51	322.75	256.22	169.25	308.15
28th day	0-15	63.54	119.37	53.78	131.05	99.77	147.03
	15-30	45.36	245.98	39.81	265.26	211.60	271.14
	30-45	132.09	80.58	184.39	226.16	217.23	159.20
	45-60	165.31	157.73	84.21	157.50	245.82	551.60

separately. Urea-neem cake blend - muriate of potash combination recorded slightly lower value when compared to muriate of potash with untreated urea.

The NH_4^+ - N status within each successive lower layer was same for all treatments at eight hours after fertilizer application, though it increased with depth.

4.3.1.2 Seventh day

Downward movement of exchangeable NH_4^+ - N and exchangeable K^+ ions were found at varying degrees in different treatments as a result of infiltration and percolation of rainwater.

NH_4^+ - N content of the top most layer (0-15 cm) increased in treatments where urea (T_2) or muriate of potash or urea-neem cake blend (T_4) were applied compared to the initial sampling, the latter recording the maximum in this layer. But treatments T_1, T_5 and T_6 showed a reduction in NH_4^+ - N level. It was found that blending of urea with neem cake maintained higher concentration of NH_4^+ - N, when applied either alone (T_4) or in combination with muriate of potash (T_6) when compared to same level of nitrogen as untreated urea (T_2).

In the second sampling after one week NH_4^+ - N content in the second layer (15-30 cm) increased for all treatments except control that received no fertilizer when compared to the initial sampling. Combined application of urea or urea-neem cake blend and muriate of potash resulted in depletion of NH_4^+ - N from surface layer and its accumulation in second layer. The NH_4^+ - N accumulation was more in T_6 recording the maximum in this layer. In both T_5 and T_6 it was more than four times the initial value, whereas in T_2 and T_4 a doubling in NH_4^+ - N content was observed. T_3 also showed an increase. Soil column receiving no fertilizer showed an increase in concentration of NH_4^+ - N with increase in depth as in the first sampling.

Compared to the initial sampling NH_4^+ - N status of 30 - 45 cm depth was reduced considerably in treatments T_1, T_3 and T_4, the reduction being more conspicuous in latter, where urea-neem cake blend was applied. In other treatments only very slight reduction was observed. Combined use of urea and muriate of potash (T_5) as well as that of urea-neem cake blend (T_6) also showed slight reduction.

In the fourth layer (45-60 cm) a reduction in NH_4^+ - N was common for all the treatments, maximum being in T_1 (Control), comparing the initial sampling.

4.3.1.3 Fourteenth day

A general reduction of NH_4^+ - N content was observed in the first two layers for all treatments except T_6 and T_4 when compared to previous two samplings. In T_6 where urea-neem cake blend along with muriate of potash was applied an increase in NH_4^+ - N content was observed in the first layer (0-15 cm) whereas it was more or more or less uniformly distributed in top two layers in T_4. T_2 showed a considerable reduction in status of NH_4^+ - N in surface layers (0-30 cm) by this time. Except the treatments which have received urea-neem cake blend either alone or in combination with muriate of potash the NH_4^+ - N was found to concentrate in the lower most layer (45-60 cm).

NH_4^+ - N content in T_3 was comparatively lesser than that of control in surface layers upto 30 cm depth whereas in T_3 it was found to accumulate in lower layers. T_4 showed a considerable increase in NH_4^+ - N status in the second layer (15-30 cm) while it was reduced considerably in T_5 and T_6, the reduction being more in T_5.

NH_4^+ - N concentration in the third layer was found to decrease in all the treatments compared to the previous sampling except in muriate of potash alone treatment (T_3), where an increase was observed. T_1, T_2 and T_3 showed an increase of NH_4^+ - N in lower most layer while others showed a decline.

4.3.1.4 Twentyfirst day

In T_2 NH_4^+ - N was found to accumulate in the lower most layer while, in T_4 it was more accumulated in the second layer. Retention of NH_4^+ - N was more in all the four layers in T_6 when compared to T_5. T_6 recorded the maximum NH_4^+ - N status in surface layer (0-15 cm). Concentration in last three layers (15-60 cm) of T_4 was comparatively greater at this time when compared to that at fourteenth day. The higher content of NH_4^+ - N in T_3 compared to T_1, observed at fourteenth day in lower layers (30-60 cm) became more conspicuous by twentyfirst day.

4.3.1.5 Twentyeighth day

At this time a general reduction in NH_4^+ - N status for all treatments in all the layers was observed except in T_6. The reduction was more conspicuous in surface layers of T_4 and T_6 when compared to other treatments and sampling periods. T_6 recorded a very high NH_4^+ - N content in lower most layer (45-60 cm) which was almost three and a half times greater than that of T_4 and double than that of T_5.

4.3.2 Exchangeable K^+ in soil at different periods

Mean concentration of exchangeable K^+ at different depths of soil during different periods of sampling is given in Table 15.

4.3.2.1 Eight hours after fertilizer application

In general exchangeable K^+ decreased with depth in soil at this stage of sampling. Treatments which received muriate of potash showed a higher content in the surface layer (0-15 cm) where fertilizers were incorporated.

4.3.2.2 Seventh day

An increase in exchangeable K^+ was observed in the surface layers of soil upto 30 cm depth for all treatments. Treatment which has received muriate of potash alone (T_3) recorded the highest content in the surface layers followed by urea-neem cake blend along with muriate of potash (T_6). Untreated urea with muriate of potash recorded comparatively lesser exchangeable K^+ content when compared to T_6 and T_3.

Table 15. Concentration of exchangeable K^+ ions in different depths at weekly intervals (Mean values in ppm)

Time	Treatments / Depth (cm)	T_1	T_2	T_3	T_4	T_5	T_6
8 hours after fertilizer application	0-15	228.00	228.00	316.54	228.00	316.00	326.44
	15-30	222.00	226.16	223.40	223.00	222.18	224.10
	30-45	176.80	174.28	176.60	176.04	175.84	176.01
	45-60	168.21	166.42	168.20	168.00	168.10	166.45
7th day	0-15	234.03	267.52	626.65	265.05	472.70	606.30
	15-30	221.32	282.15	344.21	279.23	338.43	279.50
	30-45	140.53	149.33	156.89	163.51	126.50	145.87
	45-60	129.94	136.69	157.95	156.19	170.14	165.50
14th day	0-15	179.08	224.90	554.91	210.80	454.10	489.72
	15-30	197.44	196.00	266.66	207.58	317.45	286.48
	30-45	158.00	153.10	117.75	135.45	126.00	132.20
	45-60	124.70	123.30	118.17	191.24	187.53	156.85
21st day	0-15	202.31	230.04	462.09	151.08	392.37	444.71
	15-30	169.82	186.55	339.90	201.30	336.45	262.09
	30-45	156.63	197.82	157.25	146.28	163.80	163.41
	45-60	127.49	135.81	117.72	125.00	130.94	151.69
28th day	0-15	203.20	223.22	477.28	184.88	428.06	490.11
	15-30	164.70	259.98	351.28	190.65	407.70	360.03
	30-45	200.00	165.88	137.50	209.06	162.63	262.50
	45-60	165.60	210.33	294.14	155.83	164.19	208.51

In the second layer T_3 recorded the highest exchangeable K^+ content followed by T_5. Though the same level of potassium was applied, T_6 recorded comparatively lower value than T_5.

T_2 recorded slightly higher value than T_5 in the third layer (30-45 cm) whereas the maximum was shown by T_4.

In the fourth layer (45-60 cm) T_5 and T_6 showed a higher exchangeable K^+ concentration than T_3.

4.3.2.3 Fourteenth day

At this stage also T_3 which has received muriate of potash alone showed the highest amount of exchangeable K^+, followed by T_6 in the top most layer (0-15 cm). But the exchangeable K^+ status of T_5 was slightly lower when compared to T_6.

Amont the treatments that received potassic fertiliser, T_3 recorded a lower value than that of T_5 and T_6 in the second layer (15-30 cm).

T_3 recorded the lowest exchangeable K^+ content among the treatments in the lower layer (30-60 cm).

4.3.2.4 Twentyfirst day

At fourth sampling also exchangeable K^+ concentration in the top most layer (0-15 cm) followed the same trend as that of previous times with minimum in T_4. Among the treatments T_3, T_5 and T_6 maintained a higher concentration when compared to others in the first two layers (0-30 cm).

The exchangeable K^+ content in lower layers did not show much difference among treatments.

4.3.2.5 Twentyeighth day

Exchangeable K^+ content in the surface layer (0-15 cm) followed the same trend as that at twentyfirst day.

In the second layer (15-30 cm) T_5 recorded the highest exchangeable K^+ content followed by T_6 and T_3. In the third layer (30-45 cm) T_6 recorded the maximum followed by T_4, while in the lower most layer (45-60 cm) the maximum content was observed in T_3.

4.3.3 Cumulative loss of potassium from soil columns

Mean concentration of potassium in leachate water at weekly intervals are presented in Table 17.

Table 16. Cumulative loss of potassium from soil columns at weekly intervals (Mean values in ppm)

Treatments / Time	T_1	T_2	T_3	T_4	T_5	T_6
7th day	1.18	1.13	1.16	1.08	1.18	1.38
14th day	7.88	8.06	8.98	5.31	8.61	10.39
21st day	11.54	11.33	13.88	9.21	20.82	13.48
28th day	13.63	20.42	24.05	16.03	26.00	15.96

Maximum loss of potassium also was observed from T_5 where urea and muriate of potash were applied together. T_5 did not differ much from T_3 (muriate of potash alone) in its leaching loss of potassium. Loss was considerably reduced when nitrogen was applied as urea-neem cake blend.

DISCUSSION

DISCUSSION

The results of soil column study and field experiment conducted in an Alfisol soil are discussed in this chapter. The soil column study clearly indicated the interaction of ammonium nitrogen and potassium when urea-neem cake blend was used along with potassic fertilizer in the root zone of cassava (0-30 cm).

A field experiment was also conducted which revealed some methods for better utilization of nitrification inhibitory property of neem cake in rainfed uplands without affecting the uptake and utilization of other nutrients especially potassium. As per the present package recommendation nitrogenous and potassic fertilizers are to be applied together at the time of planting and also during top dressing for cassava. A field experiment was conducted during 1981-82 at the College of Agriculture, Vellayani in red loam soil using urea-neem cake blend at 5:1 ratio for cassava. It was observed that both soil availability, percentage nitrogen in plant parts and crop uptake of nitrogen increased considerably. Concentration of potassium in all plant parts showed a decreasing trend. The treatments which received urea-neem cake blend produced poor quality tubers though an yield increase of 16.27 per cent was obtained over untreated urea. The present investigation was taken up to test whether the undesirable effect of neem cake on uptake of potassium could be overcome to a certain extent either by changing the time of application or by increasing the dose of potassic fertilizers.

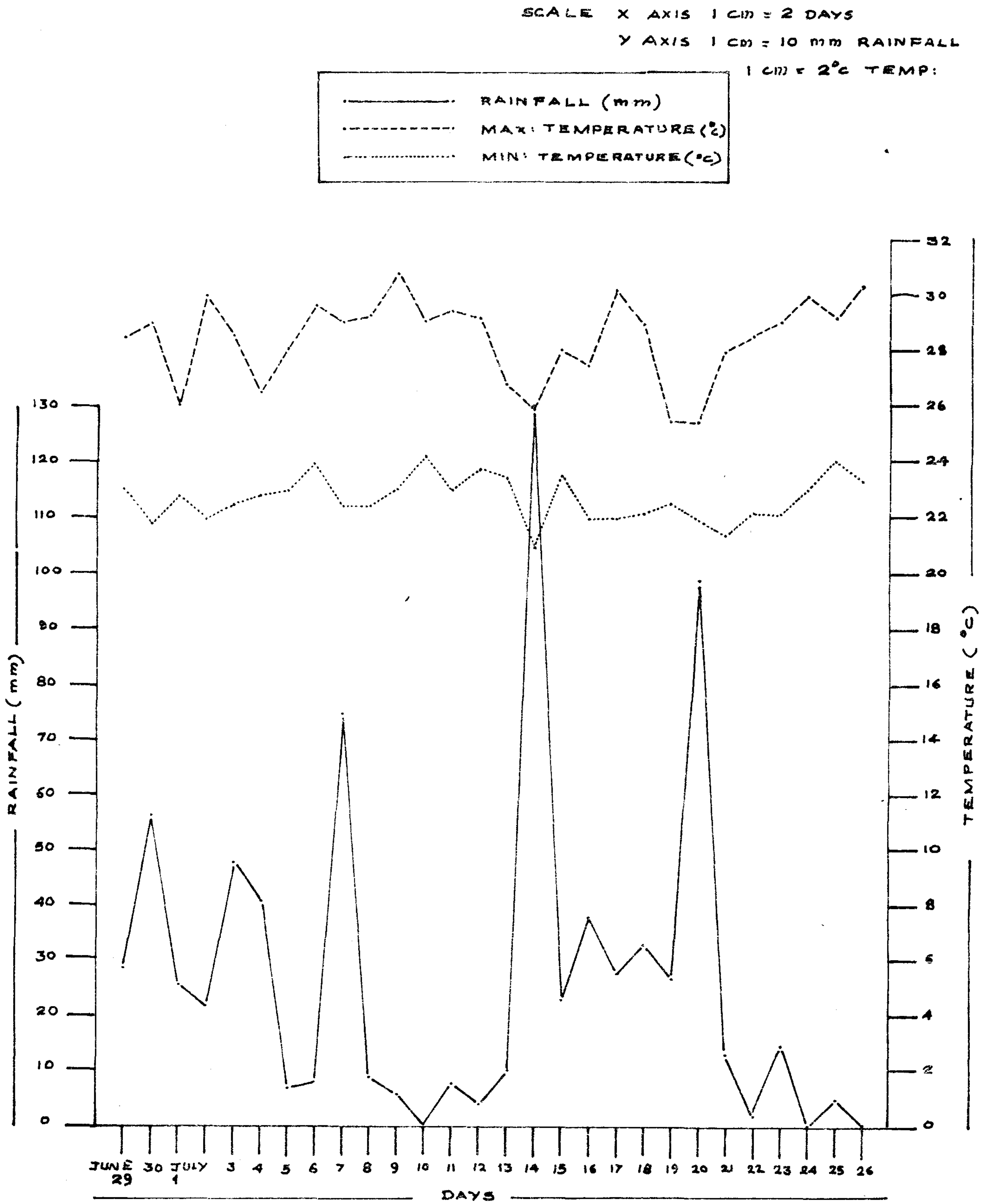
The discussion on soil column study is taken up first for a better understanding of the soil available nitrogen and potassium status, and growth and yield characters of cassava under different treatments.

5.1 Soil column experiment

5.1.1 Dynamics of NH_4^+ - N and K^+ in soil columns under different treatments

When ionisable salts are added to a water saturated soil the movement of ion pairs are almost instantaneously affected by interaction of these ions with soil colloids involving adsorption, exchange and fixation reactions. Interactions of exchangeable NH_4^+ - N and exchangeable K^+ ions when urea or urea-neem cake blend and muriate of potash were applied either alone or in combination are evaluated here. Dynamics of exchangeable NH_4^+ - N and K^+ ions through soil layers at different periods provide information on their utilisation by the crop plants with feeder roots at different depths.

FIG: 2 WEATHER CONDITIONS DURING SOIL COLUMN STUDY



5.1.2 Mobility of exchangeable NH_4^+ - N and K^+ through soil columns

NH_4^+ - N was found to be concentrated more in lower layers under natural upland conditions. This might be due to several reasons like movement along with percolation water, crop uptake from the surface layers or comparative anaerobic condition and less activity of aerobic microbes in deeper layers. Singh and Sinha (1971) also observed an increase in NH_4^+ - N with depth in some soil series of Chotanagpur.

Contrary to the above situation the exchangeable K^+ status of soil was found to decrease with depth. The K^+ ion moving downwards through soil in solution equilibriate continuously with the exchangeable cations in soil. Most of the K^+ ions in soil will remain in exchangeable form and only for a little time it remain in the soil solution as freely diffusable cation associated with freely diffusable anion. Accordingly downward passage of potassium is delayed. The extent of delay depended on cation exchange capacity and ease of replacement of exchangeable cations (Allison et al., 1959). The increased concentration in surface layers might be due to the action of plants in transporting potassium to surface soil from deeper layers (Riversat, 1974). Swarup et al. (1984) also observed that most of applied potassium was retained within top 10 cm of columns packed with forest soil under steady state saturated flow condition at the rate of 1 cm day^{-1}.

In general it was observed that the mobility of NH_4^+ - N ions was more compared to K^+ ions in fertilizer applied soil columns (Table 14 and 15 and Fig.3 and 4). Probably the time lag required for the conversion of amide nitrogen of urea to ammonium nitrogen form might have caused adsorption of K^+ ions in the exchange complex or fixation by clay minerals. NH_4^+ - N ions which are loosely held or remained in water soluble form is likely to move down, towards lower layers especially during the initial stages. A maximum rainfall of 342.00 mm was received during this period.

