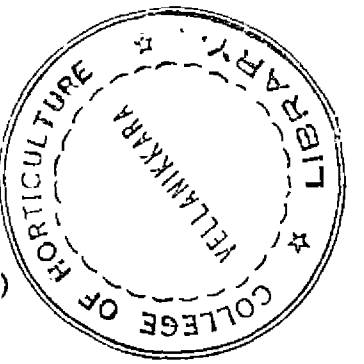
NPK REQUIREMENT OF SHORT DURATION TAPIOCA VARIETIES GROWN IN THE UPLANDS OF KUTTANAD



By

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THESIS

submitted in partial fulfilment of
the requirement for the

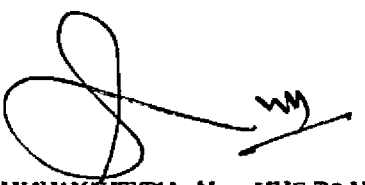
Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
Vellayani, Trivandrum
1986

DECLARATION

I hereby declare that this thesis, entitled "NPK requirement of short duration Tapioca varieties grown in the uplands of Kuttanad" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship, or other similar title, of any other University or Society.



Vellayani,
26th December, 1986.

(SUNNYKUTTY M. KURIAN)

CERTIFICATE

Certified that this thesis, entitled "NPK requirement of short duration Tapioca varieties grown in the uplands of Kuttanad" is a record of research work done independently by Sri.Sunnykutty M. Kurian 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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INTRODUCTION

INTRODUCTION

Cassava, locally known as tapioca is an important carbohydrate rich tropical root crop. The tubers are used for various purposes as food for human being, raw material for industries and as feed for livestock and poultry. The productivity of cassava in terms of biological and calorific yields is significantly higher than that of many cereal crops. It is the staple food of more than 300 million people of the world.

Cassava is cultivated in 90 countries of the world, 80 per cent of the area being located in ten countries. Among these countries, India stands as the nineth country in area and sixth in production.

Fresh tapioca tuber contains 32.4 per cent carbohydrate, 1.0 per cent protein, 0.2 per cent fat, 1.0 per cent fibre and 0.9 per cent ash (Leung et al., 1972).

Cassava is generally grown as a subsistence crop and is able to produce higher yield in soils which are considered poor. The inability of several countries to expand cereal production fast enough to meet the increasing demand often forces them to spend scarce foreign exchange to import cereals. Cassava can help to fill up this gap by increasing total food supplies because production is

possible on land that is not well suited to cereals and other food crops.

Tapioca is rapidly emerging as a crop of considerable importance in India as an important source of carbohydrate. It is the most popular subsidiary food crop of the middle and low income groups of the people in the densely populated state of Kerala. Tapioca is grown over an area of 2.43 lakh hectares in the state which accounts for 80 per cent of the total area of the crop in India. But the per hectare yield of the crop in India is very low (16.77 t/ha) as compared to the yield obtained (100 t/ha) in countries like Australia (Allen, 1979).

A very large number of cassava cultivars are in existance in the major tapioca growing regions of the world. Some of these local varieties are well adapted and largely cultivated in several regions. But most of these varieties are long duration ones, which give an economic yield only after a maturity period of ten months. However, it has been reported from different tapioca growing regions that there are varieties which can give an economic yield at the sixth month.

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Tapioca is an exhausting crop. In spite of its adaptation to low fertility, substantial increase in tuber yield was obtained through adequate fertilization. When cassava is grown, there is a significant drain on the soil nutrient reserves which, if not replenished through balanced fertilization and other agronomic practices, will result in severe reduction in growth and yield of succeeding crops. It is, therefore, essential that the cassava crop is fertilized adequately and systematically.

Different estimates on the average removal of major nutrients by cassava have been reported by several research workers. The variations in the estimates reported from different sources may be due to the differences in the geographical or ecological situations or other variable factors like original fertility status of the soil, the varietal difference, the management practices etc.

Apart from the availability of adequate quantities of nutrients in the soil it is also important to have a proper balance between the nutrient constituents present both in the soil and in the plant. It is known that all

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the essential and other beneficial elements are involved in mutual interactions. The ultimate nutrition of cassava depends both on the levels of the individual nutrients in the soil and on their relative proportions in the plant tissues.

Detailed fertilizer trials to study the effect of N P K on cassava were conducted all over the world and significant responses were obtained in these trials. In Kerala also fertilizer trials were started in cultivator's field during 1953-1957, by Potascheme in collaboration with Messers Parry and Company. The results showed that application of N P K fertilizer increased the yields by 32 to 92 per cent as compared to the cultivator's usual practice of manuring.

