NUTRITIONAL REQUIREMENT OF ARROW ROOT (*Maranta arundinacea* L.) AS PURE CROP

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Nutritional requirement of Arrow root (Maranta arundinacea L) as pure crop" 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 any other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Nutritional requirement of Arrow root (*Maranta arundinacea* L) as pure crop" is a record of research work done independently by Sri. Remesan, K.K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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CONTENTS

LIST OF TABLES

Table No.	Title	Page No.

LIST OF TABLES (Contd.)

LIST OF ILLUSTRATIONS

Introduction

INTRODUCTION

Arrow root (*Maranta arundinacea* L) constitutes one of the sources of food starch production of the tropics. It is indigenous to tropical America and has long been cultivated in West Indies particularly St. Vincent, which produces about 95 per cent of the world's commercial supply. Cultivation has spread to many other tropical countries including Brazil, India, Ceylon, Indonesia and the Philippines The arrow root appears to have been derived from the Carib word 'arunda' meaning mealy roots. Its use as antidote for arrow poisoning as well as the pointed shape of the rhizomes contribute its name 'arrow root'.

The fine grained starch, eluted from the rhizomes is the source of arrow root starch which has been high viscosity and produces a very smooth jelly or paste. It is used for infant and invalid foods. It is an ingredient of arrow root biscuits, although the amount may be very small in some brands. It is used as a base of face powder and certain types of glues. Its uses are limited by its high price as compared with other starches. The fiberous debris or bettie remaining after extraction of starch is fed to the cattle.

Arrow root has been under cultivation in India since 1831 when it is said to have been introduced from the cape of Good Hope by the Agri-Horticultural Society of India. It is sporadically cultivated in Uttar Pradesh, Bengal, Assam and Kerala. Exact statistics about area and production are not available. It is one of the vastly unexploited crops. The crop comes well under partial shade condition of coconut gardens and as intercrop with cassava in southern parts of Kerala. Thus there is a large potential of increasing its cultivation in Kerala. The rhizome contains on an average 20 per cent starch. Thus it has high potential as a food crop and also as valuable raw material for starch and biscuit industries. The crop is generally grown with very little attention utilising the residual moisture and nutrients. But the crop was found to respond well to nutrient application in countries like West Indies (Kay, 1973). In India information on the influence of different levels of fertilizers on growth and yield of arrow root is meagre. There is a great scope for increasing the yield of rhizome of arrow root by adopting a suitable fertilizer management programme. So a detailed investigation has been taken up with the following objectives:

1. To determine the effect of N, P and K on growth, yield and quality of arrow root
2. To study the uptake pattern of major nutrients
3. To work out the economics of fertilizer application of arrow root

Review of Literature

2. REVIEW OF LITERATURE

Arrow root is cultivated as a starch crop in southern parts of Kerala. The crop is generally grown mixed with other annuals and perennials without much attention. But the crop was found to respond favourably to fertilizer application. Experimental evidences on nutritional requirements of this crop are meagre. The available literature on the effect of different levels of nitrogen, phosphorus and potassium on growth, yield, quality and nutrient uptake of this crop are reviewed below. Wherever information is lacking, relevant literature on other related crops are also reviewed.

2.1 Influence of nutrients on growth characters

2.1.1 Nitrogen

Nair (1964) reported significant effect of nitrogen on plant height and number of suckers in turmeric. He found that height of the plant increased at a very slow rate upto 60 days from planting and thereafter the rate of growth increased rapidly. There was no increase in plant height after 120 days and maximum growth was observed between 90 and 120 days. He also observed that nitrogen had no significant effect on number of leaves per plant. But Purseglove (1968) observed that nitrogen at higher rates increased the plant height and number of leaves at all growth stages of arrow root. In ginger, Randhawa and Nandpuri (1969) reported that application of 100 kg/ha nitrogen increased plant height and number of branches. Kay (1973) also reported similar trends in growth habits due to increased doses of nitrogen application in arrow root.

Positive response to nitrogen application upto 312.5 kg per hectare was reported by Rao (1973) in turmeric by way of increased plant height and tillering. In a study at Solan to standardise the optimum requirement of N, P and K for turmeric it was found that different levels of nitrogen had no influence on the height of plants and number of shoots per plant even after 3 and 6 months of germination (Anon., 1977).

Higher doses of fertiliser nitrogen had no significant influence on number of shoots per plant in turmeric (Anon., 1978). Lee *et al.* ([illegible]) reported that nitrogen application significantly increased the number of third order shoots and fourth order rhizome branches in ginger. Saifudeen (1981) also observed that application of incremental doses of nitrogen resulted in an increased production of tillers in turmeric. Bourke (1985) from a series of experiments conducted on sweet potato concluded that the leaf area duration was increased by nitrogen application which inturn influenced the yield through enhanced mean tuber weight.

2.1.2 Phosphorus

Purseglove (1968) did not observe any significant influence of phosphorus on growth characters of arrow root. However maximum height of plant was registered when higher dose of phosphorus was applied while Randhawa and Nandpuri (1969) reported that application of 50 kg/ha P_2O_5 increased plant height and number of branches in ginger. Kay (1973) in a study conducted at St. Vincent observed that phosphorus had no influence in increasing the height and number of branches of arrow root. In turmeric, positive response by way of increased plant height and tillering was reported by the application of 112.5 kg/ha P_2O_5 (Rao, 1973 and Rao et al., 1975).

There was no significant response to fertilizer phosphorus on germination, average height of plants, average number of shoots per plant and storage quality of turmeric (Anon., 1977). It was also observed that phosphorus had no significant response on growth characters like average number of shoots on turmeric (Anon., 1978). In a study at Trichur, Saifudeen (1981) reported that number of tillers per clump, number of leaves per tiller and height of tillers were not influenced by incremental doses of phosphorus.

2.1.3 Potassium

Nair (1964) reported significant effect of potassium on plant height and number of suckers in turmeric. But there was no significant difference in number of leaves per plant. Height of plants and number of suckers were maximum when 70 kg/ha K_2O was applied in the form of muriate of potash. Purseglove (1968) and Kay (1973) also reported similar increase in height of plants and number of leaves with increased doses of potash in arrow root.

Rao (1973) also observed positive response to potash application in increasing plant height and tillering at higher rates. Influence of potassium on various growth attributes like average height of plants after 3 months, number of shoots per plant etc. were studied at Solan in turmeric and was found that potash had no significant influence on different growth attributes (Anon., 1977).

There was no significant response to fertiliser potassium on average number of shoots per plant in case of turmeric (Anon., 1978). Maximum number of shoots was observed with 90 kg/ha potash. In turmeric, Saifudeen (1981) reported that tiller production was influenced by incremental doses of potassium application, but number of leaves per tiller and height of plants were not influenced by potassium. Rao and Swamy (1984) observed that when rate of potassium was increased from 50 kg to 200 kg per hectare the height of plant was also increased significantly in turmeric. In ginger, Randhawa and Nandpuri (1969) reported that application of 50 kg/ha K_2O increased the height and number of branches.

In a fertilizer trial to investigate on the influence of potassium on growth and yield of [illegible] potato, [illegible] (1985) found that potassium fertilizer increased the total plant dry weight, mean leaf area and harvest index.

2.2 Influence of nutrients on yield and yield attribute

2.2.1 Nitrogen

In turmeric, Nair (1964) reported that nitrogen at 82.5 lb/acre recorded highest yield. [illegible]yadurai (1966) found that 100 kg/ha of ammonium sulphate doubled the yield over that of an unmanured crop in turmeric. Pillai (1967) could not observe any significant influence on the girth of tubers in taro by varyi[illegible] of [illegible] application. Purseglove (1968) repor[illegible] should receive from 350 to 650 kg sulphate of ammonia per hectare. Vijayan and Aiyer (1969) found that mean number of tuber/plant was increased by increasing the rate of applied N from 0 to 75 kg/ha. But further increase of N decreased the number of tubers in both H-4 and H-105. In a study at Simla, Randhawa and Nandpuri (1969) found that nitrogen at 100 kg/ha recorded the highest rhizome yield in ginger. Kay (1973) reported that the arrow root crop should receive nitrogen at the rate of 72 kg/ha for producing better yield. Muraleedharan and Balakrishnan (1972) observed that a dose of 100 kg/ha N was sufficient for the production of maximum yield in turmeric.

Highest yield has been obtained by Rao (1973) by the application of upto 312.5 kg/ha N in turmeric. Rao <u>et</u> <u>al</u>. (1975) found that 25 t [illegible] or compost and 63 kg/ha N as oil cake [illegible] for turmeric. Nambiar <u>et</u> <u>al</u>. (1976) observed [illegible] rate of applied nitrogen had no signi[illegible] length of individual tubers but the [illegible] was significantly increased in sweet potato, [illegible]

In a study at Andhra Pradesh, Rao and [illegible] observed that yields increased significantly [illegible] dosages and observed highest yield of tu[illegible] 375 kg/ha N. There was no significant re[illegible] fertilizer nitrogen on yield in turmeric, however the highest yield was recorded at the level of 90 kg/ha nitrogen closely followed by 120 kg/ha N (Anon., 1977). There was no significant response to nitrogen on the yield turmeric though the highest yield was obtained at 120 kg/ha N and the lowest yield with 90 kg/ha N (Anon., 1978). Sadanandan and Sasidhar (1979) obtained highest yield in ginger by the application of 50 kg/ha N in red loam soils of Kerala. Shah and Muthuswamy (1981) recommended application of 140 kg/ha N along with 10 t/ha of FYM for maximum production of turmeric under Tamil Nadu conditions. Lee _et al_. (1981) reported highest yield of fresh rhizomes in ginger at 200-300 kg/ha nitrogen.

It was reported by Saifudeen (1981) that the added nitrogen had no significant influence on the rhizome yield of turmeric. Rajput _et al_. (1980) reported that a dose of 150 kg/ha N was optimum for producing maximum yield in turmeric. In a study conducted at Parbhani on turmeric it was reported that maximum weight of rhizome mothersets, fingersets, number of fingersets per plant and ratio of fingersets to mothersets from plots receiving 120 kg N per hectare (Umate _et al_., 1984). Rao and Swamy (1984) reported maximum yield of 12.3 t/ha fresh rhizome with 312.5 kg/ha N in turmeric. Balashanmugham and Chezhiyan

(1986) observed a positive response of nitrogen in increasing the yield of turmeric and he reported that maximum yield was with 120 kg/ha N.

Pawar and Patil (1987) reported that 225 kg N along with 30 t/ha FYM produced maximum yield in ginger. Based on a study conducted at Kalyani, West Bengal it was reported by Maity *et al*. (1988) that maximum yield of ginger was obtained from plots receiving 120 kg/ha N.

2.2.2 Phosphorus

In a study conducted at Vellayani, Nair (1964) reported that phosphorus had no significant response in increasing the yield of turmeric. However, phosphorus at the rate of 43.25 lb/acre recorded the highest yield. Purseglove (1968) recommended 300 kg/ha super phosphate for producing an yield of 7.5 - 37 t/ha of rhizome from arrow root. Kay (1973) reported that arrow root crop should receive phosphorus at the rate of 45 kg/ha for producing successful yield. Muraleedharan and Balakrishnan (1972) reported that the yield of turmeric was significantly affected by the application of phosphorus. The treatment 100 kg/ha P_2O_5 produced maximum yield though the response was not linear.

Under Thirupathi conditions, Rao (1973) recorded highest yield through the application of 112.5 kg/ha P_2O_5

in turmeric. Highest yield was obtained by Rao and Reddy (1977) with the application of 175 kg/ha P_2O_5 in turmeric.

Phosphorus at the rate of 30 kg per hectare produced maximum yield in turmeric which was closely followed by 45 kg/ha (Anon., 1977). In turmeric the highest yield was observed with 30 kg per hectare of phosphorus and the lowest yield with 60 kg/ha P_2O_5 (Anon., 1978). Rajput et al. (1981) observed significant yield increase due to the application of 50 kg/ha P_2O_5 over no phosphorus plots in Maharashtra State. Saifudeen (1981) reported that applied phosphorus had no significant influence on yield of turmeric. Rao and Swamy (1984) reported that turmeric crop should receive 112.5 kg/ha P_2O_5 for producing the maximum yield. Pawar and Patil (1987) found that 20 kg P_2O_5 along with 30 t/ha of FYM produced maximum yield in turmeric. Maity et al. (1988) reported that 60 kg/ha P_2O_5 was optimum for producing maximum yield of green ginger.

2.2.3 Potassium

Nair (1964) showed that in turmeric potassium played a major role in yield increase than nitrogen and phosphorus and optimum level of potassium required for maximum yield was 160.5 lb/acre. An increase in number of cormels per plant in taro at enhanced rate of potassium application has been observed by Pillai (1967). Purseglove (1968) reported that arrow root crop should receive 180 kg/ha K_2O for producing maximum yield. Kay (1973) reported the potassium application of arrow root as 126 kg/ha for producing better yield. In turmeric, Muraleedharan and Balakrishnan (1972) reported that yield was influenced by incremental dose of potassium and they observed that 200 kg/ha K_2O produced the maximum yield of rhizome. Rao (1973) also reported similar result under Thirupathi conditions. Wang (1975) reported that sweet potato was particularly responsive to potassium application.

Rao and Reddy (1977) obtained a linear response to higher dose of K and the highest yield was recorded with the application of 237.5 kg/ha K_2O in turmeric. There was significant response for potassium on yield in turmeric (Anon., 1977). The highest yield was recorded at the level of 120 kg/ha K_2O followed by 90 kg/ha. Potassium at the rate of 90 kg per hectare produced maximum yield in turmeric (Anon., 1978). In a study conducted at Trichur, Saifudeen (1981) reported that potassium had no significant influence on the rhizome yield of turmeric.

Bautista and Santiago (1981) obtained increased tuber yield with increased potassium application in sweet potato. Similarly, Villareal (1982) was of the opinion that for maximum sweet potato yields, the level of potassium in soil should be increased several times more than the level of nitrogen. Hammet *et al.* (1984) found that the marketable tuber yields of sweet potato were higher with higher rates of potassium application. Nicholaides *et al.* (1985) reported that in sweet potato, total yield increased with increased rate of potassium application especially in soils of low potassium status.

Rao and Swamy (1984) reported maximum yield of fresh rhizome from the plots receiving 200 kg/ha K_2O. Highest yield was obtained by Pawar and Patil (1987) with the application of 180 kg/ha K_2O in ginger. Maity *et al.* (1988) observed maximum yield of ginger from plots receiving 90 kg/ha K_2O.

2.3 Influence of nutrients on qualitative characters

2.3.1 Nitrogen

Pillai (1967) reported that application of nitrogen significantly increased the starch content of corms in *Colocasia*. Tsuno and Fujise (1968) reported that for producing tubers of high starch content, nitrogen application should be moderate in order to prevent excessive development of the tops at the expense of tuber growth in sweet potato. Vijayan and [illegible] (1969) reported that starch and crude protein content increased significantly with increasing levels of nitrogen in cassava. As a consequence of increased dose of nitrogen supply Knavel and Lasheen (1969) observed significant decline in both total sugars and starch content in sweet potato tubers. Mandal et al. (1971) noticed maximum starch content at the nitrogen dose of 75 kg/ha in sweet potato.

Obigbesan and Agboola (1973) found increase in starch content with higher doses of nitrogen in one variety of tapioca while it decreased in another variety. In field trials conducted at Vellayani, Prema et al. (1975) found that starch and protein content of cassava tubers increased with increase in nitrogen application. Muthuswamy and Krishnamoorthy (1976) reported that there was no significant influence of nitrogen in protein content of sweet potato.

Nambiar et al. (1976) found that in sweet potato protein content increased with increasing levels of applied nitrogen and was maximum in treatments where 100 kg nitrogen was applied. Gonzales et al. (1977) reported that with additional nitrogen fertilizer, protein content of tubers and vine tips increased more than 100 per cent in sweet potato. In a fertilizer trial, Pillai and George (1978) found that starch content [illegible] with increasing nitrogen application and protein content increased from 1.93 per cent with application of 50 kg/ha N to 2.31 per cent with application of 100 kg/ha N. In tapioca Arruda et al. (1978) reported that starch content of cassava increased by application of nitrogen.

Ramanathan et al. (1980) reported that in cassava, tuber starch content was significantly increased by applied nitrogen. In contrary to this, Muthuswamy and Rao (1980) reported that starch content in cassava tubers was not affected by applied nitrogen. On the contrary, Muthuswamy and Rao (1981) found that nitrogen fertilization reduced the starch content of cassava tubers. They also reported that nitrogen application was found to increase the crude fibre content of peeled cassava tubers significantly at different months of growth which also decreased gradually from six months to harvest stage. In sweet potato Yeh et al. (1981) reported that increasing levels of nitrogen increased the protein content of both roots and aerial parts. Bartolini (1982) observed that increasing levels of nitrogen fertilizers seemed to result in an increase in the percentage of starch content of roots in sweet potato. Mandal et al. (1982), while studying the influence of nitrogen and potash on tuber yield and quality of Colocasia observed that tuber protein content increased with increasing rates of nitrogen. Constantin *et al.* (1984) reported that root weight and percentage of top grade roots increased with increased nitrogen application in sweet potato.