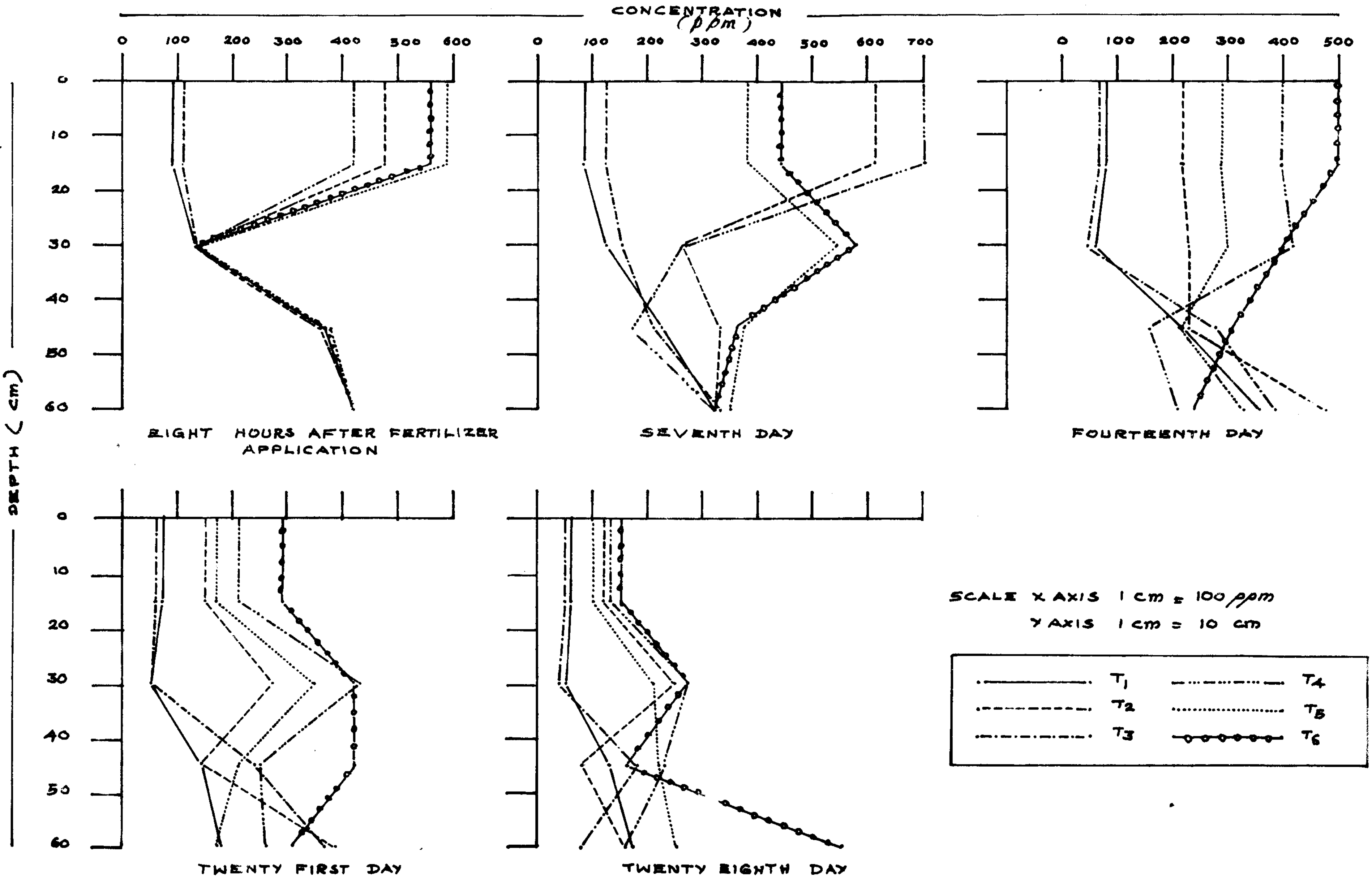
5.1.3 Interaction of exchangeable NH_4^+ - N ions with K^+ ions leading to their movement through soil columns

As generally observed the concentration of exchangeable NH_4^+ - N increased with depth in the control treatment which has received no fertilizer. But when muriate of potash was applied exchangeable NH_4^+ - N increased in the surface layer (0-15 cm) at eight hours after fertilizer application, whereas at subsequent periods of sampling increase was observed in deeper layers also.

The increase in NH_4^+ - N content in surface layer in treatment receiving muriate of potash alone (T_3) might be due to the release of NH_4^+ - N ions from fixation cites in exchange of K^+ ions from clay minerals. The increase in exchangeable NH_4^+ - N content in lower layers during subsequent periods of sampling must be due to its downwards movement in percolating water. After eight hours of fertilizer application concentration of NH_4^+ - N was more in surface layer (0-15 cm) in untreated urea when compared to urea-neem cake blend. Hydrolysis of urea might be quicker in untreated urea treatment when compared to urea-neem cake blend. The observed decrease in concentration might be either due to temporary coating effect of neem cake on urea granules or inhibitory effect on urea hydrolysis. Singh (1983) reported application of neem cake slowed urea hydrolysis.

During the later period of sampling urea-neem cake blend recorded higher exchangeable NH_4^+ - N level. The higher NH_4^+ - N level in soil must be due to inhibition of nitrification by retarding the growth of nitrifiers (Mishra et al., 1975; Nair and Sharma, 1976; Sathianathan and Padmaja, 1983a). The bitter and odourscent principle in neem cake was reported to be responsible for nitrification inhibition (Patil, 1972).

FIG: 3 EXCHANGEABLE AMMONIACAL NITROGEN IN SOIL AT WEEKLY INTERVALS



Movement of NH_4^+ - N was quicker in untreated urea, might probably due to the quick hydrolysis of urea nitrogen in that treatment and was found to concentrate in lower most layer by the second week. But in urea-neem cake blend it was retained in the top layers upto 30 cm depth. Nitrification inhibition by neem cake was reported to be maximum during first two weeks of urea-neem cake blend application to soil (Biddappa and Sarkunam, 1979; Thomas and Prasad, 1982; 1983; Sathianathan and Padmaja, 1983a).

During the third week concentration of NH_4^+ - N was more in the second layer in the treatment receiving urea-neem cake blend, probably due to lesser availability of oxygen in that layer when compared to surface layer. The inhibitory effect of neem cake has appeared to decline by the fourth week.

NH_4^+ - N was found to be more in surface layer when urea or urea-neem cake blend were applied along with muriate of potash in the first sample, taken eight hours after fertiliser application. Campino (1980) reported that application of muriate of potash enhanced the rate of nitrogen mineralisation. At seventh day sampling concentration of NH_4^+ - N was found to be more in surface layer of urea or urea-neem cake blend alone treatment whereas it was found to be concentrated in the second layer in case of urea or urea-neem cake blend applied along with muriate of potash. The NH_4^+ - N content in surface layer was 16 per cent more when urea-neem cake blend was used along with muriate of potash than that with untreated urea and muriate of potash (T_5), probably due to the inhibitory influence of neem cake on nitrification.

The mobility of NH_4^+ - N to lower layers when urea or urea-neem cake blend and muriate of potash were applied together might be caused by the time lag required for urea hydrolysis. This might have resulted in K^+ ions to occupy the exchange sites prior to NH_4^+ - N, which was likely to migrate downwards.

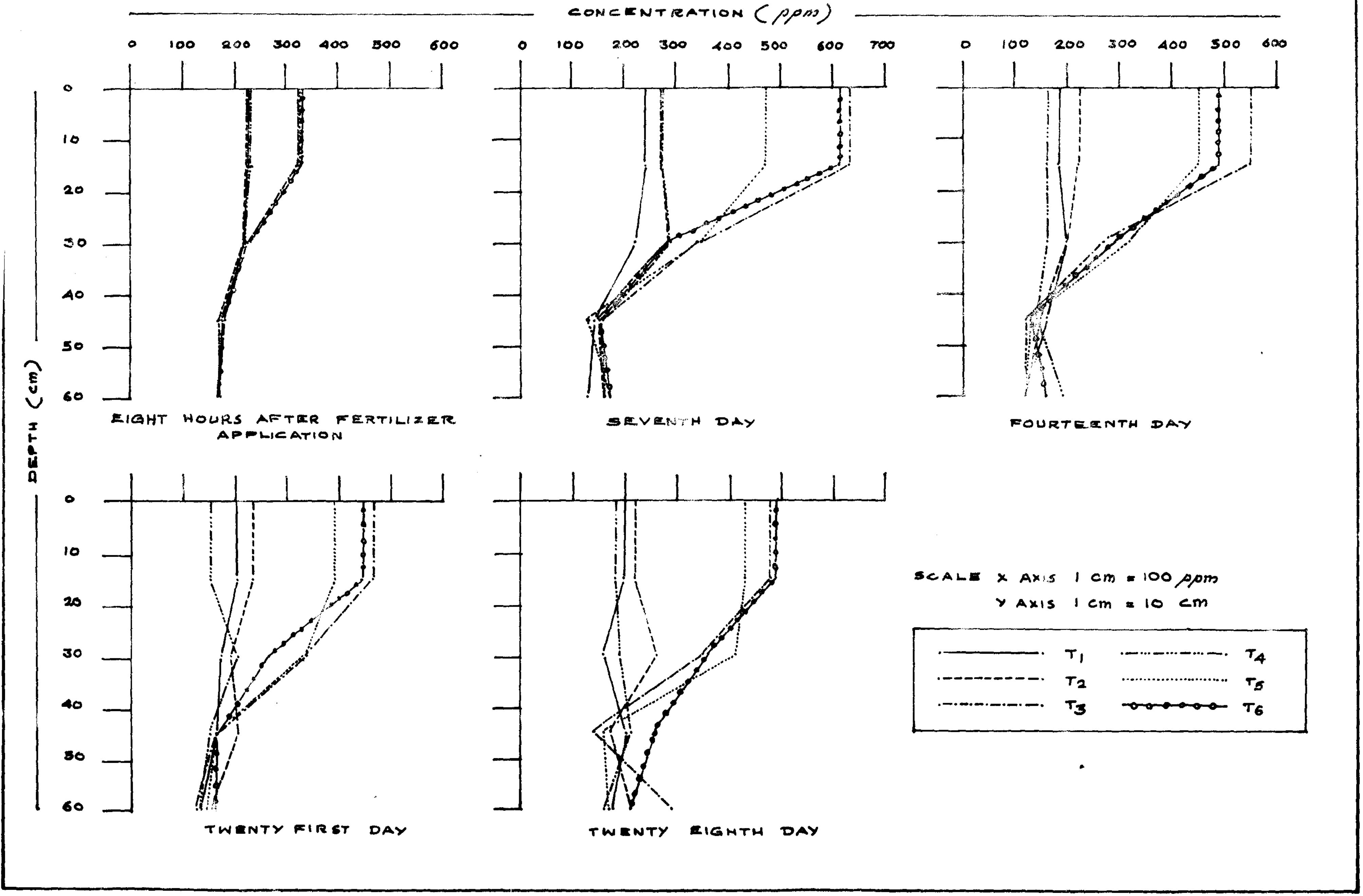
At second week of sampling NH_4^+ - N was distributed in first two layers (0-30 cm) where urea-neem cake blend alone was used, while there was a reduction in all the layers for the treatment receiving urea along with muriate of potash. NH_4^+ - N might have either undergone nitrification or have been displaced from the exchange complex by K^+ ions. In the treatment receiving urea-neem cake blend with muriate of potash also, NH_4^+ - N was concentrated in first two layers, maximum being in the top layer (0-15 cm).

It maintained 70 per cent and 33 per cent more of exchangeable NH_4^+ - N in first and second layer respectively when compared to urea along with muriate of potash. Maximum accumulation of NH_4^+ - N was observed during the second week when neem cake was mixed with urea (Reddy and Prasad, 1975).

Exchangeable NH_4^+ - N was found to migrate downwards and accumulated in second and third layer by third week and was in the lower most layer by fourth week of fertiliser incorporation. The urea-neem cake blend with muriate of potash recorded 78, 19, 99 and 82 per cent more exchangeable NH_4^+ - N in first, second, third and fourth layers respectively when compared to untreated urea with muriate of potash in the third week of fertiliser application, whereas it was 124 per cent more in the fourth layer (45-60 cm) in the fourth week. The heavy rainfall received during the period of experimentation (763.00 mm) might have caused it's downward movement.

Exchangeable K^+ on seventh day was maximum in the treatment receiving muriate of potash alone followed by that treatment receiving muriate of potash along with urea-neem cake blend. When untreated urea was applied along with muriate of potash exchangeable K^+ was 28 per cent less in surface layer (0-15 cm), whereas it was

FIG: 4 EXCHANGEABLE POTASSIUM IN SOIL AT WEEKLY INTERVALS



21 per cent more in second layer (15-30 cm) than that of urea-neem cake blend with muriate of potash. The NH_4^+ - N ions produced by urea hydrolysis might have displaced K^+ ions from the exchange complex of surface soil which might have accumulated in the second layer in the former treatment. Sudayemprasert et al. (1976) also observed that the movement of applied K involved the redistribution of exchangeable K^+ ions from 0-8 cm zone to 8-15 cm zone with some build up of exchangeable K^+ in 15-30 cm zone in sandy loam soils.

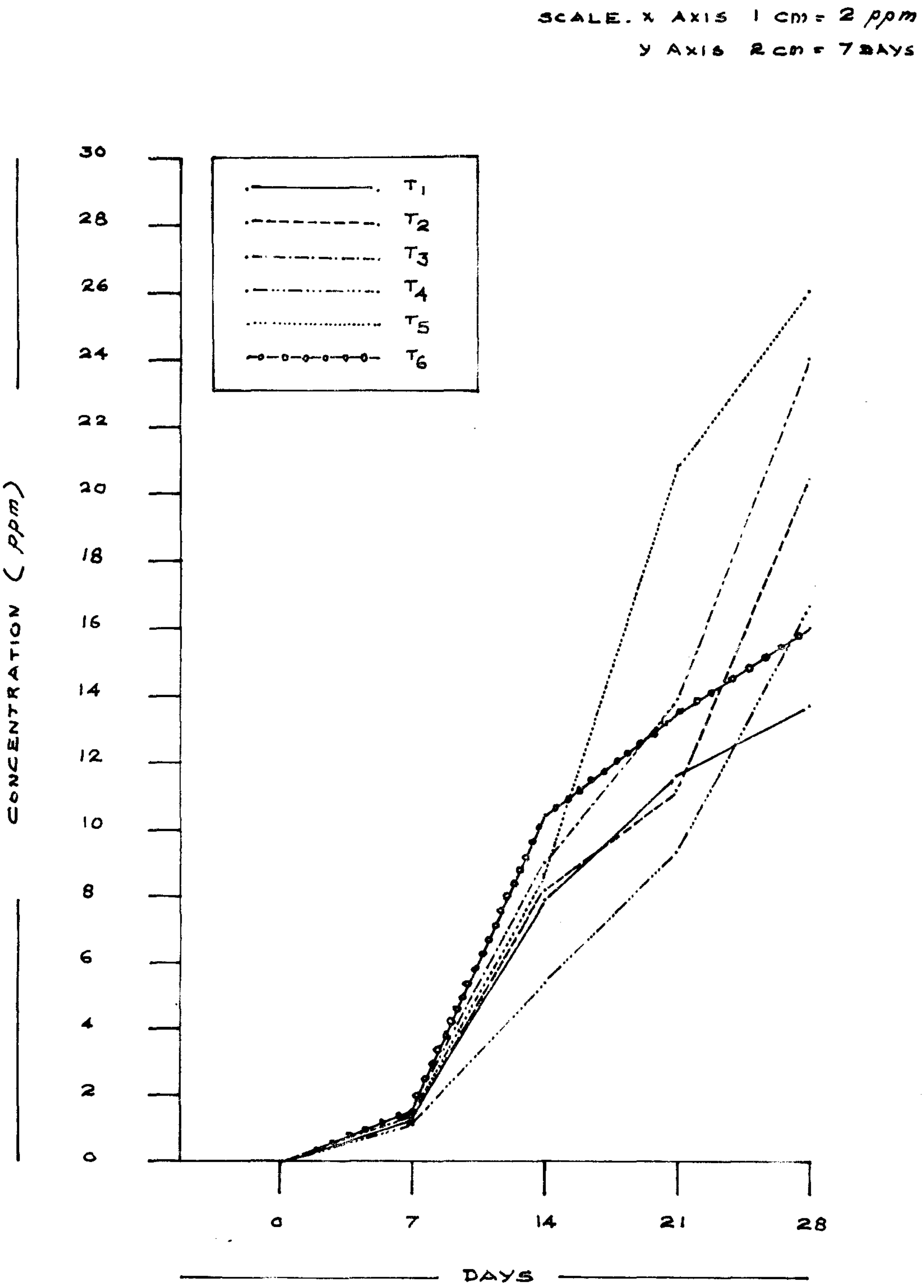
Concentration of exchangeable K^+ ions followed, the same trend as that of seventh day till the end of experiment, with muriate of potash alone recording the maximum followed by urea-neem cake blend or untreated urea along with muriate of potash. But the accumulation of exchangeable K^+ ions in the second layer (15-30 cm) was comparatively lesser in the treatment which has received muriate of potash alone, by fourteenth day (Fig.4). The migration of exchangeable K^+ ions was more when muriate of potash was applied along with urea or urea-neem cake blend.

By twenty first day the exchangeable K^+ ion concentration in the surface layer was reduced considerably in treatment receiving muriate of potash alone, probably due to leaching of exchangeable K^+ to the lower layers, particularly to the second layer (15-30 cm). A rainfall of 609.20 mm was received during this period. Treatments receiving muriate of potash along with urea or urea-neem cake blend also showed a decline in their exchangeable K^+ level in the surface layer.