All these experiments relate to the long duration tapioca varieties. Practically no fertilizer trial has been initiated to the early maturing tapioca varieties. Though in different places, different varieties of early maturing tapioca types are grown, a standard fertilizer recommendation is not available. In the different workshops and seminars also this problem has been raised by different extension officials with a demand to identify

a suitable variety having a duration of 5-6 months and to suggest a fertilizer recommendation to the same. Under these circumstances this study has been taken up with the following objectives.

1. To study the performance of short duration tapioca varieties and to select the most suitable one for the uplands of Kuttanad.
2. To study the effect of different combinations and levels of N P K on growth, yield and quality of short duration tapioca varieties.
3. To study the interaction effect of nutrition and varieties.
4. To work out the economics of different levels and ratios of N P K on short duration tapioca varieties and to find out the most profitable dose.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An investigation was conducted to identify a suitable variety of tapioca maturing in about five to six months and to find out the effect of different fertilizer doses to such varieties in the uplands of Kuttanad. Good amount of fertilizer studies on tapioca have been conducted in Kerala and elsewhere. But these relate to the long duration varieties only and studies on short duration varieties of tapioca are lacking. Hence results available on the effects of macro nutrients on the productivity and quality of tapioca with normal growth duration have been reviewed and presented below.

2.1. Nutrient removal by tapioca

Tapioca removes large amounts of nutrients from the soil especially nitrogen and potassium in each harvest. Preliminary studies conducted at Central Tuber Crops Research Institute, Trivandrum revealed that a tapioca crop with thirty tonnes of tuber yield removed 180-200 kg nitrogen, 15-22 kg phosphorus and 140-160 kg potash from a hectare (Anon. 1983).

An analysis of the results obtained in fertilizer trials conducted in Tailand during 1954-'67, 1967-'72 and

1975-'77 revealed that in three consecutive cassava croppings, the quantities removed were 103, 69 and 89 kg/ha of N P K respectively in unfertilized plots. When the plots were fertilized with higher rates of fertilizers the nutrient removal increased to 235, 60 and 250 kg/ha of N, P and K (Sittibusaya and Kurmarohita, 1978).

A crop removal to the tune of 164 kg nitrogen and 200 kg potash per hectare was reported for a 30 tonne tuber yield by Asher et al. (1980).

Food and Agriculture Organization of the United Nations conducted approximately 2,50,000 fertilizer trials and demonstrations on tapioca crops in 40 countries. From this they assessed that for maximum yield, cassava required a nutrient ratio of 1:1:2, N : P_2O_5 : K_2O respectively in West Africa and Asia, 1:1.5:1 in Latin America and 2:1:1 in Far East (Richards, 1979).

Howeler (1980) reported that tapioca absorbed potassium and nitrogen in large quantities. On an average, the crop removed about 2.3 kg nitrogen, 0.5 kg phosphorus and 4.1 kg potassium per tonne of roots.

2.2. Nitrogen

This major element is found essential for the

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proper growth and yield of tapioca. But higher rates of application result in excessive top growth at the expense of root growth.

2.2.1. Effect of nitrogen on growth characters

Mandal et al. (1975) reported significant increases in plant height with added nitrogen. They observed significant influence of nitrogen on leaf production and its retention in tapioca plant.

At 30, 60 and 90 days after planting there were no significant differences in plant heights between levels of nitrogen (Natarajan, 1975). But in later stages of growth, the highest level of nitrogen (150 kg/ha) was significant in increasing the plant height. Significant difference in leaf number due to graded levels of nitrogen was observed only in the early growth stages.

Increased leaf growth due to higher levels of nitrogen application was also reported by CIAT (1975).

Increases in plant height, leaf area, leaf area duration and leaf size by incremental doses of nitrogen were observed by Ngongi (1976).

Pillai and George (1978 a) noticed increases in plant height and weight due to higher levels of nitrogen

in H_4 variety of tapioca. But Muthukrishnan (1980) could not find any significant difference in foliage weight due to different rates of nitrogen application.

Asokan et al. (1980) found that nitrogen significantly increased the canopy weight and leaf area index.

Queiroz et al. (1980) also found significant increase in canopy yield by the presence of adequate amount of nitrogen.

Hicks and Fukai (1981) noticed no significant increase in leaf area index due to different levels of nitrogen. LAI often ranged between 3.0 and 3.5.

Holmes and Wilson (1982) reported that high nitrogen supply stimulated leaf growth. The nitrate reductace activity (NRA) was shown to be correlated with leaf growth rate and final leaf size.

A significant increase in plant top yield by nitrogen application was reported by Kang and Okeke (1984).