2.3.2 Phosphorus

Pillai (1967) reported that application of phosphorus significantly increased the starch content of corms in colocasia. In an experiment to study the effect of nitrogen and phosphorus on the yield and quality of cassava by Vijayan and Aiyer (1969) it was revealed that phosphorus had no significant influence on starch and crude protein content of tubers.

Prema *et al.* (1975) reported that the influence of phosphorus in increasing starch content was greater than that of nitrogen and there was significant influence of phosphorus in protein content of cassava tubers. Muthuswamy and Krishnamoorthy (1976) reported that there was no significant influence of phosphorus on protein content of sweet potato tubers. Constantin *et al.* (1977) after his experiment in four locations with varying levels of phosphorus application reported that phosphorus had no significant influence on fibre content of sweet potato. Pillai and George (1978) observed that phosphorus significantly influenced the starch content of cassava tubers whereas it had no significant influence on protein content. Shyu and Cheng (1978) reported that root protein content increased with increasing levels of phosphorus in <u>Dioscorea</u>. For cassava, Arruda <u>et al</u>. (1978) found that starch content increased by application of phosphorus.

Studies conducted at CIAT, Columbia on soil and plant nutrition of cassava revealed that starch content of cassava variety decreased with increased rates of phosphorus (Anon., 1980a). Hammet <u>et al</u>. (1982) reported that in sweet potato tuber protein content as a percentage of dry weight was reduced by increase in phosphorus rate. Mandardo <u>et al</u>. (1984) reported that the starch content of cassava was significantly influenced by application of phosphorus fertilizer.

2.3.3 Potassium

Mohankumar <u>et al</u>. (197[illegible]) reported the effect of potassium in increasing the starch content of cassava tubers. As a consequence of potassium application, an increase in crude protein and starch content of cassava tubers was noticed in the experiments of Pushpadas and Aiyer (1976) with cassava. Muthuswamy and Krishnamoorthy (1976) observed an increase in protein content at 50 kg/ha K_2O whereas it decreased at 100 kg/ha K_2O in sweet potato.

Rajendran et al. (1976) reported that there was significant influence of potassium in increasing the starch content of Colocasia tubers. For cassava, Ashokan and Sreedharan (1977) found the maximum starch content of tubers at 112.5 kg/ha K_2O. They also reported that there was gradual reduction in the crude protein content of cassava tubers when the levels of K were increased. In sweet potato Constantin (1977) observed that potassium application reduced the protein content and firmness in tubers but slightly increased the crude fibre content of tubers. Pillai and George (1978) reported that starch content increased with increasing potassium application whereas protein content decreased with potassium application in tapioca. Arruda et al. (1978) reported that starch content of cassava was increased by potassium application.

In a study carried out on the effect of different sources of potassium on yield and quality of cassava (Nair et al., 1980) it was found that potassium played a major role in increasing the starch content of tubers. Studies conducted at CIAT Columbia on plant nutrition of cassava revealed that 50 kg/ha K_2O increased the root starch content from 26.7 to 34.2 per cent with little increase at higher rates and starch yield/ha increased linearly with increased K rate (Anon., 1980b). Ramanathan et al. (1980) reported that potassium application significantly increased the starch content of cassava tubers.

Muthuswamy and Rao (1980) reported that starch content of cassava was increased by applied K but difference between K rates was not significant. They also reported that potash application decreased the fibre content with maturity of cassava tubers. Muthuswamy and Rao (1981) in a study on nitrogen and potassium on quality of tapioca tubers found that potash application increased the starch content of the tuber. Mandardo *et al*. (1984) reported that there was significant influence of potassium on starch content of cassava tubers. Sharafuddin and Voican (1984) found that protein content was increased with increased dose of potassium in sweet potato. As a consequence of potassium application, an increase in starch content of cassava tubers was noticed in the experiments of Nair and Aiyer (1986). They also observed that there was a negative correlation between the fibre content in cassava tubers and levels of potassium.

2.4 Influence of nutrients on nutrient content and nutrient uptake

2.4.1 Nitrogen content and uptake

2.4.1.1 Nitrogen

Nair *et al*. (1976) observed that in sweet potato total nitrogen uptake increased with applied nitrogen. Saifudeen (1981) reported [illegible]ntal dose of nitrogen significantly influenced the nitrogen percentage in leaf of turmeric. He also reported that the increasing dose of nitrogen significantly influenced the nitrogen content in pseudostem of turmeric while it had no significant effect on nitrogen content of rhizome. The nitrogen content of rhizome differed markedly at varying periods of growth. Studies conducted on the nitrogen uptake in leaf pseudostem and rhizome of turmeric by Saifudeen (1981) revealed that the fertilizer nitrogen had not influenced the uptake significantly. The nitrogen uptake in leaf increased with advancing period of growth. He also reported that varying levels of nitrogen applied did not influence the total uptake of nitrogen by the turmeric. However the total nitrogen uptake progressively increased with advancing period of growth. Purcell <u>et</u> <u>al</u>. (1982) observed that the application of nitrogen fertilizers to sweet potato increased the root nitrogen content without affecting root yields.

2.4.1.2 Phosphorus

In a field experiment on [illegible] nutrients on uptake of nutrients [illegible] (1981). He reported that application of phosphorus [illegible] different levels did not influence the nitrogen content of leaf. Nitrogen content of pseudostem did not vary significantly under different levels of phosphorus. It was also revealed that the application of incremental dose of phosphorus influenced the nitrogen content significantly. Observations on nitrogen uptake by leaves revealed that the levels of phosphorus could not influence the nitrogen uptake. The nitrogen uptake in pseudostem showed that the phosphorus did not have any influence on the uptake of this nutrient. Observations on the uptake of nitrogen in rhizome indicated that phosphorus had no effect on the uptake of nitrogen in the rhizome of turmeric. He also reported that the total uptake of nitrogen was not influenced by the varying levels of phosphorus in turmeric.

2.4.1.3 Potassium

Based on the experiments conducted at Trichur on turmeric, Saifudeen (1981) reported that the application of potassium at different levels did not influence the nitrogen content of leaf. The observations on nitrogen content of pseudostem revealed that the increasing doses of potassium could not significantly influence the nitrogen content. He also reported similar results with potassium on nitrogen content of rhizome. He observed that potassium had no significant influence on the nitrogen uptake in leaf and pseudostem. The observations on uptake of nitrogen in rhizome indicated that potassium had no effect on the nitrogen uptake in the rhizome. He also reported that the total uptake of nitrogen was influenced by the levels of potassium applied, the [illegible] uptake of nitrogen being at 40 kg/ha K_2O.

2.4.2 Phosphorus content and uptake

2.4.2.1 Nitrogen

Muthuswamy and Krishnamoorthy (1976) reported that nitrogen application had no significant influence on phosphorus content of sweet potato.

Saifudeen (1981) reported that the phosphorus content in leaf of turmeric was significantly influenced by the levels of nitrogen. It was observed that the varying levels of nitrogen had no effect on the content or uptake of phosphorus in pseudostem of turmeric. He also reported that the content of phosphorus or its uptake in rhizome of turmeric remained unaffected by the levels of applied nitrogen. He also observed that nitrogen application had no significant influence on the total uptake of phosphorus in turmeric.

2.4.2.2 Phosphorus

Muthuswamy and Krishnamoorthy (1976) reported that the percentage of phosphorus in the plant remained unaffected by the levels of phosphorus applied to sweet potato. The phosphorus content of leaf, pseudostem and rhizome in turmeric was not influenced by varying levels of phosphorus (Saifudeen, 1981). He also reported that phosphorus application had no significant influence on uptake of phosphorus in leaf, pseudostem and rhizome and on total uptake of phosphorus of turmeric.

2.4.2.3 Potassium

Muthuswamy and Krishnamoorthy (1976) reported that phosphorus content was not affected by the potassium application in sweet potato. In a study at Trichur, Saifudeen (1981) reported that potassium had no significant role in influencing the phosphorus content of leaf, pseudostem and rhizome of turmeric. However, the uptake of phosphorus in the leaf of turmeric was significantly influenced by potassium application, the maximum being at 40 kg/ha K_2O. It was also reported that the uptake of phosphorus in pseudostem and rhizome of turmeric was not affected significantly by the application of potassium while it influenced the total phosphorus uptake significantly.

2.4.3 Potassium content and uptake

2.4.3.1 Nitrogen

Tsuno and Fujise (1965) reported that higher nitrogen dose probably might have increased the potassium level in the leaves which in turn might have accelerated the photosynthetic rates of leaves resulting in higher starch accumulation in roots of sweet potato. Saifudeen (1981) reported that varying levels of nitrogen did not influence the content of potassium or its uptake in leaf, pseudostem and rhizome of turmeric. He also observed that the total uptake of potassium was not significantly influence by the different levels of nitrogen applied.

2.4.3.2 Phosphorus

Saifudeen (1981) based on the experiment conducted in turmeric at Trichur, reported that incremental doses of phosphorus could not influence the potassium content of leaf, pseudostem and rhizome of turmeric. It was also reported that levels of phosphorus could not influence the total potassium uptake of turmeric.

2.4.3.3 Potassium

In a study at Trichur, Saifudeen (1981) reported that incremental dose of potassium significantly influenced the potassium content in leaf and pseudostem of turmeric but not in rhizome. He also reported that uptake of potassium in leaf, pseudostem and in rhizome as also total uptake were significantly influence by the levels of potassium applied. In sweet potato Hammett _et al_. (1984) obtained a positive response to root potassium content at increased rate of potassium application.

Materials and Methods

MATERIALS AND METHODS

A field experiment on arrow root was conducted at the Instructional Farm, College of Agriculture, Vellayani from February to December 1988, in order to study the effect of N, P and K on growth drymatter production uptake pattern of the major nutrients, yield and quality of arrow root. The study also envisages to work out the economics of cultivation of arrow root and to arrive at the optimum fertilizer dose for maximum yield and profit.

MATERIALS

1.1. Experimental site

The field was located at 8°N latitude and at an altitude of 29 m above mean sea level.

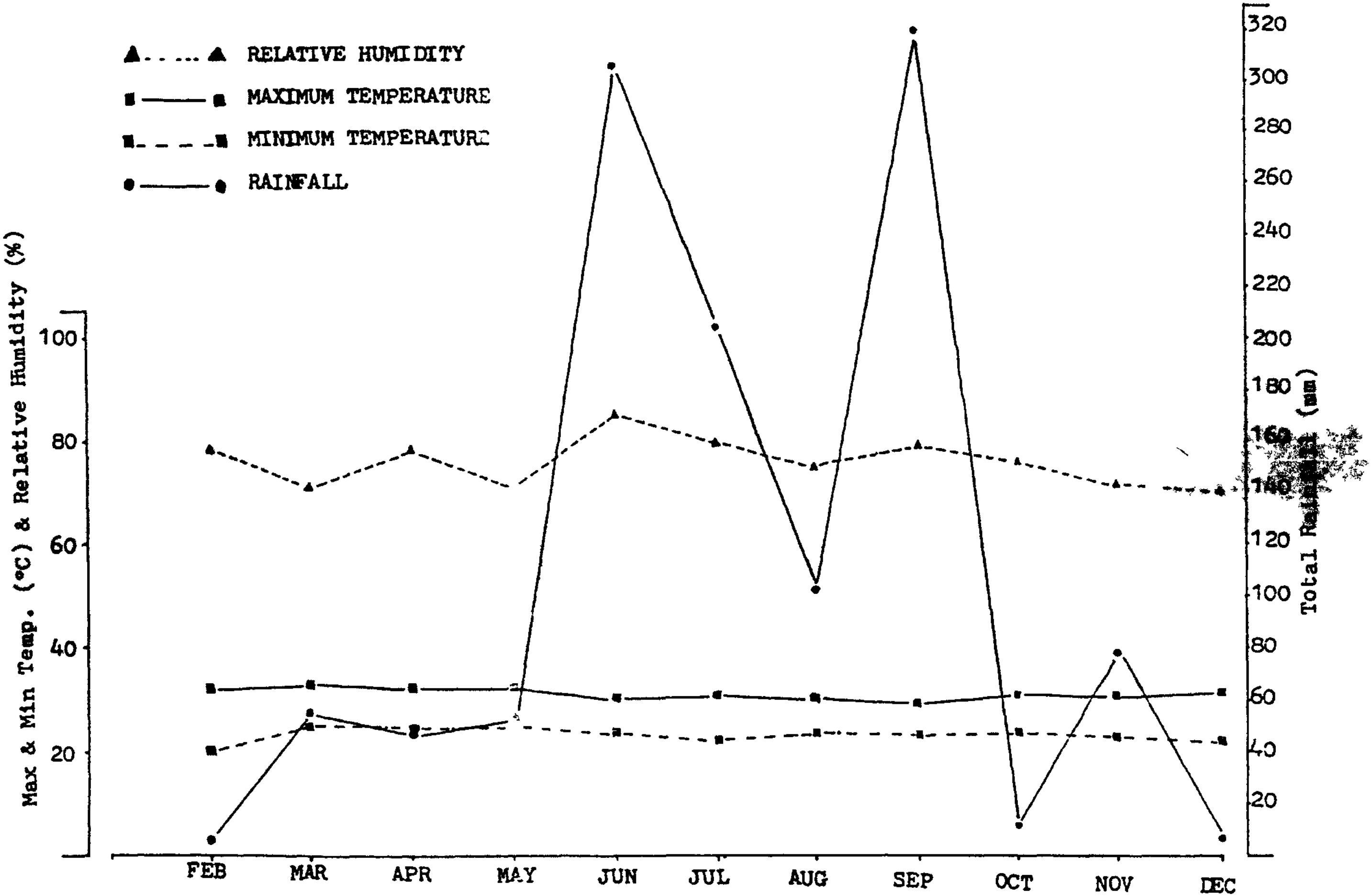
1.2. Soil

The soil of the experimental area was red loam. The data on the physico-chemical properties of the soil are given below:

A. Mechanical composition

Coarse sand	(%)	-	13.80
Fine sand	(%)	-	33.50
Silt	(%)	-	28.00
Clay	(%)	-	24.70

FIG 1 WEATHER CONDITIONS DURING THE CROP PERIOD



B. Chemical composition

pH	-	5.2
Total nitrogen	-	0.056%
Available nitrogen	-	160 kg/ha
Available P_2O_5	-	38.49 kg/ha
Available K_2O	-	53.14 kg/ha

1.3. Cropping history of the field

The experimental area was lying fallow for three months prior to the present investigation.

1.4. Season

The experiment was conducted during February-December, 1988. The crop was planted on 2nd February and harvested on 29th December 1988.

1.5. Weather conditions

The area enjoys a typical humid tropical climate. Data on maximum temperature, minimum temperature, total rainfall and relative humidity during the entire crop season are collected and presented as monthly averages in Appendix 1 and Fig. 1.

1.6. Planting material

Rhizomes of uniform size were used for planting. Arrow root rhizomes for planting were obtained from

Southern Starch Industries, Industrial Estate, Vellanad, Trivandrum.

1.7. Fertilizers

Fertilizers with following analysis were used for the experiment.