In general the treatment receiving urea-neem cake blend showed minimum exchangeable K^+ ion concentration after twenty first day of sampling in the soil layers. It was even lesser than that of control which has received no fertilizer, probably due to the displacement of exchangeable K^+ ions by NH_4^+ - N ions and its leaching in percolating rain water.

Leaching loss of exchangeable K^+ ions from soil columns under different treatments are presented in Figure 5. The loss of K^+ ions was maximum when muriate of potash was applied along with untreated urea. The loss of K^+ ions was reduced considerably when it was applied along with urea-neem cake blend indicating that a part was retained in the soil (Table 14 and 15). Hence it was concluded that increasing retention of NH_4^+ - N in soil as a result of slowed urea-hydrolysis and nitrification inhibitation by neem cake, enhanced the retention of more potassium in soil.

FIG: 5 CUMULATIVE LOSS OF POTASSIUM FROM SOIL COLUMNS



The prior occupation of exchange or adsorption sites by K^+ ions due to the increased time lag induced by neem cake in urea hydrolysis might have helped in retention of more exchangeable K^+ in soil and reduced its losses. Kosak (1973) and Best and Drover (1979) also observed movement of exchangeable potassium was negligible in soil columns packed with calcareous sandy soils and soils rich in exchangeable Mg^+ ions respectively.

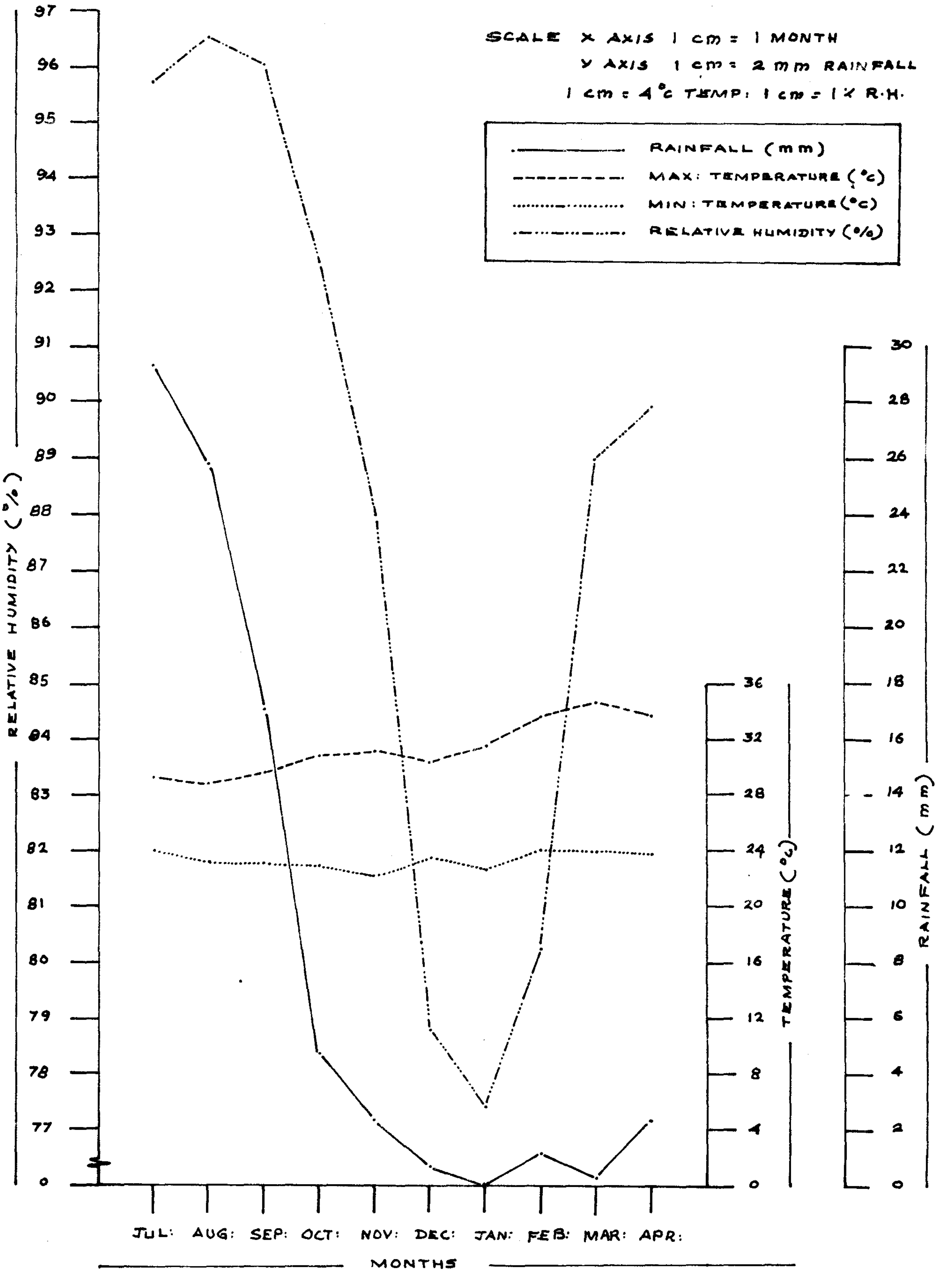
5.2 Field experiment using urea-neem cake blend

5.2.1 Influence of urea-neem cake blend, and time and rate of application of potassic fertiliser on available nitrogen status of soil and its uptake by cassava

Available nitrogen status of soil under different treatments at 24 hours after fertiliser application and at monthly intervals upto eight months after planting showed significant difference (Table 2). Treatment differences were not significant at fourth, fifth and sixth month of planting.

Available nitrogen status of soil was maximum in the treatment receiving entire quantity of nitrogen as urea-neem cake blend as single basal dressing upto two months after planting, when compared to other treatments. Neem cake blending increased available nitrogen status

FIG: 6 WEATHER CONDITIONS DURING CROP GROWTH

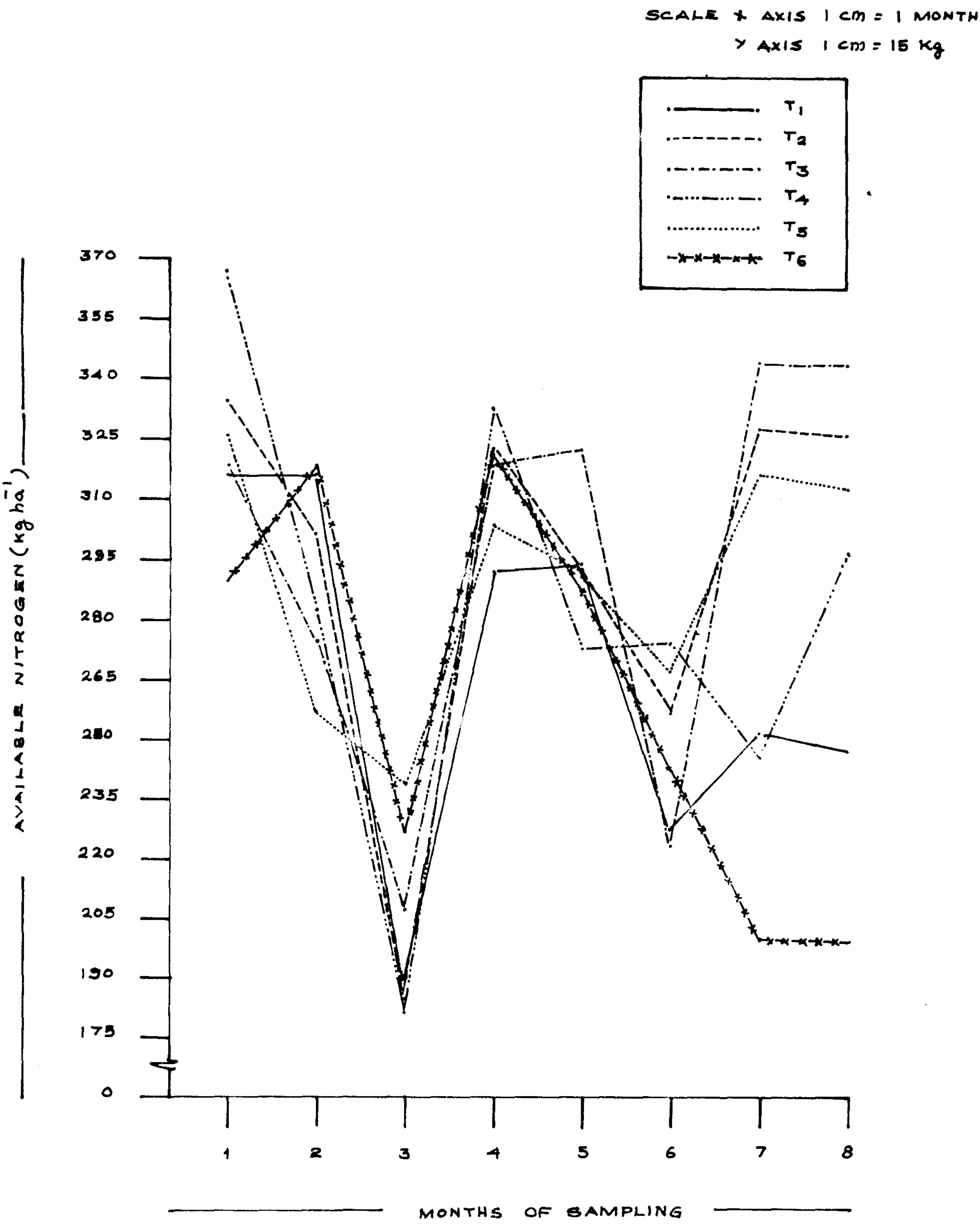


even within 24 hours of fertiliser application. According to Shankhyen and Shukla (1978) 57-82 per cent of applied urea nitrogen was hydrolised within 24 hours. The higher available nitrogen status of neem blended urea treatments might probably due to inhibition of simultaneous nitrification process in these treatments.

One month after planting available nitrogen status of all treatments was almost half except in T_4, where it was only one fourth of original level. The general reduction might probably due to the heavy rainfall received (908.00 mm) during this month as well as due to initial vigorous crop uptake. As crop uptake in T_4 was comparatively lower, the drastic reduction in available nitrogen observed one month after planting must be due to the loss by leaching (Table 2).

In general T_5 and T_6 which have received higher dose of potassium recorded comparatively lower available nitrogen probably due to displacement of ammoniacal nitrogen from exchange complex leading to its loss. Singh and Singh (1979) also observed a similar phenomenon at higher levels of potassium supply. According to them potassium fixation exceeded that of ammonium fixation and hence a major part of ammonium was kept either as water soluble or exchangeable form which might have caused its loss. The rainfall received during the initial three months was also higher (2219.60 mm).

FIG: 7 AVAILABLE NITROGEN AT MONTHLY INTERVALS



T_1 recorded a lower value for available nitrogen when compared to T_2. The rate of nitrification in treatment receiving untreated urea (T_1) might be higher leading to its loss as NO_3^- - N. T_3 which has not received potassic fertilizer at the time of planting also recorded a lower available nitrogen status than T_2, probably due to greater fixation by the soil colloids. Fixation of ammonium was more when addition of either ammoniacal or ammonium producing fertilizers preceded addition of potassic fertilizers (Raju and Mukhopadhayay, 1975).

The nitrification inhibitory property of neem cake was evident in the higher available nitrogen status of T_2 when compared to T_1 as well as higher uptake by the plants of this treatment at tuber formation stage. T_5 which has received 75 kg K_2O ha^{-1} recorded comparatively higher uptake of nitrogen, probably due to ionic competetion between potassium and ammonium ions at root exchange site. Ammonium was reported to have larger ionic size (Nielson, 1972). But same phenomenon was not observed in T_6 receiving 100 kg K_2O ha^{-1} probably due to some unfavourable nutrient interaction in plants, reducing its metabolic activity. T_6 also recorded comparatively lower dry matter production at all stages.

During the last two months before harvest, highest level of nitrogen was maintained by T_3 which has received potassium one month after application of urea-neem cake blend. A slightly lower level was found to be maintained by the treatments where both were applied simultaneously. Uptake of nitrogen was comparatively lower in T_3 when compared to T_2, probably due to higher defoliation as evident in the number of leaves retained by the plants at six month and harvest stages. Raju and Mukhopadhyay (1973) reported that when both ammoniacal nitrogen and potassium were applied together, the fixation of both were intermediate to that when they were applied separately. In general urea-neem cake blend treatments maintained a higher available nitrogen status.

During this stage a general increase in available nitrogen status was observed. The leaves and twigs were reported to transfer back a considerable portion of nutrients removed by the crop from soil by defoliation (Thampan, 1979). It was estimated that an average of 50-60 per cent of nitrogen taken up by cassava may get back to soil by defoliation. The observed increase in available nitrogen in last two months in all treatments might probably due to leaf fall (Table 4). The lesser uptake of nitrogen at harvest stage also clearly indicated

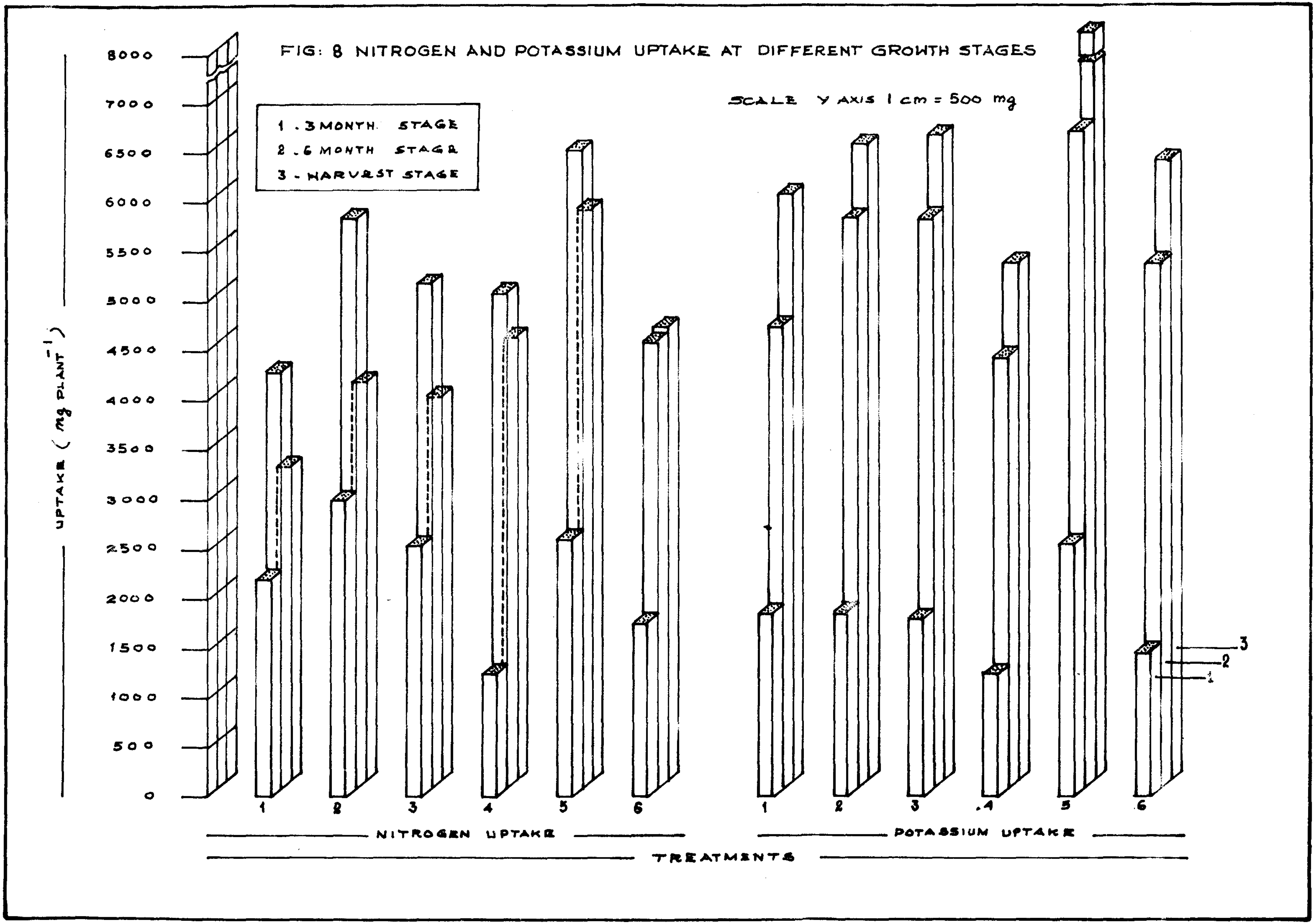


FIG: 8 NITROGEN AND POTASSIUM UPTAKE AT DIFFERENT GROWTH STAGES
SCALE Y AXIS 1 cm = 500 mg
1 . 3 MONTH STAGE
2 . 6 MONTH STAGE
3 - HARVEST STAGE
UPTAKE (mg PLANT⁻¹)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
8000
1
2
3
4
5
6
NITROGEN UPTAKE
POTASSIUM UPTAKE
TREATMENTS

