SLOW RELEASE NITROGEN IN CASSAVA NUTRITION

BY

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THESIS
Submitted in partial fulfilment of
the requirement for the degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI TRIVANDRUM
1988

DECLARATION

I hereby declare that this thesis entitled "Slow release nitrogen in cassava nutrition" 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.

Vellayani,
28/12/'88

G.S. VINOD.

CERTIFICATE

Certified that this thesis entitled "Slow-release nitrogen in cassava nutrition" is a record of research work done independently by Mr.G.S. VINOD, 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 him.

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ACKNOWLEDGEMENTS

I wish to place on record my deep sense of gratitude to Dr.V.Muraleedharan Nair, Professor, Department of Agronomy, College of Agriculture, Vellayani for suggesting the problem and for valuable guidance through out the course of investigation as well as in the preparation of the thesis. His keen interest and unstinted help have been much beyond his formal obligation as the Chairman of my Advisory committee, for which I am greatly indebted to him.

My sincere thanks are due to Dr.V.K.Sasidhar, Professor, Communication centre Mannuthy ~~College of Horticulture~~, ~~Vellanikkara~~, for his valuable suggestions and critical evaluation of the script.

I am greatly obliged to Dr.(Mrs) P.Saraswathy, Assoc Professor, Department of Agricultural Statistics for her valuable advice in the design of field experiments and scrutiny of the manuscript.

I am extremely thankful to Shri Abdul Hameed, Professor of Agricultural Chemistry and Soil Science Department, College of Horticulture, Vellanikkara for his timely help and constant encouragement.

I am specially thankful to Sri K.P.Madhavan Nair, Professor of Agronomy, College of Agriculture, Vellayani for useful suggestions and encouragements during the course of the experiment.

I owe a great debt to the large number of friends for the help rendered by them. Special mention should be made to Mr.Rajesh Chandran, Agricultural Officer, Department of Agriculture, Government of Kerala and Mr. Babu Mathew, Junior Assistant Professor, Kerala Agricultural University.

(contd...)

I wish to express my sincere thanks to Mr.Ajithkumar, Junior Programmer, Department of Agricultural Statistics and Sri L.R.K.Potti, SOS, College of Agriculture, Vellayani for the help rendered in the analysis of the data and for neatly typing the manuscripts respectively.

I am deeply indebted to my parents and brothers for their constant encouragement and manifold assistance.

The award of Junior Research Fellowship by the I.C.A.R during the tenure of the study is gratefully acknowledged.

(G.S.VINOD)

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INTRODUCTION

INTRODUCTION

Tapioca, an important source of carbohydrate, is the most popular subsidiary food crop of the middle and low income group of the people of the densely populated State of Kerala. As a subsidiary food crop of tremendous calorific value and also as a source of starch in textile industry, cassava assumes a significant role. The yield of the crop in Kerala is very low as compared to other tapioca producing regions in the world. To meet the food requirements of our fast growing population it is highly essential to increase the per hectare productivity of the crop since there is not much scope for the expension of area under cultivation. There is considerable scope for raising the productivity by the adoption of better agrotechniques. The efficient use of chemical fertilizers especially that of nitrogenous fertilizers plays a vital role, in augmenting the yield of tapioca.

Under tropical conditions, the efficiency of applied fertilizer nitrogen is very low and the food crops cultivated even under ideal farming situation seldom recover more than 50 per cent of the applied nitrogen. (Martin and Skyring, 1962). An 1 per cent increase in the recovery of applied nitrogen fertilizer would result in a saving of 1,50,000 tonnes of urea, which in terms of additional crop would be equivalent to one million tonnes of food grains (Swaminathan, 1980).

Under Kerala conditions the main reason for low efficiency of applied nitrogen is the high rainfall, resulting in intense leaching and heavy run off. This limits the availability of this nutrient during the critical periods of crop growth. The other forms of losses include volatilization, denitrification through various physical, biochemical and microbiological processes etc.

In our State, urea is the most widely used source of nitrogen which is highly water soluble. So there is considerable loss of applied nitrogen by way of leaching. The present recommendation of split application of nitrogen also becomes inefficient at times due to improper soil moisture conditions. So among the various agronomic techniques followed for conserving this nutrient, nitrogen, the use of slow release fertilizers and biological inhibitors, which inhibit the activity of nitrogen in the soil solution, were found to be effective. The use of these materials will be highly useful for a long duration crop like tapioca where availability of nitrogen can be assured during the critical growth stages of the entire growth period of the crop. This will reduce the cost of application of fertilizers also by resorting to a single basal application of nitrogen fertilizers with the inhibitors. The use of synthetic chemicals as nitrification retarders is not economical. So the use of cheap and effective indigenous sources of nitrogen inhibitors will be the best alternative.

Many of the non-edible oilcakes are reported to possess nitrification inhibitory properties. This alternate use of the oilcakes, a byproduct of the oil crushing industry, may in the long run will promote a better growth of this small scale industry in the State.

In the light of the above, the present study embodying the following objectives was taken up:-

a) To study the effect of slow release nitrogenous fertilizers on the growth and yield of tapioca.

b) To compare the efficiency of various slow-release sources.

c) To work out the economics of using slow release fertilizers.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An experiment was conducted with the object of studying the effect of slow-release nitrogenous fertilizers on the growth and yield of tapioca. Attempts are going on all over the world to reduce the loss of nitrogen and thereby to improve the efficiency of nitrogenous fertilizers. But most of the works done in this line have been in lowland condition and hence literature regarding the loss mechanism and methods for improving the nitrogen use efficiency in upland condition are meagre. Some of the relevant literature pertaining to the present study are reviewed and presented below -

2.1 Nutrient removal by tapioca

Tapioca removes large amounts of nutrients from the soil, especially nitrogen. Studies conducted at Central Tuber Crops Research Institute, Trivandrum revealed that a tapioca crop with 30 tonnes of tuber yield removes from a hectare of soil, 180-200 kg nitrogen, 15-22 kg phosphorus and 140-160 kg potash. A crop removal to the tune of 164 kg nitrogen was reported for a 30 tonnes tuber yield of tapioca by Asher et al(1980). A cassava crop removes on an average 2.3 kg nitrogen per tonne of roots produced (Howler, 1980).

2.2 Recovery of applied nitrogen

The recovery of applied fertilizers especially that of nitrogenous fertilizers is quite low. Average recovery of 10-50 per cent was reported in rice by many workers (Lakhdive and Prasad, 1971; Prasad and De Datta, 1979; Mahapatra ot al. 1980). In uplands of the tropics the losses are severe because of heavy rainfall. (Prasad, 1966; Prasad and Rajale, 1972). Fox et al (1975) obtained upto 68-69 per cent recovery of applied nitrogen in cassava. Howler (1976) reported low fertilizer efficiency in cassava due to leaching in sandy soils. In aerobic soil, the mineralisation of organic nitrogen is faster than in anaerobic situation and mineralised nitrogen is subject to various types of loss mechanisms and thus recovery is less (Alexander, 1977). Plant recovery of applied nitrogen is dependent on factors such as natural conditions of the soil as well as climatic and cultural practices (De Datta, 1977).

2.3 Losses of nitrogen from applied nitrogen

2.3.1 Leaching and run off losses

The main form of nitrogen loss in upland soils is the leaching. NO_3 nitrogen is an anion and hence it is less adsorbed on the soil colloids and so is leached away heavily.

Volk and Sweet (1955) reported that one foot layer of soil when leached with 5" of water in 24 hrs., the leachate removed 33 per cent of nitrate nitrogen and 15 per cent urea nitrogen. Owens (1960) found that the order of leachability of three forms of nitrogen is $NO_3 >$ Urea $> NH_4^+$

Mohanty and Kibe (1968) reported that by coating the fertilizer with some material, leaching losses can be reduced to 5 per cent from 50 per cent.

Timmons and Holt (1977) studied the loss of nutrients in run-off water and found that only 0.8 kg nitrogen per hectare is lost in grass lands where as in the case of other crops the loss is several times more. On draining the surface water, on the same day of fertilizer application, upto 70 per cent of the applied nitrogen is lost in runoff water (Padmaja and Koshy, 1978).

2.3.2 Denitrification

Heavy rainfall or heavy irrigation may cause the development of micro anaerobic products in uplands and thereby causing denitrification losses (Broadent *et al*,1952; Allison *et al*, 1960). Turner and Patric (1968) reported that in uplands there is easy gasseous exchange between soil and atmosphere air and when waterlogging occurs, oxygen disappears and nitrates enters the thermodynamic sequence of reduction of inorganic compounds causing the loss of nitrogen.

Lue Pilot and Patric (1972) noted a close relation between soil aeration and nitrate-reduction.

Oxygen diffusion is the most important factor regulating nitrification-denitrification processes in soil (Focht, 1979).

2.3.3 Ammonia voltilization

By volatilization, a good amount of nitrogen is lost from the applied nitrogenous fertilizers(Bouldin and Alimango, 1976; Wetsellar, 1977; Vivek and Craswell, 1979; Jain et al 1981).

Gasser (1964) and Jain et al (1981) reported volatilization losses from uplands also. Under aerobic conditions in acid soils, 6 to 12 per cent of applied nitrogen is lost within a period of 3 weeks of incubation whereas under anaerobic conditions, the loss was two to four times greater (Blasco and Cornfield, 1966).

Contrary to that Das and Khan (1967) found that soils kept submerged under about 5 mm water lost only 3.4 to 11.4 per cent of the applied nitrogen while at 40 to 60 per cent moisture saturation, the loss was 21.6 to 33.1 per cent. Jain et al (1981) observed that nitrification retarders increased NH_3 volatilization losses.

2.4 Improving the efficiency of nitrogenous fertilizers

The use of slow release nitrogen fertilizers is a very effective method for improving the nitrogen use efficiency.

Coating of the fertilizers with materials like oil cakes, plastic and other inert materials can impose a slow release nature on the fertilizer (Prasad *et al.*, 1971; Prasad and Rajale, 1972; Prasad, 1974, 1979, 1981; Prasad and Reddy, 1977).

Thailand Department of Agriculture (1966) found that better cassava yields can be obtained by the use of slow release nitrogenous fertilizers in sandy loam and sandy clay loam soils.

NOP- AMORNBORDEE V*etal* (1967) reported better cassava yields with the use of slow release fertilizers.

Among the slow-release fertilizers, sulphur coated urea is the most widely tested one. Prasad and Rao, 1978; Crasswell and Vlek, 1982; Sander and Moline, 1980 reported that in upland condition also sulphur coated urea was found to be superior.

Sathianathan (1982) obtained better cassava yields with the use of slow-release sources of nitrogen.

But in one experiment, it was found that only in sandy soil low in organic matter content, with sufficient phosphorus and potassium supply, slow-release fertilizers gave good yields (Anonymous, 1966).

2.4.1 Use of oilcakes as nitrification inhibitors

Non-edible oilcakes particularly neem and mahua have been used as a manure since long. Their manurial value and nitrifiable properties were described by Ply mann and Bal (1919), Yashwant et al (1933) and Khan (1952).

Basins et al (1971) made a breakthrough in this field by finding out that the nitrification inhibitory property of neem is due to the presence of an acrid alkaloid.

Patil (1972) suggested that neem oil contained two factions namely bitter and odourescent compounds which possessed the inhibitory property. He also reported that when the concentrationof neem oil was increased from 1.5 to 12 per cent (by weight of fertilizer) there was a corresponding decrease in nitrification rate.

Hundred kg. of nitrogen in the form of urea when coated with neem cake produced crop yields equivalent to that of 200 kg. of nitrogen in the form of urea alone (Anjiniyasharma, 1972). AICRIP studies also revealed the superior productive efficiency of neem cake treated urea (Anon, 1972).

Arunachalam and Morachan (1974) found that the favourable influence of the treatment of urea with neemcake extract in increasing the crude protein content of rice grain. Abraham et al (1976) reported that the application of 40 kg neemcakes coated urea was equivalent to 80 kg naked urea.

Shankar et al (1976) observed that in both transplanted and direct sown crops of rice, the uptake of nitrogen and phosphorus was increased in treatments, where urea was blended with neemcake.

Muthuswamy et al (1977) found the inhibitory properties of various materials including the extracts of non-edible oil cakes in garden-land soil, at two levels of nitrogen application to ragi. The results showed that the efficacy of inhibitors was in the following order, viz. Coaltar extract $>$ Sulphathiazol $>$ Mahua cake extract $>$ neemcake extract $>$ neemoil $>$ whole neemcake.

Oommen et al (1977) reported the superiority of neemcake blended urea over untreated urea. Increased crop yields through the use of neemcake was also obtained in sugarcane (Ketkar, 1978) ragi (Subbiah, 1979c) and cotton (Shivraj and Iruthayraj, 1980).

Selective inhibition of nitrozomonas by neem was observed by Mishra et al (1975).

Neemcake blended urea increased the grain and straw yield and also the uptake of nitrogen, phosphorus and potassium (Subbiah et al, 1979a and b).

Blending of urea with neemcake resulted in increased NH_4-N in the soil (Subbiah and Kothandaraman, 1980) (Sarkunah and Biddappah, 1980).

Swaminathan (1979) suggested that nitrification inhibitory properties in various non-edible oil cakes could be explored and advantageously utilised. Krishnaiah and Shinde (1979b) blended six non-edible cakes, namely, neem, mahua, undi, sal, karinja and kusum cake with urea at different rates of mixing and obtained higher rice yields. Maximum yields was reported for neemcake.

Hilgur and Shinde (1981) compared the application of urea alone with urea blends using other extracts of different oil cakes and whole cakes and found that neem cake, Karinjacake and Kunkum cake increased dry matter yield and nitrogen uptake while mahua cake reduced the yield.

Sathianathan (1982) reported increased plant height, number of leaves and tuber yield in tapioca when urea was mixed with oilcakes like neemcake and mahua cake in comparison to the application of urea alone.

But Mohanty et al (1974) found that neemcoated urea was inferior to urea lone. Thirunavakkarasan (1977) also did not obtain benefits from the coating of urea with neem. Devi et al (1980) did not find significant increase in rice yields through the use of oilcakes like neem, maroti, punna as nitrification inhibitors.