From the review made above, it was seen that on an average nitrogen application favourably encouraged the vegetative growth characters in tapioca.

2.2.2. Effect of nitrogen on yield components

Vijayan and Aiyer (1969) found that mean number of tubers per plant was increased by increasing the rate of applied nitrogen from 0 to 75 kg/ha. But further increases of nitrogen decreased the tuber number in both varieties of tapioca, M-4 and H-105.

Significant increase in the tuber number of the hybrid H-165 was observed by Mandal and Mohankumar (1972 a) by raising the level of applied nitrogen from 40 kg to 80 kg/ha beyond which there was not much difference.

In another study to find out the effect of varying levels of nitrogen on promising cassava hybrids, Mandal and Mohankumar (1972 b) found that the tuber number and average size of tubers were increased with increase in the levels of nitrogen in all the varieties tried. On the other hand, Natarajan (1975) did not get any increase in tuber number, length, or girth due to higher levels of nitrogen.

Ofori (1976) got positive response in tuber number only upto 67 kg N/ha.

Mohankumar and Mandal (1977) got a significant increase in the number of tubers per plant with increasing

levels of nitrogen.

Acosta and Pinto (1978) did not get any direct relationship between nitrogen and the number of roots per plant. However, the diameter was found increased in roots with application of 120 kg N/ha.

Asokan et al. (1980) noticed that length, girth and number of tubers did not vary significantly due to different levels of nitrogen (60, 120 and 180 kg/ha).

2.2.3. Effect of nitrogen on yield

Significant yield increases due to nitrogen application upto 100 kg/ha were reported by many workers (Mandal and Singh, 1970 and Mandal et al., 1971).

Kumar et al. (1971) found that among different levels of N tried viz., 0, 50, 100, 150 and 200 kg/ha, 100 kg N/ha was found to be the optimum beyond which the yield either tended to decrease or it was not significantly different. They also noticed significant yield increases by the application of nitrogen alone or in combination with phosphorus and potash.

Gomes et al. (1973) reported from Brazil that nitrogen fertilization had no appreciable effect on yield of tapioca. But in Colombia, Howeler (1976) observed

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yield increases due to N upto 200 kg/ha.

A local cultivar gave the maximum yield at 60 kg N/ha whereas the highest yield of another improved cultivar could be obtained only by the application of nitrogen at 120 kg/ha (Obigbesan and Fayemi, 1976). They also observed that higher rates of nitrogen tended to reduce the yield.

Mohankumar and Maini (1977) secured significant yield increases by the application of 100 kg N/ha at Central Tuber Crops Research Institute, Trivandrum.

Yield reduction at higher rates of nitrogen application was reported by CIAT (1978).

Gomes et al. (1979) got significant response to nitrogen application only in one place in a series of experiments carried out at eight places in Brazil. Yield depressions in tapioca to the extent of 11-14 per cent at 150 kg N/ha as compared to 50 kg N/ha were observed by Muthuswamy and Chiranjivi Rao (1979).

Results of field trials conducted in the red sandy loam soils of North Malabar showed significant increases in yield due to higher rates of nitrogen application upto 180 kg/ha (Asokan et al., 1980).

Ramanathan et al. (1980) showed that application of nitrogen at higher levels did not significantly influence the fresh tuber yield, although there was a numerical increase in yield at 120 kg N/ha in field experiments conducted at Coimbatore and Bhavanisagar centres.

Research carried out in Brazil showed that although uptake of N by cassava was high, it did not always result in yield increases. In some cases productivity had been reduced (Gomes and Howeler, 1980).

Kang and Wilson (1980) reported that the nitrogen requirement of cassava was comparatively low.

In a fertilizer trial in four sites at Brazil there was response in the yield at 90 kg N/ha in one centre and there was no response in other centres (Moraes et al., 1981).

Kang and Okeke (1984) established that N application increased plant top yield and foliar N percentage with no significant effect on root yield.

2.2.4. Effect of nitrogen on quality

2.2.4.1. Dry matter content

Varying levels of nitrogen did not produce any

difference in the dry matter content of tapioca tuber (Vijayan and Aiyer, 1969).

Obigbesan and Agboola (1973) recorded reductions in the dry matter yield of tapioca tuber with increasing doses of nitrogen.

Nitrogen nutrition was not effective in making differences in the dry matter content of tuber (Mohankumar and Maini, 1977).

Pillai and George (1978 c) observed significant reduction in the edible portion of tuber by nitrogen fertilization.

Rate of dry matter production was found to be a linear function of LAI upto 80 days after planting and thereafter associated with NAR upto final harvest (Barrus et al., 1978).