Urea	-	46% N
Superphosphate	-	16% P_2O_5
Muriate of potash	-	60% K_2O

METHODS

2.1. Details of the treatments

The treatment consisted of factorial combinations of four levels of nitrogen, four levels of phosphorus and four levels of potassium.

i) Levels of nitrogen

n_0 - 0 kg N/ha

n_1 - 50 kg N/ha

n_2 - 100 kg N/ha

n_3 - 150 kg N/ha

ii) Levels of phosphorus

p_0 - 0 kg P_2O_5/ha

p_1 - 25 kg P_2O_5/ha

p_2 - 50 kg P_2O_5/ha

p_3 - 75 kg P_2O_5/ha

iii) Levels of potassium

k_0 - 0 kg K_2O/ha

k_1 - 50 kg K_2O/ha

k_2 - 100 kg K_2O/ha

k_3 - 150 kg K_2O/ha

Treatment combinations

$n_0p_0k_0$	$n_1p_0k_0$	$n_2p_0k_0$	$n_3p_0k_0$
$n_0p_0k_1$	$n_1p_0k_1$	$n_2p_0k_1$	$n_3p_0k_1$
$n_0p_0k_2$	$n_1p_0k_2$	$n_2p_0k_2$	$n_3p_0k_2$
$n_0p_0k_3$	$n_1p_0k_3$	$n_2p_0k_3$	$n_3p_0k_3$
$n_0p_1k_0$	$n_1p_1k_0$	$n_2p_1k_0$	$n_3p_1k_0$
$n_0p_1k_1$	$n_1p_1k_1$	$n_2p_1k_1$	$n_3p_1k_1$
$n_0p_1k_2$	$n_1p_1k_2$	$n_2p_1k_2$	$n_3p_1k_2$
$n_0p_1k_3$	$n_1p_1k_3$	$n_2p_1k_3$	$n_3p_1k_3$
$n_0p_2k_0$	$n_1p_2k_0$	$n_2p_2k_0$	$n_3p_2k_0$
$n_0p_2k_1$	$n_1p_2k_1$	$n_2p_2k_1$	$n_3p_2k_1$
$n_0p_2k_2$	$n_1p_2k_2$	$n_2p_2k_2$	$n_3p_2k_2$
$n_0p_2k_3$	$n_1p_2k_3$	$n_2p_2k_3$	$n_3p_2k_3$
$n_0p_3k_0$	$n_1p_3k_0$	$n_2p_3k_0$	$n_3p_3k_0$
$n_0p_3k_1$	$n_1p_3k_1$	$n_2p_3k_1$	$n_3p_3k_1$
$n_0p_3k_2$	$n_1p_3k_2$	$n_2p_3k_2$	$n_3p_3k_2$
$n_0p_3k_3$	$n_1p_3k_3$	$n_2p_3k_3$	$n_3p_3k_3$

2.2. Experimental design and layout

The experiment was laid out in a 4^3 partially confounded factorial experiment in RBD with two replications. This design was converted to 2^6 experiment using psuedo factors A & B for N, C and D for P and E & F for K. In each replication three different effects were randomly selected for confounding. Thus four other effects were confounded automatically in each replication.

2.2.1. Effects selected for confounding

Replication 1

a) Randomly selected effects	b) Effects confounded automatically
1. ABC	1. ABDE
2. CDE	2. ACDF
3. BDF	3. BCEF
	4. AEF

Replication 2

a) Randomly selected effects	b) Effects confounded automatically
1. ACD	1. ABCE
2. BDE	2. BCDF
3. ABF	3. ADEF
	4. CEF

Replication I

								Blocks
$N_1P_1K_2$	$N_3P_2K_2$	$N_1P_3K_1$	$N_0P_0K_3$	$N_3P_1K_0$	$N_3P_0K_1$	$N_0P_2K_0$	$N_2P_3K_3$	1
$N_0P_2K_2$	$N_2P_1K_2$	$N_1P_1K_0$	$N_0P_0K_1$	$N_3P_0K_0$	$N_3P_0K_3$	$N_3P_3K_1$	$N_1P_3K_3$	2
$N_2P_2K_1$	$N_3P_1K_3$	$N_1P_2K_3$	$N_3P_0K_2$	$N_3P_3K_0$	$N_0P_3K_2$	$N_0P_1K_1$	$N_1P_0K_0$	3
$N_1P_0K_3$	$N_0P_3K_0$	$N_2P_2K_3$	$N_3P_3K_2$	$N_0P_1K_3$	$N_3P_2K_1$	$N_3P_0K_0$	$N_1P_2K_1$	4
$N_0P_3K_1$	$N_0P_1K_2$	$N_3P_1K_0$	$N_2P_2K_2$	$N_1P_0K_3$	$N_3P_3K_3$	$N_1P_2K_0$	$N_2P_0K_1$	5
$N_3P_1K_3$	$N_2P_1K_1$	$N_2P_3K_2$	$N_3P_0K_0$	$N_3P_2K_3$	$N_0P_2K_1$	$N_0P_0K_3$	$N_1P_3K_0$	6
$N_0P_2K_3$	$N_3P_1K_3$	$N_0P_0K_0$	$N_3P_2K_1$	$N_2P_3K_0$	$N_1P_1K_1$	$N_1P_2K_3$	$N_3P_0K_2$	7
$N_3P_0K_3$	$N_0P_1K_0$	$N_1P_0K_1$	$N_3P_3K_1$	$N_3P_1K_2$	$N_1P_2K_2$	$N_0P_3K_3$	$N_2P_2K_0$	8

Replication II

								Blocks
$N_2P_1K_3$	$N_1P_3K_3$	$N_0P_1K_0$	$N_3P_0K_1$	$N_2P_2K_2$	$N_0P_2K_1$	$N_1P_0K_2$	$N_3P_3K_0$	1
$N_2P_3K_0$	$N_2P_0K_1$	$N_1P_2K_1$	$N_3P_1K_3$	$N_1P_1K_0$	$N_0P_3K_3$	$N_3P_2K_3$	$N_0P_0K_2$	2
$N_1P_2K_2$	$N_2P_3K_3$	$N_3P_2K_1$	$N_0P_0K_1$	$N_3P_1K_0$	$N_0P_3K_0$	$N_1P_1K_3$	$N_2P_0K_2$	3
$N_2P_1K_1$	$N_3P_3K_2$	$N_1P_3K_1$	$N_0P_2K_3$	$N_1P_0K_0$	$N_3P_0K_3$	$N_0P_1K_2$	$N_2P_2K_0$	4
$N_2P_2K_1$	$N_3P_3K_3$	$N_1P_3K_0$	$N_2P_1K_0$	$N_0P_1K_3$	$N_1P_0K_1$	$N_0P_2K_3$	$N_3P_0K_2$	5
$N_1P_2K_3$	$N_3P_1K_1$	$N_0P_3K_1$	$N_0P_0K_0$	$N_2P_0K_3$	$N_3P_2K_0$	$N_2P_3K_2$	$N_1P_1K_2$	6
$N_2P_1K_2$	$N_1P_0K_3$	$N_0P_2K_0$	$N_0P_1K_1$	$N_1P_3K_2$	$N_3P_0K_0$	$N_3P_2K_3$	$N_3P_3K_1$	7
$N_2P_3K_1$	$N_3P_1K_1$	$N_1P_2K_0$	$N_0P_0K_3$	$N_2P_0K_0$	$N_3P_1K_2$	$N_0P_3K_2$	$N_3P_2K_3$	8

Fig 2 Lay out Plan of the Experiment.

The procedure followed for the allocetion of various treatments to different plots was in accordance with Yates (1937). The layout plan is given in Fig. 2. The details of the layout are furnished below.

Treatment combinations	-	64
Replications	-	2
Number of blocks	-	16
Total number of plots	-	128
Gross plot size	-	3.9 x 3.9 m
Net plot size	-	2.1 x 2.1 m
Spacing	-	30 x 30 cm

2.3. Field culture

2.3.1. Preparation of the field

The land was prepared after thorough ploughing and was cleaned out of stubbles. Then the field was laid out into blocks and plots. No organic manures were applied at the time of plot preparation.

2.3.2. Fertilizer application

Nitrogen, phosphorus and potassium were applied to the plots in the form of urea, superphosphate and muriate of potash respectively in appropriate quantities according to the treatment schedule. Full dose of phosphorus, one-third nitrogen and one-third potassium were applied as basal dose one day prior to planting. The one-third nitrogen and one-third potassium were applied on 60th day after planting. Remaining one-third nitrogen and one-third potassium were applied on 120th day after planting.

2.3.3. Seed rhizomes and planting

Seed rhizome weighing 10-15 g each and with at least two viable healthy buds were used. The seed rhizomes were planted at a spacing of 30 cm between rows and 30 cm between plants and covered with a thin layer of soil.

2.3.4. After cultivation

Thinning and gap filling with seedlings of similar age were done 20 days after planting. Hand weeding was done 30th, 60th and 120th day after planting.

2.3.5. Harvesting

Crop was ready for harvest 10 months after planting. Harvesting was done by pulling out the plants and the rhizomes were separated from the shoot portion. The border rows and observation plants were harvested separately from each plot. The rhizome and shoot portion from the net plots were weighed and recorded. The shoot portion from the net plot was sun dried for three days and the dry weight recorded.

3. Observations recorded

3.1. Growth characters

1. Height of plants
2. Number of leaves/plant
3. Number of suckers/hill
4. Leaf area index
5. Drymatter production

3.2. Yield and yield components

1. Number of rhizomes/plant
2. Length of rhizome
3. Girth of rhizome
4. Mean weight of rhizome
5. Rhizome yield
6. Wet weight of plant at harvest
7. Cost benefit ratio

3.3. Chemical analysis

Plants were analysed for nitrogen, phosphorus and potassium on 120, 160, 200, 240, 280 days after planting and at harvest.

3.3.1. Nitrogen content in the plant sample

i) Percentage of nitrogen in plant sample

3.3.2. Phosphorus content in plant sample

i) Percentage of phosphorus in plant sample

3.3.3. Potash content in plant sample

i) Percentage of potash in plant sample

3.3.4. Uptake of nitrogen by plants

3.3.5. Uptake of phosphorus by plants

3.3.6. Uptake of potash by plants

3.3.7. Nitrogen content in rhizome at harvest

3.3.8. Phosphorus content in rhizome at harvest

3.3.9. Potash content in rhizome at harvest

3.3.10. Quality characteristics

i) Starch yield

ii) Protein content of rhizome

iii) Fibre content of rhizome

4. Sampling procedure

A single line of outer plants in each plot was left out as border row. The next row of plants all around in each plot was set apart for destructive sampling. The subsequent row was again left out as border row, thus making the net plot area to 2.1 x 2.1 m with 7 rows and 7 plants per row. For chemical analysis studies five plants were uprooted at a stretch from the destructive row at 120, 160, 200, 240, 280 and at the time of harvest. These plants were used for determining leaf area, drymatter production and for chemical analysis. Five plants were selected randomly from the net plot and tagged for biometric observations.

5. Details of observation

5.1. Height of plants

Observation on height of plant was recorded on the tagged plants at 120, 160, 200, 240, 280 and at the time of harvest. The height of the plants from the ground level to the growing tip was measured in centimetres and the average height per plant was worked out and recorded.

5.2. Number of leaves

The number of leaves of the observational plants were recorded at the above stages and the average number of leaves/plant was then worked out.

5.3. Number of suckers

Number of suckers present on each of the 5 observational plants were counted and the average number per plant was worked out.

5.4. Leaf area index

Leaf area was determined by using leaf area meter.

From this LAI was worked out by using the following formula suggested by Watson (1947).

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

5.5. Drymatter production

Five sample plants each uprooted at different stages were used for the determination of dry weight. The samples were dried in a hot air oven at a temperature of 70°C for three days and then dry weights were recorded and expressed in kg/ha.

6. Post harvest observations

6.1. Number of rhizomes/plant

At the time of harvesting five observational plants were uprooted and the number of rhiscmes were recorded and the average number of rhizomes per plant was then worked out.

6.2. Length of rhizome

The average length of tubers was worked out by measuring the length of tubers taken at random from the observation plants and expressed in cm.

6.3. Girth of rhizome

Girth measurement were recorded from the same tubers that were used for length measurements. Girth values were recorded at three portions, one in the middle and the others a quarter distance from both ends of the tuber. The average of these three figures of all the sample tubers was designated as mean girth.

6.4. Shoot yield

The total fresh weight of shoots from the net plot was recorded at the time of harvest.

6.5. Rhizome yield

At the time of harvest the fresh weight of rhizomes per plot was recorded after removing the soil adhering to the tubers. This value was converted to rhizome yield in t/ha.

7. Chemical analysis

Plant samples collected for recording dry weight were used for chemical analysis. At harvest, the observational plants were used for plant and rhizome analysis.

7.1. Total nitrogen content

Total content of nitrogen was estimated by modified micro-kjeldahl method as given by Jackson (1967).

7.2. Uptake of nitrogen

This was calculated from the nitrogen content of the plant and total dry weight of the sample plants at various stages. The uptake values were expressed in kg/ha.

7.3. Total P content

Phosphorus content was estimated colorimetrically (Jackson, 1967) after wet digestion of the sample using 2:1 mixture of nitric acid and perchloric acid and developing colour by vanado-molybdo phosphoric yellow colour method and read in Spectronic 2000.

7.4. Uptake of phosphorus

This was estimated from phosphorus content and the total dry weight of the sample plants at various stages. The uptake values were expressed in kg/ha.

7.5. Total potash content

Total potash content in plant was estimated by flame photometric method after wet digestion of the sample using di-acid mixture.

7.6. Uptake of potash

This was calculated based on dry weight of the plant and potash content of plant at various stages. The uptake values were expressed in kg/ha.

8. Quality attributes

8.1. Protein content of rhizome

The percentage of protein was calculated by multiplying the percentage of nitrogen in rhizome by the factor 6.25 (A.O.A.C., 1969).

8.2. Starch content of rhizome

The starch content was estimated by using potassium ferricynide method (Ward and Pigman, 1970). The values were expressed as percentage of fresh weight.

8.3. Starch yield

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

8.4. Fibre content of rhizome

Crude fibre content of rhizome was determined by the method of A.O.A.C. (1975).

9. Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The soil samples collected were analysed for total nitrogen, available phosphorus and available potash content. Total nitrogen content was estimated by modified micro-kjeldahl method. Available phosphorus content was estimated by Bray's method-I (Jackson, 1967) and available potash by ammonium acetate method (Jackson, 1967).

10. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for 4^3 partially confounded factorial experiment and significance was tested by F-test (Cochran and Cox, 1965).

The statistical analysis of the data were carried out by the Keltron Versa IWS computer at College of Agriculture, Vellayani.

Results and Discussion

4. RESULTS AND DISCUSSION

The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from February to December 1988 to identify nutritional requirement of arrow root. The various observations recorded were statistically analysed and the salient features of the results and discussions are presented below:

4.1. Growth characters

4.1.1. Height of plants

The data on height of plants recorded at various stages of growth were analysed separately and mean values presented in the Table 1.

The results showed that the plant height increased significantly with increase in levels of nitrogen upto 150 kg. There was a progressive increase in the height of plants with advancing age of the crop. During the first observation (120 DAP) treatment n_3 produced maximum height which was on par with n_2 and n_0 recorded the minimum height. The treatment n_3 was found to register significantly higher plant height at 160, 200 and 280 DAP as well as at harvest. The treatment n_0 registered the lowest plant height at all the stages of growth.

Table 1. Effect of treatments on height of plant (cm) during various growth stages

	Days after planting (DAP)					
Treatment	120	160	200	240	280	Harvest
n_0	39.77	43.53	46.70	50.23	51.88	51.74
n_1	44.16	48.19	51.48	53.40	56.40	56.54
n_2	47.03	50.64	53.66	56.65	58.12	58.75
n_3	48.68	52.32	55.83	58.57	60.42	60.20
CD	1.672	1.658	1.840	2.628	1.182	1.216
p_0	44.48	48.47	51.43	53.35	56.51	56.14
p_1	44.18	48.09	51.28	54.38	56.01	56.39
p_2	44.40	48.23	51.65	54.67	56.05	56.17
p_3	46.58	49.88	53.33	56.44	58.25	58.53
CD	1.672	NS	NS	NS	1.182	1.216
k_0	41.84	45.48	48.83	50.44	53.49	53.85
k_1	44.06	47.78	51.15	54.51	56.32	56.45
k_2	46.02	50.02	52.92	56.09	57.58	57.46
k_3	47.71	51.40	54.78	57.79	59.44	59.48
CD	1.672	1.658	1.840	2.628	1.182	1.216

Different levels of phosphorus had visible influence in increasing the plant height only during 120 and 280 DAP and at the time of harvest. The treatment P_3 recorded significantly higher plant height as compared to P_2, P_1 and P_0 which remained on par during the above three stages of growth.

Potassium had a significant effect on the height of plants at all stages. The plant height increased with increase in levels of potassium and k_3 produced maximum plant height. At 160 DAP k_3 and k_2 were found to be on par and was superior to k_1 and k_0. The treatment k_3 was significantly superior to k_2, k_1 and k_0 at 200 DAP. At 240 DAP k_3 and k_2 were found to be on par. However, k_3 was significantly superior to k_2, k_1 and k_0 at 280 DAP and at harvest.