2.4.2 Use of Urea Super Granules (U.S.G.)

The efficiency of applied urea can be increased by using the large sized urea super granules (U.S.G.)(Anon.1977). Prasad (1979) reported that the use of Urea super granule gave higher fertilizer nitrogen efficiency than ordinary urea in the case of rice, maize, sugarcane and other crops. Horn (1979) suggested that urea super granule (1 gm size) exposes lesser surface area than prilled urea therefore it may have slow release properties. Apparao (1983) observed a significant increase in paddy yields with urea super granule application compared to urea applied in splits or in a single dose basally. Rambabu et al (1983) reported that under flooded conditions, placement of nitrogen as U.S.G. in rootzone was most effective in increasing drymatter production, paddy yields total N-uptake and apparent recovery of applied nitrogen.

2.5 Effect of nitrogen on growth characters

High nitrogen rates increased the weight of stem and leaves, total dry weight of plant, top to root ratio and plant height of tapioca (Krochamal and Samuels, 1970, Cheo-Samut, 1974).

Mandal *et al* (1970) found significant increase in plant height and number of leaves in cassava with increased nitrogen. Increased leaf growth was reported in tapioca due to higher levels of nitrogen (CIAT, 1975).

Increased plant height, leaf area, leaf size were observed by Ngongi, (1976) in tapioca with incremental dose of nitrogen. Ratnanakul (1976) reported that nitrogen above 50 kg/ha increased the fresh weight of stems.

Increased plant height and weight due to higher levels of nitrogen was observed by Pillai and George (1978). Ramanujan and Indira (1980) observed that incremental doses of nitrogen increase the leaf number and height of plants.

Ashokan (1980) reported that nitrogen significantly increases the canopy weight per plant and leaf area index. But Muthukrishnan (1980) could not find significant differences in foliage weight due to different rates of nitrogen. Several workers reported enhancement of leaf area and leaf number due to higher doses of nitrogen in colocasia. (Premraj et al. 1980; Mohandas and Sethumadhavan, 1980) Increased leaf growth with increased nitrogen was observed by Holmes and Wilson (1976).

Ramanujan (1982) reported increased dry matter production, petiole length and leaf area index with higher rates of nitrogen upto 150 kg/ha.

Nair (1982) noted, significant influence of the different levels of nitrogen on plant height, number of nodes, number of functional leaves and also on the leaf area index.

Sathianathan (1982) observed increased plant height and number of leaves with increased levels of nitrogen.

2.6 Effect of nitrogen on yield components

Vijayan and Aiyer (1969) reported that the mean number of tubers per plant was increased by increasing the rate of applied nitrogen from 0 - 75 kg/ha.

Morita (1969) reported that tuber development and thickening were more satisfactory in sweet potato plants supplied with nitrogen.

Mandal and Mohankumar (1972a) observed that the number of tubers increase with higher doses of nitrogen upto a limit.

Increase in the levels of nitrogen increased the number of tubers and the average size of tubers (Mandal and Mohankumar, 1972b).

Alexander (1973) observed no effect of nitrogen in increasing the girth of tuber in sweet potato.

But Natarajan (1975) did not get any increase in tuber number, length or girth due to incremental doses of nitrogen.

Ofori (1976) got positive response in tuber number upto 67 kg nitrogen per hectare.

Mohankumar and Mandal (1977) reported that a significant increase in the number of tubers per plant can be obtained by increasing the dose of nitrogen.

Acosta and Pinto (1978) observed that eventhough the root girth increase with increase in nitrogen levels, the number of roots per plant do not very much.

Asokan et al (1980) found that the length, girth and numbers did not vary significantly due to different levels of nitrogen.

Studies at Vellayani revealed that higher levels of nitrogen favourably influenced the number of tubers, tuber weight, length of tuber, and top yield of tapioca but the effect on the girth of the tuber and on the utilisation index were not significant (Nair, 1982).

Sathianathan (1982) reported that there is no significant difference in number of tubers per plant with different levels of nitrogen.

2.7 Effect of nitrogen on yield

Significant yield increases upto 100 kg N/ha were observed by Mandal and Singh (1970). Increase in tapioca yield with increase in nitrogen levels upto 200 kg N/ha was reported by Howler (1976).

Kumar et al (1976) reported significant yield increases by the application of nitrogen.

A local cultivar gave the maximum yield at 60 kg N/ha whereas the highest yield of an improved cultivar could be obtained only by the application of nitrogen at 120 kg/ha (Obigbesan and Fayemi, 1976).

Saraswat and Chettiar (1976) reported the highest yield of 33.4 tonnes/ha with a nitrogen application at 130 kg/ha.

Ngongi (1976) found significant increase in yield with moderate rates of nitrogen application (50 to 100 kg/ha. But higher rates decreased yields by producing excessive top growth at the expense of root growth.

Mohankumar and Maini (1977) got significant yield increase by the application of 100 kg nitrogen/ha at Central Tuber Crops Research Institute.

Gomes _et al_ (1979) observed significant yield increase by nitrogen application in Brazil.

Muthuswamy and Chiranjivi Rao (1979) found yield depressions in tapioca to the extent of 11-14 per cent at 150 kg N/ha as compared to 50 kg N/ha.

Asokan _et al_ (1980) noticed increased yields due to higher dose of nitrogen in the red sandy loam soils of North Malabar.

Significant increase in tuber yield was noticed upto 150 kg N/ha by Ramanujam, T. (1982).

Nitrogen exerted significant effect on tuber yield at Vellayani (Nair, 1982).

Sathianathan (1982) reported higher tuber yields with higher levels of nitrogen.

2.8. Effect of nitrogen on quality

2.8.1 Dry matter content

Pillai (1967) reported that nitrogen increases the per cent of dry matter content of tapioca tuber.

Vijayan and Aiyar (1969) found that the varying levels of nitrogen did not produce any difference in the dry matter content of tapioca tuber.

2.9 Effect of nitrogen on nutrient uptake

Mohankumar and Nair (1969) reported increase in the percentage of nitrogen and also of potassium in plant parts with increases in the rates of nitrogen application.

Rajendran et al (1976) noticed increased potassium uptake by higher doses of nitrogen. Increased nitrogen content of plant was recorded by Pushpadas et al (1976) with higher levels of nitrogen nutrition.

A decrease in phosphorus and potassium contents of leaf blade and stem of tapioca was observed by Okeke et al (1979b) due to nitrogen nutrition. But petiole potassium showed a linear response to applied nitrogen.

Nair (1982) reported the significant effect of nitrogen in respect of the uptake of this nutrient, in tapioca under Vellayani conditions.

2.10 Effect of nitrogen on soil nutrient status

Nair (1982) observed that the available nitrogen content of soil increased with an increase in the dose of nitrogen applied.

The effects of neem coated urea and rubber coated urea, on the available nitrogen content of soil were on par in an experiment on cassava under Vellayani conditions(Sathianathan, 1982).

2.8.3 Crude protein content

Pillai (1967) reported that crude protein content of tuber was significantly increased with the application of higher doses of nitrogen. Vijayan and Iyer (1969) found nitrogen had significant effect on increasing the crude protein percentage of tuber.

Nair (1982) reported that the crude protein content increased significantly with incremental doses of nitrogen at Kayamkulam and Vellayani.

2.8.4 HCN content

Indira et al (1972) noticed that application of nitrogen increased the HCN content of tapioca tubers.

Higher rates of nitrogen increased the HCN content of tubers (Obigbesan, 1973; Mohankumar and Maini, 1976 and Muthukrishnan, 1980).

Eventhough an increase in HCN content was noticed in a local cultivar with higher level of nitrogen, Obigbesan and Fayemi (1976) could find a decrease of HCN in an improved cultivar by nitrogen fertilization.

Nair (1982) observed increased HCN content in tapioca tubers with higher levels of nitrogen application.

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Babu Mathew (1987) could not find any significant difference in the total nitrogen percentage of soil, in rice, treated with urea super granules, neemcoated urea and prilled urea. Their effects on the total nitrogen percentage of soil were on par.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An experiment was conducted to study the effect of the various slow release sources of nitrogen on cassava at the Instructional farm attached to the College of Agriculture, Vellayani during 1985- '86. The sources used were urea, neem cake coated urea, urea super granules and the rubber cake coated urea. The details of the materials used and methods adopted in the experiment are given in this chapter.

3.1. Experimental site

The experiment was conducted at the Instructional farm attached to the College of Agriculture, Vellayani. Vellayani is situated at 8.5° north latitude and 76.9° east longitude and at an altitude of 29 metres above mean sea level.

3.2 Soil

The soil of the experimental site was red loam with the following physioc-chemical properties.

A. Mechanical composition

Coarse sand	(%)	-	13.70
Fine sand	(%)	-	33.40
Silt	(%)	-	28.00
Clay	(%)	-	24.90

B. Chemical composition

pH - 5.3

Total Nitrogen - 0.045%

Available P_2O_5(kg/ha)- 42

Available K_2O(kg/ha) - 50.25

3.3. Cropping history of the field

The experimental area was lying fallow for seven months prior to the present field experiment.

3.4 Season

The experiment was started during the month of November 1985 just after the receipt of the late North-east monsoon showers and the crop was harvested during September 1986. The crop was raised as a completely rainfed one.

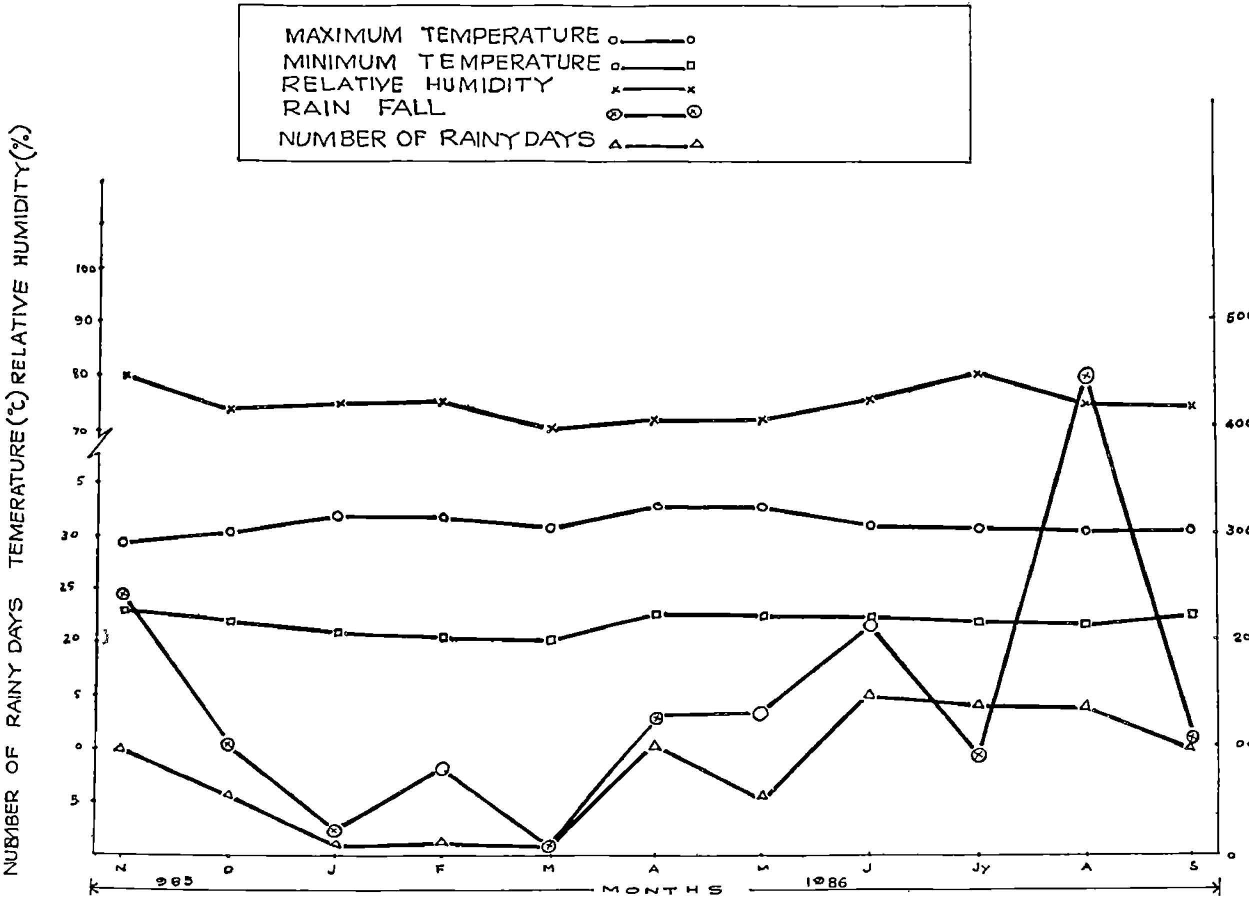
3.5 Weather conditions

The total annual rainfall of Vellayani was 2053 mm. The mean annual maximum and minimum temperature are 30.4°C and 24.3°C respectively. The weather conditions prevailed during the cropping period is shown in Figure 1 and the relevant data are given in Appendix-I.

3.6 Planting material

The variety Sree Visakha (H-1687) was used for the trial. The planting material required for the study was obtained from Central Tuber Crops Research Institute,Sreekaryam, Trivandrum.

FIG 1 WEATHER CONDITIONS DURING THE CROP PERIOD



Sree Visakha is a semi-branching, medium tall variety having ten months' duration. It's flesh colour is yellow and it contains 26 per cent starch. It shows high degree of tolerance to cassava mosaic and is less susceptible to pests like termites, scale insects etc.

3.7 Land preparation

The land was dug twice using spade before the commencement of the rains. Clod crushing and levelling operations were done. The plots were marked with pegs and bunds formed. Mounds were made after the application of basal dose of fertilizers.

3.8 Design and layout

The experiment was laid out as a 4 x 5 rectangular lattice design (Incomplete block design) with 3 replications (Fig.2).