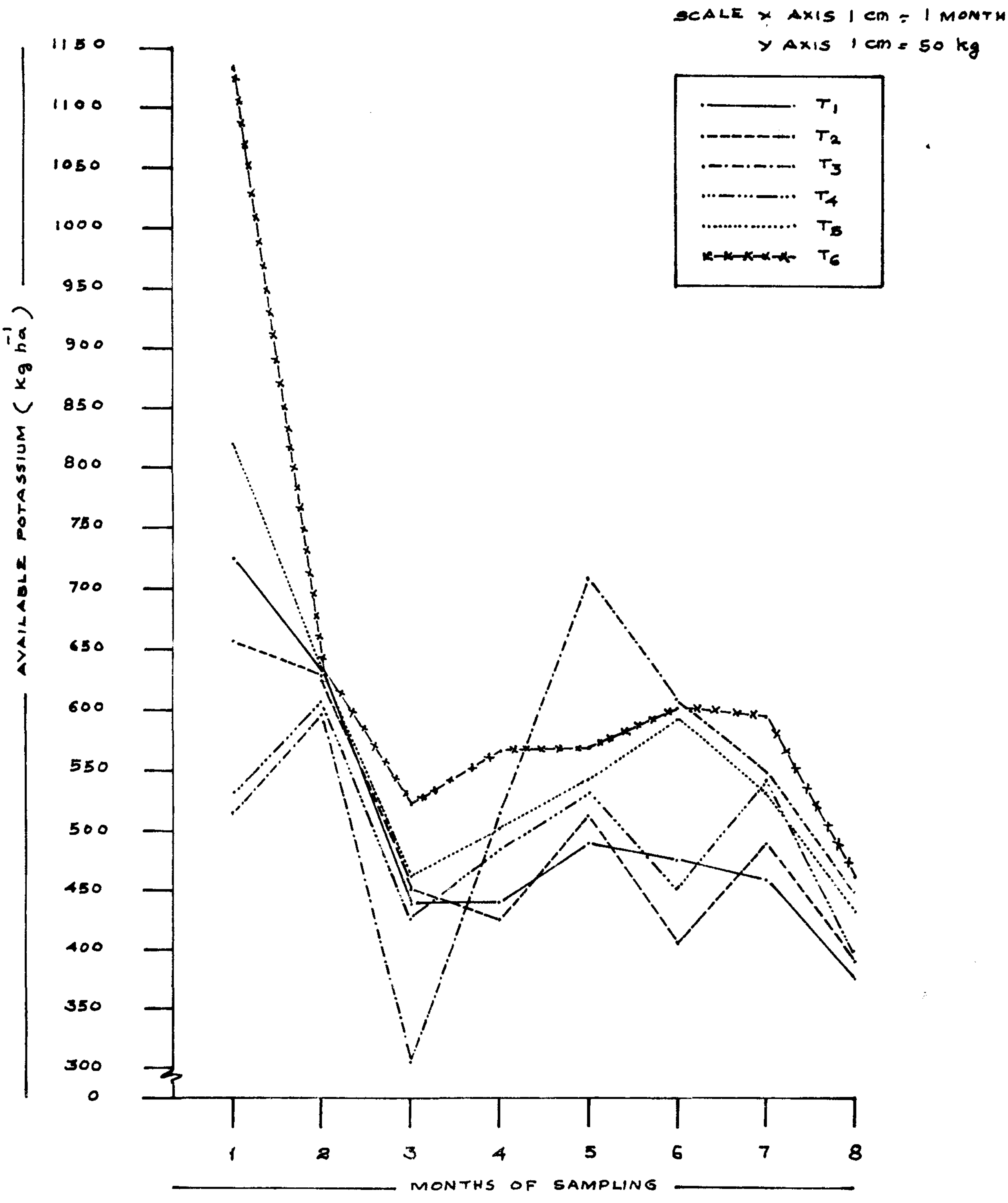
this factor (Table 11). T_1 which has received untreated urea recorded the lowest nitrogen uptake.

5.2.2 Influence of urea-neem cake blend and time and rate of application of potassic fertilizer on available potassium status of soil and its uptake by cassava

Table 3 and figure 9 represent available potassium status of soil under different treatments. Urea-neem cake blend (T_2) significantly reduced soil available potassium within 24 hours of fertiliser application when compared to untreated urea (T_1). It followed the same trend upto three month stage of the crop. Low soil available potassium was recorded only during the early period of crop growth where rainfall received was high (2219.60 mm) and potassium might have lost in runoff water. Boodt et al. (1979) also reported that run off loss of potassium was much more when compared to its loss in percolating water.

The treatments that have not received basal dressing of potassium recorded lowest soil available potassium. Higher rates of potassium correspondingly increased available potassium status of soil. A decrease was noted in soil available potassium status with crop growth due to crop uptake (Table 3 and Fig.9) and other losses.

FIG: 9 AVAILABLE POTASSIUM AT MONTHLY INTERVALS



The treatment that has received potassium one month and three months after planting recorded lowest soil available potassium during the first three months. But the uptake was only slightly lower than the treatments which has received potassium at the time of planting and two months after that. Soil column study also indicated that when either urea or urea-neem cake blend alone were applied the exchangeable potassium in soil increased when compared to the treatment without any fertiliser. Farina and Graven (1972) also observed an increase in soil available potassium due to application of nitrogen fertilizers.

Soil available potassium as well as crop uptake was higher in this treatment at six month and harvest stages when compared to simultaneous application of both the fertilizers (Fig. 9 and 8).

The treatment where entire quantity of nitrogen was applied in single basal dressing as urea-neem cake blend and potassium at one month and two months after planting recorded minimum potassium uptake at all the three major growth stages. This might be due heavy loss of nitrogen in the initial stages of crop growth. The rainfall received during the first month of planting was maximum (908.70 mm). The loss of nitrogen was indicated by lower available nitrogen level in soil from second month onwards

(Fig.7). The lesser nitrogen uptake caused minimum dry matter production (Fig.8) and potassium uptake at major growth stages. Application of nitrogen along with potassium was necessary for increasing the uptake of potassium in cassava (Mohankumar and Nair, 1969).

Treatments which received higher rate of potassium maintained higher soil available potassium status. But potassium uptake of T_6 receiving 100 kg K_2O ha^{-1} were comparatively lesser than T_5 that received 75 kg K_2O ha^{-1}. Lesser crop uptake could be attributed to lesser dry matter production consequent to some nutrient imbalance in the plant.

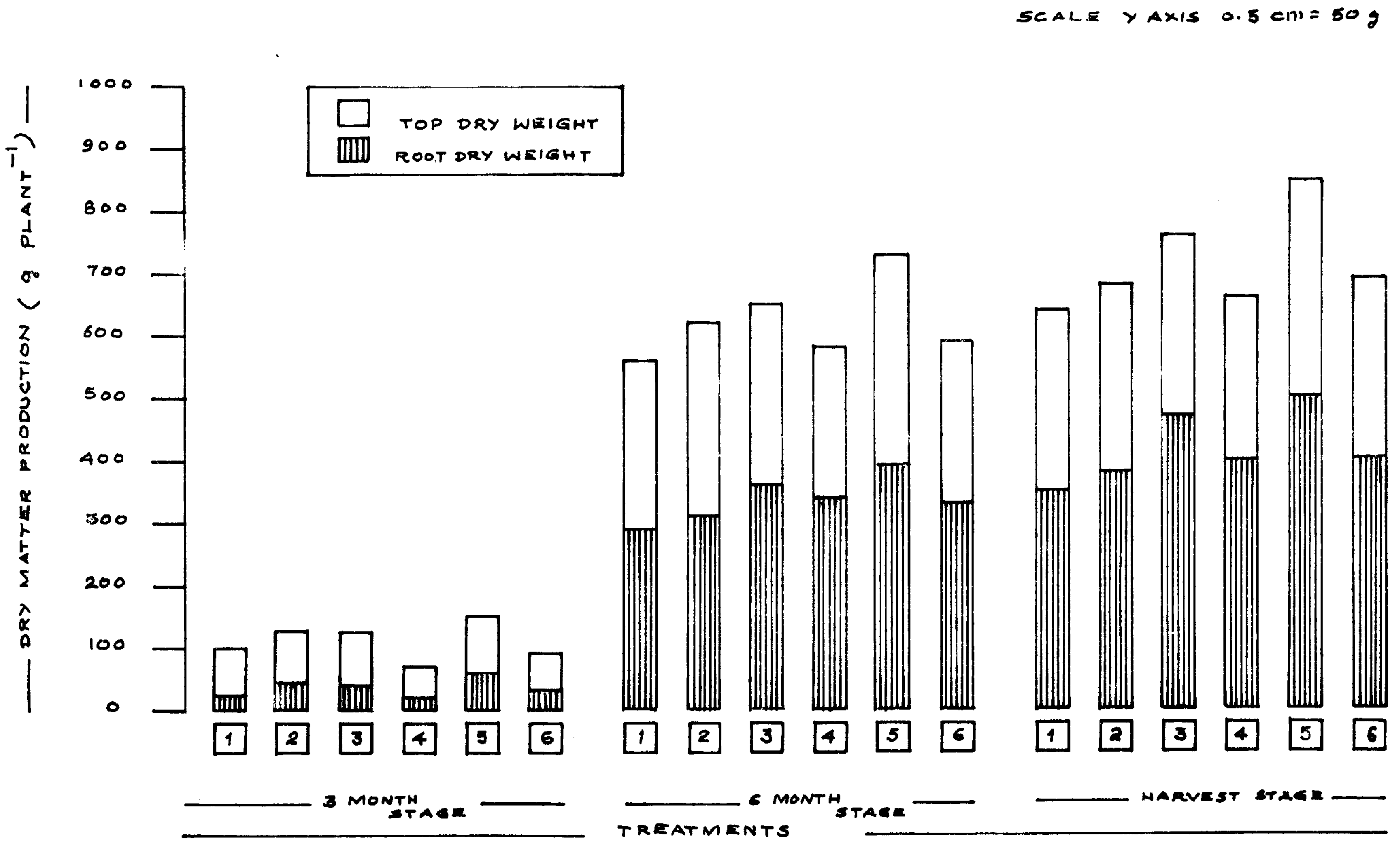
5.2.3 Influence of urea-neem cake blend, and time and rate of application of potassic fertilisers on growth and dry matter production in cassava

Treatment receiving 75 kg K_2O ha^{-1} along with 50 kg N as urea-neem cake blend recorded maximum plant height at sixth month and harvest stages, probably due to better balance of nitrogen and potassium in plants. The same treatment recorded comparatively lower number of leaves at harvest stage. Natarajan (1975) obtained significantly higher plant height at 150 kg ha^{-1} level of potassium when compared to lower levels. A beneficial effect of potassium on plant height was reported by Ngongi (1976) also.

The same treatment recorded the highest shoot weight, root weight and root to shoot ratio at tuber formation stage. But at tuber filling stage the ratio was comparatively lower due to higher shoot growth at this stage when compared to other treatments. Higher production of leaves at this stage would have increased photosynthetic efficiency of the crop and increased potassium supply might have resulted in better conversion of photosynthates to starch. The accumulation of starch resulted in better tuber filling and increased root weight at harvest stage leading to a better root to shoot ratio (Table 5). Addiscott (1974) reported the special role of potassium in carbohydrate synthesis, its conversion to starch and building up of storage organs in root crops.

The treatment where 50 kg N was applied as urea-neem cake blend along with 50 kg K_2O in two splits increased shoot weight when compared to untreated urea. This might be evidently due to higher availability and increased uptake of nitrogen throughout the period of crop growth. Use of neem cake inhibit nitrification and regulate nitrogen supply by reducing the leaching losses of nitrogen (Subbiah et al., 1978 a and b). The increased nitrogen uptake at tuber formation, tuber filling and harvest stages increased shoot weight at these stages (Fig.10). The increased nitrogen

FIG: 10 DRY MATTER PRODUCTION AT DIFFERENT GROWTH STAGES



availability increased the weight of stems, leaves and total dry weight of plants (Krochmal and Samuels, 1970; Cheo-Samut, 1974). At tuber formation stage the root to shoot ratio was comparatively higher as a result of greater tuber weight. Higher availability of nitrogen during the early period might have caused production of large number of tubers resulting higher tuber weight. Increased nitrogen supply had a favourable influence on tuber number (Degeus, 1967; Vijayan and Aiyer, 1969). The root to shoot ratio was lower at tuber filling and harvest stages due to increased shoot weight in the treatment that received urea-neem cake blend (T_2) when compared to untreated urea (T_1).

When potassium was applied one month and three months after planting shoot weight though showed a decrease, tuber weight was found to increase at six month and harvest stages and resulted in maximum root to shoot ratio at harvest stage. The increased root weight observed might evidently due to better accumulation of starch in tubers induced by higher potassium availability and uptake. Both available potassium in soil and potassium uptake by the plant was found to be higher after final application of potassic fertilizer (Fig.9 and 8). Addiscott (1974) also reported the role of potassium in synthesis and translocation of starch and thus better potassium availability at tuber filling stage enhanced tuber growth.

The reduction in tuber yield in the treatment receiving urea-neem cake blend along with muriate of potash at 50 kg level might be due to low potassium availability in soil. Though soil column study indicated that application of urea-neem cake blend along with muriate of potash increased exchangeable ammonium nitrogen and retained much of exchangeable potassium in surface layers (0-30 cm), the response was not observed in the crop growth. Under field condition available potassium was found to decrease, probably due to run off loss during the heavy rains received in initial period of growth as reported by Boodt et al. (1979).

The treatment where entire quantity of nitrogen was applied as urea-neem cake blend in single basal dose; shoot growth was considerably reduced at all major growth stages. The root to shoot ratio was not minimum or it was rather high due to lower shoot weight when compared to root weight. As the retention of available nitrogen in soil was found to be maximum for one month (Sathianathan and Padmaja, 1983a) when urea-neem cake blend at 5:3 ratio was used, much of nitrogen might have lost in the initial stages itself, and thus reduced shoot weight.

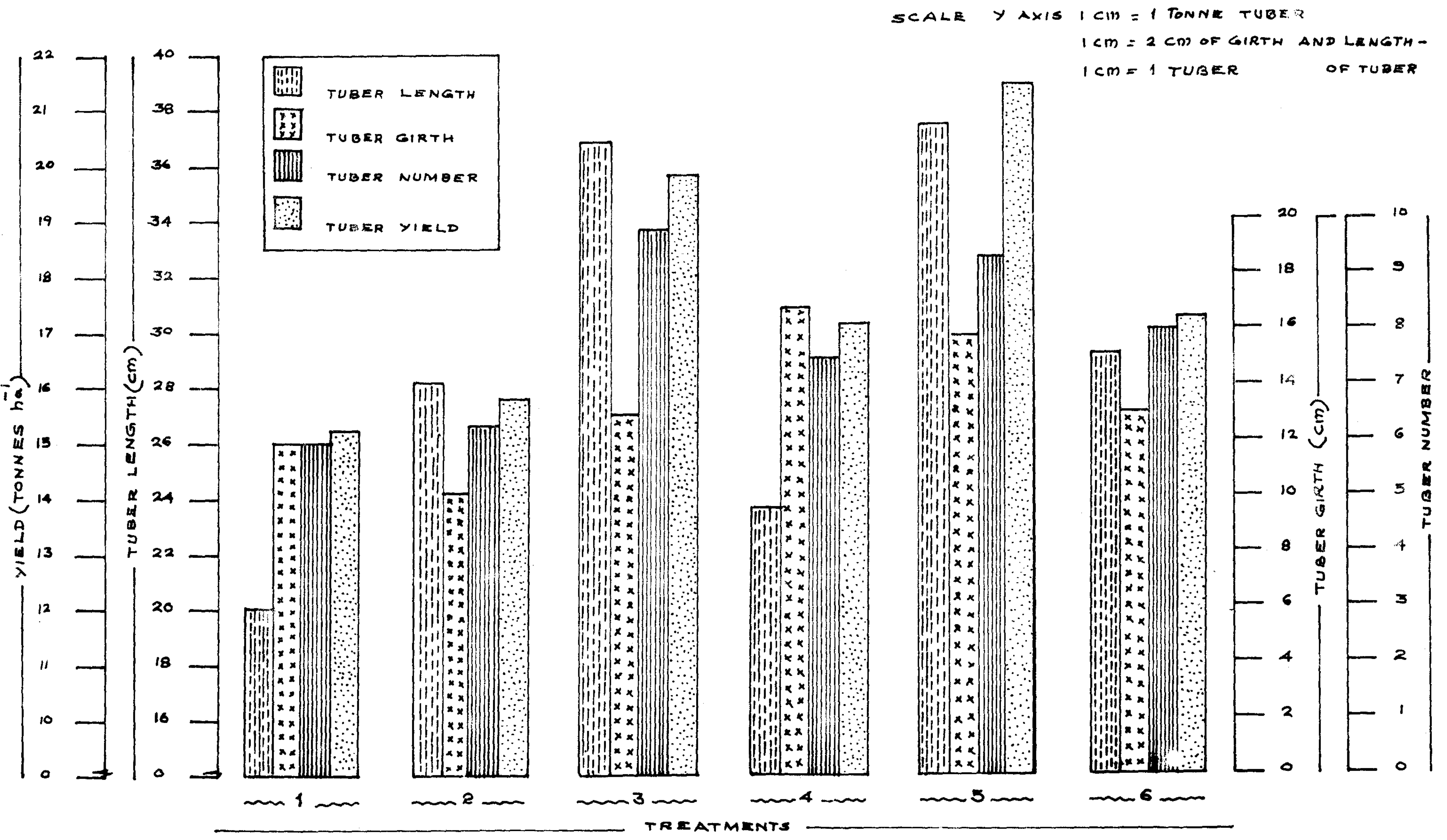
When 100 kg K_2O ha^{-1} was applied along with 50 kg N as urea-neem cake blend, there was a considerable reduction in growth of plant, probably due to some imbalance in absorption and utilisation of nitrogen and potassium by plants. Chanda (1958) reported the influence of nitrogen and potassium interaction on tuber yield. According to him, greatest yield can be obtained from the use of nitrogen and potassium in 1: 1.45 ratio and use of potassic fertilisers beyond this level reduced tuber yield.