Results from the experiment clearly showed that the height of plant was increased by nitrogen nutrition and the maximum height was observed at the higher levels of nitrogen application. Eventhough the vegetative parts are not counted as economically important in arrow root, it definitely contribute to tuber production through enhanced source activity. The influence of nitrogen on vegetative growth of plants is a well established phenomenon which needs no detailed discussion. Similar increase in

Table 2. Effect of treatments on number of leaves per plant during various growth stages

	Days after planting (DAP)					
Treatment	120	160	200	240	280	Harvest
n_0	11.09	11.83	11.33	14.81	11.38	10.05
n_1	12.12	13.13	17.73	17.74	13.83	11.84
n_2	13.52	13.51	19.76	18.27	15.25	12.28
n_3	14.97	14.23	24.88	20.14	16.94	14.21
CD	1.259	0.568	0.971	0.884	0.747	0.487
p_0	12.46	13.32	18.73	17.26	14.50	11.85
p_1	13.26	13.20	17.60	18.67	15.12	12.71
p_2	12.20	12.88	17.98	17.90	12.71	11.09
p_3	13.87	13.32	19.39	17.13	15.10	12.74
CD	1.259	NS	0.971	0.884	0.747	0.487
k_0	11.99	12.13	17.16	16.02	13.74	11.51
k_1	12.71	13.22	17.94	17.24	14.45	12.13
k_2	13.24	13.72	17.71	18.58	15.31	12.91
k_3	13.85	13.65	20.88	19.13	13.91	11.84
CD	1.259	0.568	0.971	0.884	0.747	0.487

height of the plant due to higher levels of nitrogen application has been reported by Nair (1964), Purseglove (1968), Nandpuri (1969) and Saifudeen (1981).

It can be observed from the data that only the highest dose of phosphorus could influence the height of plants at all stages of growth. However, significant increase in plant height was visible only at 120 DAP and towards maturity of the crop. Purseglove (1968) also reported such increase in height of plant with higher doses of phosphorus.

The data also showed that potassium application influenced the height of plant during all stages of growth of the plant. Potassium at 150 kg/ha as K_2O was found to increase the height of the plant significantly. Increased growth of plants with increased rate of potassium application was reported by Purseglove (1968), Randhawa and Nandpuri (1969), Kay (1973) and Anon. (1978).

4.1.2 Number of leaves/plant

During the entire growth period the treatment n_3 significantly influenced the number of functional leaves per plant. At 120 DAP, the treatment n_1 and n_0 were on par while n_2 and n_1 were on par at 160 and 240 DAP. The treatment n_0 invariably recorded the minimum number of leaves per plant at all stages of growth (Table 2).

Phosphorus influenced the number of functional leaves per plant at all stages of growth except on 160 DAP. However, no definite trend was observed.

Potassium significantly influenced the number of functional leaves per plant at all stages. During the early vegetative growth (120 and 160 DAP), k_3 was found on par with k_2 and k_1 levels. At 200 and 240 DAP the treatment k_3 retained the maximum number of functional leaves though it was on par with k_2. Leaf retention was found to be higher in the treatment k_2 at 280 DAP and at harvest. At these two stages the highest dose and lowest dose were found on par. During all the growth stages treatment k_0 recorded the minimum number of leaves.

The data presented showed the significant influence of nitrogen on the number of functional leaves per plant at different stages of growth. The number of leaves actually reflect the active vegetative growth of the plant. Vigorous top growth subsequent to nitrogen application was reported by Purseglove (1968), Rao (1973) and Anon (1978).

Different levels of phosphorus influenced the number of leaves retained per plant at different stages of the growth except on 160th day. But the results obtained did not reflect any regular pattern. Thus, it appears that enhanced rates of phosphorus application has no definite role in influencing the retention of functional leaves.

The number of functional leaves retained per plant was significantly influenced by the levels of potassium. The influence of higher levels of potassium was visible during the peak vegetative growth (200 and 240 DAP) and was less pronounced during the early and late stages of growth. The lack of response to added levels of potassium at these two stages reveals that the soil supply is sufficient to meet the growth requirements when the source activity is less.

4.1.3. Number of suckers/plant

The results presented in the Table 3 shows that the effect of nitrogen was significant in increasing the number of suckers per plant at various stages of growth. Incremental dose of nitrogen increased number of suckers/plant. In all stages, n_3 produced maximum and n_0 produced minimum number of suckers/plant.

In the early stages of growth (upto 160 DAP), eventhough n_3 recorded the maximum number of suckers per plant it was found on par with the treatment n_2. Afterwards treatment n_3 was found significantly superior to all other treatments. It can also be observed that in all stages of growth treatment n_2 and n_1 were on par. Similarly, treatment n_1 and n_0 were also found on par throughout the growth period of the crop.

Phosphorus had no significant influence on number of suckers per plant.

Potassium had significant influence on number of suckers per plant at all stages of crop growth except on 160 DAP. In all stages k_3 produced maximum and k_0 produced minimum suckers per plant. The treatment k_3 was found significantly superior to all other treatments except on 120 DAP when it was found on par with k_1. In all other growth stages the treatment k_2, k_1 and k_0 were found on par.

The nutrient nitrogen increased the number of suckers per plant throughout the life period of the plant. There was a corresponding increase in number of suckers per plant with increase in dose of nitrogen. The influence of higher levels of nitrogen in increasing the vegetative growth is a well established phenomenon. Similar influence of nitrogen on the number of suckers per plant was reported by Lee et al. (1981) and Saifudeen (1981).

Phosphorus was found not influencing the number of suckers per plant during the entire growth period of the

Table 3. Effect of treatments on number of suckers per plant during various growth stages

Treatments	Days after planting (DAP) 120	160	200	240	280	Harvest
n_0	3.19	3.33	3.44	3.44	3.44	3.47
n_1	3.20	3.44	3.57	3.57	3.57	3.57
n_2	3.37	3.64	3.80	3.81	3.82	3.82
n_3	3.61	3.86	4.18	4.19	4.19	4.16
CD	0.323	0.282	0.246	0.253	0.252	0.255
p_0	3.45	3.52	3.83	3.86	3.86	3.86
p_1	3.36	3.62	3.74	3.76	3.77	3.74
p_2	3.16	3.49	3.64	3.64	3.64	3.64
p_3	3.41	3.64	3.76	3.74	3.74	3.77
CD	NS	NS	NS	NS	NS	NS
k_0	3.16	3.51	3.56	3.60	3.61	3.61
k_1	3.43	3.54	3.73	3.71	3.71	3.68
k_2	3.19	3.44	3.67	3.68	3.68	3.71
k_3	3.59	3.78	4.03	4.01	4.01	4.01
CD	0.323	NS	0.246	0.253	0.252	0.255

plant. Several workers like Kay (1973), Anon (1977) and Anon (1978) also reported the irregular response of nutrient phosphorus on the production of suckers per plant.

The number of suckers per plant was significantly influenced by nutrient potassium at all growth stages except on 160 DAP. The highest dose of 150 kg/ha K_2O recorded significantly higher number of suckers per plant. The other levels of potash were found on par showing that the highest dose of potash alone had a visible influence on the number of suckers per plant. The influence of potash on vegetative growth of plant has already been discussed.

4.1.4. Leaf Area Index

The effects of treatments on LAI presented in Table 4 reveal that enhanced rates of nitrogen application increased LAI significantly till 240 DAP. There was a gradual decline in leaf area index from 240 DAP until harvest. The treatment n_3 was found to be significantly superior to all other treatments. The treatment n_2 and n_1 were found on par in all growth stages except on 200 DAP. LAI was low in treatments receiving n_0.

Phosphate application was found to influence the LAI only from 200 DAP. The treatment p_3 was found to

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

Days after planting (DAP)

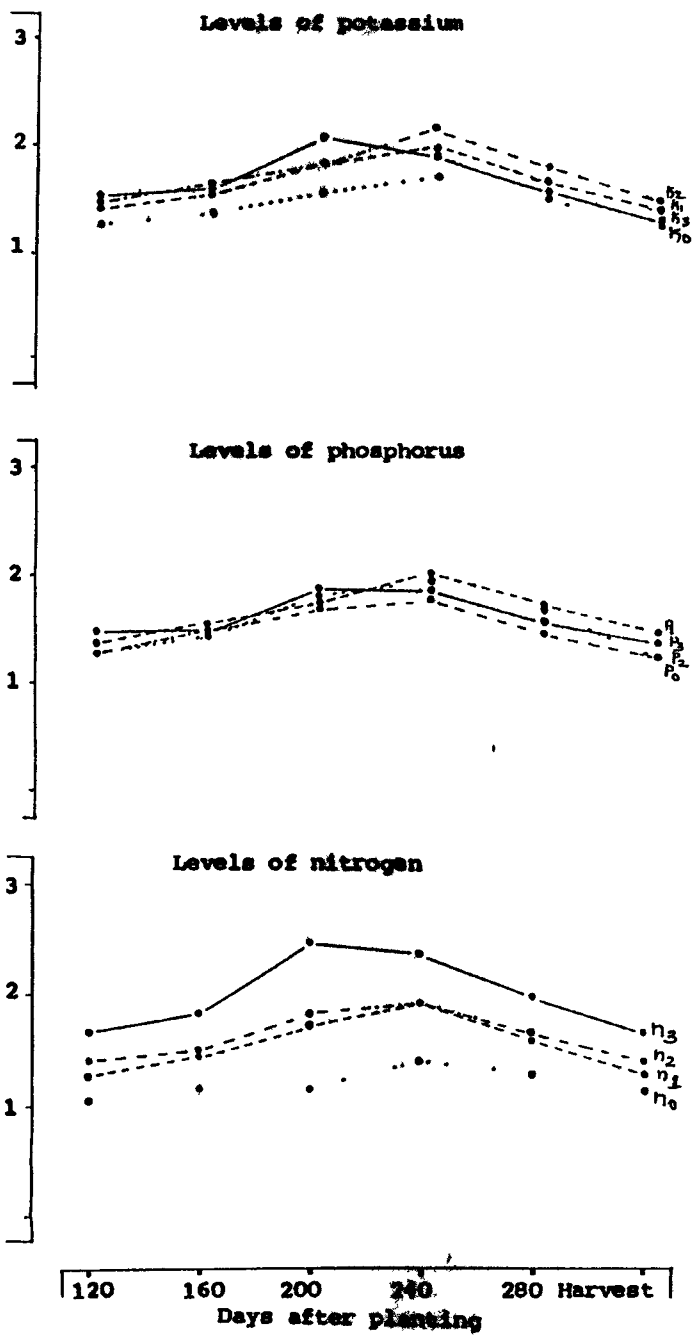
Treatments	120	160	200	240	280	Harvest
n_0	1.05	1.15	1.13	1.34	1.25	1.08
n_1	1.26	1.42	1.65	1.91	1.55	1.28
n_2	1.39	1.[illegible]7	1.79	1.91	1.62	1.36
n_3	1.67	1.82	2.47	2.35	1.96	1.61
CD	0.171	0.133	0.100	0.111	0.130	0.104
p_0	1.28	1.43	1.81	1.91	1.58	1.29
p_1	1.37	1.53	1.72	2.00	1.71	1.46
p_2	1.28	1.46	1.69	1.74	1.45	1.25
p_3	1.44	1.44	1.82	1.85	1.64	1.34
CD	NS	NS	0.100	0.111	0.130	0.105
k_0	1.19	1.30	1.49	1.65	1.48	1.24
k_1	1.32	1.49	1.77	1.91	1.61	1.35
k_2	1.41	1.54	1.76	2.09	1.73	1.47
k_3	1.46	1.52	2.01	1.85	1.56	1.29
CD	0.171	0.134	0.100	0.112	0.131	0.105

register maximum LAI and was on par with p_0 at 200 DAP. In later stages of growth the treatment p_1 was found to register increased leaf area index. However, it can be observed from the data that the effect of different levels of phosphorus in increasing LAI is not consistent.

Different rates of potassium applied were found to influence the LAI differently at various stages of growth. In the early stages upto 160 DAP treatment k_3 and k_2 were found on par. At 200 DAP the treatment k_3 significantly increased the LAI while k_2 and k_1 remained on par. In the later stages of the growth from 240 DAP, the treatment k_2 was found to increase the LAI significantly. During these stages treatment k_1 and k_3 were found on par. LAI was minimum in the treatment k_0 at all stages of growth.

Nitrogen significantly influenced the LAI at various stages of growth of the plant. Application of 150 kg/ha N recorded maximum LAI at all growth stages. The influence of nitrogen as a factor in influencing the LAI 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 in size and hence to make available larger surface area for photosynthesis. When concentration of nitrogen in the plant is high more of the drymatter produced is diverted to the aerial parts increasing the LAI.

Fig 3 Effect of treatments on Leaf Area Index



The different rates of phosphorus could influence the LAI only from 200 DAP. However, a regular pattern of influence was lacking under different levels of supply. The total absence of a steady response to added levels of phosphate indicates that phosphorus has no definite role to play in influencing the LAI.

LAI was significantly influenced by higher levels of potassium in the early stages of plant growth upto 200 DAP. From 240 DAP onwards highest dose of 150 kg/ha and lowest doses were found to be on par. An almost similar pattern of response was visible in the number of functional leaves retained per plant (Table 2).

4.1.5 Drymatter production

The data (Table 5) revealed that the total drymatter production was significantly influenced by nitrogen nutrition during the different growth stages. There was a progressive increase in drymatter production with increasing rates of nitrogen application. The treatment [illegible] showed the highest drymatter content in all the growth stages while the treatment n_0 recorded the lowest.

The effect of different levels of phosphorus in increasing the total drymatter was significant at [illegible]

Table 5. Effect of treatments on dry weight of plants (kg/ha) during various growth stages

	Days after planting (DAP)					
Treatments	120	160	200	240	280	Harvest
n_0	801.03	930.53	1036.31	1212.65	1393.06	1503.96
n_1	1124.00	1380.71	1672.62	1956.56	2198.21	2355.09
n_2	1316.56	1720.84	2036.46	2526.06	1753.09	2940.65
n_3	1524.34	2007.50	2509.75	2924.21	3200.21	3407.21
CD	95.428	83.810	77.974	72.048	76.234	72.304
p_0	1123.06	1456.46	1825.65	2117.37	2325.06	2445.21
p_1	1210.36	1525.81	1724.53	2126.56	2345.40	2554.78
p_2	1166.86	1392.43	1639.37	1958.21	2195.31	2343.87
p_3	1265.48	1664.87	2065.59	2420.34	2678.81	2863.06
CD	95.428	83.810	77.974	72.048	76.231	72.304
k_0	974.83	1260.09	1516.87	1821.06	2035.81	2191.21
k_1	1086.77	1410.28	1665.09	1955.31	2162.68	2318.75
k_2	1280.69	1583.09	1843.12	2293.00	2556.03	2750.25
k_3	1423.67	1786.12	2230.03	2553.12	2790.06	2946.71
CD	95.428	83.810	77.974	72.048	76.231	72.304

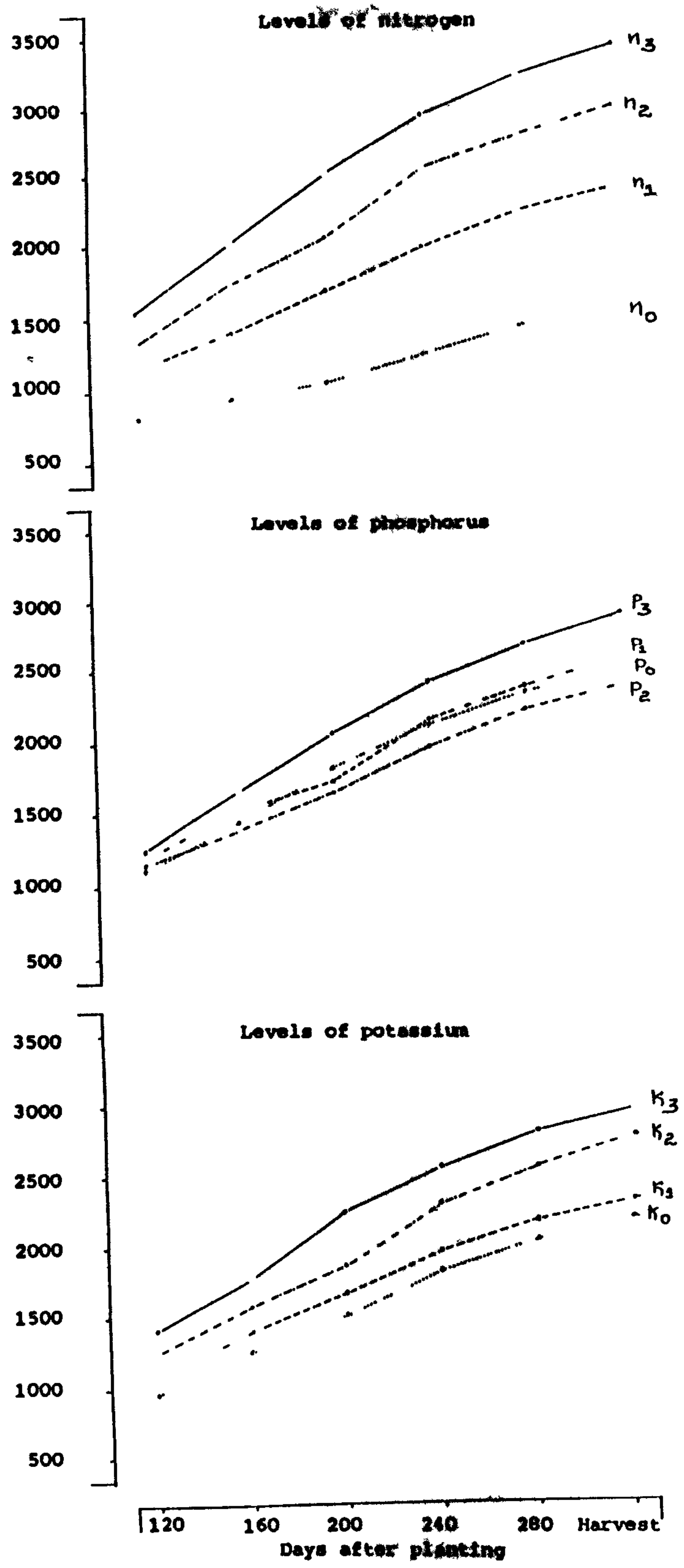
stages of growth. The treatment p_3 registered significantly higher drymatter production at all stages of growth except on 120 DAP when it remained on par with p_1. The treatment p_2 recorded the lowest drymatter production in all the growth stages except at 120 DAP.