Total dry matter yield increased with N application and the maximum was reached at approximately 40-80 kg N/ha (Keating and Evenson, 1981).

2.2.4.2. Starch content

Many workers have reported the beneficial effect of nitrogen nutrition in increasing the starch content of

tapioca tuber (Mandal et al., 1971; Natarajan, 1975 and Pillai and George, 1978 c).

Obigbesan and Agboola (1973) observed increases in starch content with higher doses of nitrogen in one variety of tapioca, while it decreased in another variety.

Starch content of tubers was not affected by the level of nitrogen (Mohankumar and Maini, 1976 and Muthuswamy and Chiranjivi Rao, 1979).

2.2.4.3. Crude protein content

Crude protein content of tubers of M-4 variety of tapioca was found to increase from 1.93 per cent with 50 kg N/ha to 2.13 per cent with 100 kg N/ha (Pillai and George, 1978 c).

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

2.2.4.4. HCN content

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

Several workers showed that high rates of nitrogen application increased the HCN content of tubers

(Obigbesan, 1973; Mohankumar and Maini, 1976 and Muthukrishnan, 1980).

Muthuswamy and Rao (1981) found that HCN content significantly increased with N application.

Nair (1982) also got an increased HCN content of tubers with higher levels of nitrogen application at Vellayani and Kayamkulam in two seasons of the trials conducted.

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

2.2.4.5. Cooking quality

Cooking quality of tubers assessed by a taste panel was found to be reduced significantly by higher level of nitrogen (Prema et al., 1975).

Nair (1976) observed a high percentage (75%) of non bitter tubers at 50 kg N/ha as compared to 63 per cent in the case of 75 kg N/ha and 69 per cent in the case of 100 kg N/ha. Nitrogen application at 75 kg/ha produced a higher percentage of soft textured tubers as against a

lower percentage observed in nitrogen application at the rate of 50 and 100 kg/ha.

A definite influence of the levels of nitrogen on the cooking quality of tubers could not be observed by Mohankumar and Maini (1977).

Sheela (1981) also reported reduction in cooking quality of tuber due to higher levels of nitrogen application.

Nair (1982) observed a reduction in cooking quality of tubers by higher levels of nitrogen.

2.2.5. Effect of nitrogen on nutrient uptake

Mohankumar and Nair (1969) noticed increases in the percentage of nitrogen and potassium in plant parts with increases in the rate of nitrogen application.

On the basis of field experiments conducted in the acid laterite soils, Rajendran et al. (1976) observed an increased potassium uptake by higher doses of nitrogen.

Pushpadas et al. (1976) recorded increases in nitrogen content of plant with higher levels of nitrogen nutrition.

A decrease in phosphorus and potassium contents of leaf blade and stem of tapioca was observed by

Okeke et al. (1979) due to nitrogen nutrition. But petiole potassium showed a linear response to applied nitrogen.

Nair (1982) observed a significant influence of nitrogen nutrition on the uptake of potassium during the different growth stages of the crop.

2.3. Potassium

Tapioca requires adequate supply of potassium for the synthesis and translocation of starch. Sreeponk (1977) reported that the primary factor limiting cassava production was potassium availability. Potash deficiency would not only reduce tuber yields but also unfavourably affect the quality traits such as starch content of tubers.

2.3.1. Effect of potassium on growth characters

Ngongi et al. (1976) reported increases in plant height, leaf area and leaf size with incremental doses of potash from 0-240 kg/ha. But maximum values of plant fresh weight and total dry matter were observed at low levels of potash application.

Several investigators could not get significant response to levels of potassium on such growth characters as plant height, number of leaves and topyield (stem and

leaves) of tapioca (Pushpadas and Aiyer, 1976 and Ramaswamy and Muthukrishnan, 1980).

Asokan and Sreedharan (1980) observed increases in plant height and top yield at higher levels of potash application.

Ramanujam (1982) observed increases in plant height, nod number, leaf size and leaf area index by potassium fertilizers as compared to control in cassava variety H-2304. But application of potassium beyond 50 kg K_2O/ha showed no appreciable change in leaf area index, crop growth rate and dry matter production.

Nair (1982) also showed significant differences in plant height during growth stages at two locations to different rates of potassium. But the effect of potassium was not significant in number of leaves and leaf area index.

Kang and Okeke (1984) observed that K application significantly increased plant top yield and foliar K content.

2.3.2. Effect of potassium on yield components

Mandal and Mohankumar (1972 a) noticed no differences in the number of tubers by the application of low levels of potash ranging from 40-80 kg/ha. But tuber

number was significantly high at 120 kg K_2O/ha.