Number of blocks per replication	- 5
Number of plots per block	- 4
Total number of treatments per replication.	- 20

3.8.1 Treatments

Factorial combinations of 4 sources and 5 levels of nitrogen constituted the treatments.

FIG 2 LAY OUT PLAN

REPLICATION 1

$S\ n$	$S\ n_2$	$S\ n_3$	$S\ n_4$	B
$S\ n_5$	S_2n	S_2n_2	S_2n_3	B2
S_2n_4	S_2n_5	$S_3\ n$	$S_3\ n_2$	B3
S_3n_3	S_3n_4	$S_3\ n_5$	$S_4\ n$	B4
S_4n_2	S_4n_3	S_4n_4	$S_4\ n_5$	B5

REPLICATION 2

B	$S\ n_5$	S_2n_4	S_3n_3	S_4n_2
B2	$S\ n$	S_2n_5	S_3n_4	$S_4\ n_3$
B3	$S\ n_2$	S_2n	S_3n_5	$S_4\ n_4$
B4	$S\ n_3$	S_2n_2	S_3n	S_4n_5
B5	$S\ n_4$	S_2n_3	S_3n_2	$S_4\ n$

REPLICATION _ 3

S_2n_3	$S_3\ n$	$S_3\ n_5$	S_4n_3	B
$S\ n_2$	S_2n_4	S_4n	$S_4\ n_5$	B2
$S\ n_4$	S_2n_2	S_3n_4	$S_4\ n_2$	B3
$S\ n$	$S\ n_5$	S_3n_2	S_4n_4	B4
$S\ n_3$	S_2n	S_2n_5	S_3n_3	B5

TREATMENTS

SOURCES OF NITROGEN

S	UREA
S_2	NEEM COATED UREA
S_3	UREA SUPER GRANULES
S_4	RUBBER CAKE COATED UREA

LEVELS OF NITROGEN

n_1	50 kg N/ha
n_2	75 kg N/ha
n_3	100 kg N/ha
n_4	125 kg N/ha
n_5	150 kg N/ha

(1) Sources of nitrogen

s_1 - Prilled urea

s_2 - Urea neem cake blend in the ratio 5:1

s_3 - Urea super granules

s_4 - Urea rubber cake blend in the ratio 5:1

(2) Levels of nitrogen

n_1 - 50 kg N/ha

n_2 - 75 kg N/ha

n_3 - 100 kg N/ha

n_4 - 125 kg N/ha

n_5 - 150 kg N/ha

3.8.2 Treatment combinations

1.	s_1n_1	2.	s_1n_2	3.	s_1n_3	4.	s_1n_4	5.	s_1n_5
6.	s_2n_1	7.	s_2n_2	8.	s_2n_3	9.	s_2n_4	10.	s_2n_5
11.	s_3n_1	12.	s_3n_2	13.	s_3n_3	14.	s_3n_4	15.	s_3n_5
17.	s_4n_1	18.	s_4n_2	18.	s_4n_3	19.	s_4n_4	20.	s_4n_5

3.8.3 Time of application of fertilizers

Source s_1 applied as 1/3 basal + 1/3 sixty days after planting + 1/3 ninety days after planting.

source s_2 applied as full basal.

source s_3 applied as full basal

source s_4 applied as full basal

3.8.4 Plot size and spacing

Plot size	-	5.4 x 4.5 m	(gross)
		4.5 x 3.6 m	(net)
spacing	-	90 x 90 cm	

3.9 Planting

Planting was done on 15th November 1985. The cuttings of length 20 cm were planted vertically at the rate of 1 sett/ mound at the centre of the mound, at a depth not exceeding 6 cm.

3.10 Fertilizer application

3.10.1 Nitrogen

Nitrogen was applied as the different forms mentioned earlier and the calculated amounts of nitrogen were given as per treatment schedule. Urea and the oil cakes were mixed in the ratio of 5: 1 just before application.

3.10.2 Phosphorus

Phosphorus was given as super-phosphate containing 16 per cent P_2O_5 uniformly to all plots at the rate of 100 kg P_2O_5/ha as basal dressing.

3.10.3 Potassium

Potassium was given as muriate of potash which contains 60 per cent K_2O and the calculated amounts were given in 3 splits, first split as basal, second dose two months after planting and the final dose 3 months after planting.

3.11 After cultivation

Germination of setts was satisfactory and the ungerminated setts were removed and replanted with fresh setts ten days after planting. After retaining two healthy sprouts, all other sprouts were removed after 30 days. Weeding and earthing up were done as per the package of practices recommendations of K.A.U. ie., 2 months after planting and 3 months after planting.

3.12 Harvest

The crop was harvested 10 months after planting, ie. on 15th September 1986. The plants selected for biometric observations were uprooted on the previous day of general harvest and necessary observations were recorded.

3.13. Biometric observations

3.13.1. Pre-harvest observations

Four plants were selected from each plot at random and were tagged. The following observations were made on these plants, at intervals of 30 days from planting to harvest and the mean values were worked out.

3.13.1.1 Plant height

Height of the tallest of the two stems of each plant was measured from the base of sprouts to the tip of the unopened bud.

3.13.1.2 Number of nodes per plant

The number of fully opened leaves as well as the leaf scars were counted from the base to the tip of the stem on both the shoots.

3.13.1.3 Number of functional leaves per plant

The number of fully opened leaves or functional leaves was counted from the base to the tip of the stem on both the shoots. [Ramanujam and Indra 1978]

3.13.1.4 Leaf Area Index

The leaf area was calculated using the linear measurement method suggested by Ramanujan and Indira (1978). The L.A.I. was worked out by the following formula as suggested by Watson (1947).

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

3.13.2 Post harvest observations

The sample plants selected for biometric observations were harvested on the previous day of general harvest. The following observations were made on these plants, mean values were calculated and recorded.

3.13.2.1 Number of tubers per plant

The tubers from the observational plants were separated and counted.

3.13.2.2 Tuber weight/plant

The mean tuber weight/plant was worked out by dividing the fresh tuber weight of sample plants by the number of tubers.

3.13.2.3 Length of tuber

The length of medium sized tubers from the sample plants were measured.

3.13.2.4 Girth of tuber

Girth measurements were recorded from those tubers which were used for length measurements. Girth values were recorded at three places of the tuber, one at the centre and the other two at half way between the centre and the two ends of the tubers. Average of these three measurements was taken as the girth of the tuber.

3.13.2.5 Tuber yield

After carefully pulling out the plants from the net plot, the tubers were separated, cleaned and the fresh weight of tubers recorded.

3.13.2.6 Top yield

The total weight of stems and leaves of the plants from the net plot was recorded soon after harvest.

3.13.2.7 Utilisation index

Ratio of the root weight to top weight (stem and leaves) which is an important yield determined of tapioca was calculated for each treatment.

3.14 Quality attributes

3.14.1. Starch content

Starch content of the flesh tuber was estimated by using potassium ferricyanide method. The values are expressed as percentage on fresh weight basis.

3.14.2. Starch yield

Starch yield in kg/ha was calculated by multiplying the percentage of starch with the tuber yield in kg/ha.

3.14.3. Hydrocyanic acid content

Hydrocyanic acid content of tuber samples was estimated colorimetrically by sodiumpicrate method (Indira and Sinha, 1969).

3.14.4. Crude protein content

The nitrogen content of tuber was determined by the modified microKjeldahlmethod (Jackson, 1967) and the crude protein estimated by multiplying thenitrogen values by the factor 6.25 (A.O.A.C. 1969).

3.14.5 Dry matter production

One day before the final harvest, one plant from each plot was carefully pulled out, the roots were separated and washed and the tops separated into leaves and stem. Each part was weighed fresh and sub-samples were taken and dried in the oven at 80°C to constant weight and dry weights of the various plant parts were determined and recorded.

3.15 Chemical analysis

3.15.1 Chemical analysis

3.15.1 Plant analysis

a. Nitrogen

Total nitrogen of the plant samples were determined by the modified microkjeldahl method (Jackson, 1967).

b. Potassium

Potassium was determined flame-Photometrically using Elico flame photometer.

3.15.2 Uptake studies

a. Uptake of Nitrogen

Different plant parts such as leaves, stems and roots were analysed separately for nitrogen and the total uptake was calculated based on the nitrogen content of the parts and their respective dry weights.

b. Uptake of potassium

The potassium content in the different plant parts such as leaves, stem and roots were estimated separately and the total uptake was computed based on the potassium content of the parts and their corresponding dry weights.

3.16 Soil analysis

The soil in the field was analysed for the various physico-chemical properties before the commencement of the experiment. Plot-wise analysis of soil samples for available nitrogen and potassium was done soon after the harvest.

3.16.1 Analytical methods

The methods followed for the analysis of soil (Physical and chemical properties) are given below.

3.16.1.1 Mechanical analysis

The international pipette method (Piper, 1950) was used for the mechanical analysis of initial soil sample.

3.16.1.2 Soil pH

The pH was determined with Elico pH metre (Jackson, 1967

3.16.1.3 Organic carbon

Walkley and Black's wet exidation method as described by Jackson (1967) was used for the estimation of organic carbon.

3.16.1.4 Total nitrogen

Modified microkjeldahl method (Jackson, 1967) was used for the estimation of total nitrogen content of soil.

3.16.1.5 Available phosphorus

Available phosphorus was found by Bray's I method (Jackson, 1967).

3.16.1.6 Available potassium

Available potassium was extracted by neutral normal ammonium accetate solution and determined by a flame photometer (Jackson, 1967).

3.17. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for 4 x 5 rectangular lattice (Cochran and Cox). The standard error of means and the critical difference have been provided for all statistical analysis whereever F-test was significant. In general, the results and discussion are based at probability level of 0.05.

RESULTS

4. RESULTS

4.1 Growth characters

4.1.1 Plant height

The data on plant height at various stages of growth are presented in Table 1.

30 D.A.P.

Plant height at 30 days after planting was not influenced by the application of different sources of nitrogen.

As regards the levels of nitrogen the effect on plant height 30 days after planting was significant. Highest plant height was observed with the application of nitrogen @ of 150 kg/ha which was on par with 125 kg N/ha and 100 kg N/ha.

The interaction effect of the sources of nitrogen and levels of nitrogen was not significant.

60 D.A.P.

Plant height at 60 days after planting was influenced by the different sources of nitrogen tried. Neem coated urea recorded the highest plant height which was on par with urea super granule and rubber cake coated urea was found to be inferior to all the other sources.

Table 1. Effect of treatments on the height of plants at various growth stages(cm)

Treatments	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days	270 days	At harvest
s_1	21.42	28.69	38.12	49.68	66.32	91.53	111.05	120.70	135.20	148.21
s_2	22.47	34.76	44.93	60.68	78.88	95.78	114.35	133.20	144.61	156.04
s_3	23.31	34.05	43.86	58.48	78.35	99.98	116.10	138.33	147.46	158.26
s_4	20.49	33.39	43.41	55.16	72.63	92.25	109.60	120.34	131.92	141.02
SE	1.04	1.29	1.47	1.71	3.09	2.51	2.80	4.11	3.72	4.33
CD	NS	2.66	3.04	3.52	6.35	5.17	5.76	8.46	7.65	8.90
n_1	20.36	30.04	39.15	51.00	67.87	84.44	103.86	120.80	130.23	141.85
n_2	20.76	32.02	41.13	54.48	72.31	89.85	108.21	122.58	134.27	147.17
n_3	22.33	32.89	41.90	56.15	74.88	94.92	111.94	128.55	140.50	150.52
n_4	22.34	33.56	44.02	58.35	75.11	100.00	115.96	130.42	144.34	154.85
n_5	23.81	35.12	46.73	60.65	80.06	105.20	123.81	138.52	149.64	159.99
SE	1.15	1.45	1.65	1.91	3.45	2.82	3.13	4.59	4.16	4.84
CD	2.38	2.99	3.40	3.94	7.10	5.79	6.44	9.45	8.56	9.95

With respect to the levels of nitrogen, there was significant effect. Application of nitrogen @ 150 kg/ha produced, tallest plants compared to those treated with 75 kg N/ha and 50 kg N/ha.

The interaction effect was not significant.

90 D.A.P.

Plant height at 90 D.A.P. was significantly influenced by the sources of nitrogen. Neem coated urea recorded the maximum height which was on par with that of urea super granule and rubber cake coated urea. Prilled urea recorded the lowest plant height.

Levels of nitrogen had significant effect, on plant height. Nitrogen applied @ 150 kg/ha produced the tallest plants but its effect was on par with that of the application of 125 kg N/ha.

The interaction effect was not significant in this respect.

120 D.A.P.

It was evident from the results that there was significant influence of the sources of nitrogen on plant height at 120 days after planting. Neem coated urea recorded the maximum height but its effect was on par with that of urea super granule. Prilled urea was found to be the inferior source at this stage.

Levels of nitrogen also expressed significant effect on plant height at this stage. Nitrogen applied @ 150 kg/ha resulted in maximum plant height but its effect was on par with the level of 125 kg/ha. Nitrogen applied at the rate of 50 kg/ha resulted in the lowest plant height.

The interaction effect was not significant.

150 D.A.P.

The data revealed significant influence of the sources and levels of nitrogen on plant height at 150 days after planting.

The sources, neem coated urea and urea super granule produced tallest plants which were significantly superior to urea and rubber cake coated urea.

The nitrogen level of 150 kg/ha produced tallest plants which was significantly, superior to all the other levels. The levels of 75, 100 and 125 though on par were significantly superior to 50 kg/ha.

The interaction effect was not significant.

180 D.A.P.

The different sources of nitrogen tried exerted significant influence on plant height at 180 days after planting. Urea super granules produced tallest plants which was on par with neem coated urea. Other sources were significantly inferior.

The levels of nitrogen exerted significant influence on plant height. The nitrogen levels of 125 and 150 kg/ha produced the tallest plants which were on par. The levels of 50, 75 and 100 kg/ha of nitrogen were significantly inferior in this respect.

The interaction effect was not significant.