Potassium significantly increased the total drymatter production at various stages. In all the stages of growth the treatment k_3 resulted in maximum drymatter production and k_0 the minimum. There was a gradual increase in drymatter production with increase in dose of potassium.

Total drymatter production was significantly increased by incremental dose of nitrogen. Application of 150 kg nitrogen per hectare recorded the highest drymatter production throughout the growth period. An increase in concentration of nitrogen in the plant parts facilitates enhanced growth rates resulting in a proportionate increase in total drymatter production.

Different levels of phosphorus significantly increased the total drymatter production. An application of 75 kg/ha P_2O_5 increased the total drymatter production throughout the growth period. It was also observed that the lower levels of phosphorus could not exert any significant influence in total drymatter production. The lack of response to lower levels of phosphate application may

Fig.4. Effect of treatments on dry weight of pl



be attributed to the fact that a level minimum is required to satisfy the phosphorus fixation capacity of the soil.

Total drymatter production was considerably enhanced at higher rates of potassium application. An application of 150 kg/ha K_2O maintained higher total drymatter production in all growth stages. It was already seen that height of plant, number of suckers per plant and uptake of potassium were increased by potassium nutrition which inturn might have contributed towards higher total drymatter production.

4.2 Yield components and yield

4.2.1 Number of rhizomes/plant

It is evident from the data (Table 6) that the different levels of nitrogen significantly influenced the number of rhizomes per plant. The treatment n_2 registered the maximum number of rhizomes followed by n_3, n_1 and n_0. The treatment n_3 remained on par with n_1 while n_1 was on par with n_0.

Different rates of phosphorus did not influence the number of rhizomes per plant.

Incremental dose of potassium increased the number of rhizomes upto the highest level (k_3).

Data revealed that there is significant influence of nitrogen nutrition on the production of rhizomes.

Table 6. Effect of treatments on number, length and girth (cm) of rhizome at harvest

Treatments	Number of rhizome/plant	Length (cm)	Girth (cm)
n_0	4.068	14.37	5.36
n_1	4.143	16.25	5.65
n_2	4.318	16.02	5.69
n_3	4.221	14.41	5.64
CD	0.08462	0.7262	0.2220
p_0	4.168	14.23	5.314
p_1	4.250	16.64	5.756
p_2	4.146	14.75	5.467
p_3	4.187	15.42	5.811
CD	NS	0.7262	0.2220
k_0	3.931	14.11	5.151
k_1	4.106	15.24	5.588
k_2	4.284	15.45	5.638
k_3	4.431	16.24	5.971
CD	0.08462	0.7262	0.2220

Application of 100 kg/ha nitrogen produced maximum number of rhizomes where as the highest level and lowest levels resulted in reduced number of tubers per plant. Nayan and Aiyer (1969) found that the mean number of tubers per plant was increased by increasing the rate of applied nitrogen from 0 to 75 kg/ha in cassava. They also reported that further increase in nitrogen application resulted in lower number of tubers per plant in both cassava cultivars.

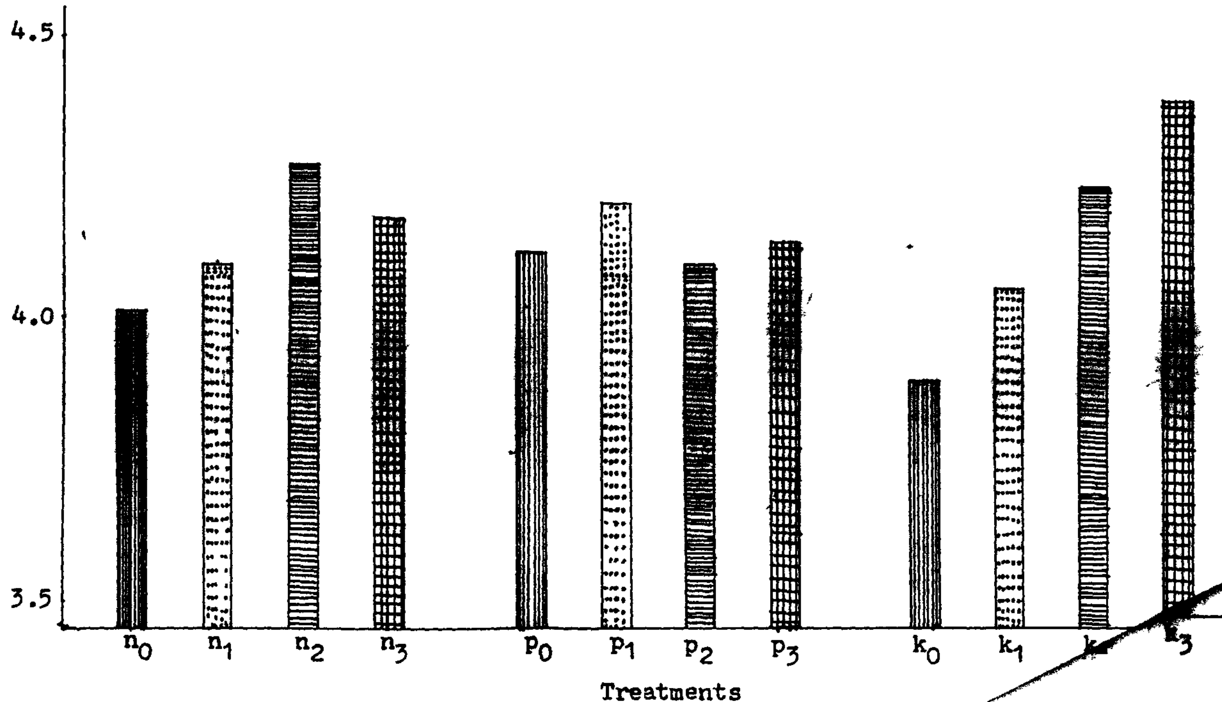
Phosphorus was not found influencing the number of tubers per plant. This may be attributed to the general lack of response of tuber crops to different levels of phosphate application.

Application of potassium significantly enhanced the number of rhizomes per plant. The increase in number of rhizomes was observed upto highest dose of 150 kg/ha K_2O. An increase in number of cormels per plant in taro at enhanced rates of potassium application has been observed by Pillai (1967).

4.2.2. Length of rhizome

The data on length of rhizome as influenced by nutrient level are presented in Table 6. Data showed different levels of nitrogen influenced the length of rhizome. The maximum length of rhizome was observed in

FIG 5 EFFECTS OF TREATMENTS ON NUMBER OF RHIZOMES PER PLANT



treatment n_1 followed by n_2 and they were found on par. While the other treatments n_3 and n_0 were also found on par.

The levels of phosphorus were found to influence the length of rhizome. The treatment p_1 recorded maximum length followed by p_3 and p_2, the latter remaining on par. The lowest length was recorded by p_0 which was found on par with the treatment p_2.

The data clearly showed the influence of potassium in increasing the length of rhizome. The treatment k_3 recorded the maximum length of rhizome and it was found significantly superior to other treatments. The minimum length was recorded by the treatment k_0 while the other treatments k_2 and k_1 were found on par.

The data showed that higher levels of nitrogen were not influential in increasing the length of rhizome. No nitrogen application and highest dose of 150 kg/ha nitrogen were found on par. Eventhough 50 kg/ha nitrogen resulted in maximum length it was found on par with 100 kg/ha nitrogen. Nambiar et al. (1976) observed that increasing rate of applied nitrogen had no significant effect on length of individual tubers in sweet potato.

Application of phosphorus influenced the length of rhizomes wherein phosphorus at the rate of 25 kg/hectare recorded the maximum length. However, the highest dose of 75 kg/ha P_2O_5 and 50 kg/ha P_2O_5 were found on par. The treatments that received no phosphorus and 50 kg/ha P_2O_5 were also found on par. This result clearly showed that higher levels of phosphorus could not influence the length of rhizome.

The maximum length of rhizome was observed at highest level of potassium application. The positive role of potassium nutrition on tuber development was highlighted by several workers like Wang (1975) and Jana (1982) etc. in related crops.

4.2.3. Girth of rhizome

The data (Table 6) revealed that nitrogen influenced the girth of rhizome significantly. The treatment n_2 recorded the maximum girth but it was found on par with n_1 and n_3. The minimum girth was recorded [illegible].

Effect of phosphorus was also found [illegible] in increasing the girth of rhizome. The tre[illegible] recorded maximum girth and was on par with [illegible]. p_2 and p_0 were also found on par.

Different rates of potassium increased the girth of rhizome significantly. Girth of rhizome was maximum at the k_3 level. There was an increase in girth of rhizome as the rate of potassium increased from k_1 to k_3. The treatments k_2 and k_1 were found on par. The minimum girth was recorded in the treatment k_0.

Eventhough the 100 kg/ha nitrogen recorded the maximum girth it was found on par with 50 and 150 kg/ha nitrogen. Pillai (1967) could not observe any significant influence on the girth of tubers in taro by varying levels of nitrogen application.

Application of 75 kg/ha P_2O_5 recorded the maximum girth. But it was found on par with 25 kg/ha P_2O_5. While application of 50 kg/ha P_2O_5 was found on par with plots receiving no phosphorus. It is clear from the data that the lower dose of 25 kg/ha P_2O_5 is equally effective if not better than 75 kg/ha P_2O_5 in increasing the girth of tuber.

Maximum tuber girth was observed with highest dose of potassium application. The tubers swell and increase in size when the potassium application is increased. The most important manurial effect of potassium in arrow root is the enlargement of rhizome both in length and girth. Similar results were also reported by Bourke (1985) and Nicholaides <u>et</u> <u>al</u>. (1985) in related crops.

4.2.4. Mean weight of rhizome

The data (Table 7) clearly showed increase in rhizome weight due to increase in nitrogen levels, rhizome weight increased with the highest level of nitrogen.

Phosphorus also showed its influence in increasing mean rhizome weight. Treatment p_3 recorded maximum mean tuber weight and was found on par with p_2. The lowest mean weight of rhizome was recorded by p_0 and this was found on par with the treatment p_1.

Different rates of applied potassium significantly influenced the mean rhizome weight. The treatment k_3 was significantly superior to k_2, k_1 and k_0. The treatment k_0 recorded the minimum rhizome weight.

The data clearly show that the nitrogen influenced the mean rhizome weight significantly. Rhizome mean weight increased significantly by every increase in the level of nitrogen application from 0 to 150 kg/ha N. The mean rhizome weight is an important yield determinant of arrow root. As already discussed nitrogen has definite beneficial influence on the photosynthetic activity of leaves. The increased photosynthetic activity might have resulted in higher production of photosynthates that are translocated to the developing rhizomes and thereby increasing the mean

Table 7. Effect of treatments on yield (kg/ha) mean weight of Rhizome and wet weight of plant at harvest

Treatments	Yield (kg/ha)	Mean weight of Rhizome	Wet weight of plant at harvest (kg/ha)
n_0	11471.59	25.173	20614
n_1	12860.56	27.73	22832
n_2	14299.06	29.47	28527
n_3	14689.44	30.593	32636
	Sig	Sig	Sig
p_0	12823.78	27.219	23753
p_1	13044.34	27.448	24523
p_2	13418.63	28.860	22725
p_3	13811.34	29.430	27648
	Sig	Sig	Sig
k_0	11301.47	25.560	21009
k_1	12663.63	27.510	22480
k_2	14030.13	29.316	26669
k_3	15102.81	30.581	28482
CD	368.230	0.668	597

weight. Bourke (1985) reported increase in tuber weight with nitrogen nutrition in sweet potato.

Phosphorus also exerted its influence on this yield attribute. Phosphorus at the rate of 75 kg/ha P_2O_5 registered higher mean rhizome weight.

The mean rhizome weight registered progressive with increasing level of potassium application. The translocation of assimilates by potassium nutrition might have led to an increase in mean rhizome weight. Several workers have reported an increase in tuber weight due to potassium nutrition in related tuber crops (Bautista and Santiago, 1981; Hammett _et al_., 1984).

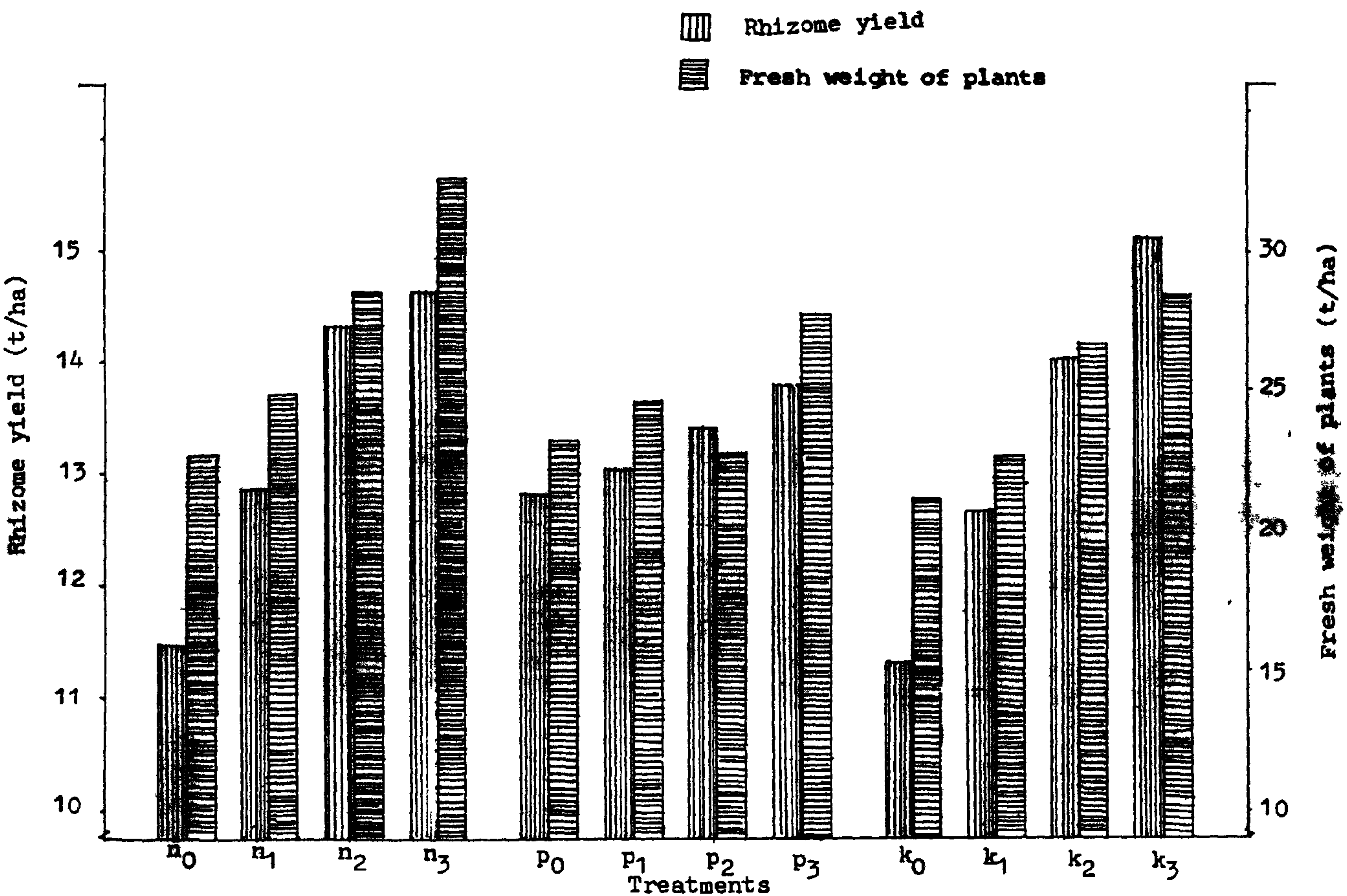
4.2.5. Weight of plant at harvest

The data (Table 7) revealed that plant weight was increased by nitrogen nutrition. Nitrogen showed significant increase in plant weight upto the highest level (n_3).