5.2.4 Yield attributes and yield at harvest stage

The treatment receiving 75 kg K_2O ha^{-1} along with 50 kg N as urea-neem cake blend recorded the highest tuber yield of 21.20 tonnes ha^{-1} evidently due to higher number of tubers, better tuber length and girth (Plate I and II). Better availability and uptake of both nitrogen and potassium and also other nutrients might be responsible for increasing the final tuber yield (Table 4, Fig.11). Increasing nitrogen supply had a favourable influence on tuber number (Degues, 1967; Vijayan and Aiyer, 1969; Sathianathan, 1982), while potassium contribute towards tuber size (Degues, 1967; Muthuswamy, 1978).

Changing time of application of potassic fertiliser when applied along with urea-neem cake blend in two splits recorded next higher yield which was not significantly lower than that of former treatment. These two treatments significantly differed from other treatments in tuber yield,

FIG: 11 YIELD ATTRIBUTES AND TUBER YIELD



changing time of application of potassic fertiliser was found to increase tuber number as well as tuber length which might have contributed towards better tuber yield (Plate III).

Application of untreated urea along with muriate of potash at 50 kg level recorded minimum tuber yield (Plate IV). All yield attributing characters except tuber girth were found to be minimum in this treatment. Minimum tuber girth was recorded by urea-neem cake blend with muriate of potash at 50 kg level. But tuber number and tuber length were greater in this treatment than that of untreated urea (Plate IV), evidently due to increased nitrogen availability and uptake. The comparative reduction in yield observed at 100 kg K_2O ha^{-1} when compared to 75 kg K_2O ha^{-1} might be due to nitrogen potassium imbalance in the plant.

5.2.5 Relationship between nitrogen and potassium uptake to plant dry weight and tuber yield

Figure 12 and 13 present the relationship between nitrogen and potassium uptake to plant dry weight and tuber yield respectively. Nitrogen uptake at harvest stage was significantly correlated with tuber yield (0.626**), shoot dry weight (0.499*) and total plant dry weight (0.638**) at the same stage. Potassium uptake at all major growth

Plate - I. Effect of treatments on tuber development of cassava.

1 - 50 kg N as urea + 50 kg K_2O as muriate of potash (½ basal + ½ 2 months after planting)

2 - 50 kg N as urea-neem cake blend + 50 kg K_2O as muriate of potash (½ basal + ½ 2 months after planting)

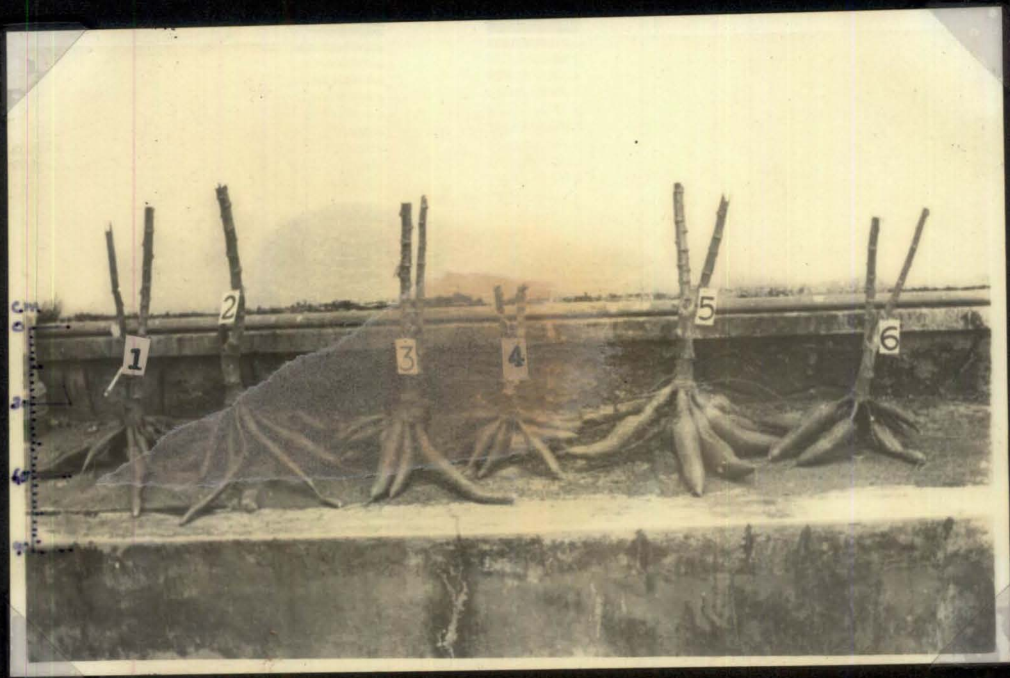
3 - 50 kg N as urea-neem cake blend (½ basal + ½ 2 months after planting) + 50 kg K_2O as muriate of potash (½ 1 month + ½ 3 months after planting)

4 - 50 kg N as urea-neem cake blend (full basal) + 50 kg K_2O as muriate of potash (½ 1 month + ½ 2 months after planting).

5 - 50 kg N as urea-neem cake blend + 75 kg K_2O as muriate of potash (½ basal + ½ 2 months after planting)

6 - 50 kg N as urea-neem cake blend + 100 kg K_2O as muriate of potash (½ basal + ½ 2 months after planting)

Plate - II Effect of changing time of application and increased rate of potassium on tuber development of cassava.


cm
1
2
3
4
5
6

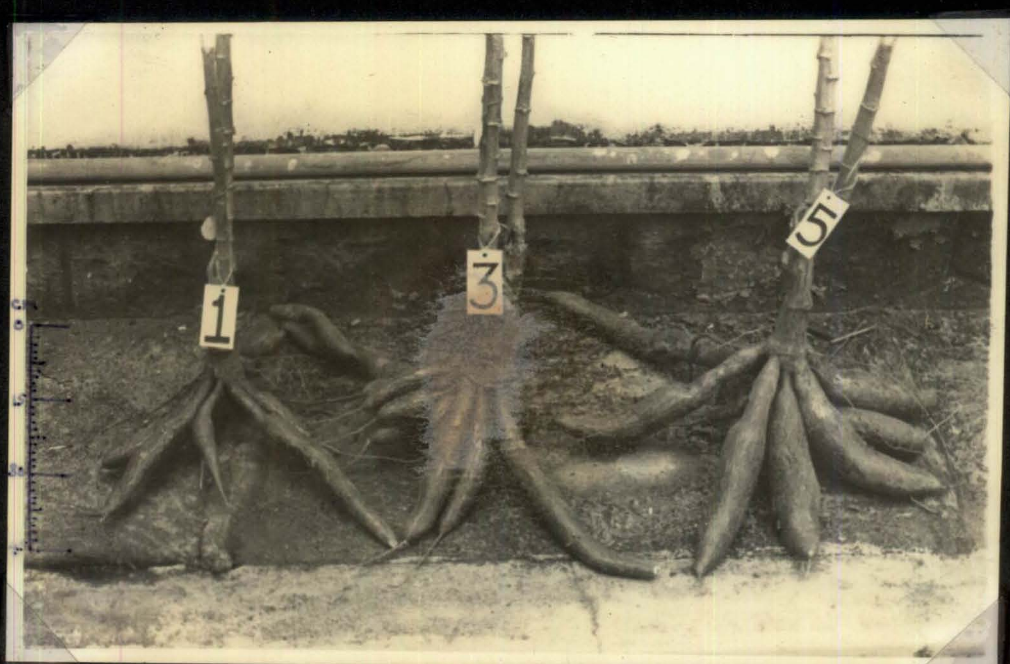

cm
1
3
5

Plate - III Effect of changing the time of application of urea-neem cake blend and muriate of potash on tuber development of cassava.

Plate - IV Effect of neem cake blending of urea on tuber development of cassava.


3
4

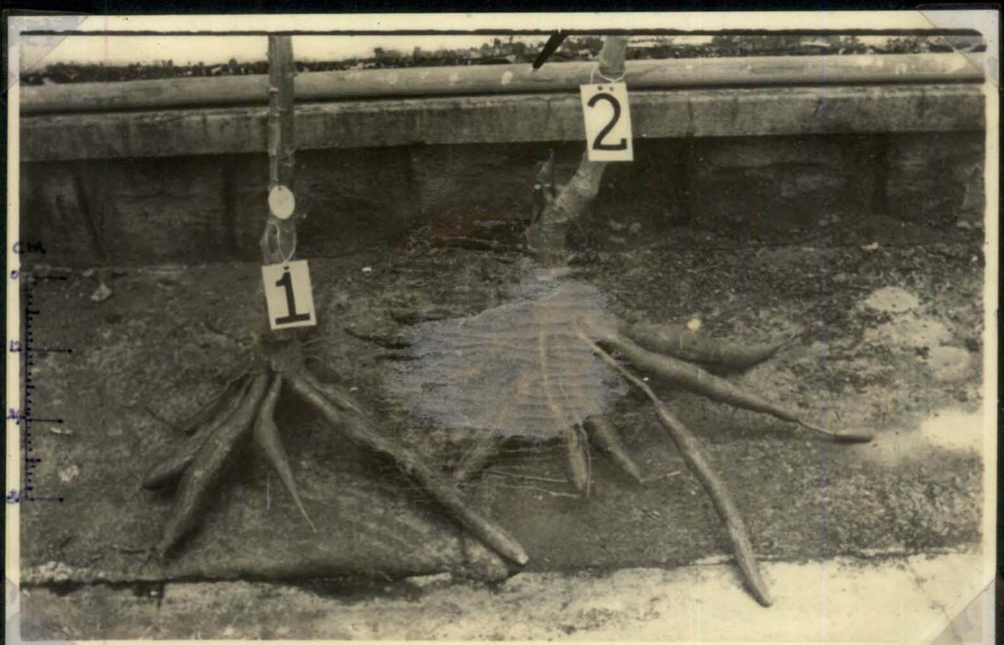

1
2

FIG: 12 _ RELATIONSHIP OF NITROGEN UPTAKE TO (A) TUBER YIELD (B) TOTAL PLANT DRY WEIGHT AND (C) SHOOT DRY WEIGHT AT HARVEST STAGE

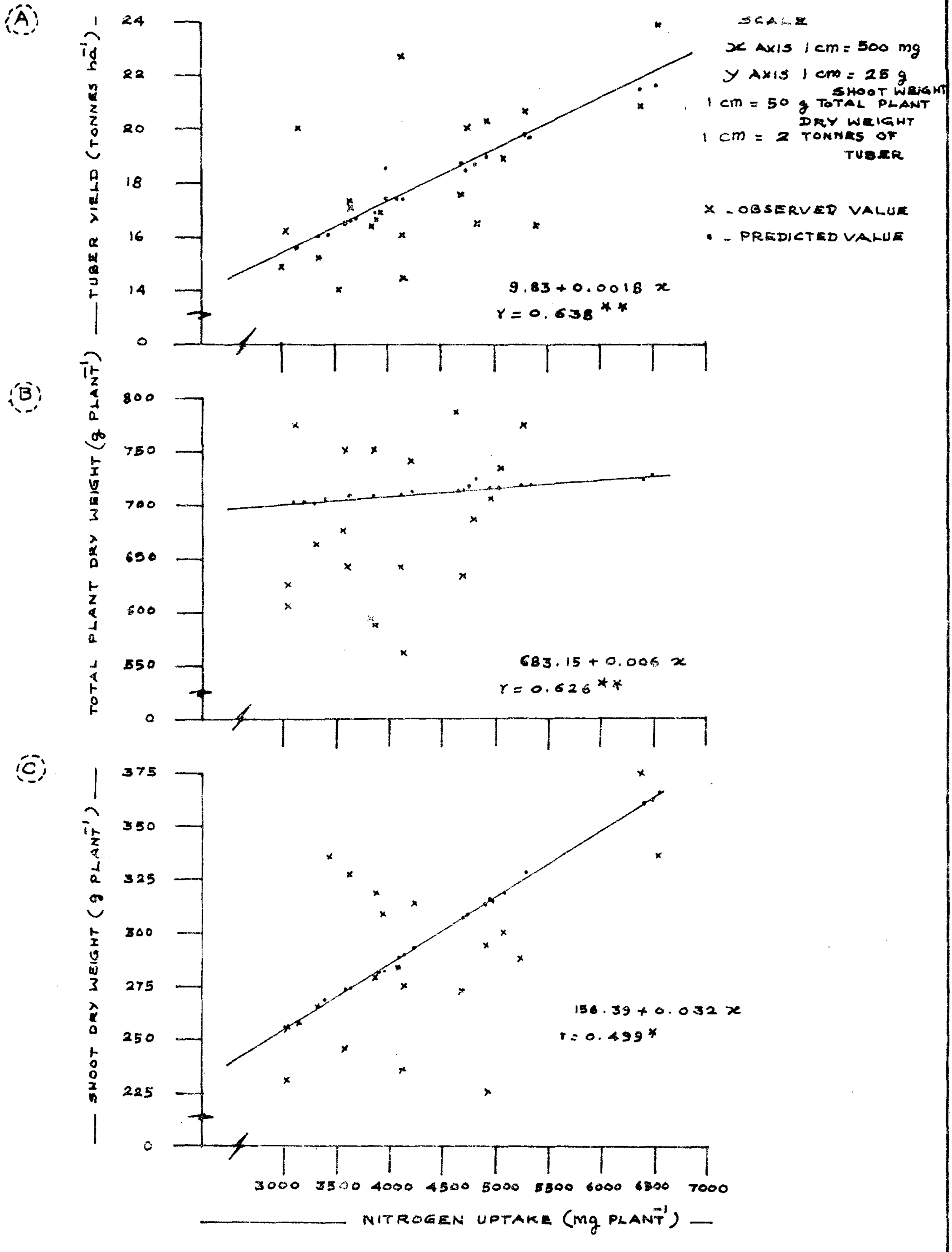
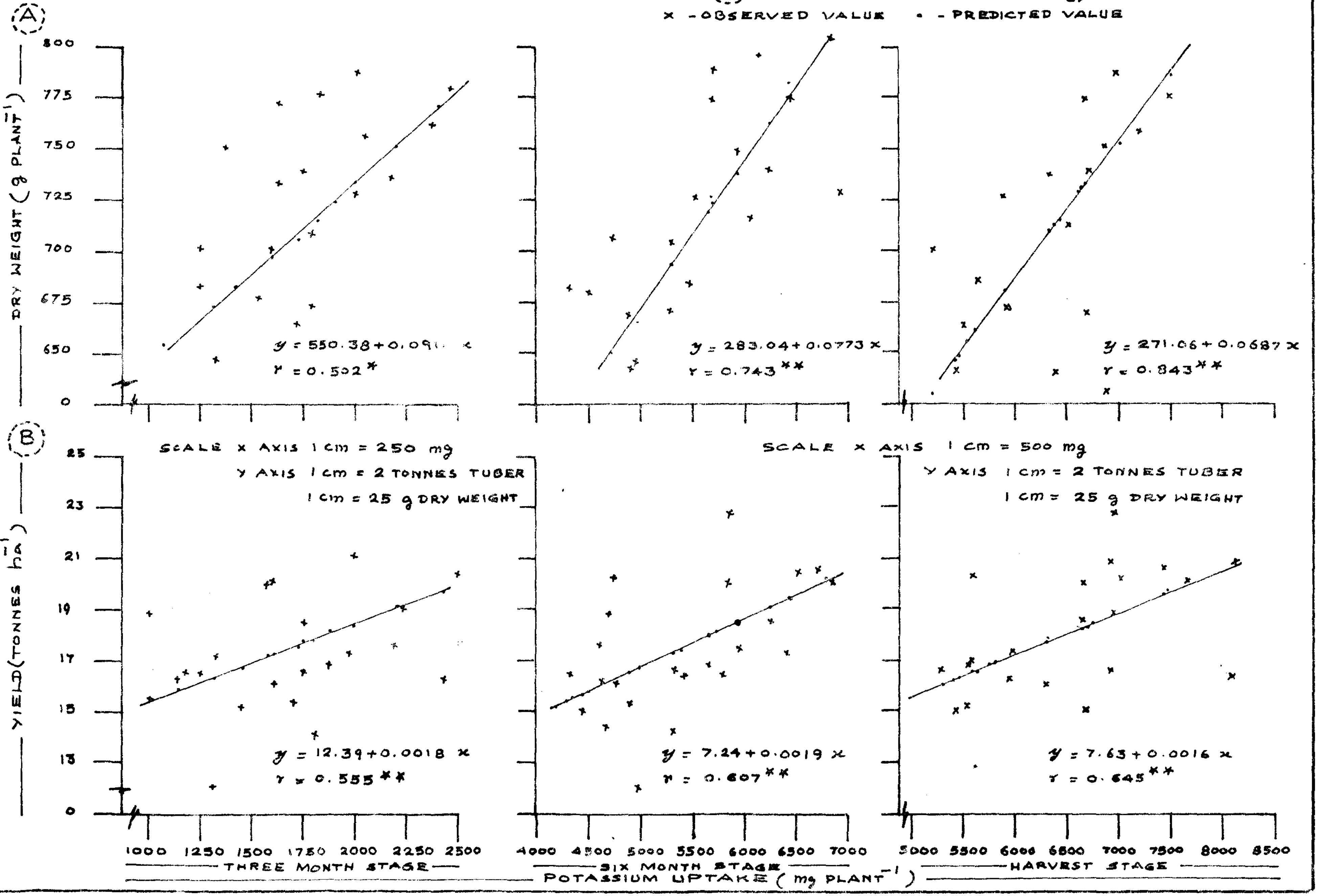


FIG: 13 _ RELATIONSHIP OF POTASSIUM UPTAKE TO (A) PLANT DRY WEIGHT AND (B) TUBER YIELD



stages were significantly correlated to plant dry weight and tuber yield. At three month stage, potassium uptake maintained a correlation coefficient of 0.555** with tuber yield and 0.502* with total plant dry weight. But at six month stage (0.607** and 0.743** respectively)and harvest stage (0.645** and 0.843** respectively) it was highly correlated with tuber yield and total plant dry weight. The influence of nitrogen and potassium uptake on plant dry weight and tuber yield were revealed earlier by Malavolta et al. (1955).