<u>210 D.A.P.</u>

The influence of the sources of nitrogen was significant at this stage. Urea super granule produced the tallest plants which was significant superior to all others. The neem coated urea was significantly superior to urea and rubber cake coated urea.

The effect of the levels of nitrogen was also significant. A significant increase in plant height was observed at the highest dose of nitrogen ie. 150 kg/ha. The plant height at 125 kg/ha though inferior to the highest dose of nitrogen was significantly superior to all others.

The interaction effect was not significant.

<u>240 D.A.P.</u>

The data provided in the table revealed significant influence of both the sources and levels of nitrogen on plant height at 240 days after planting.

Urea super granules produced the tallest plants at this stage which was significantly superior to all others.

Application of the highest level of nitrogen resulted in the production of the tallest plants. The level of 100 and 125 kg/ha were on par and the others were significantly inferior.

The interaction effect was not significant.

270 D.A.P.

The sources of nitrogen revealed significant influence on plant height. Urea super granule and neem coated urea which were on par were found to be superior to urea and rubber cake coated urea.

With respect to the levels of nitrogen, nitrogen application @ 150 kg/ha was significantly superior to all others. The effect of nitrogen @ 125 kg/ha though inferior to n_5 was on par with n_3 and significantly superior to n_1 and n_2. The interaction effect was not significant at this stage.

At harvest

The effect of the sources of nitrogen was significant. Urea super granules recorded the maximum height but was on par with that of neem coated urea. Urea and rubber cake coated urea recorded the lowest plant heights.

The levels of nitrogen also exerted significant influence on plant height. Application of nitrogen @ 150 kg/ha recorded maximum height which was significantly superior to all other levels. This was followed by n_4, n_3, n_2 and n_1. The effect of interaction was not significant.

4.1.2 Number of nodes

The data on the number of nodes at various growth stages are presented in Table 2.

30 D.A.P.

There was no significant difference in the number of nodes produced due to the effect of the sources of nitrogen or due to the levels of nitrogen. The interaction effect was also not significant.

60 D.A.P.

At this stage, the data presented in Table 2, revealed that the node number was altered significantly by the sources of nitrogen and levels of nitrogen. Though the highest number of nodes was noticed in neem coated urea it was on par with urea super granule and rubber cake coated urea.

The node number was the highest in treatment n_5 which was followed by n_3, n_4 and n_2.

90 D.A.P.

The influence of the sources of nitrogen was significant, at this stage. Urea super granules was superior in this respect as compared to other sources.

With respect to the levels of nitrogen the number of nodes was significantly higher at n_5 level as compared to all the other levels of nitrogen. The effect of n_4, n_3 and n_2 were on par.

Table 2. Effect of treatments on the number of nodes/plant at various growth stages

Treatments	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days	270 days	At harvest
s_1	22.53	42.57	53.43	94.95	105.15	138.70	160.17	164.53	187.98	199.85
s_2	21.80	46.90	56.23	112.80	115.80	138.52	156.07	162.96	194.22	214.17
s_3	21.13	45.63	58.87	106.07	110.62	154.33	180.91	191.56	203.23	224.66
s_4	20.53	44.38	50.99	107.65	110.50	140.39	161.90	152.91	171.42	191.95
SE	1.07	1.42	1.50	3.71	2.56	3.17	7.14	7.14	5.85	7.17
CD	NS	2.93	3.09	7.63	5.27	6.85	6.52	14.69	12.02	14.75
n_1	19.11	41.35	53.08	98.02	102.27	131.42	154.09	155.82	181.27	194.46
n_2	21.17	43.85	55.36	100.77	107.15	141.29	163.98	165.13	180.13	194.83
n_3	22.19	46.75	57.23	108.75	111.65	142.88	162.00	171.08	187.33	205.63
n_4	22.31	44.40	57.63	104.94	112.44	145.92	168.38	162.00	196.99	216.50
n_5	22.73	48.00	61.11	114.34	119.08	153.43	175.38	185.87	199.84	226.89
SE	1.18	1.59	1.68	4.15	2.86	3.29	3.55	8.43	6.54	8.02
CD	NS	3.28	3.46	8.53	5.89	6.77	7.29	17.33	13.45	26.49

120 D.A.P.

Number of nodes was found to be significantly influenced by the different sources of nitrogen. Neem cake coated urea produced the highest number of nodes. The effect of the different levels of nitrogen was significant in this attribute. The level 150 kg N/ha produced the maximum number of nodes and n_1 level the minimum.

150 D.A.P.

The number of nodes at this stage was significantly influenced both by the sources of nitrogen and levels of nitrogen.

The effect of neem coated urea was significant and resulted in the production of the highest number of nodes. Number of nodes was significantly higher at n_5 level compared to all the other levels.

180 D.A.P.

The effect of sources of nitrogen was significant on the number of nodes. Urea super granule was found to be the best source in producing the highest number of nodes.

The levels of nitrogen also exerted significant influence on the number of nodes. Response to n_5 level was significantly higher compared to other levels. Treatments n_2, n_3 and n_4 were on par at this stage.

210 D.A.P

Sources of nitrogen exhibited significant effect on the node number at this stage of growth. Urea super granule was found to be the superior source as compared to all other sources in respect of node number. With respect to the incremental doses of nitrogen, the effect on the number of nodes was superior. Treatment n_5 produced the highest number of nodes which was followed by n_4, n_2 and n_3. The interaction was significant.

240 D.A.P.

There was significant effect of the sources of nitrogen on the number of nodes at this stage. Urea super granule was found to be the best source.

The effect of nitrogen levels was also significant in this respect. Treatment n_5 produced the highest number of nodes at this stage. This was followed by n_3, n_2 and n_4.

270 D.A.P.

Both the sources of nitrogen and levels of nitrogen exerted significant influence on the number of nodes at this stage. Urea super granule was found to be the best source at this stage also. This was closely followed by neem coated urea.

Treatment n_5 produced the highest node number through on par with n_4.

At harvest

The data clearly indicated that there was significant effect of the sources of nitrogen on the number of nodes. Though urea super granule produced the highest number, it was found to be on par with neem coated urea.

The levels of nitrogen also exerted significant influence on the node number. The n_5 level of nitrogen produced the highest number of nodes but was on par with n_4.

4.1.3 Number of functional leaves

The data on the number of functional leaves at various growth stages are presented in Table 3.

30 D.A.P.

The different sources of nitrogen were not influential in producing significant variations in the number of leaves.

But the effect of the levels of nitrogen was significant. The highest leaf number was observed in treatment n_5 which was on par with n_4 but significantly superior to other treatments.

The interaction effect was significant.

60 D.A.P.

It is evident from the results that the effect of sources of nitrogen and nitrogen levels were significant. Neem cake

Table 3. Effect of treatments on the number of functional leaves at various growth stages

Treatments	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days	270 days	At harvest
s_1	19.23	28.50	23.67	32.62	39.60	60.33	71.28	57.20	52.47	40.45
s_2	18.76	32.33	25.28	34.20	37.08	59.57	71.17	56.96	51.53	47.34
s_3	17.53	30.59	24.78	34.28	62.98	75.77	62.13	62.13	58.14	50.13
s_4	17.05	31.35	24.22	34.82	36.03	51.60	62.65	56.66	48.07	39.31
SE	0.98	1.18	0.95	1.30	1.55	1.79	1.76	4.12	4.03	2.04
CD	NS	2.42	NS	NS	NS	3.68	3.62	NS	8.29	4.19
n_1	16.02	28.08	22.60	31.07	34.88	52.19	62.98	32.84	44.73	39.27
n_2	17.54	29.62	23.08	32.88	37.04	55.98	66.77	54.09	48.75	41.83
n_3	18.10	31.66	24.36	34.50	38.10	57.63	70.29	59.34	51.00	43.63
n_4	19.31	30.54	25.15	34.52	37.34	62.52	74.79	61.38	53.88	45.87
n_5	19.75	33.06	27.25	37.43	41.40	64.79	76.25	63.53	61.50	50.96
SE	1.09	1.31	1.07	1.45	1.73	1.99	2.77	4.16	4.51	2.28
CD	2.24	2.70	2.19	2.99	3.55	4.11	4.46	9.48	7.28	4.69

coated urea was superior to all other sources in this respect, which was closely followed by rubber cake blended urea.

The different rates of nitrogen increased the number of leaves. Application of nitrogen at the highest level of 150 kg/ha produced significantly higher number of leaves. Treatments n_3 and n_4 were on par with each other. But the interaction effect was not significant.

<u>90 D.A.P.</u>

With respect to the sources of nitrogen, the effect was not significant, but there was considerable influence of the levels of nitrogen application on the number of functional leaves at this stage.

The highest number of leaves was observed in the treatment receiving the highest level of nitrogen ie. 150 kg N/ha. But the treatment n_3 and n_4 were on par.

<u>120 D.A.P.</u>

As regards the source of nitrogen, the effect was not significant. The data showed considerable influence of the rates of nitrogen application on the number of leaves at this stage. Number of leaves was highest at n_5 level whereas n_3 and n_4 were on par.

The interaction effect was not significant at this stage also.

150 D.A.P.

The data revealed that the number of leaves was not influenced significantly by the various sources of nitrogen applied.

The levels of nitrogen had significant effect on the number of leaves. The highest level of nitrogen produced the highest number of leaves at this stage also. The treatments n_2, n_3 and n_4 were on par at this stage.

180 D.A.P.

The leaf number at 150 days after planting was significantly influenced both by the sources of nitrogen and levels of nitrogen applied.

Urea super granules produced the highest number of leaves which was significantly superior to all other treatments. Treatments urea and neem coated urea were next in order.

With respect to the levels of nitrogen, the leaf number was the highest in the highest level of nitrogen application (150 kg N/ha). Treatment n_4 followed n_5 in this respect where as n_2 and n_3 were on par.

210 D.A.P.

The different source of nitrogen revealed significant influence on the number of leaves. Urea super granules was superior to all the other sources. Prilled urea and neem coated urea which were on par were superior to rubber cake coated urea.

As regards the levels of nitrogen, though the treatment n_5 produced the highest leaf number it was on par with n_4. The treatment n_4 was significantly superior to n_3, n_2 and n_1 in this attribute.

240 D.A.P.

The effect of the sources of nitrogen was not significant at this stage. The data showed that the levels of nitrogen exerted significant influence on this growth character at this stage. The number of leaves at n_5 was the highest. Treatment n_4 and n_3 were on par at this stage.

270 D.A.P.

The data revealed that the effect of the sources of nitrogen was significant at this stage. Urea super granules showed definite superiority over all other treatments.

In the case of the levels of nitrogen, the effect of the incremental doses of nitrogen was conspicuous in this respect. The highest number of leaves was observed at the highest rate of nitrogen application (n_5).

At harvest

The data showed that the leaf number was significantly influenced by the sources of nitrogen as well as by the levels at this stage. Urea supergranule was significantly superior to all other treatments. This was followed by neem coated urea and rubber cake coated urea.

As regards the levels of nitrogen, the highest nitrogen level produced the highest leaf number which was significantly superior to all other treatments. Treatments n_2 , n_3 and n_4 were on par at this stage.

4.1.4. Leaf Area Index

The data on L.A.I. at various growth stages are presented in Table 4.

30 D.A.P.

With respect to the different sources of nitrogen there was significant influence on L.A.I. Neem cake coated urea was found to be the best source of nitrogen followed by urea super granule which was on par with rubber cake coated urea.

As regards, the levels of nitrogen, LAI was found to increase significantly with increase in the dose of applied nitrogen. Though the highest dose of nitrogen recorded highest LAI value, it was on par with n_4 which in turn was on par with n_3 and n_2.

Table 4. Effect of treatments on the Leaf Area Index at various growth stages

Treat-ments	30 days	60 days	90 days	120 days	150 days	180 days	210 days	240 days	270 days	At harvest
s_1	0.21	0.47	0.25	0.41	0.55	1.04	1.41	1.21	0.98	0.71
s_2	0.28	0.58	0.29	0.50	0.66	1.05	1.41	1.22	0.96	0.83
s_3	0.24	0.51	0.26	0.57	0.71	1.11	1.50	1.32	1.08	0.88
s_4	0.23	0.53	0.27	0.45	0.60	0.91	1.25	1.21	0.90	0.69
SE	0.01	0.03	0.01	0.04	0.02	0.03	0.04	0.05	0.04	0.04
CD	0.03	0.07	NS	0.09	0.04	0.06	0.07	0.10	0.08	0.07
n_1	0.21	0.44	0.24	0.40	0.60	0.91	1.11	1.12	0.84	0.69
n_2	0.23	0.52	0.25	0.41	0.63	0.99	1.17	1.15	0.91	0.73
n_3	0.24	0.53	0.26	0.46	0.68	1.01	1.49	1.26	0.97	0.76
n_4	0.25	0.53	0.28	0.53	0.65	1.10	1.58	1.31	1.04	0.80
n_5	0.27	0.60	0.32	0.61	0.75	1.13	1.62	1.35	1.15	0.89
SE	0.01	0.04	0.01	0.05	0.02	0.04	0.04	0.06	0.05	0.04
CD	0.03	0.08	0.03	0.10	0.05	0.07	0.08	0.12	0.09	0.08

60 D.A.P.

The effect of the sources of nitrogen was not significant. The levels of nitrogen showed significant difference in LAI values at this stage. The LAI value at n_5 was significantly superior to all other levels.

90 D.A.P.

The data revealed that the effect of levels of nitrogen alone was significant at this stage of observation. The treatment n_5 recorded the highest LAI value which was significantly superior to all other levels.

120 D.A.P.

The data revealed that the effect of the different sources of nitrogen on LAI was significant. Urea super granule was found to be the best source compared to Prilled urea and rubber cake coated urea, but its effect was on par with that of neem cake coated urea.

The effect of levels of nitrogen was significant in this respect. The LAI observed at n_5 level was the highest. This was on par with n_4.

150 D.A.P.

Here the data showed that the different sources had significant effect on the leaf area index. All the sources were significantly different in their effects. Urea super granule recorded the maximum value of LAI.