The effect of phosphorus was also found significant. The treatment p_3 recorded the maximum yield followed by p_1, p_0 and p_2.

Plant weight increased significantly with potassium nutrition. Treatment k_3 gave the highest yield followed by k_2 and k_1. The minimum yield was recorded by treatment k_0.

FIG. 6 EFFECT OF TREATMENTS ON RHIZOME YIELD AND FRESH WEIGHT OF PLANTS



Weight of plant was significantly influenced by nitrogen application. Progressive increase in plant weight with incremental doses of nitrogen was observed and maximum was attained at 150 kg/ha nitrogen. Contributing factors for plant yield such as height of plant, number of suckers and number of leaves were increased by high rates of nitrogen application (Tables 1, 2 and 3). Similar increase in plant yield due to higher rates of nitrogen application has been reported by Tsuno (1981) and Poolperm (1987) in sweet potato.

Phosphorus influenced the plant weight significantly and the highest level of 75 kg/ha was superior to the lower levels. Lowest plant yield was recorded by 50 kg/ha P_2O_5. At the final stages of growth of the plant, 75 kg/ha P_2O_5 recorded maximum plant height besides maintaining higher tuber girth and mean tuber weight. This might have increased the plant weight at harvest.

There was significant effect in plant weight due to potassium nutrition. There was progressive increase in plant weight with increase in the dose of potassium. This indicates the influence of potassium on the fresh weight of plants.

4.2.6. Rhizome yield

The data on rhizome yield as influenced by fertilizer levels are presented in Table 7 and illustrated graphically in Fig. 6. The statistical analysis of rhizome yield showed significant differences among rates of nutrients applied. Nitrogen exerted significant influence on rhizome yield. There was an increase in rhizome yield when the level of nitrogen was enhanced from n_0 to n_3.

Higher levels of phosphorus significantly influenced the rhizome yield. Treatment p_3 gave highest yield followed by p_2. The minimum yield was reported by treatment p_0 and was found to be on par with the treatment p_1.

The effect of potassium was also significant in increasing the yield. The treatment k_3 registered the highest yield and was significantly superior to the other levels. The treatment k_0 recorded the lowest yield.

The rhizome yield increased significantly with increase in rates of nitrogen application. Highest yield was observed when nitrogen was applied @ 150 kg/ha. This clearly indicates that arrow root responds favourably to enhanced rates of nitrogen application. The yield of arrow root depends to a great extent on the assimilate accumulation in the roots. The effect of nitrogen in promoting the synthesis of carbohydrates is well known. It can be observed from the results that the total drymatter production was significantly increased by nitrogen application (Table 5). Many workers have reported increased yield in arrow root by nitrogen application (Purseglove, 1968 and Kay, 1973).

The data showed that higher levels of phosphorus significantly influenced the tuber yield. Phosphate @ 75 kg/ha and 50 kg/ha as P_2O_5 registered significantly higher yield over the other levels. This clearly show that arrow root requires higher levels of phosphorus nutrition for satisfactory rhizome yield. Workers like Rajput et al. (1981) and Tsuno (1981) have also reported the importance of phosphorus in tuber production of related crops.

By the application of incremental dose of potassium rhizome yield increased upto the level of 150 kg/ha K_2O. Potassium has been identified as being essential for the normal photosynthetic activity of the leaves. Potassium is also involved in the activation of enzymes responsive for starch synthesis and plays a direct role in the translocation of assimilates to the developing tubers. This is evident from the data on length and girth of rhizome (Table 6). All these factors reveal the beneficial effect of potassium nutrition on the yield of arrow root.

Thus the combined effect of all these factors favourably influenced the rhizome production at higher levels of potassium nutrition. Kay (1973) reported an increase in rhizome yield due to potassium nutrition.

4.3 Quality attributes

4.3.1 Starch yield

It is seen from the Table 8 that the starch yield was increased significantly by increased level of nitrogen nutrition. The treatment n_3 gave the maximum starch yield followed by n_2, n_1 and n_0. The treatments n_3 and n_2 were found on par.

The different levels of phosphorus were also found to increase the starch yield significantly. The treatment p_3 recorded the maximum starch yield followed by p_2, p_1 and p_0.

There was a progressive increase in starch yield with incremental dose of potassium; the higher levels being significant to lower levels.

The results showed that the starch yield increased significantly with nitrogen application upto the highest level (150 kg/ha N). This treatment was found on par with 100 kg/ha N. The higher starch yield obtained at this level may probably due to [illegible]

FIG. 7 EFFECT OF TREATMENTS ON STARCH CONTENT OF RHIZOME

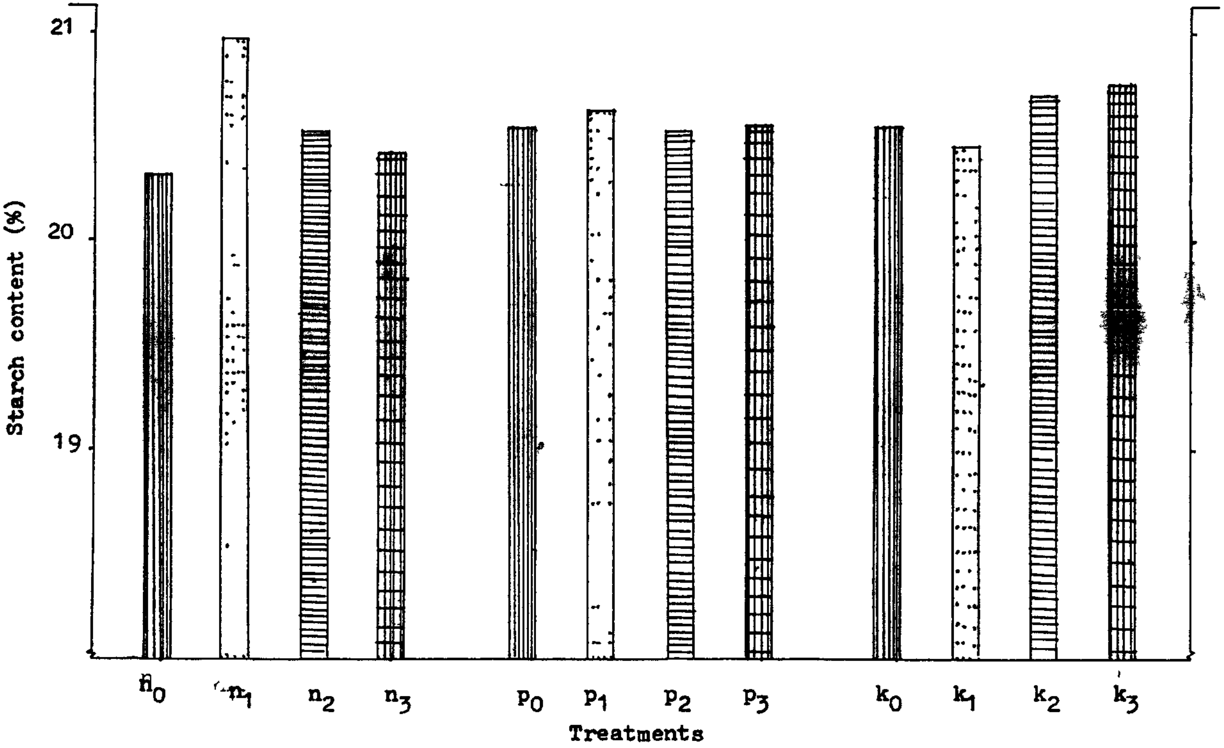


Table 8. Effect of treatments on starch content (%), starch yield (kg/ha), fibre content and protein content (%) of Rhizome

Starch content (%), starch yield (kg/ha), fibre content (%), protein (%) - Rhizome

Treatments	Starch content (%)	Starch yield (kg/ha)	Fibre (%)	Protein (%)
n_0	20.32	686.77	0.73	1.07
n_1	20.99	795.13	0.85	1.52
n_2	20.53	864.54	0.96	2.02
n_3	20.43	884.106	1.13	2.11
CD	0.6503	23.655	0.01	0.04
p_0	20.55	776.21	0.87	1.58
p_1	20.64	792.90	0.90	1.67
p_2	20.53	811.34	0.94	1.74
p_3	20.56	849.92	0.96	1.71
CD	NS	23.69	0.01	0.04
k_0	20.58	648.85	0.97	1.62
k_1	20.45	762.98	0.93	1.67
k_2	20.71	855.90	0.90	1.69
k_3	20.76	937.06	0.87	1.73
CD	NS	23.655	0.01	0.04

activity achieved through the maintenance of increased leaf area. Increase in starch yield of tubers by nitrogen nutrition has been reported by several workers like Mandal et al. (1971) and Bartolini (1982) in sweet potato.

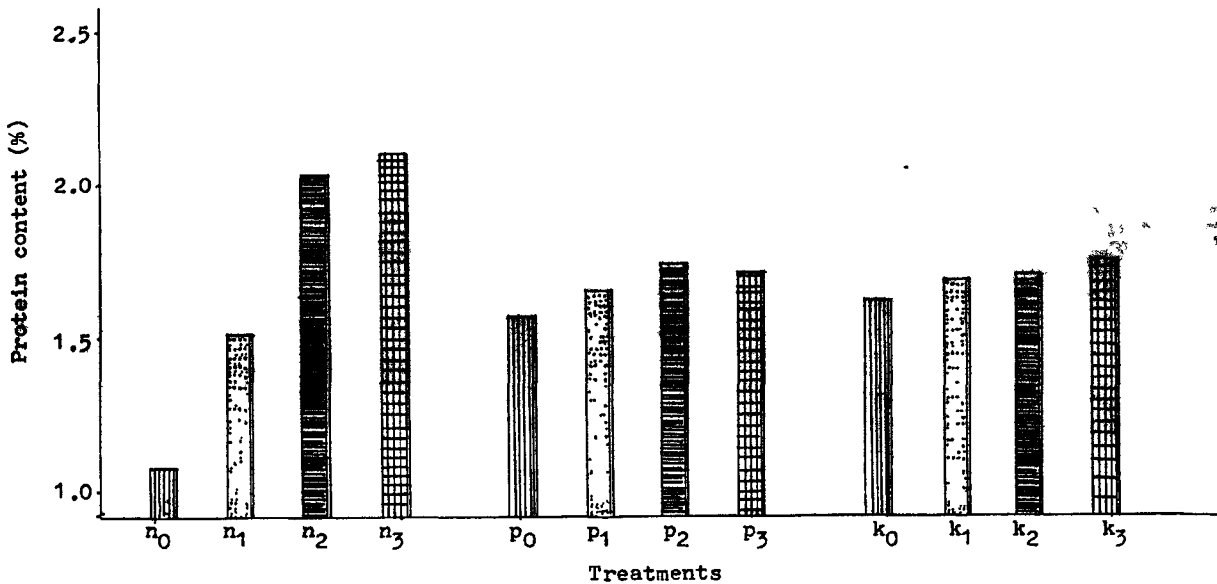
Different levels of phosphorus also exerted significant influence on the starch yield; the highest level of 75 kg/ha P_2O_5 was found significantly superior to other levels. The most important function of phosphorus in plant life is its role in energy storage and transfer.

Starch yield was influenced by potassium nutrition and maximum values were noticed at higher levels of potassium. The beneficial effect of potassium on starch yield can be attributed to the role of potassium in carbohydrate synthesis and translocation. Sharafudeen and Voican (1984) also reported that higher dose of potassium significantly increased the starch yield in sweet potato.

4.3.2. Protein content of rhizome

The data on crude protein content of tuber presented in Table 8 showed that the different levels of nitrogen influenced the crude protein content significantly. Crude protein content was significantly increased upto the highest level of nitrogen (n_3).

FIG. 8 EFFECT OF TREATMENTS ON PROTEIN CONTENT OF RHIZOME



Phosphorus also exerted significant influence on this quality attribute. The maximum crude protein content was observed in treatment p_2 followed by p_3, p_1 and p_0.

Different rates of applied potassium significantly influenced the crude protein content of arrow root. The treatment k_3 registered the highest crude protein percentage while k_2 and k_1 were found on par.

Nitrogen profoundly influenced the crude protein content of tubers. Protein content was increased significantly by nitrogen upto highest level (150 kg/ha nitrogen). The favourable effect of nitrogen nutrition on protein synthesis and carbohydrate accumulation has already been discussed. Increase in crude protein content of tuber of related crops by the application of nitrogen was reported by Nambiar _et al_. (1976) and Constantin _et al_. (1984).

Higher levels of phosphorus also exerted significant influence on protein content of the rhizome. But the highest level 75 kg/ha P_2O_5 was found on par with 50 kg/ha showing that the different levels exert almost equal influence.

The influence of potassium on this quality trait was also significant. As the levels of potassium increased the protein content also increased upto the highest level. Similar results were reported by Muthuswamy and

Krishnamoorthy (1976) and Constantin *et al*. (1977) on related tuber crops.

4.3.3. Fibre content of rhizome

The data (Table 8) showed that the crude fibre content of arrow root rhizome was influenced by the nutrient levels.

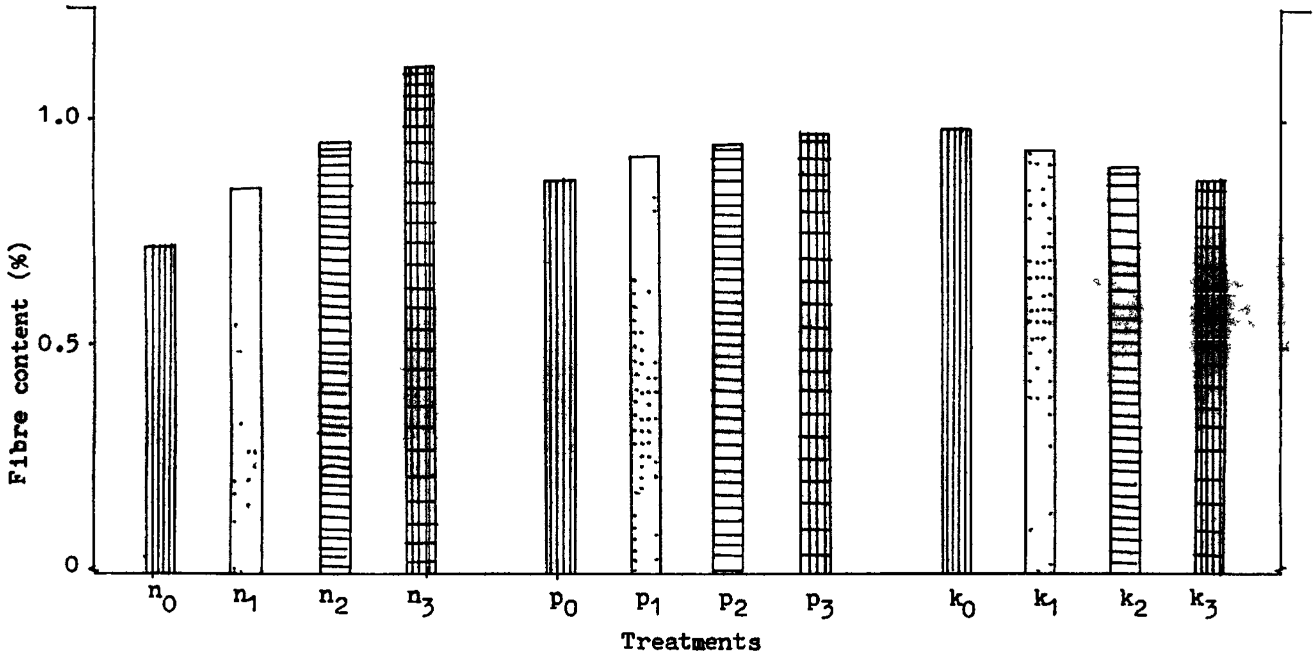
The different nitrogen levels significantly increased the crude fibre content of rhizome. The treatment n_3 produced the maximum crude fibre content followed by n_2, n_1 and n_0.

Different rates of phosphorus also influenced crude fibre content. Crude fibre content was maximum at p_3 level followed by p_2, p_1 and p_0.

The different rates of potassium significantly influenced the crude fibre content. The treatment k_0 registered the highest crude fibre content followed by k_1, k_2 and k_3.

The data clearly show that higher levels of nitrogen significantly influence crude fibre content. As the levels of nitrogen increased crude fibre content also increased. Muthuswamy and Rao (1981) found that nitrogen fertilization increased the crude fibre content of peeled cassava tubers.

FIG. 9 EFFECT OF TREATMENTS ON FIBRE CONTENT OF RHIZOME



In the case of phosphorus also crude fibre content increased with increase in levels of phosphorus.