5.2.6 Economics of cultivation

Cost of production and net income were worked out and from this benefit/cost ratio was computed (Table 17). Maximum benefit was obtained when rate of potassium was raised from 50 kg K_2O ha^{-1} to 75 kg K_2O ha^{-1} when applied along with urea-neem cake blend (T_5). Blending of urea with neem cake increased nitrogen use efficiency. Changing the time of application of potassic fertilizer to one month and three months after planting (T_3) also increased the benefit obtained per rupee invested. These two treatments differed significantly from other treatments.

5.2.7 Quality attributes

The treatment that received urea-neem cake blend and muriate of potash at 50 kg level recorded high crude

Table 17. Economics of cultivation (Mean values in rupees)

Treatments	Total cost of cultivation	Gross income	Net income	Benefit-cost ratio
T_1	7519.50	13900.00	6380.50	0.85
T_2	7621.00	14350.00	6729.00	0.88
T_3	7771.35	17320.00	9549.00	1.23
T_4	7711.00	15325.00	7614.00	0.99
T_5	7672.00	18550.00	10878.00	1.42
T_6	7723.00	15400.00	7677.00	0.99
CD			1624.35	0.233
SEm ±			538.99	0.074

protein and HCN content when compared to untreated urea, with minimum starch content. This might be due to the increased availability and uptake of nitrogen by the use of urea-neem cake blend. Increased nitrogen supply reduced starch content (Vijayan and Aiyer, 1969; Sathianathan and Padmaja, 1983b) and increased crude protein and HCN content (Vijayan and Aiyer, 1969; Prabhakar et al., 1979).

In the treatment where potassium was applied one month and three months after planting starch content was increased whereas crude protein and HCN content showed a decrease. The increased starch content might be due to better potassium uptake which increased starch synthesis and its translocation to tubers at the expense of protein synthesis (Table 13). Better potassium availability enhanced starch content and reduced crude protein and HCN content of tubers (Natarajan, 1975; Asokan and Sreedharan, 1977; 1978). Thus changing time of application of potassium not only increased tuber production but also improved the quality of tubers.

In the treatment where entire quantity of nitrogen was applied as urea-neem cake blend in single basal dressing showed lower starch content and maximum HCN content. In this treatment potassium uptake was minimum (Fig.8) which might have resulted in low starch content and high HCN content.

The treatment receiving 75 kg K_2O ha^{-1} recorded highest starch content and crude protein content. HCN content was also high in this treatment evidently due to increased nitrogen and potassium uptake. HCN content was almost double in this treatment when compared to that received potassium at one month and three months after planting.

The treatment receiving 100 kg K_2O ha^{-1} also showed high crude protein and HCN content, probably due to the increased utilization of nitrogen resulting an increase in nitrogen fractions of tuber.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

An investigation was carried out at the College of Horticulture, Vellanikkara, during the year 1983-84 to study how best the nitrification inhibitory property of neem cake could be utilized for increasing nitrogen use efficiency of upland crops without affecting the utilization of other nutrients. This work was taken up as the continuation of a post-graduate programme conducted at the College of Agriculture, Vellayani, where non-edible oilcakes at different ratios were tested and screened for their nitrification inhibitory property. Urea-neem cake blend at 5:3 ratio was found to be the best in inhibiting nitrification effectively. A field experiment conducted using urea-non edible oil cake blended materials with cassava as the test crop indicated that though soil availability and crop uptake of nitrogen increased considerably, crop utilization of potassium showed drastic reduction resulting a slight yield increase with low quality tubers.

The present investigation was taken up to study the feasibility of utilisation of the nitrification inhibitory property of neem cake without affecting the uptake and utilization of potassium by cassava either by changing the time of application or by increasing the dose of potassium.

The dynamics of NH_4^+ - N and K^+ through the profile when urea or urea-neem cake blend, and muriate of potash either alone or in combination were applied are evaluated in a soil column study.

The results obtained and conclusions drawn are summarised below.

1) In soil column study NH_4^+ - N was found to concentrate in lower layers beyond 30 cm depth, whereas K^+ was found more concentrated in surface layers upto 30 cm depth under natural condition.

2) When muriate of potash was applied in the surface 15 cm depth, NH_4^+ - N in the surface layer increased within eight hours after fertilizer application whereas at subsequent periods of sampling increase was observed in the deeper layers also.

3) When untreated urea granules were applied along with potassic fertilizer, a major part of NH_4^+ - N was found either concentrated in the lower layer beyond 45 cm or nitrified and lost whereas when urea-neem cake blend at 5:3 ratio were applied along with potassic fertilizer, a major

part of nitrogen was retained in NH_4^+ - N form in the surface layer upto two weeks. By the third week it was found to migrate to the third layer and by the fourth week to the fourth layer.

4) Soil columns receiving untreated urea showed drastic reduction in NH_4^+ - N in the surface layers upto 45 cm after the first week whereas in columns receiving urea-neem cake blend it was found to be more concentrated in the surface 30 cm upto three weeks with slight reduction in the surface layer after the first week.

5) Soil columns receiving untreated urea and that of urea-neem cake blend did not differ much in NH_4^+ - N concentration by the fourth week in all the layers except third (30-45 cm), probably the inhibitory effect of neem cake might have lost by this period.

6) Application of muriate of potash alone maintained highest exchangeable K^+ status in the surface layer (0-15 cm) followed by urea-neem cake blend along with muriate of potash.

7) Analysis of leachate water indicated that the leaching loss of potassium was maximum when muriate of potash was applied along with untreated urea. Loss was

reduced considerably when it was applied along with urea-neem cake blend, probably due to retention of more potassium in exchange complex as a result of the time lag induced by neem cake in urea hydrolysis.

8) In the field experiment, higher soil available nitrogen was estimated in treatments receiving urea-neem cake blend, even within 24 hours after fertilizer application. The higher available nitrogen status might be probably due to the inhibition of simultaneous nitrification process in these treatments.

9) When nitrogen was applied as one single basal dose of urea-neem cake blend, soil available nitrogen was very high only during the first month of planting. The nitrification inhibitory property of urea might have lost by that time resulting the loss of nitrogen from soil.

10) Application of 75 kg K_2O ha^{-1} along with 50 kg N as urea-neem cake blend showed comparatively lower available nitrogen status due to higher nitrogen utilisation by the crop as evidensed by high crop uptake. But at 100 kg K_2O ha^{-1} level crop uptake as well as soil available nitrogen status were low due to some nutrient imbalance in the plants. This is evident in lower dry matter production recorded by the crop.

11) Application of urea-neem cake blend reduced available potassium status of soil when compared to untreated urea treatment at same level of nitrogen and potassium application, probably due to displacement of potassium from exchange complex and the displaced potassium might have been lost by run off water.

12) When muriate of potash was applied one month and three months after planting and urea-neem cake blend half as basal and other half two months after planting uptake of potassium was not reduced considerably though potassium status of soil showed a slight decrease at three month stage of the crop.

Soil column study also indicated that when either urea or urea-neem cake blend, was applied exchangeable potassium in the soil increased.

13) Soil available potassium as well as crop uptake was higher at the six month and harvest stages by changing the time of application of potassium to one month and three months after planting.

Tuber production at the sixth month and harvest stages also showed considerable increase due to better conversion of photosynthates to starch and its translocation to tubers. At both these stages potassium uptake was also comparatively higher for this treatment when compared to others.

14) 75 kg K_2O ha^{-1} increased uptake of all the nutrients. Uptake of potassium was significantly higher than that at 100 kg K_2O ha^{-1}.

15) Soil available potassium was very high in the initial stages in the treatment which has received 100 kg K_2O ha^{-1} but the difference was negligible in the later stages. As the crop uptake was also less, potassium must have been lost from soil due to the heavy rainfall received.

16) Soil available potassium was high at the highest level of potassium supply, but potassium uptake was less even in the initial stages probably due to some imbalance in plants leading to lesser uptake of all the nutrients and lesser dry matter production.

17) Treatment receiving 75 kg K_2O ha^{-1} along with 50 kg N as urea-neem cake blend recorded the highest shoot weight, root weight and root to shoot ratio at three month stage indicating better shoot growth and root growth in the initial stages. During the later stages though this treatment recorded maximum root weight the root to shoot

ratio was lower when compared to others. At the harvest stage the treatment which has received potassium one month after nitrogen application recorded the maximum root to shoot ratio due to better tuber production when compared to shoot growth.

18) Highest tuber yield of 21.39 tonnes ha^{-1} was recorded by the treatment receiving 75 kg K_2O ha^{-1} evidently due to better tuber length, girth and tuber number per plant.

19) The treatment which has received potassium one month after basal application and top dressing of urea-neem cake blend recorded the second best yield which was statistically on par with that treatment receiving 75 kg K_2O ha^{-1}.

20) Starch and crude protein content was highest in the treatment receiving 75 kg K_2O ha^{-1}.

Results of the investigation indicated clearly that urea-neem cake blend at 5:3 ratio reduce loss of nitrogen since nitrogen is retained in ammonium form in the root zone of cassava for two to three weeks. Moreover it helps to retain a part of potassium of muriate of potash also in the surface layers. In order to derive maximum benefit from the applied NK fertilizers, 50 kg K_2O ha^{-1} has to be applied one month after application of urea-neem cake blend. Alternatively the supply of 75 kg K_2O ha^{-1} will also result in higher tuber production. But the benefit per rupee invested was more with higher rate of potassium (75 kg K_2O ha^{-1}) applied along with 50 kg N as urea-neem cake blend which was also on par with 50 kg K_2O ha^{-1} applied one month after application of urea-neem cake blend.

REFERENCES

REFERENCES

*Acosta, C. and Pinto, J. 1978. Influence of NPK on cassava yield in North Columbia. Informe de Progresso. 1976-1977, Bogotta-1978, 137-138

Addiscott, T.M. 1974. Potassium in relation to transport of carbohydrates and ions in plants. Proceedings of 10th Congress, International Potash Institute, Berne, 205-220

Allison, F.E., Roller, E.M. and Adams, J.E. 1959. Soil fertility studies in lysimeters containing Lakeland sand. USDA tech. Bull. 1199

Aminoff, D., Binkley, W.W., Schaffer, R. and Mowry, W.R. 1970. Analytical Methods for Carbohydrates. Chemistry and Biochemistry, II (B). Academic Press, New York, 760-764

Anjaniyasharma, D. 1972. Studies on the relative efficiency of fertilizer nitrogen with and without nitrification inhibitors in IR 8 rice. Andra agric. J. 19, 139-144

Anonymous, 1965. A study on the response of cassava to different kinds of slow release nitrogen fertilizer application. Annual Report, Thailand Department of Agriculture, 168-170

Anonymous, 1972. Annual Report. All India Coordinated Agronomic Experiment Scheme, Minicoi, p. 23

Anonymous, 1977. Fertilizer urea-its efficient use. Fertil. News 22, 3-19

Anonymous, 1982. Tapioca (*Manihot esculenta*). *Package of Practices Recommendations*. Kerala Agricultural University, Vellanikkara, pp. 199

Anonymous, 1983. *Two Decades of Research, 1963-1983*. Central Tuber Crops Research Institute, Trivandrum, 52-57

Aomine, S. 1951. The fixation of ammonium in soils: 1. Ammonium fixation of some soils in South-Eastern provinces of Japan. *J. Sci. Soil Manure* **22**, 83-97

Arulmozhiselvam, K. 1985. Efficiency of ureagypsum and Rockphosphate - Coated urea. M.Sc. (Ag) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore

Asokan, P.K. and Nair, R.V. 1982. Determination of level and time of application of N and K for cassava. *J. Root Crops* **8**, 58-60

Asokan, P.K. and Sreedharan, C. 1977. Influence of levels and time of application of potash on growth, yield and quality of tapioca (*Manihot esculenta* Crantz.) *J. Root crops* **3**, 1-14

Asokan, P.K. and Sreedharan, C. 1978. Effect of levels and time of application of potash on growth and yield of tapioca. *Agric. Res. J. Kerala* **16**, 18-23

Bains, S.S., Prasad, R. and Bhatia, P.C. 1971. Use of indigenous materials to enhance the efficiency of fertilizer nitrogen for rice. *Fertil. News* **16**, 30-32

Beauchamp, E.G. 1982. Fixed ammonium and potassium release from two soils. *Commun. Soil Sci. Pl. Anal.* **13**, 927-943

Best, E.K. and Drover, D.P. 1979. The downward movement of surface applied potassium ions in a Papuan soil. Commun. Soil Sci. Pl. Anal. 10, 1469-1479

Bhaumik, H.D. 1966. Foliar application of urea for higher crop yields. Fertil. News 11, 20-24

Bhide, V.K. and Motiramani, D.P. 1964. Effect of fertilizers on available potassium in soils of Madhya Pradesh. J. Indian Soc. Soil Sci. 12, 37-42

Biddappa, C.C. and Sarkunam, V. 1979. Efficiency of use of coated and blended urea with coaltar and neem cake. Annual Report, Central Rice Research Institute, Cuttuck, p. 61

Black, C.A. 1969. Soil Plant Relationships. 2nd edn. Wiley Eastern Private Limited, New Delhi, pp.792

Boodt, M., Berghe, C.V.D. and Gabriels, D. 1979. Fertilizer losses associated with soil erosion. Soil Physical Properties and Crop Production in Tropics (ed. Lal, R. and Greenland, D.J.). John Wiley and Sons, New York, 455-465

Bosewell, F.C. 1977. Seasonal anhydrocus ammonia application for corn with and without nitrification inhibitor. Agron. J. 69, 102-106

Bosewell, F.C. and Anderson, O.F. 1968. Potassium movement in fallowed soils. Agron. J. 60, 688-691

Bray, R.H. and Kurtz, L.T. 1945. Determining total organic and available forms of phosphate in soils. Soil Sci. 59, 39-45

Broadbent, F.E. and Stojanovic, B.J. 1952. Proc. Soil Sci. Soc. Am. 353-363 as quoted by Prasad, R., Rajale, G.B. and Lakhdive, B.A. 1971. Nitrification retarders and slow release N fertilizers. Adv.Agron. 23, 337-383

*Bruijn, G.H. 1971. A study on the cyanogenic character of cassava (Manihot esculenta Crantz.). Medelingen Landbouwhogeschool, Wageningen 71, pp.140

Campino, I. 1980. More available nitrogen through phosphorus and potassium fertilisation on grassland. Proceedings of an International Symposium of the European Grassland Federation, Netherland, 25-29

Chan, S.K. and Lee, C.S. 1982. Relationship of tuber yield, starch content and starch yield of cassava with potassium status of fertilizer. Fifth International Symposium on Tropical Root and Tuber Crops, 461-473

Chanda, T.R. 1958. Fertiliser experiments on tapioca in Kerala State. J. Indian Soc. Soil Sci. 6, 53-63

Cheng, K.L. and Bray, R.H. 1951. Determination of calcium and mangnesium in soils and plant materials. Soil Sci. 72, 449-458

Cheo-Samut, S. 1974. Cumulative effects of fertilizer on cassava production. Annual Report, Centro International de Agricultura Tropica, 181-184

Correa, A., Tanaka, R.T., Guedes, G.A.A., Andrade, A.M.S. and Rocha, B.V. 1981. Phosphorus levels and date of N and K application in cultivation of cassava (Manihot esculenta Crantz.) on a dark red latosol. Anais Congress Brasileira de Mandioca 1, 317-323

Cours, G., Fritz, J. and Ramachadimby, G. 1961. Phyllodermic diagnosis of the nutritional status of manioca. Fertilite 12, 3-20

*DeGeus, J.G. 1967. Root crops - cassava. Fertilizer Guide for Tropical and Subtropical Farming. Zurich. centre d' Etude-de' Azote 181-185

Dhar, B.K. 1981. Fertilizer consumption trends and necessity for increasing fertiliser use efficiency. Indian Fmg 31, 5-13

*Farina, M.P.W. and Graven, E.H. 1972. Effects of rainfall and differential application of N, P, K and Ca on downward movement of K in an Avalon medium sandy loam cropped with maize. Agrochemophysica 4, 93-98