The results showed that levels of nitrogen exerted significant influence on LAI at the stage. The highest value of LAI noted at n_5 levels was significantly superior to all other levels.

180 D.A.P.

The data revealed significant influence of both the sources nitrogen and levels of nitrogen on the LAI values at 180 days after planting. Though urea super granules recorded the highest value of LAI, it was on par with neem coated urea. LAI value was the highest at n_5 level but was on par with n_4. Treatments n_1 and n_2 were on par in this respect.

210 D.A.P.

The effect of the sources of nitrogen was significant. Urea super granule was found to be significantly superior to all others at this stage.

As regards the levels of nitrogen n_5 and n_4 were significantly superior to all other levels.

240 D.A.P.

The effect of the sources of nitrogen was not significant. The levels of nitrogen had significant effect on LAI at this stage. The highest value was observed at n_5 level which was on par with n_4 and n_3 levels.

270 D.A.P.

Significant effect of the sources of nitrogen on LAI was observed at this stage. Urea super granule was found to be the best source.

LAI was significantly high at the highest dose of nitrogen. The values at n_4 and n_3 levels were on par.

At harvest

The results clearly showed that there was significant effect of the sources of nitrogen on LAI. LAI values were significantly higher in the case of urea super granule and neemcake coated urea.

With respect to the levels of nitrogen, different levels had significant effect on LAI. n_5 level recorded the highest value of LAI which was significantly superior to all others.

4.2 Yield components and yield

4.2.1 Tubers / plant

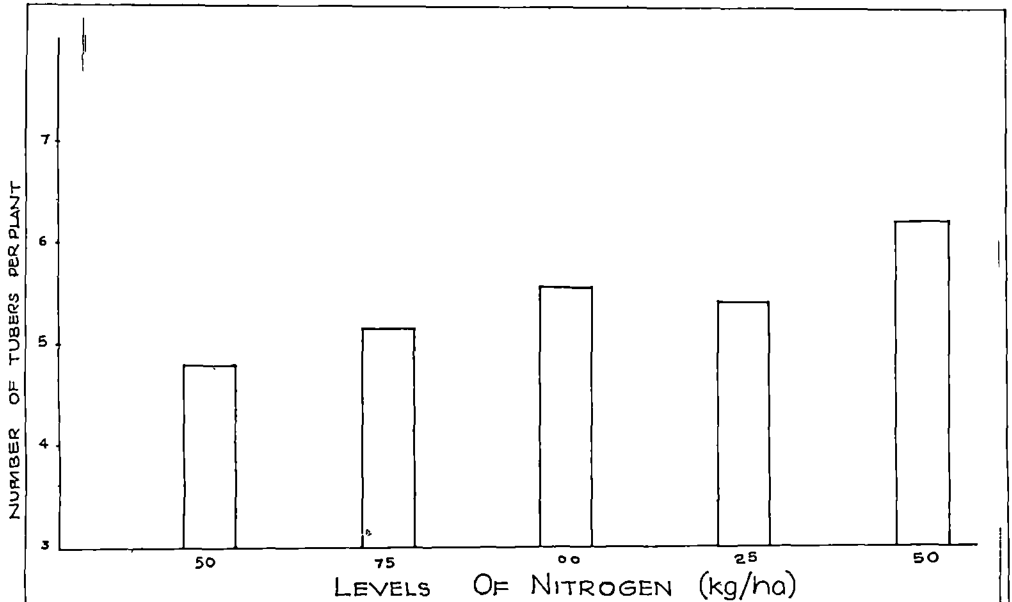
The data shown in table 5 and illustrated in Fig.3 showed that both the sources and levels of nitrogen had significant effect on number of tubers/plant. The source-level interaction was also significant.

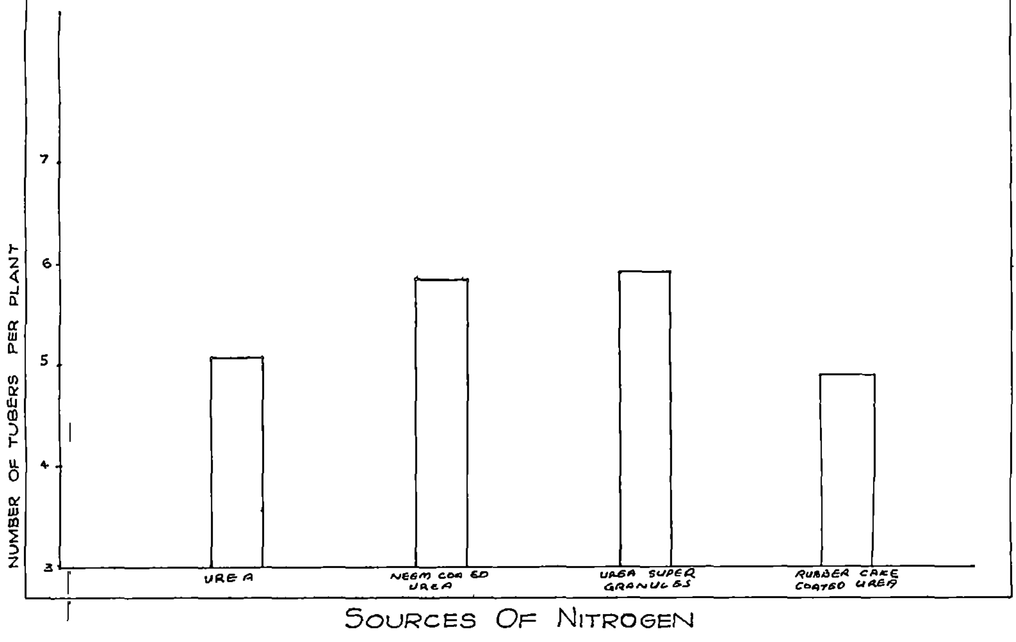
Table 5. Effect of treatments on the number of tubers per plant

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	4.50	5.17	5.33	4.08	6.33	5.08
s_2	5.58	6.33	5.33	5.25	6.75	5.85
s_3	5.66	5.16	6.25	6.08	6.17	5.86
s_4	3.67	4.08	5.17	6.17	5.58	4.93
Mean	4.85	5.19	5.52	5.39	6.20	

	F	CD(5%)	S.E
Between sources	Sig.	0.55	0.27
Between levels	Sig.	0.62	0.30
Interaction	Sig.	1.23	0.59

FIG 3 EFFECT OF TREATMENTS ON THE NUMBER OF TUBERS PER PLANT





The highest tuber number was observed in urea super granule which was on par with neem coated urea. Tuber number in rubber cake coated urea was the lowest but was on par with urea.

With respect to the levels of nitrogen, the number of tubers per plant was found to increase with incremental dose of applied nitrogen. Tuber number was the highest with the treatment receiving 150 kg N/ha. Treatment n_2, n_3 and n_4 were on par. The lowest number was recorded in n_1.

4.2.2 Tuber weight/plant

Data presented in Table 6 and illustrated in Fig.4 revealed that the effects due to the different sources of nitrogen and also due to the different levels of nitrogen was significant. The maximum value for tuber weight per plant was shown by urea super granule which was significantly superior to all others. This was followed by neem coated urea, urea and rubber cake coated urea.

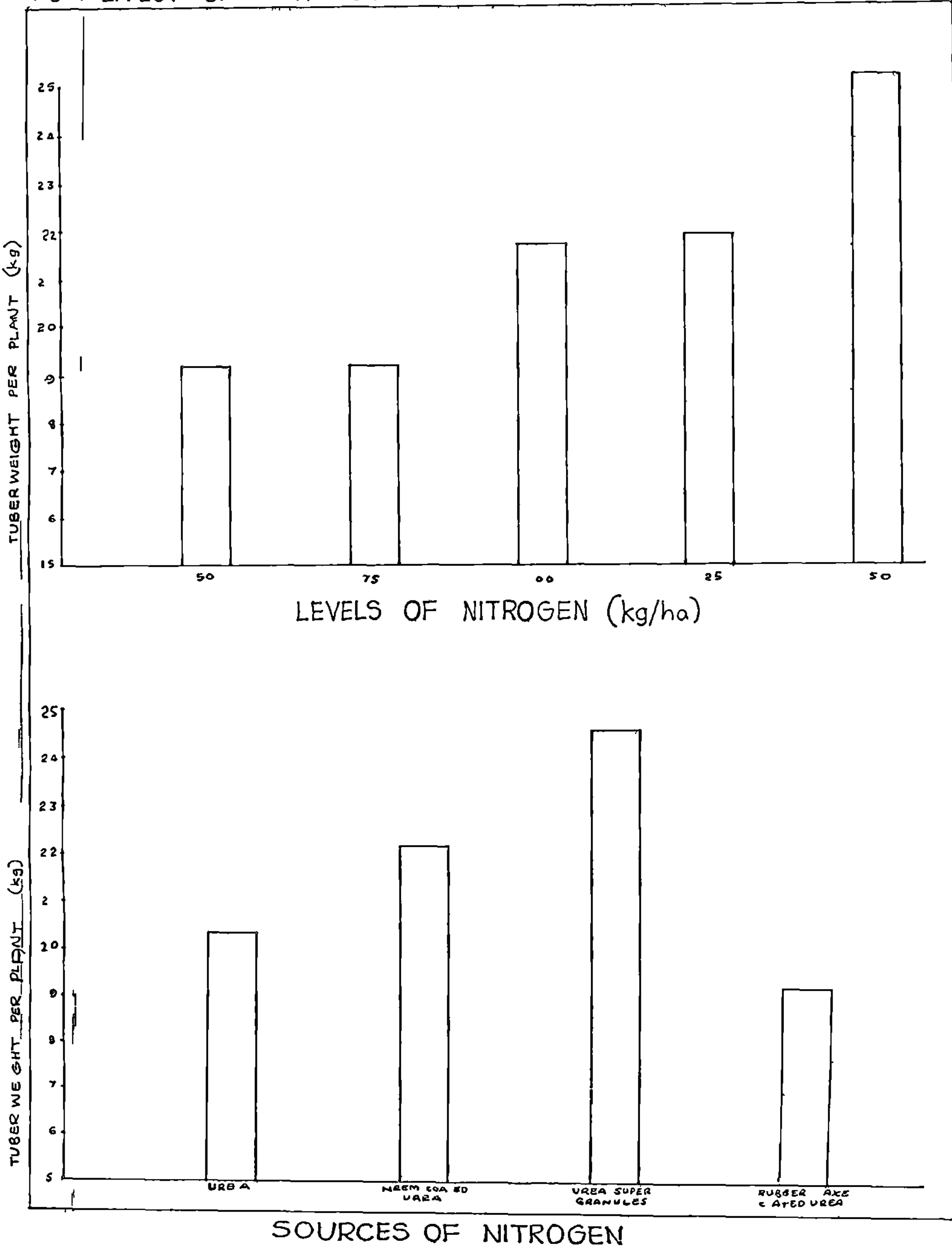
As regards the levels of nitrogen, maximum tuber weight was recorded by the n_5 level. The effects due to n_4 and n_3 levels were on par. Similarly treatments n_2 and n_1 were on par.

Table 6. Effect of treatments on the tuber weight per plant (kg)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	1.79	1.89	1.84	1.94	2.67	2.03
s_2	2.05	2.09	2.21	2.36	2.34	2.21
s_3	2.03	2.06	2.69	2.68	2.79	2.45
s_4	1.86	1.66	1.92	1.81	2.27	1.91
Mean	1.93	1.66	2.17	2.19	2.52	

	F	CD(5%)	S.E.
Between sources	Sig	0.19	0.09
Between levels	Sig.	0.21	0.10

Fg 4 EFFECT OF TREATMENTS ON THE TUBERWEIGHT PER PLANT



4.2.3 Length of tuber

Data presented in Table 7 showed that the different sources and levels of nitrogen influenced the length of tuber significantly. The interaction was also significant.

Urea super granules recorded the highest tuber length which was on par with neem coated urea. The sources prilled urea and rubber cake coated urea were on par.

Incremental doses of nitrogen significantly influenced the tuber length. Maximum tuber length was recorded at n_5 level which was significantly superior to all other levels. Treatments n_3, n_4 and n_2 were on par.

4.2.4 Girth of tuber

Neither the source nor the levels of nitrogen influenced the girth of tuber (Table 8).

Maximum tuber girth was by urea super granules though not statistically superior to other sources. The n_4 level produced the highest girth though not superior to others.

4.2.5 Tuber yield

Data presented in Table 9 and illustrated in Fig. 5 clearly revealed that both the sources of urea and levels of nitrogen exerted significant influence on tuber yield, but the source- level interaction was not significant.