On the contrary, increase in levels of potassium caused a reduction in the crude fibre content of rhizomes. As the level of potassium increased from 0 to 150 kg/ha K_2O the crude fibre content was reduced significantly. Similar decrease in crude fibre content towards maturity have been reported by Muthuswamy and Rao (1980) on cassava.

4.4. Nutrient uptake

4.4.1. Uptake of nitrogen

The data (Table 9) clearly show significant effect of nitrogen on the uptake of this element at various growth stages. Plant uptake of nitrogen increased with increase in nitrogen application upto the highest level (n_3) of the nutrient.

The plant uptake of nitrogen was influenced significantly by the levels of phosphorus at all stages of growth. The treatment p_3 significantly increased the nitrogen uptake at all stages of growth. At 120 DAP eventhough the treatment p_3 increased nitrogen uptake it was found on par with p_2. The treatment p_1 and p_0 were also found on par. At 160 DAP p_3 was found significantly superior to other treatments while p_2, p_1 and p_0 remained

Table 9. Effect of treatments on uptake of Nitrogen (kg/ha) during various growth stages

Days after planting (DAP)

Treat-ments	120	160	200	240	280	Harvest
n_0	7.17	8.12	8.835	10.08	11.47	11.94
n_1	14.84	16.01	17.46	19.05	20.53	21.54
n_2	21.72	25.54	25.98	26.95	27.47	27.63
n_3	25.72	29.25	32.81	23.04	33.34	33.88
CD	1.645	1.355	1.255	1.051	1.046	0.887
p_0	16.00	18.08	21.02	21.21	21.51	21.94
p_1	16.08	18.23	19.75	21.34	22.52	23.09
p_2	18.05	18.36	18.64	19.34	20.84	21.70
p_3	19.30	23.52	26.64	27.11	27.18	27.34
CD	1.645	1.355	1.255	1.051	1.046	0.887
k_0	14.42	17.67	19.37	20.50	21.00	21.11
k_1	16.22	18.70	20.68	20.14	20.69	21.35
k_2	18.13	19.96	21.16	22.66	23.96	24.73
k_3	20.66	22.59	25.53	25.22	26.33	26.72
CD	1.645	1.645	1.255	1.051	1.046	0.887

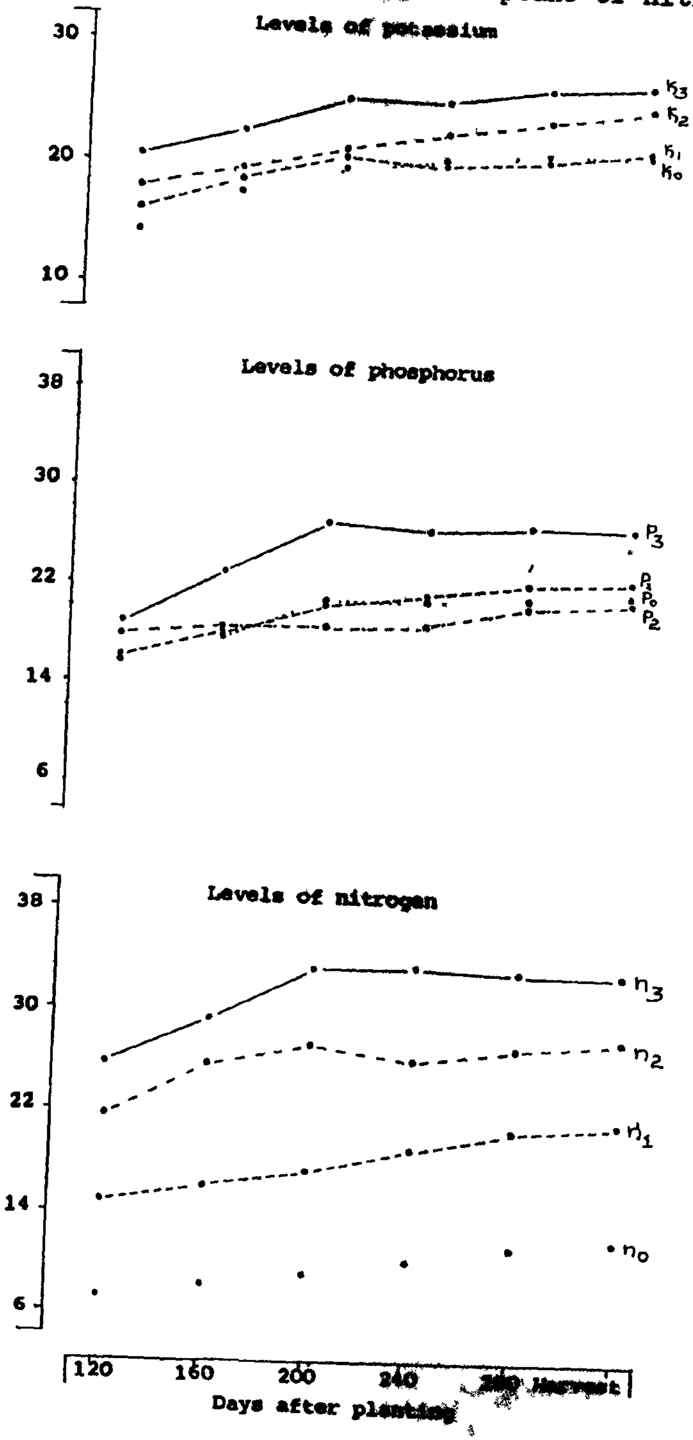
on par. At 200 DAP treatment p_3 was significantly superior to other treatments followed by p_0, p_1 and p_2. However, from 240 DAP onwards p_3 was followed by p_1, p_0 and p_2.

Plant uptake of nitrogen was found significantly influenced by the levels of potassium. The treatment k_3 significantly increased the nitrogen uptake at all stages of growth and was found significantly superior to the lower levels. At 160 DAP, 200 DAP and at time of harvest k_3 was followed by k_2, k_1 and k_0. However, at 240 DAP and at 280 DAP k_3 was followed by k_2, k_0 and k_1.

The data clearly show that plant uptake of nitrogen increased progressively with higher levels of application of nitrogen and the maximum was obtained at the highest level of nitrogen irrespective of the stage of growth. A perusal of the data on drymatter production will clearly reveal the superiority of higher levels of nitrogen in enhancing the drymatter yield which has bearing on nutrient uptake. Increase in uptake of nitrogen by high rates of application of the nutrient has already been established in related crops (Nambiar _et al._, 1976 and Purcell _et al._, 1982).

The effect of phosphorus levels in increasing nitrogen uptake was noticed throughout the growth period of the crop. 75 kg/ha P_2O_5 significantly increased the

Fig 10 Effect of treatments on uptake of nitrogen



nitrogen uptake. The data on drymatter production (Table 5) also clearly show the influence of highest level of phosphorus (75 kg/ha P_2O_5) in increasing the drymatter production.

Different levels of potassium also influenced the uptake of nitrogen and the effect was significant at all stages of growth, the highest level having a pronounced effect. Ramon and Donald (1967) observed increases in content of nitrogen in the plant parts of Colocasia by potassium application. Bourke (1985) reported an increase in nitrogen uptake of sweet potato at higher rates of potassium application.

4.4.2. Uptake of phosphorus

The data on uptake of phosphorus at various stages of growth are presented in Table-10. Nitrogen application significantly influenced the uptake of phosphorus throughout the period of growth. The uptake of phosphorus was lowest at n_0 level and highest at n_3 level.

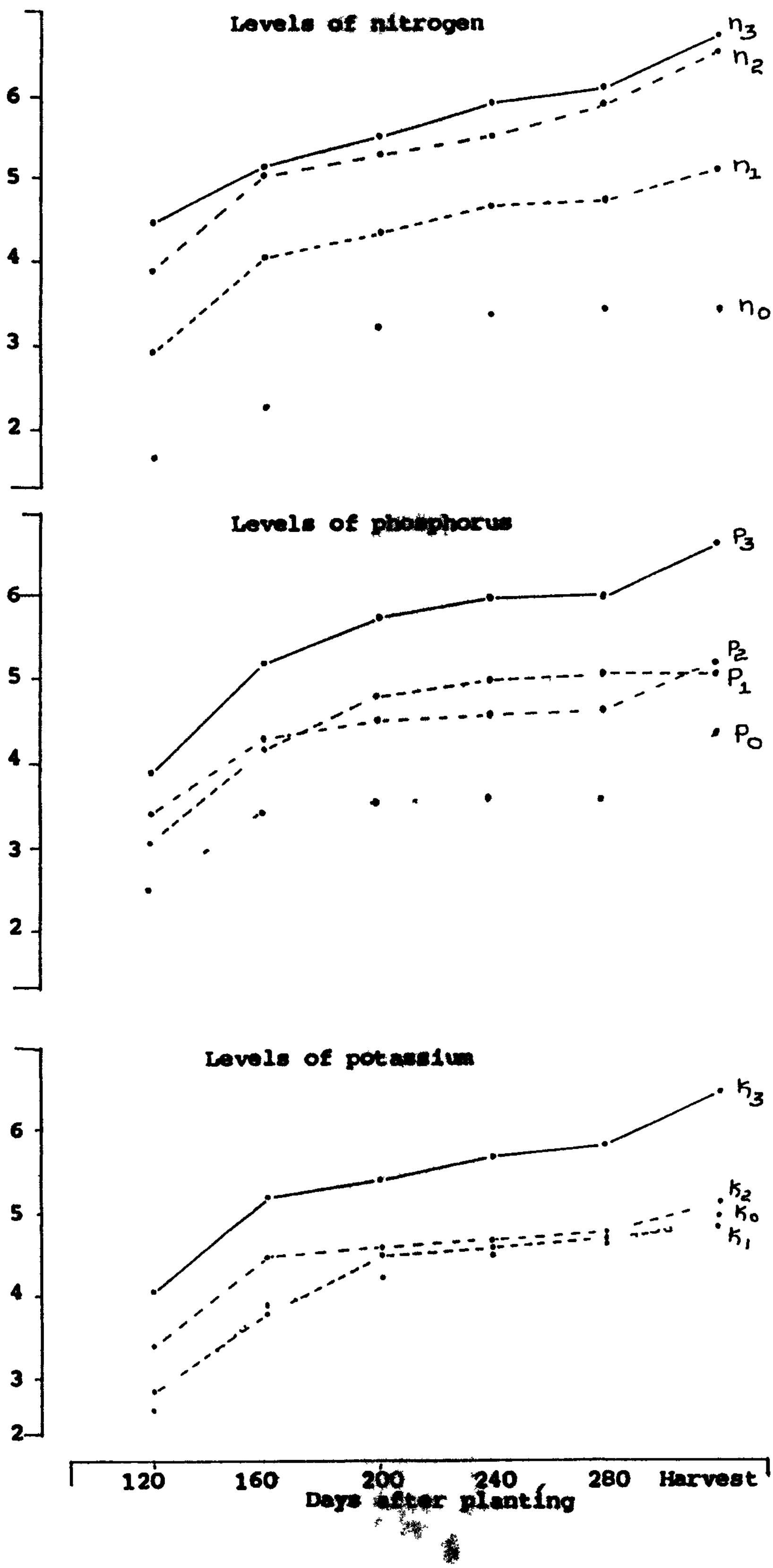
Phosphate application at different levels did influence the uptake of phosphorus by plant. The highest level of p_3 registered significantly higher uptake at all stages of plant growth. However, the difference between p_2 and p_1 levels was not marked. Phosphorus uptake was lowest in the treatment p_0.

Table 10. Effect of treatments on uptake of phosphorus (kg/ha) at various stages of growth

Days after planting (DAP

Treatments	120	160	200	240	280	Harvest
n_0	1.73	2.36	3.27	3.35	3.38	3.38
n_1	2.97	4.10	4.37	4.64	4.71	5.07
n_2	3.91	5.02	5.27	5.56	5.93	6.50
n_3	4.41	5.19	5.54	5.88	6.02	6.66
CD	0.344	0.277	0.297	0.366	0.348	0.389
p_0	2.57	3.44	3.54	3.58	3.58	4.48
p_1	3.07	4.27	4.83	4.99	5.05	5.07
p_2	3.43	4.35	4.55	4.56	4.62	5.18
p_3	3.94	5.29	5.86	5.98	5.98	6.78
CD	0.344	0.277	0.297	0.366	0.348	0.389
k_0	2.65	3.87	4.20	4.51	4.56	4.97
k_1	2.84	3.79	4.48	4.52	4.61	4.88
k_2	3.41	4.47	4.51	4.55	4.58	5.09
k_3	4.11	5.28	5.39	5.64	5.76	6.56
CD	0.344	0.277	0.297	0.366	0.348	0.389

Fig 11 Effect of treatments on uptake of phosphorus



The influence of potash in enhancing the phosphorus uptake was present throughout the growth period of the crop. The highest level of potash application (k_3) registered significantly higher uptake values at all stages of observation. However, the differences among the other levels were not pronounced.

The phosphorus uptake pattern followed a trend similar to that of drymatter production. Though the content of phosphorus in plant parts decreased with age of the crop, there was progressive increase in the uptake of this element due to increased drymatter production and continued absorption. The lower phosphorus uptake observed in this crop agrees with the finding that tuber crops, in general, remove smaller amounts of phosphorus.

4.4.3. Uptake of potassium

The data on Table-11. reveal the significant influence of nitrogen on the uptake of potassium at different stages of growth. The superiority of the higher levels of nitrogen in enhancing the uptake of potassium was visible from 200 DAP and the trend was maintained till harvest. However, the differences in potassium uptake at the n_2 and n_3 levels of nitrogen application were not significant except at harvest stage.

Table 11. Effect of treatments on uptake of potassium (kg/ha) at various stages of growth

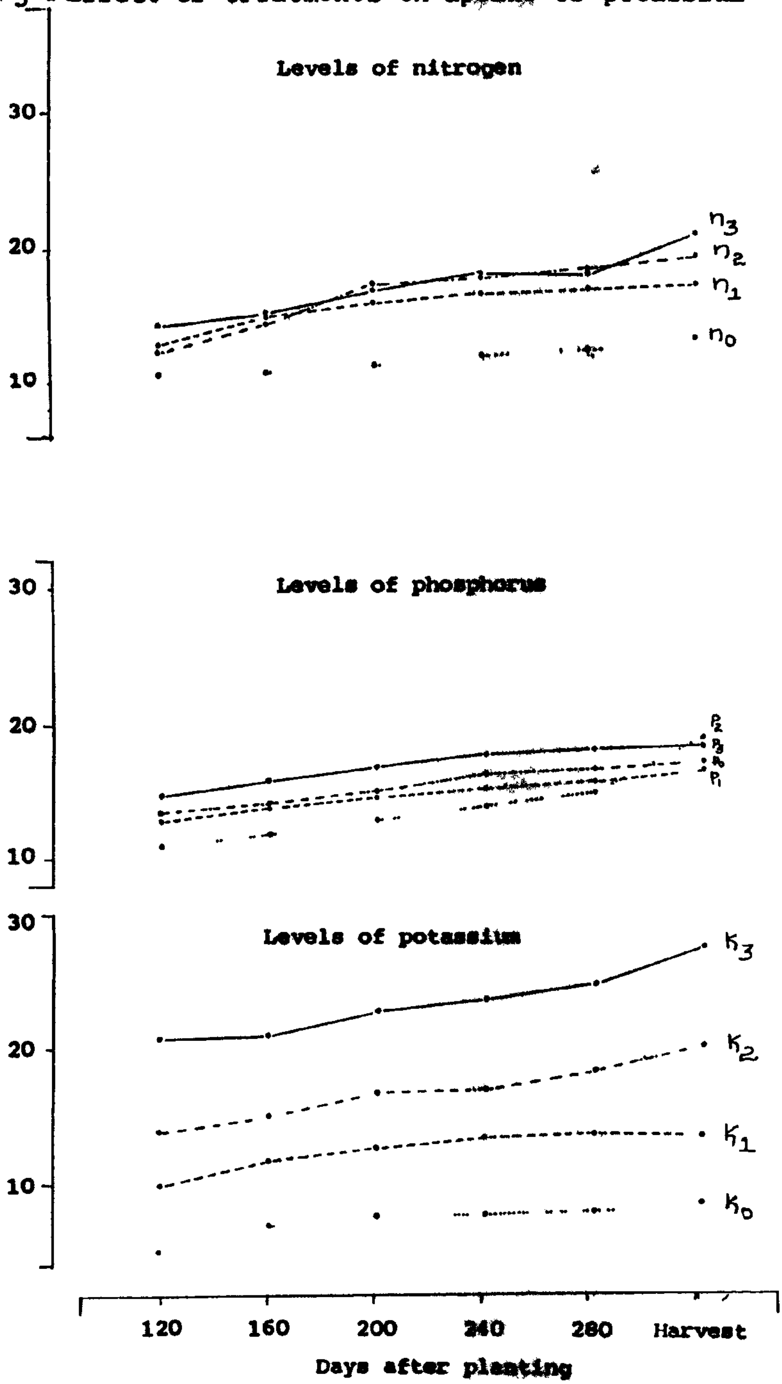
Treat-ments	Days after planting (DAP)					
	120	160	200	240	280	Harvest
n_0	10.79	10.80	11.77	12.02	12.25	13.26
n_1	13.69	15.35	16.06	16.18	16.43	17.31
n_2	14.56	15.71	16.70	17.12	18.17	19.04
n_3	12.83	14.72	17.17	17.90	18.14	21.58
CD	2.101	1.556	0.992	1.614	1.533	1.616
p_0	13.32	14.16	14.78	14.87	15.71	17.29
p_1	13.83	14.04	14.94	16.32	16.37	16.54
p_2	11.13	12.05	13.62	14.09	15.52	18.92
p_3	14.75	16.01	16.98	17.89	18.01	18.43
CD	2.101	1.556	0.992	1.614	1.533	1.616
k_0	5.39	6.94	8.16	8.17	8.27	8.74
k_1	10.12	12.02	13.01	13.86	13.95	14.00
k_2	14.19	15.74	17.14	17.61	18.61	20.43
k_3	20.90	21.78	23.34	24.04	25.14	28.00
CD	2.101	1.556	0.992	1.614	1.533	1.616

Different levels of phosphorus also exerted considerable influence on the uptake of potassium at all stages of growth. The highest level of phosphorus application (p_3 level) maintained significantly higher uptake of potassium over other levels except at the time of harvest. The differences among the lower levels of phosphorus, however, were not conspicuous in influencing the potassium uptake.