*Forno, D.A. 1977. Mineral nutrition of cassava with special reference to nitrogen. Ph.D. Thesis submitted to University of Queensland, Brisbane

*Fox, R.H., Talleyrand, H. and Scott, T.W. 1975. Effect of nitrogen supply on the yield and nitrogen content of cassava. J. agric. Univ.P.Rico 59, 115-124

Ghosh, A.B. and Hassan, R. 1980. Nitrogen fertility status of soils of India. Fertil. News 25, 19-24

Ghosh, G. 1976. Downward movement of some cations in soil column. Indian J. agric. Res. 10, 213-216

Goring, C.A.I. 1962a. Control of nitrification by 2-chloro-6 (trichloromethyl) pyridene. Soil Sci. 93, 211-218

Goring, C.A.I. 1962b. Control of nitrification of ammonium fertilisers and urea by 2 - chloro-6 (trichloromethyl) pyridene. Soil Sci. 93, 431-439

Hamamoto, M. 1966. IBDU as a slow acting nitrogen fertiliser and studies in the field in Japan. The Fertil. Soc. 90, 1-77

*Hanway, J.J., Barber, S.A., Bray, R.H., Caldwilt, A.C. and Kurtz, L.T. 1962. North Central regional potassium studies: III. Field studies with corn. North Central Reg. Publ. pp.135

Hanway, J.J., Scott, A.D. and Stanford, G. 1957. Replaceability of ammonium fixed in clay minerals as influenced by ammonium or potassium in the extracting solution. Proc. Soil Sci. Soc.Am. 21, 29-34

Hendrickson, L.L., Keeny, D.R., Walsh, L.M. and Liegel, E.A. 1978. Evaluation of nitrapyrin as a means of improving nitrogen efficiency in irrigated sands. Agron. J. 70, 699-704

Hesse, P.R. 1971. A Textbook of Soil Chemical Analysis. John Murray (Publishers) Ltd., London, pp.520

Hovland, D. and Caldwell, A.C. 1960. Potassium and magnesium relationships in soil and plants. Soil Sci. 89, 92-96

Howeler, R.H., Edwards, D.G. and Asher, C.J. 1982. Micronutrient deficiencies and toxicities of cassava plants grown in nutrient solution:I. critical tissue concentrations. J. Pl. Nutr. 5, 1059-1076

Indira, P. and Sinha, S.K. 1969. Colorimetric method of determination of HCN in tubers and leaves of cassava. Indian J. agric. Sci. 39, 1021-1023

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice Hall of India, Pvt. Ltd. pp.498

*Jacoby, T. 1965. Nutrition and manuring of tropical root crops. Varlagrgesells chaft fur Ackerban mbh Hanover. Green Bull. 19, 9-16

*Jurkowska, H. and Wojciechowicz, T. 1976. Effect of some inhibitors on yield of plants as well as uptake of some nutrients. Acta-Agraria et silvestria Agraria 16, 21-37

Kadrekar, S.B. 1977. Vertical distribution of soil potassium. Indian J. agric. Chem. 10, 71-80

Kanapathy, K. 1974. Fertilizer experiments on shallow peat, under continuous cropping with tapioca. Malayan agric. J. 49, 403-412

Kang, B.T. 1984. Potassium and magnesium responses of cassava grown in Ultisol in South Nigeria. Fertil. Res. 5, 403-410

Kanwar, J.S. 1974. Assessment of potassium fertilizer in the tropics and subtropics of Asia. Proceeding of the 10th congress, International Potash Institute, Berne

Kar, A.K., Chattopadhyay, J.P. and Dhua, S.P. 1975. Relative fixation of added potassium and ammonium in some acid soils. J. Indian Soc. Soil Sci. 23, 428-433

Kardos, L.T. 1964. Soil fixation of plant nutrients. Chemistry of the Soil (ed. Bear, S.F.) Oxford and IBH Publishing Co. New Delhi, 369-439

*Katyal, J.C. and Pillai, K.G. 1975. Research in India on fertilizer use efficiency. Paper presented at Annual Conference, International Rice Research Institute, Los Banos, Philippines

Kaushal, G.S. and Verma, G.P. 1967. Ammonia fixation in some profile soils of Madhya Pradesh JNKVV Res. J. 1, 72-80

Keeny, D.R. and Nelson, D.W. 1982. Nitrogen-inorganic forms. Methods of Soil Analysis (ed. Page, A.L.) Part 2, 2nd edn. American Society of Agronomy, Madison, Wisconsin, 643-693

Ketkar, C.M. 1978. Note on neemcake blended urea for nitrogen economy in paddy and sugarcane. Proceedings of the India/FAO/Norway Seminar on the Development of the Complementary Use of Mineral Fertilizers and Organic Materials in India. Ministry of Agriculture and Irrigation, Department of Agriculture, Krishi Bhavan, New Delhi, 153-156

Khan, A. 1952. Manure and its source from oil cakes. J. Sci. club 5, 14-21

Kozak, M. 1973. Migration and fixation of potassium in sandy soils of Hungary. Potash Rev. subject 4, Soil Science, 54th Suite, 11

Krochmal, A. and Samuels, G. 1970. Influence of NPK levels on the growth and tuber development of cassava in tanks. Caiba 16, 35-43

Kumar, B.M., Mandal, R.C. and Magoon, M.L. 1971. Influence of potash on cassava. Indian J. Agron. 16, 82-84

Lindsay, W.L. and Norvell, W.A. 1978. Development of DTPA soil test for Zinc, iron, Manganese and copper. Soil Sci. Soc. Am. J. 42, 421-428

*Maglhaes, P.C., Begazo, J.C., Paula, J.F. and Defelipq, B.V. 1980. Effects of levels, time and localization of KCl on some cassava root characteristics. Revista Ceres 27, 215-233

Mahapatra, I.C. 1970. Proper fertiliser use can bring a breakthrough in Rice production. Indian Fmg 20, 12-13

Malavolta, E., Graner, E.A., Goury, T., Sober, B.M.O.C. and Pancheco, J.A.C. 1955. Studies on mineral nutrition of cassava (*M. utilissima* Pohl.) *Pl. Physiol.* **30**, 81-82

Mandal, R.C., Singh, K.D., Magoon, M.L. and Maini, S.B. 1970. Response of cassava to different levels of NPK and organic manure. *Annual Report*, Central Tuber Crops Research Institute, Trivandrum, 16-17

Martin, A.E. and Skyring, G.W. 1962. Losses of nitrogen from soil/plant. A review of nitrogen in tropics with particular reference to pastures. *A Symposium Commonwealth Bureau of Pastures and Field Crops Bull.* **46**, 19-34

Mathers, A.C., Stewart, B.A. and Grunes, D.L. 1982. Effects of a nitrification inhibitor on the potassium, calcium and magnesium composition of winter wheat forage. *Agron. J.* **74**, 569-573

Mishra, M.M., Neelakantan, S., Khandelwal, K.C., Bhardwaj, S.K. and Vyas, S.R. 1975. Margosa (neem) seed cake as an inhibitor of nitrification, *Soil biol. Biochem.* **7**, 183-184

Mohankumar, B. and Nair, P. G. 1969. Influence of nitrogen and potash on yield and nutrient uptake of cassava (H-97). *Annual Report*, Central Tuber Crops Research Institute, Trivandrum, 38-40

Mohankumar, C.R. and Hrishi, N. 1973. Effect of F.Y.M. and NPK alone and in combination on the yield of cassava, H-226. *Annual Report*, Central Tuber Crops Research Institute, Trivandrum, 30-32

Mohankumar, C.R. and Mandal, R. 1977. Studies on the production economics of high yielding varieties of tapioca to the application of nitrogen. *J. Root Crops* **3**, 63-65

More, S.D. and Varade, S.B. 1982. Efficiency of soil water potential on transformation of added nitrogen in Vertisol. J. Indian Soc. Soil Sci. 30, 531-533

Muthuswamy, P. 1978. Studies of the influence of nitrogen and potash fertilisation on growth, nutrient content, uptake and starch production in tapioca (Manihot esculenta Crantz.). Ph.D. Thesis submitted to Tamil Nadu Agricultural University, Coimbatore

Muthuswamy, P. and Rao, C.K. 1981. Influence of N and K on the quality of tubers at different months of growth. Madras agric. J. 68, 169-173

Nair, P.G., Kumar, B.M. and Rajendran, N. 1980. Effect of different sources of potassium on yield and quality of cassava. J. Root Crops 6, 21-24

*Nair, P.K. and Sharma, V.P. 1976. Utility studies on controlled release nitrogenous fertilizers and nitrification retarders in maize. Comptes-Rendus 4e Colloque International Sur le Control L Alimentation des Plantes Cultives. Gent. 2, 531-541

Nambiar, E.P., Nair, J. and Subramoney, N. 1966. Studies on the Kattampally swamp soils. J. Indian Soc. Soil Sci. 14, 13-17

Natarajan, M. 1975. The effect of different levels of nitrogen and potash on the growth, yield and quality of tapioca variety, H-165. M.Sc. (Ag). Thesis submitted to Kerala Agricultural University, Vellanikkara

*Ngongi, A.G.N. 1976. Influence of some mineral nutrients on growth, composition and yield of cassava (Manihot esculenta Crantz.) Ph.D. Thesis submitted to N.Y. Cornell University, Ithaca

Nielson, J.D. 1972. Fixation and release of potassium and ammonium ions in Danish soils. Pl. Soil 36, 71-88

*Nopamornbordee, V., Nakavirojana, C., Roong R.S., Kitchaichananontha, P. and Kanakorn, P. 1967. Methods of nitrogen application for cassava - Effect of slow release N fertilisers on cassava yield. Annual Report, Thailand Department of Agriculture, 1114-1119

Obigbesan, G.O. and Fayemi, A.A.A. 1976. Investigations on Nigerian root and tuber crops. Influence of nitrogen fertilisation on the yield and chemical composition of cassava cultivars (Manihot esculenta) J. Agric. Sci. 86, 401-406

Okeke, J.D., Obigbesan, G.C. and Kang, B.T. 1979. Effect of fertilizer application on nutrient concentration and growth relations in cassava. J. Root crops 5, 1-7

Pathak, A.N. and Srivastava, H.S. 1963. Ammonium fixation in soils. Agra Univ. J. Res. 12, 99-107

Patil, N.D. 1972. Neem (Azadirachta indica, L.) Oil as nitrification inhibitor. Fertil. News 17, 37-38

Patrick, W.H., and Wyatt, R. 1964. Soil nitrogen loss as a result of alternate submergence and drying. Proc. Soil Sci. Soc.Am. 28, 647-653

Peech, M., Alexander, L.T., Dean, L.H. and Reed, J.E.1947. Methods of Soil Analysis for Soil Fertility Investigations. USDA Circ, pp.757

Pill, W.G. and Sparks, O.L. 1982. Effects of nitrapyrin and nitrogen form on tomato growth, water relations and ion composition. J. Am. Soc. Hort. Sci. 107, 487-492

*

Pillai, K.G. 1967. Studies on the response of N, P and K in conjunction with Ca on the growth yield and quality of tapioca (Manihot utilissima Pohl.) var. Malayan-4. M.Sc. (Ag.) Thesis submitted to University of Kerala, Trivandrum

Pillai, K.G. and George, C.M.1978. Quality of tubers in tapioca (Manihot utilissima Pohl.) var. Malayan-4, as influenced by N, P, K and Ca fertilization. Agric. Res. J. Kerala 16, 166-170

Piper, C.S. 1950. Soil and Plant Analysis. University of Adelaide, Australia, pp. 368

Prabhakar, M., Mohankumar, C.R. and Nair, G.M. 1979. Permanent manurial trial in cassava. Annual Report, Central Tuber Crops Research Institute, 22-24

*Prasad, J.D., Bashour, I.J., Sofi, I and Al-hindi, A.1981. Movement of applied phosphorus and potassium in acid soils. Annual meetings, American Society of Agronomy, Madison, Wisconsin, USA

Prasad, R. 1966. Slow acting nitrogenous fertilisers and nitrification inhibitors. Fertil. News 11, 27-32

Prasad, R. 1979. Increasing fertilizer nitrogen efficiency with slow release fertilisers and nitrification inhibitors. Fertil News 24, 25-32

Prasad, R. 1981. Use of controlled release fertilizers and nitrification retarders - prospects and problems. Paper presented at National Seminar on Current Thoughts in Soil and Fertilizer Research in Relation to Crop Production held at IARI New Delhi,Aug. 11 to Sep.3 1981

Prasad, R. and Lakhdive, B.A. 1969. Note on nitrification of ammonium sulphate and losses of nitrogen under water logged conditions. Indian J. agric. Sci. 39, 259-262

Prasad, R., Rajale, G.B. and Lakhdive, B.A. 1970. Effect of time and methods of application of urea and its treatments with nitrification inhibitor on the yield and nitrogen uptake by irrigated upland rice. Indian J. agric. Sci. 40, 1118-1127

Prasad, R., Rajale, G.B. and Lakhdive, B.A. 1971. Nitrification retarders and slow release N fertilizers. Adv. Agron. 23, 336-389

Prasad, R. and Thomas, J. 1981. Forms, Contents, distribution, evaluation of fertilizers and use efficiency of nitrogen. Review of Soil Research in India. Part I. 12th International Congress of Soil Science, New Delhi

Prasad, R., Tukhede, B.B. and Das, V.K. 1966. 2-chloro 6 (trichloromethyl) - pyridine for reducing nitrogen losses from upland paddy soils. Curr. Sci. 35, 312-313

Prema, L., Thomas, E.J. and Aiyer, R.S. 1975. The usefulness of sensory methods of analysis by a taste panel in differentiating the quality of cassava tubers under different manurial treatments. Agric. Res. J. Kerala 13, 141-145

Prince, A.L., Zimmerman, M. and Bear, F.E. 1947. The magnesium supplying power of 20 New Jersey soils. Soil Sci. 63, 69-78

Pushpadas, M.V. and Aiyer, R.S. 1976. Nutritional studies on cassava (Manihot esculenta Crantz.): II. Effect of potassium and calcium on yield and quality of tubers. J. Root Crops 2, 42-50

Pushpadas, M.V., Vijayan, M.R. and Aiyer, R.S. 1975. Nutritional studies on cassava (*Manihot esculenta* Crantz.). *J. Root Crops* **1**, 63-67

*Rajale, G.B. 1970. Agronomic evaluation of nitrification retarders and slow release nitrogen fertilizers for irrigated upland Rice. Ph.D. Thesis submitted to IARI, New Delhi

Rajendran, N., Nair, P.G. and Kumar, B.M. 1976. Potassium fertilization of cassava in acid laterite soils. *J. Root Crops* **2**, 35-38

Raju, G.S.N. and Mukhopadhyay, A.K. 1973. Effect of added potassium and time of application on ammonium fixation in two soils of West Bengal. *J. Indian Soc. Soil Sci.* **21**, 53-56

Raju, G.S.N. and Mukhopadhyay, A.K. 1975. Effect of sequence of addition of potassium and ammonium and pre adsorbed cations on fixation of applied ammonium ions in soils. *J. Indian Soc. Soil Sci.* **23**, 172-176

Ramamoorthy, B. and Bajaj, J.C. 1969. Available nitrogen, phosphorus and potassium status of Indian Soils. *Fertil. News* **14**, 25-36

Ramanujam, T. and Indira, P. 1979. Growth Analysis in cassava. *Annual Report*, Central Tuber Crops Research Institute, Trivandrum, 43-44

Ratnanakul, S. 1976. The response of cassava to N and P fertilizer. *Report on Soil, Field Crop and Fertilizers*. Department of Agriculture, Thailand pp.110

Reddy, R.N.S. and Prasad, R. 1975. Studies on mineralisation of urea, coated urea and nitrification inhibitor treated urea in soil. *J. Soil Sci.* **26**, 304-312

Shankhyan, S.D. and Shukla, U.C. 1978. Transformation and losses of soil and urea-nitrogen in five soils. Indian J. agric. Chem. 11, 25-36

Sharma, R.C. and Grewal, J.S. 1978. Efficient use of urea for potatoes grown in acidic brown hill soils of Simla. J. Indian potato Ass. 5, 141-150

Shivaraj, A. and Iruthayaraj, M.R. 1980. Effect of nitrogen inhibitors under different levels and time of application on seed cotton yield. Madras agric. J. 67, 807-810

Singh, B. and Singh, A.P. 1979. Fixation of potassium in soils as affected by an ammonical fertilizer. J. Indian Soc. Soil Sci. 27, 272-276

Singh, K.D. 1974. Effect of different crop rotations on the utilisation of various forms of soil N, P and K. Indian J. agric. Sci. 44, 329-338

Singh, K.D.N. and Sinha, H. 1971. Distribution of ammonium in soil profiles. Indian J. agric. Chem. 4, 97-104

Singh, V. 1983. Application of neem cake or its extract on urea hydrolysis. Indian J. agric. chem. 16, 153-158

Snedecor, G.W. and Cochran, W.G. 1967. Statistical Methods 6th edn. Oxford and IBH Publishing Co. New Delhi, pp.593

Sowden, F.J., Maclean, A.A. and Ross, G.J. 1978. Native clay fixed ammonium content and fixation of added ammonium of some soils of Eastern Canada. Can. J. Soil Sci. 58, 27-39