Table 7. Effect of treatments on the length of tuber (cm)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	23.42	24.83	27.33	27.00	23.67	25.25
s_2	22.42	28.33	27.50	28.00	31.00	27.45
s_3	26.50	25.17	30.75	26.17	33.50	28.39
s_4	22.17	23.17	22.25	21.00	25.50	22.82
Mean	23.63	25.38	26.89	25.54	28.40	

	F	CD(5%)	S.E.
Between sources	Sig.	1.47	0.72
Between levels	Sig.	1.65	0.80
Interaction	Sig	3.29	1.60

Table 8. Effect of treatments on the girth of tuber (cm)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	15.69	15.73	16.07	18.37	17.20	16.59
s_2	15.40	16.40	16.18	15.83	16.70	16.10
s_3	16.17	17.23	17.77	16.33	17.03	16.91
s_4	16.00	15.68	15.53	16.75	15.77	15.95
Mean	15.79	16.26	16.38	16.82	16.67	

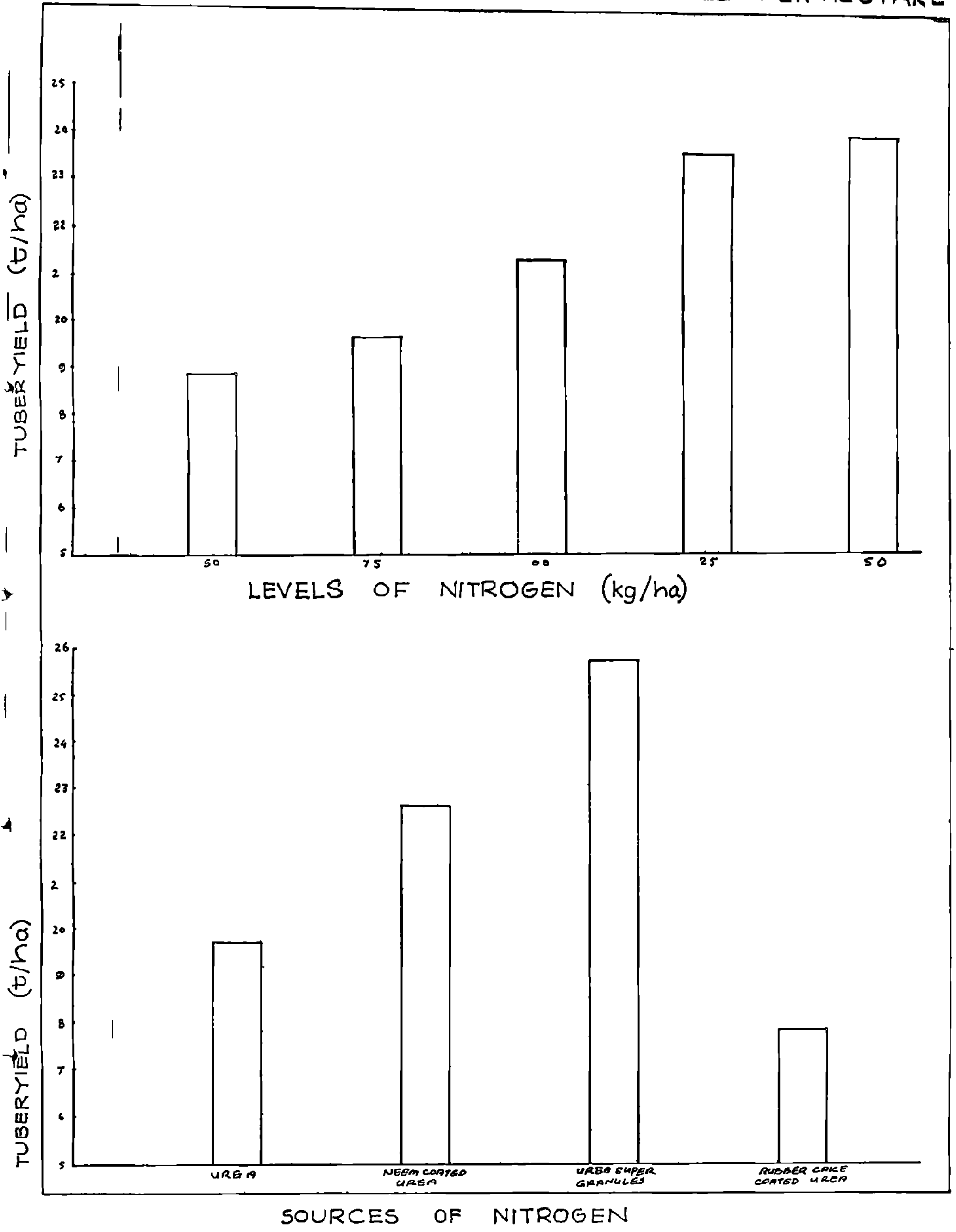
	F	CD(5%)	SE
Between sources	N.S	-	0.29
Between levels	N.S	-	0.33

Table 9. Effect of treatments on the tuber yield(t/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	16.23	19.10	18.61	21.90	22.44	19.95
s_2	19.18	18.81	24.21	24.39	26.35	22.59
s_3	23.54	23.38	25.51	27.35	28.47	25.65
s_4	16.65	16.81	16.80	20.41	18.13	17.76
Mean	18.89	19.53	21.29	23.51	23.85	

	F	CD(5%)	S.E
Between sources	Sig.	2.96	1.44
Between levels	Sig.	3.31	1.61

Fig 5 EFFECT OF TREATMENTS ON TUBER YIELD PER HECTARE



Urea super granules recorded the maximum yield of 25.6 t/ha and was significantly superior to all the other sources. Rubber cake coated urea produced the lowest yield but was on par with prilled urea.

The data showed that an increase in the dose of nitrogen significantly increased the tuber yield. Maximum tuber yield was shown by the highest level of nitrogen ie. 150 kg/ha, but it's effect was on par with that of n_4 and n_3 levels. n_1 level gave the lowest yield and its effect was on par with that of n_2 and n_3 levels.

4.2.6 Top yield

The data in Table 10 revealed that top yield increased significantly with the difference in the sources of nitrogen. Top yield was the highest in urea super granule which was significantly superior to all others. The effects due to the other sources were on par.

Incremental doses of nitrogen increased the top yield significantly. Maximum top yield was observed at n_5 level though it's effect was on par with that of n_4 and n_3 levels.

4.2.7 Utilisation Index (U.I.)

Utilisation index was significantly affected by the different sources of nitrogen (Table 11). The effects due to neem coated urea, urea super granule and urea were on

Table 10. Effect of treatments on the top yield (t/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	7.69	7.74	8.85	8.31	10.25	8.57
s_2	7.90	8.34	9.42	9.59	9.99	9.25
s_3	10.53	10.04	11.07	11.88	11.97	11.10
s_4	7.41	8.21	9.55	9.51	9.29	8.70
Mean	8.38	8.83	9.72	9.82	10.38	

	F	CD(5%)	S.E
Between sources	Sig.	0.82	0.39
Between levels	Sig.	0.92	0.45

Table 11. Effect of treatments on utilisation index

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	2.43	2.40	2.39	2.61	2.80	2.53
s_2	2.23	2.31	2.50	2.73	2.84	2.52
s_3	2.19	2.43	2.49	2.65	2.74	2.50
s_4	1.99	2.19	2.21	2.14	2.29	2.16
Mean	1.60	2.33	2.39	2.53	2.66	

	F	CD(5%)	S.E
Between sources	Sig.	C.27	0.13
Between levels	Sig.	C.29	0.14

par and the rubber cake coated urea was inferior to all the others.

Utilisation index was found to increase with an increase in applied nitrogen. It was higher at n_5 level compared to n_1, n_2 and n_3.

4.3 Quality attributes

4.3.1 Starch content

Neither the sources nor the levels and source-level interaction did influence the starch content of tuber (Table 12).

Among the sources, neem coated urea recorded the highest starch content though not significantly superior to other sources.

With respect to the levels of nitrogen, n_4 level showed the maximum starch content and n_2 level recorded the lowest value.

4.3.2 Starch yield

There was significant influence of the different sources of nitrogen on starch yield (Table 13). Urea super granule was found to be the best source followed by neem coated urea. The effects of prilled urea and rubber cake coated urea were on par.

Table 12. Effect of treatments on the starch content of tubers (%)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	26.70	26.07	26.95	26.74	25.89	26.47
s_2	26.30	26.32	26.56	27.48	27.75	26.88
s_3	26.53	25.19	26.69	25.93	26.36	26.14
s_4	26.19	26.39	26.23	26.54	26.37	26.34
Mean	26.43	25.99	26.61	26.72	26.59	

	F	CD(5%)	S.E
Between sources	N.S	-	0.41
Between levels	N.S	-	0.52

Table 13. Effect of the treatments on starch yield (t/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	4.32	4.96	5.02	5.87	5.79	5.19
s_2	5.04	5.04	5.43	6.44	7.09	5.98
s_3	6.27	6.07	6.78	7.09	7.49	6.73
s_4	4.43	4.44	4.38	5.43	4.73	4.66
Mean	4.99	5.09	5.65	6.21	6.27	

	F	CD(5%)	S.E
Between sources	Sig.	0.74	0.36
Between levels	Sig.	0.83	0.40

The levels of nitrogen also had significant influence on starch yield (Table 13). Starch yield was significantly high at n_5 level compared to the lowest 3 levels but on par with n_4 level.

The source-level interaction was not significant.

4.3.3 Hydrocyanicacid content

Data presented in Table 14 showed that the effect of the different sources of nitrogen on HCN content was not significant.

But the different levels of nitrogen tried, exerted significant influence on HCN content of tuber. The n_5 level showed the maximum HCN content and the n_1 level, the minimum. The effects of n_5 and n_4 were on par and also of n_3 and n_2.

4.3.4 Crude protein content

The results presented in Table 15 showed that neither the source nor the levels did influence the crude protein content.

Neem coated urea recorded the maximum crude protein content though not significantly superior to other sources. The maximum crude protein content was recorded at n_5 level of nitrogen.

Table 14. Effect of treatments on the Hydrocyanic acid content of tubers (μ-gms/gm)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	41.66	44.75	46.66	50.33	53.66	47.40
s_2	40.16	46.00	51.92	51.92	54.33	48.79
s_3	43.66	44.33	48.33	52.33	53.50	48.43
s_4	41.33	46.53	49.00	49.66	54.66	48.23
Mean	41.70	45.40	48.90	51.06	54.03	

	F	CD(5%)	S.E
Between sources	N.S	-	1.09
Between levels	Sig.	3.39	1.65

Table 15. Effect of treatments on the crude protein content of tubers (%)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	1.92	1.44	2.04	1.99	2.23	1.92
s_2	2.02	2.02	1.72	2.58	2.13	2.09
s_3	1.80	1.27	2.19	1.64	1.98	1.77
s_4	1.10	1.66	1.11	1.66	2.48	1.60
Mean	1.71	1.59	1.76	1.96	2.21	

	F	CD(5%)	S.E
Between sources	N.S	-	0.03
Between levels	N.S	-	0.04

4.3.5 Total dry matter

The different levels and sources of nitrogen influenced the total dry matter content significantly but the source-level interaction was not significant (Table 16).

Among the sources, urea super granule was found to be the best in producing more dry matter followed by neem coated urea. The effects of prilled urea and rubber cake coated urea were inferior and was on par with each other.

With respect to the levels of nitrogen, there was significant progressive increase in total dry matter production with incremental doses of nitrogen.

4.4. Nutrient Uptake

4.4.1 Nitrogen uptake

Data showed that the different sources of nitrogen and levels of nitrogen tried, had significant influence on the nitrogen uptake by plants (Table 17).

Urea super granules was found to be superior to all other sources followed by neem coated urea. Prilled urea recorded the lowest uptake but was on par with rubber cake coated urea.

The effect of levels of nitrogen was significant in this respect. Among the levels tried n_5 was significantly superior to n_3 and n_2 but on par with n_4 level.

Table 16. Effect of treatments on the total dry matter production (t/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	8.27	9.98	10.22	11.57	12.57	10.52
s_2	9.59	10.23	12.82	13.32	14.69	12.13
s_3	11.15	11.93	14.51	15.37	16.88	13.97
s_4	8.19	9.34	10.85	11.44	12.19	10.40
Mean	9.29	10.37	12.10	12.92	14.08	

	F	CD(5%)	S.E
Between sources	Sig.	0.49	0.24
Between levels	Sig.	0.56	0.27

4.4.2 Potassium uptake

The data presented in Table 18 showed that the different sources and levels of nitrogen exerted significant influence on the potassium uptake by plants. However, source-level interaction was not significant.

Among the sources, urea super granule recorded the highest potassium uptake followed by neem coated urea. The treatments urea super granules and neem coated urea were on par.

Incremental doses of nitrogen resulted in an increase in the potassium uptake by plants. But the three higher levels of nitrogen were on par in this respect.

4.5 Soil analysis after the experiment

4.5.1 Total nitrogen

The data presented in Table 19 revealed that the effects of the different sources of nitrogen and the levels of nitrogen were not significant on the total nitrogen content of the soil after the experiment.

Though urea super granule recorded the highest total nitrogen after the experiment, there was no significant difference between the sources.

Table 18. Effect of treatments on the total uptake of potassium (kg/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	28.87	35.79	36.34	41.32	44.32	31.50
s_2	36.02	36.14	46.61	48.43	52.58	43.90
s_3	37.53	47.25	53.70	58.75	48.61	49.10
s_4	37.72	31.79	39.90	43.41	44.18	39.40
Mean	35.04	37.74	44.14	47.97	47.45	

	F	CD(5%)	S.E
Between sources	Sig.	5.91	2.87
Between levels	Sig.	6.61	3.21

Table 19. Effect of treatments on the total nitrogen content of soil after the trial (%)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	0.076	0.076	0.089	0.086	0.083	0.082
s_2	0.086	0.076	0.079	0.083	0.093	0.083
s_3	0.076	0.086	0.083	0.093	0.086	0.085
s_4	0.080	0.083	0.076	0.073	0.089	0.080
Mean	0.079	0.080	0.082	0.084	0.087	

	F	CD(5%)	S.E
Between sources	N.S	-	-
Between levels	N.S	-	-

Treatment n_5 though recorded the highest value of total nitrogen in soil there was no significant difference between the different levels.

4.5.2 <u>Available potassium</u>

The data revealed that the different sources and levels of nitrogen had no significant effect on the available potassium content of soil (Table 20).

Though not significant prilled urea was inferior to all the other slow release sources. Treatment s_3 registered the highest value.

Table 20. Effect of the treatments on the available potassium content of the soil after the trial (kg/ha)

Sources	Levels of nitrogen					Mean
	n_1	n_2	n_3	n_4	n_5	
s_1	70.00	76.66	65.00	78.33	68.33	71.66
s_2	56.66	75.00	83.33	68.33	65.00	69.66
s_3	71.66	61.66	68.33	66.66	70.00	67.66
s_4	65.00	73.33	78.33	56.67	75.00	69.66
Mean	65.83	71.64	73.74	67.49	69.58	

	F	CD(5%)	S.E
Between sources	N.S	-	6.12
Between levels	N.S	-	6.38

DISCUSSION

5. DISCUSSION

The present investigation elucidates, the effect of some sources of slow release nitrogen at varying levels of nitrogen on the growth and yield performance of tapioca. The results of the investigation are discussed below.