Potassium application at enhanced rates remarkably influenced the potassium uptake by the plant. The k_3 level registered the highest uptake in the early stages of growth and the superiority over other levels of potassium was maintained till harvest. The uptake of potassium followed the order of $k_3 > k_2 > k_1 > k_0$ throughout the period of plant growth.

Nitrogen influenced the uptake of potassium and its effect was significant at all stages of growth. Though, the uptake of potassium was highest when nitrogen was applied @ 150 kg/ha, it remained on par with 100 kg/ha except at the time of harvest. Enhanced rates of potassium uptake is associated with a correspondingly higher rate of nitrogen application because of the synergestic effect of nitrogen on potassium. Increased uptake of potassium by the application of nitrogen has been reported in sweet potato (Tsuno and Fujise, 1965).

Fig 12 Effect of treatments on uptake of potassium



Phosphorus application at the highest level (75 kg/ha P_2O_5) alone was helpful in enhancing the potassium uptake. The lack of response to lower levels of phosphorus application in enhancing the drymatter production has already been explained.

Higher uptake of potassium was associated with higher rates of application of potassium. Potassium application at higher rates have been helpful in promoting the growth and yield of arrow root as has been observed in this study. This has contributed to the higher uptake of potassium by the plant. Saifudeen (1981) observed that the uptake of potassium in leaf, pseudostem and in rhizome were significantly influenced by potassium application in turmeric.

4.5 Soil nutrients after experiment

4.5.1 Available nitrogen

It is seen from the data that (Table 12) with the enhancement in the rate of nitrogen application the available nitrogen content of the soil increased significantly. The highest values obtained in the treatment n_3 was significantly higher than the lower levels.

Effect of phosphorus in increasing the nitrogen content of soil was also found significant. The treatment p_3

recorded the highest value followed by p_2, p_1 and p_0 while higher levels p_3 and p_2 and lower levels p_1 and p_0 were found on par.

Effect of potassium levels in increasing the available nitrogen content was not significant.

Available nitrogen content of the soil increased by application of higher doses of nitrogen such increases in nitrogen status consequent in nitrogen application is a well established fact. Rajendran et al. (1971) observed an increase in available nitrogen content of soil by application of 100 kg nitrogen per hectare to tapioca.

Available nitrogen content of soil was significantly influenced by different levels of phosphorus only the 75 kg P_2O_5/hectare and 50 kg P_2O_5/ha significantly influence the available nitrogen. In the uptake of nutrient nitrogen only the highest level was found effective. This may have increase the available nitrogen content in soil.

The influence of potassium on available nitrogen content was not found effective. At higher levels of potassium the utilisation of nitrogen was higher as seen from the data presented on nitrogen uptake [illegible] may have caused reduction in available nitrogen content at highest level of potassium.

Table 12. Effect of treatments on the available nitrogen, phosphorus and potassium contents (kg/ha) of soil after experiment

Treatments	Available nitrogen	Available phosphorus	Available potassium
n_0	149.13	32.99	56.81
n_1	161.82	46.41	58.43
n_2	212.13	36.83	61.91
n_3	246.81	39.01	64.23
CD	11.673	5.341	4.152
p_0	158.91	28.94	56.81
p_1	162.43	34.64	58.90
p_2	199.13	41.83	59.20
p_3	210.81	48.64	62.29
CD	11.673	5.341	4.152
k_0	175.45	39.10	48.91
k_1	184.13	38.81	67.13
k_2	193.82	42.28	63.82
k_3	201.48	46.71	70.91
CD	11.673	5.341	4.152

4.5.2 Available phosphorus

The available phosphorus content was influenced by different levels of nitrogen. The treatment n_1 recorded the highest values followed by n_3, n_2 and n_0.

The effect of phosphorus application was significant in this soil character. The treatment p_3 was found significantly superior to other levels.

The different potassium levels did not influence the available phosphorus content in the soil.

The data showed that available phosphorus was influenced by 50 kg/ha N. The highest level of 150 kg/ha N, 100 kg/ha N and no application of nitrogen were found on par. It can be seen from the data on uptake of phosphorus (Table 10) that uptake of phosphorus also significantly influenced by higher levels of nitrogen. As the uptake of phosphorus was significantly influenced by the higher levels of nitrogen, the available P_2O_5 content in the soil was less influenced by higher levels of nitrogen.

The different levels of phosphorus significantly influence the soil phosphorus status. With the incremental doses of phosphorus the available phosphorus content of the soil increase significantly. The highest value of phosphorus was noticed at 75 kg P_2O_5/ha, plant uptake of phosphorus was significantly influenced by different levels of nitrogen, potassium and that of element itself upto 200 days after planting. In the later stages there was slight decrease in uptake of phosphorus. This might have lead to an increase in available phosphorus content of the soil.

The influence of potassium was not significant in influencing the phosphorus content in the soil after the experiment. The data presented in the uptake of phosphorus shows that the highest level of potassium significantly influence the phosphorus uptake at various stages of growth. This increased uptake by the plant due to the influence of potash might have reduced the phosphorus content of the soil.

4.5.3 Available potassium content of the soil

The data on Table 12 reveal that the available potassium content of soil did not show any difference between nitrogen levels.

Phosphate application did not influence the available potassium content of the soil.

The effect of potash application was significant in influencing the available potassium content of the soil. The highest level of potash application (k_3) registered significantly highest content of potassium.

The results showed that available potassium content of soil was not significantly influenced by nitrogen and phosphorus application. Potassium nutrition significantly increased the available potassium content of the soil showing the highest value at the maximum potassium level (150 kg/ha K_2O). Several workers have reported increase in available potassium content of soil by application of higher doses of potassium (Mohankumar et al., 1971 and Rajendran et al., 1972).

4.6 Economics of fertilizer application

The data in Table 13 show that application of Nitrogen @ 150 kg/ha resulted in highest net return (Rs.9311/ha) and highest benefit cost ratio of 2.[illegible] The net return per Rupee invested was also maximum (1.[illegible]) in this treatment. Application of phosphorus @ 75 kg/ha gave maximum net return (Rs.8310/ha) and benefit cost ratio. Potassium application @ 150 kg/ha resulted in highest net return of Rs.8380/ha and benefit cost ratio of 2.919. The net return per rupee invested was also maximum with 150 kg/ha K_2O.

Table 13. Economics of fertilizer application

Treatments	Cost of cultivation (Y) Rs.	Gross return (X) Rs.	Net return (X-Y) Rs.	Benefit Cost Ratio $\frac{X}{Y}$	Net return/Re invested
n_0	3930.00	9091.00	5161.00	2.313	1.313
n_1	4197.00	9791.00	5594.00	2.333	1.333
n_2	4463.00	10789.00	6326.00	2.420	1.420
n_3	4730.00	14041.00	9311.00	2.968	1.968
p_0	3930.00	9091.00	5161.00	2.313	1.313
p_1	4086.00	9454.00	5368.00	2.314	1.314
p_2	4243.00	10320.00	6077.00	2.432	1.432
p_3	4399.00	12709.00	8310.00	2.889	1.889
k_0	3930.00	9091.00	5161.00	2.313	1.313
k_1	4076.00	10272.00	6196.00	2.520	1.520
k_2	4221.00	12161.00	7940.00	2.881	1.881
k_3	4367.00	12747.00	8380.00	2.919	1.919

Cost of 1 kg N = Rs.5.33

Cost of 1 kg P_2O_5 = Rs.6.25 price of arrow root tuber/kg - Re.1/-

Cost of 1 kg K_2O = Rs.2.91

Summary

SUMMARY

A field experiment on arrow root was conducted in order to study the effect of N, P and K on growth, yield and quality of arrow root and uptake pattern of major nutrients. The experiment was laid out in a 4^3 partially confounded factorial in RBD with 0, 50, 100 and 150 kg/ha N, 0, 25, 50 and 75 kg/ha P_2O_5 and 0, 50, 100 and 150 kg/ha K_2O. The results of the investigations are summarised below:

The application of 150 kg nitrogen resulted in the maximum height of the plant. Phosphorus did not exert any influence on this growth character. However, potassium @ 150 kg/ha registered the maximum height of the plant at all growth stages.

The number of leaves were maximum when nitrogen was applied @ 150 kg/ha. The levels of phosphorus and potassium were influencial in increasing the number of leaves though no definite trends were observed.

The number of suckers were maximum when nitrogen was applied @ 150 kg/ha. Phosphate application had no influence on the number of suckers per plant. Potassium application increased the number of suckers per plant and the maximum was observed at 150 kg per hectare.

Nitrogen application influenced the leaf area index and the maximum was observed at 150 kg/ha. Different rates of phosphorus influenced the leaf area index in most of the growth stages. Potassium application increased the leaf area index and the maximum was observed at 150 kg/ha.

The total dry matter production was highest at the highest levels of nitrogen and potassium (150 kg N and 150 kg/ha K_2O). The levels of phosphorus were also influential in increasing the total dry matter production, though no definite trends were observed.

Application of 100 kg/ha N and 150 kg/ha K_2O resulted in the maximum number of rhizomes per plant. Phosphate application did not influence the number of rhizomes per plant.

The length of rhizome was found to be influenced by the levels of nitrogen, phosphorus and potassium. Rhizome length was maximum by the application of 50 kg N, 25 kg P_2O_5 and 150 kg K_2O/ha.

Girth of rhizome were influenced by the levels of nitrogen, phosphorus and potassium. The girth of rhizome was maximum when nitrogen, phosphorus and potassium were applied at rates of 100, 75 and 150 kg/ha respectively.

Maximum mean rhizome weight was obtained by the application of 150 kg N, 75 kg P_2O_5 and 150 kg K_2O per hectare.

The fresh weight of plants was maximum when nitrogen, phosphorus and potassium were applied at the rates of 150, 75 and 150 kg/ha respectively.

Rhizome yield was found to be influenced by the levels of nitrogen, phosphorus and potassium. The rhizome yield was maximum when nitrogen, phosphorus and potassium were applied at the rates of 150, 75 and 150 kg per hectare respectively.

Starch yield of the rhizome was found to be influenced by the levels of nitrogen, phosphorus and potassium and it was maximum with 150 kg N, 75 kg P_2O_5 and 150 kg K_2O per hectare.

Nitrogen application increased the protein content of rhizome and 150 kg/ha N resulted in the maximum value. Protein content was also influenced by higher levels of phosphorus and potassium.

Nitrogen application increased the crude fibre content of rhizome and was maximum at 150 kg/ha N. Phosphorus also influenced the crude fibre content of the rhizome. As the level of potassium increased, the fibre content showed a progressive decrease.

Plant uptake of nitrogen was influenced by the levels of nitrogen, phosphorus and potassium at all growth stages. There was a progressive increase in uptake of nitrogen with advancing age of the crop. Plant uptake of nitrogen was the highest at the highest levels of nitrogen, phosphorus and potassium.

Plant uptake of phosphorus was influenced by the levels of nitrogen, phosphorus and potassium at all stages of the growth. The uptake of phosphorus was highest at the higher levels of nitrogen, phosphorus and potassium.

There was a progressive increase in plant uptake of potassium with advancing age of the crop. Plant uptake of potassium was maximum at the highest levels of nitrogen, phosphorus and potassium.

Available nitrogen content of the soil was highest when nitrogen and phosphorus were applied @ 150 and 75 kg/ha respectively. However available nitrogen content of soil was not influenced by levels of potassium.

Available phosphorus content was significantly influenced by nitrogen and potassium levels and it was maximum at 75 kg/ha P_2O_5.

Available potassium content of the soil was not influenced by the levels of nitrogen and phosphorus and the highest value was observed at 150 kg/ha K_2O.

The economics worked out showed that an application of 150 kg nitrogen, 75 kg P_2O_5 and 150 kg per hectare K_2O gave the maximum net return and benefit cost ratio.

Future line of work

1. It is observed from the present investigation that the yield increases significantly with the highest dose of nitrogen, phosphorus and potassium. A study with the higher doses of N, P and K is necessary to fix the optimum dose of these nutrients.

2. Arrow root requires about 60 days for complete establishment in the field and tuber initiation will start only from 4th month onwards. So basal application of N and K can be avoided. Study may be initiated to find out the optimum stage for fertilizer application.

3. In present study, organic manure application was not included. So study may initiated to assess the effect of organic manure with N, P and K.

4. The present study was carried out as a pure crop. So study have to be conducted to assess the nutrient requirements of this crop when it is grown as intercrop with cassava, banana, coconut and other crops.

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* Original not seen

Appendix

Weather conditions during crop period (February 1988 - Dec. '88)

Sl. No.	Month	Average temperature °C		Total rainfall (mm)	Average Relative Humidity (%)
		Maximum	Minimum		
1	February	32.29	22.52	6.6	78.41
2	March	33.23	25.15	55.3	71.29
3	April	32.83	24.80	49.2	78.63
4	May	32.60	25.40	51.9	71.00
5	June	30.60	23.90	308.0	85.00
6	July	31.10	22.60	204.8	79.00
7	August	30.56	23.89	102.3	75.45
8	September	29.81	23.56	320.6	79.28
9	October	31.14	23.99	11.6	75.80
10	November	31.04	22.97	78.8	71.36
11	December	31.76	22.27	6.4	70.19

NUTRITIONAL REQUIREMENT OF ARROW ROOT (*Maranta arundinacea* L.) AS PURE CROP

BY

REMESAN, K. K.

ABSTRACT OF A THESIS

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

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ABSTRACT

A field experiment was conducted in garden lands of Instructional Farm of College of Agriculture, Vellayani, to study the effect of N, P and K on growth, yield and quality of arrow root and uptake pattern of major nutrients. The treatments in the experiment consisted of four levels of nitrogen (0, 50, 100 and 150 kg/ha N). Four levels of phosphorus (0, 25, 50 and 75 kg/ha P_2O_5) and four levels of potassium (0, 50, 100 and 150 kg/ha K_2O). The experiment was laid out in 4^3 partially confounded factorial in RBD with two replications.

Different growth attributes like height of plants, number of leaves, number of suckers per plant, leaf area index were maximum at higher levels of nitrogen and potassium. The total drymatter production was highest by the application of 150 kg N, 75 kg P_2O_5 and 150 kg K_2O per hectare. The highest value of rhizome number, length of rhizome and girth of rhizome were obtained by the application of 100 kg/N, 75 kg/ha P_2O_5 and 150 kg/ha K_2O. Maximum mean rhizome weight was with 150 kg N/ha, 75 kg P_2O_5 and 150 kg K_2O per hectare. Fresh weight of plants was maximum with highest levels of nitrogen, phosphorus and potassium. Rhizome yield was maximum when nitrogen, phosphorus and potassium were applied at the rate of 150, 75 and 150 kg/ha

respectively. Highest levels of nitrogen, phosphorus and potassium increased the starch, yield and protein content of rhizome. Nitrogen nutrition increased the crude fibre content of rhizome, but potassium application decrease the fibre content. The plant uptake of nitrogen, phosphorus and potassium was maximum at highest level of these nutrients. Maximum benefit cost ratio and net return were obtained by the application of 150 kg/ha N, 75 kg/ha P_2O_5 and 150 kg/ha K_2O.