Sparks, D.L., Martens, D.C. and Zelazny, L.W. 1983. Plant uptake and leaching of applied and indigenous potassium in Dothan soils. Abstract of Sixth International Potash Institute Competition for young research workers, Berne 8, 45-46

Stanford, G. and Pierre, W.H. 1947. The relation of potassium fixation to ammonium fixation, Proc. Soil Sci. Soc. Am. 11, 155-160

Steinck, O. 1974. The relation between potassium and nitrogen in the production of planting material. Proceedings of Tenth Congress, International Potash Institute, Berne, 189-196

Subbiah, B.V. and Asija, G.L.A. 1956. A rapid procedure for the estimation of available nitrogen in soils. Curr. Sci., 25, 259-260

Subbia, S. 1979. Influence of neem cake mixed ammonium sulphate on the yield and nutrient uptake by IR 20 rice (Oryzo sativa L.) Madras agric. J. 66, 678-686

Subbiah, S. and Kothandaraman, G.V. 1980. Effect of neem cake blending of urea on ammonical and nitrate nitrogen content in soils under field conditions. J. Indian Soc. Soil Sci. 28, 136-137

Subbiah, S., Kumar, R.S., Ramanathan, K.M. and Krishnamoorthy, K.K. 1979 a. Effect of neem seed crush blended urea on the yield of finger millet Co 7 in two different soils. Madras agric. J. 66, 53-55

Subbiah, S., Ramanathan, K.M., Francis, H.J. and Kothandaraman, G.V. 1979 b. Effect of neem cake blended urea application on the yield and nutrient uptake of rice. Madras agric. J. 66, 789-793

Subbiah, S., Ramanathan, K.M., Francis, H.J., Sureshkumar, R. and Kothandaraman, G.V. 1982. Influence of nitrogenous fertilizers with and without neem cake blending on the yield of Finger millet (Eleucine coracana Gaertn). J. Indian Soc. Soil Sci. 30, 37-43

Sudayemprasert, R.L., Blevins, H. and Chaewsamoot, S. 1976. Movement of nitrate, chloride and potassium in sandy loam soil. Pl. Soil 45, 227-234

Swaminathan, M.S. 1979. An integrated strategy for increasing the production and consumption of oil seeds and oils in India. Report of International Congress on Oil Seeds and Oils New Delhi, 16-21

Swarup, A., Beese, F. and Ulrich, B. 1984. The effect of potassium chloride on ion dynamics and budget in a slightly acidic forest soil. J. Pl. Nutr. Soil Sci. 146, 772-782

Thampan, P.K. 1979. Field culture, Mineral nutrition and fertilisation. Cassava, Kerala Agricultural University, Vellanikkara, pp. 242

Thomas, J. and Prasad, R. 1982. Studies on mineralisation of neem and sulphur coated and N-serve treated urea. Fertil. News 27, 39-43

Thomas, J. and Prasad, R. 1983. Mineralisation of urea, coated urea and nitrification inhibitor treated urea in different rice growing soils. J. Pl. Nutr. Soil Sci. 146, 341-347

Thomas, W. 1937. Foliar diagnosis, principles and practices. Pl. Physiol. 12, 571-599

Vijayan, M.R. and Aiyer, R.S. 1969. Effect of N and P on the yield and quality of cassava. Agric. Res. J. Kerala 7, 84-90

Walkley, A. and Black, T.A. 1934. An examination of the Degtjareff method for determination of soil organic matter and a proposed modification of the chromic acid titration. Soil Sci. 37, 29-36

Walsh, T. and Donhoe, O. 1945. Magnesium deficiency in some crop plants in relation to level of potassium nutrition. J. agric. Sci. 35, 254-263

*Wasink, H.M. 1974. To study the use of neem (Azadirachta indica L.) seed cake coated (mixed) urea in the economy of nitrogen for growing wheat (variety Kalyan sona) M.Sc. (Ag) Thesis submitted to Punjabrao Krishi Vidyapeeth, Akola

Welch, L.F. and Scott, A.D. 1961. Availability of non-exchangeable soil potassium to plants as affected by added potassium and ammonium. Proc. Soil Sci. Soc. Am. 25, 102-104

Wholey, D.W., 1980. Fertilize cassava to produce better quality planting material. Tropical Root and Tuber Crops Newsl. 11, 17-20

*Wicke, H.J. 1968. Effect of heavy potash dressing on the yield and nutrient content of plants grown in pot experiments. Albrecht-Thaer-Arch. 12, 903-916

Wijler, J. and Delwiche, C.C. 1954. Investigations on the denitrifying process in soil. Pl. Soil 5, 1-18

Wilde, S.A., Voigt, G.K. and Iyer, J.G. 1972. Soil and Plant Analysis for Tree Culture 4th edn (ed. Chesters, G.) Oxford and IBH Publishing Co. 111-123

Yadav, J.S.P. 1984. Presidential address - 48th Annual Convention of the Indian Society of Soil Science. J. Indian Soc. Soil Sci. 32, 1-8

Yashwant, I., Wed, D. and Pansi, V.G. 1933. Nitrogen balance in black cotton soils in Malwa plateau. J. agric. Sci. 1, 820-832

*Originals not seen

APPENDICES

APPENDIX - I

Weather conditions during crop growth at monthly intervals (Daily average)

Month	Rainfall (mm)	Temperature (°C)		Relative humidity at 8 a.m. (%)
		Maximum	Minimum	
July	29.31	29.09	24.02	95.71
August	25.80	28.75	23.68	96.52
September	17.04	29.23	23.35	95.57
October	4.83	30.85	23.25	92.48
November	2.45	30.96	22.39	88.03
December	0.76	30.45	23.60	78.81
January	0.00	31.56	22.74	77.48
February	1.28	33.87	24.08	80.28
March	0.33	34.50	24.00	89.07

APPENDIX - II

Weather conditions during the soil column experiment

Date	Rainfall (mm)	Temperature (°C)	
		Maximum	Minimum
29.6.84	29.40	28.50	23.00
30.6.84	57.40	29.00	21.80
1.7.84	25.70	26.00	22.80
2.7.84	22.40	30.00	22.00
3.7.84	47.80	28.60	22.40
4.7.84	40.60	26.50	22.80
5.7.84	7.20	28.00	23.00
6.7.84	7.90	29.70	24.00
7.7.84	75.10	29.00	22.50
8.7.84	8.80	29.30	22.50
9.7.84	5.80	30.80	23.00
10.7.84	1.20	29.00	24.20
11.7.84	7.80	29.40	23.00
12.7.84	4.20	29.20	23.80
13.7.84	9.50	26.80	23.50
14.7.84	130.40	26.00	21.00
15.7.84	23.20	28.00	23.50
16.7.84	38.00	27.50	22.00
17.7.84	27.70	30.20	22.00
18.7.84	32.80	29.00	22.20
19.7.84	26.50	25.50	22.50
20.7.84	99.00	25.50	22.03
21.7.84	12.60	28.00	21.50
22.7.84	1.90	28.60	22.20
23.7.84	14.90	29.00	22.20
24.7.84	0.00	30.00	23.00
25.7.84	5.20	29.20	24.00
26.7.84	0.40	30.40	23.50

APPENDIX - III

Abstract of analysis of variance of soil available nitrogen at monthly intervals after fertilizer application (Mean sum of squares)

Source	df	24 hours after fertilizer application	1 month	2 months	3 months	4 months	5 months	6 months	7 months	8 months
Block	3	33649.499*	4317.940**	2880.520*	1016.920	189.511	685.574	1482.630	1270.378	714.231
Treatment	5	221589.366**	2539.767*	2905.059*	2151.687*	906.180	1090.007	2304.850	13010.212**	12530.725**
Error	15	11118.706	623.678	966.016	563.565	673.990	1814.967	8538.471	688.026	560.071

APPENDIX - IV

Abstract of analysis of variance of soil available potassium at monthly intervals after fertilizer application (Mean sum of squares)

Source	df	24 hours after fertilizer application	1 month	2 months	3 months	4 months	5 months	6 months	7 months	8 months
Block	3	60702.265	80434.935	8993.588	13845.002**	27100.511**	18877.418	13771.712*	9314.022	1606.469
Treatment	5	3052576.615**	210442.395**	2015.961	20076.514**	10165.811	28125.059*	31388.402**	8762.123	4916.861
Error	15	95595.500	29419.761	1151.208	2062.954	7069.650	6782.701	3396.950	10311.817	2062.656

* Significant at 0.05 level
** Significant at 0.01 level

APPENDIX - V

Abstract of analysis of variance of growth characters at different growth stages
(Mean sum of squares)

Source	df	Plant height		Plant girth		Number of leaves	
		6 month stage	Harvest stage	6 month stage	Harvest stage	6 month stage	Harvest stage
Block	3	0.435	0.388	1.093	0.302	70.152	141.374**
Treatment	5	0.121*	0.072	0.398	0.251	19.475	25.791**
Error	15	0.039	0.045	0.352	0.509	15.986	2.191

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - VI

Abstract of analysis of variance of dry matter production at different growth stages (Mean sum of squares)

Source	df	Shoot weight	Root weight	Total dry weight	Root to shoot ratio
3 month stage					
Block	3	72.440	9.383	42.460	0.017
Treatment	5	1176.081**	565.311*	3522.204**	0.047**
Error	15	73.696	139.128	85.762	0.008
6 month stage					
Block	3	4378.066*	3822.600	10742.221	0.026
Treatment	5	38706.380**	5257.000	19060.640	0.987*
Error	15	1141.193	3083.060	12097.466	0.023
Harvest stage					
Block	3	3574.230	5435.700*	5751.057	0.120
Treatment	5	3732.761	11890.560**	23789.863**	0.288**
Error	15	3623.412	1227.221	4124.369	0.051

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - VII

Abstract of analysis of variance of nitrogen concentration in plant parts at different growth stages (Mean sum of squares)

Source	df	Lamina			Petiole			Stem			Tuber		
		3 month stage	6-month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage
Block	3	0.189	0.006	0.157	0.002	0.048	0.025	0.090	0.034*	0.031*	0.008	0.003	0.003
Treatment	5	3.467**	0.209	0.181	0.058**	0.166**	0.041*	0.067	0.076**	0.106**	0.069*	0.016*	0.019**
Error	15	0.164	0.171	0.088	0.001	0.019	0.011	0.071	0.008	0.006	0.020	0.005	0.002

APPENDIX - VIII

Abstract of analysis of variance of phosphorus concentration in plant parts at different growth stages (Mean sum of squares)

Source	df	Lamina			Petiole			Stem			Tuber		
		3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage
Block	3	0.004	0.002*	0.007	0.004	0.002	0.014*	0.005*	0.001	0.003*	0.0002	0.001*	0.0009*
Treatment	5	0.002	0.001	0.006	0.020*	0.003*	0.005	0.006*	0.003*	0.003	0.0002	0.0001	0.000[illegible]
Error	15	0.002	0.0004	0.003	0.005	0.0009	0.004	0.001	0.0009	0.0002	0.0002	0.0002	0.000[illegible]

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - IX

Abstract of analysis of variance of potassium concentration in plant parts at different growth stages (Mean sum of squares)

Source	df	Lamina			Petiole			Stem			Tuber		
		3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage	3 month stage	6 month stage	Harvest stage
Block	3	0.228**	0.031	0.020	0.474**	0.013	0.092	0.010	0.021	0.025	0.015	0.011	0.009
Treatment	5	0.094*	0.043*	0.018	0.051	0.028	0.396**	0.359	0.048**	0.043*	0.023	0.014	0.022*
Error	15	0.023	0.014	0.033	0.068	0.014	0.032	0.024	0.009	0.010	0.015	0.009	0.006

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - X

Abstract of analysis of variance of nutrient uptake at 3 month stage of crop growth (Mean sum of squares)

Source	df	N	P	K	Ca	Mg
Block	3	153173.860	1945.080	235004.006	64902.070*	10828.133*
Treatment	5	1433631.176**	31246.380**	764444.253**	150406.869**	24596.331**
Error	15	271190.333	2314.890	134831.919	15896.736	2991.368

APPENDIX - XI

Abstract of analysis of variance of nutrient uptake at 6 month stage of crop growth (Mean sum of squares)

Source	df	N	P	K	Ca	Mg
Block	3	322802.053	23035.803	540504.420	1108121.433	108621.648
Treatment	5	2420382.504	8327.303	272137.831*	363005.756	260883.201*
Error	15	1366525.840	10054.141	622986.500	574668.590	78062.917

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - XII

Abstract of analysis of variance of nutrient uptake at harvest stage of the crop (Mean sum of squares)

Source	df	N	P	K	Ca	Mg
Block	3	1596576.477**	116346.853**	1978092.600*	38807.566	12593.125
Treat-ment	5	2876025.370**	46878.185*	3607823.440**	166792.944	184771.098**
Error	15	124210.881	10555.026	446090.020	179481.525	34789.199

* Significant at 0.05 level

** Significant at 0.01 level

APPENDIX - XIII

Abstract of analysis of variance of yield attributes, yield and economics of cultivation (Mean sum of squares)

Source	df	Tuber number	Tuber girth	Tuber length	Tuber yield	Net income	Benefit cost ratio
Block	3	1.153	0.634	8.562	13.622**	7660373.061**	0.117*
Treatment	5	9.342*	19.247**	196.009**	2.505**	11925620.800**	0.188**
Error	15	2.386	0.499	8.285	2.064	1162053.860	0.024

APPENDIX - XIV

Abstract of analysis of variance of quality attributes of tuber (Mean sum of squares)

Source	df	Dry matter content of tuber	Starch	Crude protein	HCN content
Block	3	1.328	4.099	0.120	68.531
Treatment	5	0.978	41.043**	0.760**	9673.669**
Error	15	1.413	3.401	0.090	131.060

* Significant at 0.05 level

** Significant at 0.01 level

POTASSIUM UTILIZATION IN CASSAVA (*Manihot utilissima* Pohl.) AS INFLUENCED BY NEEM CAKE - UREA BLEND

By

MANORAMA THAMPATTI K. C.

ABSTRACT OF A THESIS

submitted in partial fulfilment of

the requirement for the degree

Master of Science in Agriculture

Faculty of Agriculture

Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

Vellanikkara - Trichur

1985

ABSTRACT

Potassium utilisation in cassava (*Manihot utilissima* Pohl.) as influenced by neem cake-urea blend

An investigation was carried out at the College of Horticulture, Vellanikkara, during the year 1983-84, which include a soil column study to understand the dynamics of NH_4^+ - N and K^+ ions when applied as urea or urea-neem cake blend either alone or along with muriate of potash.

The columns were filled with soil collected from the field surface upto 60 cm depth. Each 15 cm was taken as a separate layer maintaining the same bulk density as observed in the field. Fertilizer treatments comprising, no fertilizer, urea or urea-neem cake blend to supply 100 ppm N and muriate of potash to supply 100 ppm K either alone or in combination were applied to the surface 15 cm soil and mixed thoroughly.

The study indicated that under natural conditions NH_4^+ - N was concentrated more in the lower layers of soil beyond the root zone of cassava whereas potassium was concentrated more in the surface layers of 0-30 cm depth. Application of muriate of potash either alone or in combination with urea-neem cake blend increased potassium in the surface layer within eight hours after fertilizer application.

When untreated urea granules were applied along with potassic fertilizer, a major part of NH_4^+ - N was found

either concentrated in lower layers, or nitrified and lost. But when urea-neem cake blend was applied along with potassic fertilizer a major part of nitrogen was retained as NH_4^+ - N in the surface layers upto two weeks and later it moved downwards.

There was a drastic reduction of NH_4^+ - N status in the surface layers upto 45 cm after one week in untreated urea, whereas urea-neem cake blend maintained much of NH_4^+ - N in the surface 30 cm upto three weeks.

Application of muriate of potash maintained highest potassium status followed by urea-neem cake blend along with muriate of potash. The maximum leaching loss of potassium was observed from untreated urea when applied along with muriate of potash. The loss was reduced considerably when potassic fertilizer was applied along with urea-neem cake blend.

A field experiment was conducted as a continuation of the study carried out at the College of Agriculture, Vellayani, where urea-neem cake blend at 5:3 ratio increased nitrogen availability, nitrogen uptake and yield. But it had an adverse effect on potassium utilization of the crop resulting in poor quality tubers and the yield increase observed was not significant. The present experiment was planned to tide over this difficulty either by changing the time of application or increasing the rate of potassic fertilizer

Results of the experiment clearly showed that urea-neem cake blend increased nitrogen use efficiency of cassava as evident in higher soil available nitrogen and higher nitrogen uptake by the crop.

When muriate of potash was applied one month after application of urea-neem cake blend, the uptake of potassium was not reduced considerably in the initial stages and at the same time uptake was comparatively higher at the sixth month and harvest stages.

Potassium at 75 kg K_2O ha^{-1} increased uptake of all nutrients and also produced maximum tuber yield of 21.39 tonnes ha^{-1}, whereas application of potassium one month after application of urea-neem cake blend recorded 19.76 tonnes ha^{-1} of tuber yield which was on par with the former treatment. Potassium uptake at all major growth stages were significantly correlated with plant dry weight and tuber yield.

Maximum benefit per rupee invested was obtained when the rate of potassium was raised from 50 kg K_2O ha^{-1} to 75 kg K_2O ha^{-1} along with 50 kg N as urea-neem cake blend. Changing the time of application of potassic fertilisers to one month and three months after planting also increased the benefit obtained. Both these treatments were on par with each other and significantly superior to others.