5.1. Growth characters

5.1.1 Plant height

Eventhough the vegetative parts are not included as the economic portion of the produce in tapioca, it definitely contributes to tuber production by acting as a photosynthetic factory for the manufacture of starch. Height forms an essential component in the production of leaves which act as the source. The importance of nitrogen in influencing the plant height is to be viewed in this context. At almost all the stages of crop growth, the height of plants was favourably and significantly influenced by the slow release sources of nitrogen as compared to the prilled urea (Table 1.). The effect of the different levels of nitrogen was also significant through out the crop growth stages (Table 1). The slow-release sources would have prevented the leaching and run-off losses by inhibiting nitrification process and also by releasing the absorbable form very slowly and thereby making the nitrate nitrogen available for a longer period.

Seshadri (1976) in cotton and Oommen et al (1977) in rice and Sathianathan (1982) in tapioca, also obtained increased plant height with the use of slow release sources of nitrogen. Much of the applied nitrogen in the plots where prilled urea was the source would have been lost in the percolating water and thereby restricting the plant height, as is observed the present study.

Among the different sources, urea super granule was found to be superior in most of the growth stages in augmenting plant height, followed by neem coated urea. Urea supergranule and neem coated urea would have conserved nitrogen to the maximum extent and thus favourably influenced the plant growth to record the maximum plant heights. During the early stages, neem coated urea performed better than urea supergranules, but after the 5th month urea supergranule showed the superiority, indicating that it is a better source of slow release nitrogen than neem coated urea. This may probably be due to the fact that urea supergranule exposes lesser surfaces area for reaction with soil as compared to other sources. This would have resulted in a longer period of availability of nitrogen. Studies of Horn (1979) lend support to this finding. As regarding neem coated urea, neemcake is known to contain an alkaloid nimbidin which would have suppressed the population of nitrifying bacteria and thereby prolonged the period of availability of nitrogen. Similar results was obtained by Sathianathan (1982) in tapioca.

Rubber cake coated urea did not maintain significant superiority over untreated urea during the later stages. During the early stages, the superiority of rubber cake coated urea over untreated urea may probably be due to the fact that the entire dose of rubber cake coated urea was applied as basal dressing where as in the case of prilled urea only one third of the total dose was applied at this stage. Similar result was reported by Sathianathan (1982) in tapioca.

As regards the levels of nitrogen, it may be particularly seen that the height was enhanced by nitrogen application upto the highest level. The influence of nitrogen on vegetative growth of plants is a well established phenomina which needs no detailed discussion. Similar increases in plant height due to higher levels of nitrogen application have been reported in tapioca by several workers like Natarajan (1975); Mandal et al (1975) and Nair (1982).

5.1.2 Number of nodes

The different sources and levels of nitrogen significantly and positively influenced the number of nodes (Table 2).

During the early stages there was not much difference in the performance of urea super granule, neem coated urea and rubber cake coated urea in respect of the number of nodes. But during the later stages, urea super granule was superior to all other sources. Here the nitrogen availability might have been prolonged throughout the growth of the plant especially in the later stages of growth which may be due to the lesser area of contract of urea super granule with the soil. Neem coated urea was second in the order of the slow release sources of urea. The beneficial effect neem coated urea may due to the presence of nimbidin which might have resulted in a prolonged availability of nitrogen.

Maximum number of nodes were produced at the highest level of nitrogen application. Number of nodes actually reflects the number of leaves produced and this is a cardinal index for measurement of vegetative growth of tapioca. Krochmal and Samuels (1967) in tank culture study have very well demonstrated the influence of nitrogen on the vegetative growth of tapioca, where in a marked increase in the vegetative growth of tapioca by higher levels of nitrogen application was observed. Similar results were reported by Nair (1982).

5.1.3 Number of functional leaves

The sources of nitrogen showed significant influence during some of the growth stages while the levels exerted influence at almost all the stages (Table 3). During the early stages, the influence of slow release sources was not significant in this aspect.

Urea super granule was found to be superior to other sources during the later stages. This might be due to the favourable effect of urea super granule rendering a prolonged availability of nitrogen even at the later stages of growth. Similar results were obtained by Rambabu et al (1983) in paddy.

Some nitrification inhibitory compounds like nimbidin present in neem cake might have inhibited the nitrification process and thereby made a continued availability of nitrogen throughout the growth period of the plant. This is reflected in the production of a higher number of leaves in the treatment. Sathianathan (1982) also obtained similar results in tapioca.

There was not much difference in the performance of rubber cake coated urea and prilled urea, showing that eventhough rubber cake coated urea is a slow release source of nitrogen it is in no way better than prilled urea in producing more number of leaves. Sathianathan (1982) reported similar results.

There was significant positive influence of the levels of nitrogen on the number of leaves. Mandal (1975), Ngongi (1976) and Nair (1982) also have reported similar positive influence of nitrogen on leaf number of tapioca.

5.1.4 Leaf area Index (L.A.I.)

Both the sources and levels of nitrogen showed significant influence on L.A.I. during most of the growth stages. (Table 4). The importance of nitrogen as a factor in influencing L.A.I. has been reported in many crops. According to Russel (1973), as nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have larger surface area available for photosynthesis.

Urea super granule was found to be superior to all the other sources, neem coated urea stands second. Performance of rubber cake coated urea was in no way better than that of prilled urea. Increase in L.A.I. was also due to an increase in leaf number due to the influence of various sources. Urea super granule produced more number of leaves and so it recorded the highest L.A.I.

So is the case of neem coated urea also which produced more number of leaves than rubber cake coated urea and prilled urea and hence recorded highest L.A.I.

As regards the levels of nitrogen, there was an increase in L.A.I. with the application of incremental doses of nitrogen. For many crops, the amount of leaf area available for photosynthesis is roughly proportional to the amount of nitrogen applied. Increase in L.A.I. was also due to an increase in leaf number at higher levels of nitrogen. Increases in leaf area due to incremental doses of nitrogen were reported by Ngongi (1976) and Nair (1982) in tapioca.

5.2. Yield components and yield

5.2.1 Number of tubers

The effect of both the sources of nitrogen and levels of nitrogen on the number of tubers per plant was significant (Table 5). Urea super granule showed the highest number which was a par with neem coated urea. The beneficial effects of these slow release sources of nitrogen might have provided a steady supply of nitrogen to plants, which in turn favourably, influenced this important yields components. Sathianathan (1982) also observed more number of tubers per plant in tapioca with the use of neem coated urea. Rubber cake coated urea did not show any superiority over prilled urea in its influence on production of tubers.

As regards the levels of nitrogen, there was significant effect with the incremental doses of nitrogen.

Here, maximum number of tubers was obtained by the application of 150 kg N/ha. Crops such as tubers which are grown for carbohydrates show a higher rate of photosynthesis consequent on increased leaf area obtained by nitrogen application. (Russel, 1973). This might have led to the production of larger number of tubers in plots supplied with higher doses of nitrogen. Several investigators like Vijayan and Aiyer (1969) Mandal and Mohankumar (1972a) and Nair (1982) have observed increases in tuber number of tapioca due to nitrogen nutrition.

5.2.2 Tuber weight per plant

The mean tuber weight is another important yield determinant of tapioca. The influence of both the sources of nitrogen and levels of nitrogen on mean tuber weight was significant as is shown in Table 6 and Fig.4. Urea super granule recorded the maximum tuber weight followed by neem coated urea. The increased photo synthetic activity due to the production of more number of leaves in these treatments as discussed earlier, by the prolonged availability of nitrogen might have resulted in the production of more assimilates which in turn have been deposited in the tubers, thereby resulting in higher mean tuber weight.

The effect of the incremental levels of nitrogen was also significant. Similar results were obtained by Mandal and Mohankumar (1972b) and also by Nair (1982).

5.2.3 Length of tubers

It was observed from Table 7 that the effects of the sources of nitrogen and levels of nitrogen on the length of tubers were significant. Among the sources, urea super granule recorded the highest tuber length though it's effect was on par with that of neem coated urea. The beneficial effect of slow release sources of nitrogen was revealed in this attribute also.

The higher levels of nitrogen produced more tuber length. The better growth performance of plants observed at higher levels of nitrogen application had led to the production of longer tubers. Similar results were reported by Nair (1982) in tapioca.

5.2.4 Girth of tubers

The effect of both the sources of nitrogen and levels of nitrogen on the girth of tubers were not significant (Table 8). The lack of response may probably be due to the fact that this may be a genetic character. Nair (1982) also reported similar results in tapioca.

5.2.5 Tuber yield

Data presented in Table 9 and illustrated in Fig.5 clearly showed the significant influence of the different slow release sources of nitrogen and levels of nitrogen on tuber yield of tapioca in the present study.

Among the sources tried, urea super granule produced the highest tuber yield followed by neem cake coated urea. The yields obtained in the other two treatments such as prilled urea and rubber cake coated urea were definitely inferior.

In a long duration crop like tapioca, the fertilizer application is needed to be adjusted to ensure fair and steady supply of nutrients according to the crop requirements. NH_4 + nitrogen released on urea hydrolysis undergoes faster nitrification and the nitrates thus formed do not remain in the soil for any length of time under the heavy rainfall conditions of Kerala. The plants under prilled urea application might have suffered nitrogen deficiency at later critical stages of growth. This was very well revealed by the poor growth performance of plants in plant height, functional leaves, L.A.I. etc. Consequently the yield attributes such as mean tuber number, tuber weight were also unfavourably affected. This might be the reason for the low yield of plants which received prilled urea. Urea super granule and neem cake coated urea by providing a slow and steady nitrification favoured the supply of nitrogen for a longer period which resulted in a greater uptake of nitrogen by the plants resulting the higher tuber yield. The data on growth performance such as plant height, functional leaves and L.A.I. which were already discussed clearly revealed the superiority of the slow release sources like urea super granule and neem coated urea. Similar results of increased tuber yields, with the use of slow-release sources of nitrogen in cassava were reported by the Thailand Department of Agriculture(1965; 1966), NOP-AMORNBORDEE.V. et al (1967), Offori,C.S. (1976) and Sathianathan (1982).

Increased and prolonged availability of nitrogen increased plant height, number of leaves and leaf area Index which would have resulted in a higher rate of photo-synthesis and consequently a higher tuber yield. Prasad (1979) also reported that the use of urea super granule gave higher fertilizer nitrogen efficiency than ordinary urea and produced higher yields in rice, maize, sugarcane and other crops. Similarly Apparao (1983) observed a significant increase in paddy yields with urea super granule application compared to urea application.

Increased yield through the use of neem cake coated urea was reported by Sathianathan (1982) in tapioca.

As regards the incremental doses of nitrogen, tuber yield increased significantly by nitrogen application. The highest tuber yield was observed by an application of 150 kg N/ha (n_5) but its effect was on par with that of 125 kg N/ha and 100 kg N/ha levels.

Nitrogen is a component of chlorophyll and plays a vital role in the photosynthesis of plants. The yield of cassava depends more upon the extent of assimilation and assimilate accumulation in the roots. Assimilation in turn depends on the extent of the assimilating surface. The influence of nitrogen in increasing the assimilating surface (leaf area) of plant is well known. The up-take of nitrogen was more or less in proportion to the tuber production. Many workers have reported yield increases in tapioca by nitrogen application (Mandal and Singh, 1970; Mohankumar and Maint, 1977 and Nair (1982).

Eventhough the source-level interaction was not significant, the highest tuber yield was recorded by the application of urea super granule applied @ 150 kg/ha, clearly indicating it's superiority over the other sources.

5.2.6 Top yield

In the present study, the various slow-release sources of nitrogen and levels of nitrogen significantly influenced the top yield (Table 10).

Among the sources, urea super granule was found to be superior to all the other sources. Being a slow release source of urea, the prolonged supply of nitrogen from urea super granule seemed to enhance the overall growth of plants. Plant height and number of functional leaves which are the contributing factors for top yield were increased by the continued supply of nitrogen from this slow release source.

As regards the levels of nitrogen, progressive increases in top yield with incremental doses of nitrogen was observed in the present study and the maximum yield was recorded by the application of 150 kg N/ha. An analysis of the data on plant height and functional leaves of the plant clearly revealed the favourable influence of higher doses of nitrogen on the vegetative growth characters which contribute to the top growth in tapioca. Similar results have been reported from C.I.A.T. (1975) and also by Nair (1982).

5.2.7 Utilisation index

The data from Table 11 clearly revealed the significant influence of the sources of nitrogen and levels of nitrogen on this yield attribute.

All the slow release sources were found to record a lower utilisation index compared to prilled urea. The top growth might have responded strongly to the prolonged availability of nitrogen from the slow release sources. This tended to decrease the ratio. This might be the reason for the lower utilisation index values, for the slow release sources. Similar result was reported by Sathianathan (1982) in tapioca.

As regards the levels of nitrogen, incremental doses produced higher utilisation index. Higher levels of nitrogen would have stimulated the leaf growth resulting in efficient photosynthesis and higher tuber yields. So the utilisation index values also have been increased. Nair (1982) also reported similar trend in tapioca.

5.3. Quality attributes

5.3.1 Starch content and starch yield

Starch content of tubers was not significantly influenced either by the sources of nitrogen or the levels of nitrogen (Table 12).

But the results showed that there was significant influence of both the sources of urea and the levels of nitrogen on the starch yield (Table 13).

Among the sources, the highest starch yield was recorded by urea super granules followed by neem coated urea and the least by rubber cake coated urea. Though there was no significant difference in the starch content of tubers, the highest tuber yields recorded by urea super granules and neem coated urea might have lead to the production of high starch yields.

The levels of nitrogen also have influenced the starch yield significantly. The increase in starch yield might be due to the increased tuber yields obtained by the incremental doses of nitrogen as discussed earlier. Nair (1982) also reported increased starch yields with incremental doses of nitrogen in tapioca.

5.3.2 HCN content

The results showed that the influence of the sources of nitrogen on H.C.N. content was nonsignificant, but the levels of nitrogen had significant effect on the HCN content of tubers (Table 14).

Among the sources, prilled urea recorded the lowest HCN content. The relatively low availability of nitrogen during the later stages of growth in this treatment might be the reason for the low HCN content.

Increasing the levels of nitrogen significantly enhanced the HCN content. A high level of nitrogen fertilization results in a high level of cyanogenic glucosides in the tuber (Sinha, 1969), which upon hydrolysis releases the poisonous hydrocyanic acid. Several workers have reported similar increases in the HCN content of tuber by nitrogen fertilization (Indira et al 1972; Mohankumar and Maini 1976, Nair, 1982).

5.3.3 Crude protein

The effect of both the sources of nitrogen and the levels of nitrogen on the crude protein content of tuber was not significant (Table 15).

Among the sources, urea super granules followed by neem coated urea recorded the higher crude protein contents though not statistically superior to the other sources. The prolonged supply of nitrogen in the plots treated with these slow release sources would have enhanced the synthesis of aminoacids and polymerisation of it into proteins. Arunachalam and Morachan (1974) obtained higher protein content in rice with neem coated urea. Sathianathan (1982) also obtained higher crude protein content with the use of neem coated urea in tapioca.

Protein content increased with the incremental doses of nitrogen. Increase in crude protein content of tubers by the application of nitrogen was reported by Hukkeri (1968) in potato, Mohandas and Sethumadhavan (1980) in colocasia and Nair (1982) in tapioca.

5.34 Total dry matter

Data in Table 16 clearly revealed that the total dry matter content was significantly influenced by the sources of nitrogen and the levels of nitrogen.

Among the sources urea super granule recorded the highest dry matter production followed by neem coated urea.

Rubber cake coated urea and prilled urea were inferior in this respect. The better nitrogen use efficiency of the plants treated with urea super granule and neem coated urea have resulted in enhanced growth of plants. This might have led to a higher assimilate production resulting in higher tuber yield. Hence the slow release sources were responsible in increasing the total dry matter production. Rambabu (1983) reported an increase in dry matter content of rice by the use of urea super granules.

As regards the levels of nitrogen, the effect of the incremental doses on the dry matter content was highly significant. Higher levels of nitrogen enhanced the growth performance and nitrogen uptake and thereby the total biological yield was increased. This might be the reason for higher dry matter production. Pillai and George (1978c) and Nair (1982) also obtained similar results.

5.4 <u>Nutrient uptake</u>

5.4.1 Uptake of nitrogen

The different sources of nitrogen and levels of nitrogen have significantly influenced the nitrogen uptake (Table 17).

Among the sources urea super granule recorded the maximum nitrogen uptake followed by neem coated urea.

Prilled urea showed the lowest nitrogen uptake but it's effect was on par witn rubber cake coated urea. Urea super granule due to it's slow release nature showed better efficiency in the utilisation of applied nitrogen. The runoff and leaching losses may be reduced to the minimum and the nitrogen availability might have been prolonged. This resulted in a higher uptake of nitrogen in this treatment. As regards the neem coated urea the alkaloid nimbidin present in neemcake might have reduced the rate of nitrification so as to make continued availability of nitrogen even during the later stages, resulting in higher nitrogen uptake. Similar results were obtained by Chakravarthi (1979) in rice and Sathianathan (1982) in tapioca.

In the case of prilled urea, loss of nitrate nitrogen by runoff and leaching might have occured.So the nitrogen uptake was also minimum. But the effect of prilled urea was on par with that of rubber cake coated urea. Sathianathan (1982) also obtained similar results.

Plant uptake of nitrogen increased with higher levels of nitrogen application. The increased uptake of nitrogen by higher rates of application of the nutrient is a well established phenominon. Pushpadas et al (1976) and Nair (1982) recorded similar observations in tapioca.

5.4.2 Uptake of Potassium

The data (Table 18) revealed that as in the case of nitrogen, the total potassium uptake was also significantly influenced by the different sources and levels of nitrogen.

Among the sources urea supergranule, recorded the maximum potassium uptake followed by neem coated urea. Increased and prolonged nitrogen supply to the plant have enhanced the shoot and root growth as discussed earlier, which demanded a higher requirement of other nutrients also especially potassium. Thus higher values of potassium uptake was observed. Sathianathan (1982) also observed higher potassium uptake with slow release sources like neem cake coated urea than prilled urea.

As regards the levels of nitrogen, Kumar _et al_ (1971) and Nair (1982) have reported increase in potassium uptake by higher doses of nitrogen in tapioca.

5.5 Soil analysis after the experiment

5.5.1 Total nitrogen

The total nitrogen content of soil did not show significant variations with the different sources and the levels of nitrogen (Table 19).

The total nitrogen content in the soil after the experiment was more or less the same in the plots applied with prilled urea, urea super granule, rubber cake coated urea and neemcake coated urea. Similar results were reported by Babu Mathew (1987) in paddy with the use of slow-release sources of nitrogen.

5.5.2 Available potassium

The effect of both the sources and levels of nitrogen on the available potassium status of soil was also not significant. Study revealed that the sources and levels of nitrogen could not alter the available potassium status of soil. Similar rssults were reported by Nair (1982) in tapioca.

5.6 Economics of using the slow-release sources of nitrogen

From the results given in Table 21 it is clear that the slow release sources of nitrogen like neemcake coated urea and urea super granules gave higher net returns, than the prilled urea. But the rubber cake coated urea recorded the lowest net returns.

Eventhough the maximum yield was recorded by the urea super granules the profit obtained was lesser than that obtained from neem coated urea. The high cost of the material ie; Rs.17/ kg of N, and the more of manual labour required for its application are the reason for the high cost of cultivation in the use of urea super granules which in turn resulted in a lesser net profit than the use of neemcake coated urea.

From the data it is evident that maximum profit/ha was obtained with the use of neemcoated urea. The higher yields obtained and the lesser labour consumption due to it's application entirely as basal resulted in a lesser cost of cultivation and hence the maximum net returns. Neem coated urea application @ 150 kg N/ha gave the highest profit (ie. ₨.4913/ha) followed by the level 100 kg N/ha (Net return - ₨.4140/ha).

From the study it is evident that neemcoated urea is more economical than all the other sources of nitrogen tried.

Table 21. Economics of application of the slow-release sources of nitrogen

No.	Treatments	Cost of cultivation. (Rs./ha)	Yield (t/ha)	Value of tuber (Rs./ha)	Profit (Rs./ha)
1.	Urea @ 50 kg N/ha	8300	16.23	8115	- 185
2.	" 75 kg N/ha	8521	19.61	9805	1284
3.	" 100 kg N/ha	8671	18.61	9305	634
4.	" 125 kg N/ha	8801	21.90	10950	2149
5.	" 150 kg N/ha	8952	22.44	11220	2268
6.	Neem coated urea @ 50 kg N/ha	7540	19.18	9590	2050
7.	" 75 kg N/ha	7801	18.81	9405	1604
8.	" 100 kg N/ha	7965	24.21	12105	4140
9.	" 125 kg N/ha	8101	24.39	12195	4094
10.	" 150 kg N/ha	8262	26.35	13175	4913
11.	Urea super granules @ 50 kg N/ha	8946	23.54	11770	2824
12.	" 75 kg N/ha	9621	23.38	11690	2069
13.	" 100 kg N/ha	10296	25.51	12755	2459
14.	" 125 kg N/ha	10971	27.33	13665	2694
15.	" 150 kg N/ha	11646	28.47	14235	2589
16.	Rubber cake coated urea @ 50 kg N/ha	7530	16.65	8325	795
17.	" " 75 kg N/ha	7791	16.81	8405	614
18.	" 100 kg N/ha	7955	16.80	8400	445
19.	" 125 kg N/ha	8090	20.41	10205	2115
20.	" 150 kg N/ha	8252	18.13	9065	813

<u>Cost of fertilizers</u>

P_2O_5 @ Rs.6.80/kg

K_2O @ Rs.1.66/kg

Urea @ Rs.5.65/kg of N

Neemcoated urea @ Rs. 6.05/kg of N

Urea super granule @ Rs. 17.00/kg of N

Rubber cake coated urea @ Rs.5.85/kg of N

<u>Cost of labour</u>

Men - Rs.28.00/man

Women - Rs.25.00/Woman

Value of tapioca tuber - Rs.50.00/quintal.

SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSIONS

An investigation was undertaken at the College of Agriculture, Vellayani during the year 1985-86 to study the effect of slow release sources of nitrogen on tapioca. The different sources of nitrogen used were urea, urea super-granules, neemcake coated urea and rubbercake coated urea at levels of 50 kg, 75 kg, 100 kg, 125 kg and 150 kg N/ha. The experiment was conducted in a 4 x 5 rectangular lattice design with 3 replications. The results of the investigation are summarised below.

1. The application of urea supergranule resulted in the maximum plant height. Maximum height was recorded at the nitrogen level of 150 kg /ha.

2. The maximum number of functional leavos were observed when the source tried was urea supergranule. Application of nitrogen at 150 kg/ha resulted in the production of the highest number of functional leaves.

3. As regards the number of nodes the effect of urea supergranule and neem coated urea were on par. The bigest level of nitrogen ie. 150 kg/ha produced the highest number of nodes.

4. Leaf area index was the highest in the treatment receiving urea supergranule. Similarly leaf area index was found to increase with incremental doses of nitrogen especially at the higher levels.

5. The highest tuber number was observed in the urea supergranule treated plots. Tuber number was the highest in treatment receiving 150 kg N/ha.

6. Use of urea supergranules resulted in maximum tuber weight. The application of 150 kg N/ha resulted in the maximum tuber weight.

7. Length of tubers was appreciably influenced by treatments. The effect of urea supergranules and neemcake coated urea were on par. The tuber length was the maximum at the highest level of nitrogen ie. 150 kg/ha.

8. The maximum tuber yield was recorded by urea supergranule application. Among the levels of nitrogen tried, 150 kg N/ha resulted in the maximum tuber yield.

9. Urea supergranule resulted in the highest tuber yield. Top yield was the maximum with nitrogen application at the level of 150 kg/ha.

10. Utilisation index was the maximum for prilled urea. The application of 150 kg N/ha gave the highest utilisation index.

11. Though the starch content was influenced neither by the sources nor by the levels of nitrogen, starch yield was significantly influenced by the treatments. Among the sources urea supergranule gave the maximum starch yield and among the levels tried 150 kg N/ha registered the highest yield.

12. Hydrocyanic acid content was not influenced by the sources of nitrogen but it showed an increasing trend with incremental doses of nitrogen tried and was the maximum at the level of 150 kg N/ha.

13. Incremental doses of nitrogen increased the crude protein content of tubers and 150 kg/ha resulted in the maximum value.

14. Urea supergranule was found to be the best in producing more of drymatter followed by neemcake coated urea. Among the levels of nitrogen there was significant progressive increase in the total drymatter production with incremental doses of nitrogen.

15. Nitrogen uptake was the maximum in the treatment using urea supergranule followed by neemcake coated urea. Among the levels tried, the highest value was observed at 150 kg N/ha.

16. Urea supergranule and neemcake coated urea were on par in respect of potassium uptake by plants. The higher levels of nitrogen showed higher uptake of potassium.

17. As regards the total nitrogen content of the soil after the experiment, there was no significant difference between the sources and also the levels of nitrogen tried.

18. The different sources and levels of nitrogen had no effect on the available potassium content of soil.

19. The study reveals that the use of neemcake coated urea was more economical than the application of urea and all other slow release sources of nitrogen.

Some of the future lines of investigation which the present study has opened up are -

1. Detailed studies on similar lines can be taken up in the various agroclimatic zones of the State using different varieties and different sources of nitrogen.
2. Similar studies can be carried out in other long duration tuber crops of the State.

3. Search for indigenous materials having nitrification inhibitory property is to be continued, so that the treatment of nitrogenous fertilizers with them can be tried.

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* Original not seen

APPENDICES

APPENDIX - I

Weather data during the crop period

Month		Temperature (°C)		Rain-fall (mm)	R.H.	No. of rainy days
		Maximum	Minimum			
November	(1985)	29.60	23.30	242.8	80.25	10
December	(1985)	31.10	22.40	102.8	74.31	6
January	(1986)	32.20	21.40	21.6	75.46	2
February	"	32.00	20.80	86.0	76.00	3
March	"	31.50	20.70	8.6	69.95	2
April	"	33.90	23.50	125.5	73.00	10
May	"	33.70	23.10	132.1	73.15	6
June	"	31.10	23.10	224.3	76.65	15
July	"	30.80	22.90	94.4	79.00	13
August	"	30.30	22.40	449.3	74.55	13
September	"	30.30	23.40	102.4	74.00	10

ABSTRACT

An investigation was undertaken at the College of Agriculture, Vellayani during the year 1985-86 to study the affect of slow-release nitrogen sources on cassava. The variety used for the trial was Sree Visakha. The treatments consisted of four sources namely urea, neemcake coated urea, urea super granule and rubber cake coated urea each at five levels of nitrogen (50, 75, 100, 125 and 150 kg /ha). The experiment was laid out in a 4 x 5 rectangular lattice design with three replications.

Application of slow release sources of nitrogen like urea super granule and neem cake coated urea enhanced the growth characters of tapioca such as plant height, number of functional leaves, number of nodes and the leaf area index. Higher levels of nitrogen gave better results in the growth characters.

The highest number of tubers, maximum tuber weight and the highest tuber yield were recorded by the urea super granule application, followed by neem cake coated urea. Among the levels of nitrogen tried, the level 150 kg / ha gave the highest yield.

Starch content, crude protein content and the hydrocyanic acid contents were not affected by the slow-release source of nitrogen while higher levels of nitrogen application increased the hydrocyanic acid content and the crude protein content.

Urea super granule recorded the highest nitrogen uptake and potassium uptake followed by neem cake coated urea. There was no significant difference in the total nitrogen content of the soil with the use of slor-release sources of nitrogen.

The treatment combination of neem coated urea tried at 150 kg N/ha resulted in the maximum net return. Though urea super granule gave the maximum yield its cost of cultivation was higher than that of the other sources. So it is more economical to use neem cake coated urea than urea super granule.

So in general, the slow-release sources of nitrogen like urea super granule and neem cake coated urea resulted in a better performance than prilled urea.