Application of potash beyond 100 kg/ha had no significant influence on tuber size (Mohankumar and Hrishi, 1973).

The highest rate of flesh to rind was obtained by an application of 150 kg/ha of K (Natarajan, 1975).

Ofori (1976) observed that the tuber number and tuber weight were increased by K application.

Higher rates of potassium did not influence tuber number but significant difference in tuber size was observed. Harvest index was not affected by the sources or rates of potassium tried (Ngongi et al., 1976).

Pushpadas and Aiyer (1976) also observed that K application increased the edible portion of the tuber.

Eventhough, Godfrey and Garber (1978) could get significant increases in the weight of storage roots of cassava by potassium fertilization, no significant influence was noticed in the number of storage roots.

Pillai and George (1978 b) showed that application of K increased the weight of edible portion.

The beneficial effect of potassium in increasing the utilization index of tapioca was reported by Obigbesan (1977).

Asokan and Sreedharan (1980) found that utilization index showed a decrease beyond the application of 75 kg K_2O/ha.

The number of roots and root weight were not significantly affected by the different levels of K_2O applied (Magalhaes et al., 1980).

Nair (1982) reported an increase in the tuber number at Kayamkulam and Vellayani at different rates of applied potassium. Incremental doses of potassium increased tuber weight significantly upto the highest level. The length and girth of tuber were not influenced by the levels of potassium. Utilization index increased significantly due to potassium nutrition.

Mohankumar et al. (1984) found that plots receiving potash alone were seen to produce smaller tubers.

2.3.3. Effect of potassium on yield

The reasons for poor yield of cassava were attributed to the low consumption of fertilizers per unit area by this crop and the disproportionately less use of K (Kanwar, 1974). It was also seen that K was the main element responsible for limiting the yield of this crop, which was reported to be a heavy feeder of K (Anon. 1975).

Pushpadas and Aiyer (1976) secured maximum tuber yields for a hybrid variety of tapioca H-105 with 250 kg K_2O/ha.

Yield depressions in cassava were reported at high rates of potash application by CIAT (1974).

Rajendran et al. (1976) reported that 100 kg K_2O/ha was the optimum dose and higher rates resulted in luxury consumption.

Experiment at Vellayani showed that there was no significant difference in yield between K levels of 50 kg and 100 kg/ha whereas 150 kg level gave a maximum yield of 38.36 t/ha (Natarajan, 1975).

In a trial to study the potassium tolerance of cassava cultivars by application of 0-220 kg K_2O/ha, it was observed that lack of potassium reduced yields to 70 per cent of maximum (CIAT, 1977).

Sitiboot et al. (1978) studied the growth response of cassava to different rates of potassium in two soil types of low available K (18 and 20 ppm). The treatments consisted of 0, 50, 100, 200 and 400 kg K_2O/ha while the yield increase at 200 kg K_2O/ha over the control was 64 per cent in one soil type, it was only 21 per cent in the other soil.

Gomes et al. (1979) got significant response to K application in two out of eight experiments conducted in Brazil.

Asokan and Sreedharan (1980) noticed maximum tuber yield at 112.5 kg of K_2O/ha.

Nair et al. (1980) tried different levels and sources of potassium on yield. Among the different levels tried 100 kg K_2O/ha was found to be the optimum for tuber yield.

Asokan et al. (1980) reported a significant reduction in the tuber yield when the application of potash was increased to 180 kg/ha and they got a maximum yield for a hybrid variety H-105 at 120 kg/ha.

Higher levels of potassium could not produce significant yield increases in tapioca (Ramaswamy and Muthukrishnan, 1980).

Patterson et al. (1981) from Australia reported that they did not get any response to the application of K.

Ramanujum (1982) noticed yield response to potassium nutrition in tapioca only upto 50 kg K_2O/ha. Potassium application resulted in a yield increase of 10-16 per cent over control.

Nair and Kumar (1982 a) reported that 100 kg K_2O/ha is the optimum for tuber yield of cassava. Cultivar H-97 gave a yield of 30.74 t/ha with 100 kg K_2O/ha as compared to 25.54 t/ha in no K treatment.

Gomes and Ezeta (1982) found that on soils with a K content of 77 ppm, there was no response to the levels of application of K while in another soil with 43 ppm K the application of 80 kg K_2O/ha increased production from 10.9 to 21.5 t/ha.

Kang and Okeke (1984) also reported a significant increase in root yield by K application.

2.3.4. Effect of potassium on quality

2.3.4.1. Dry matter content

Obigbesan (1973) observed increase in tuber dry matter content with higher rates of potassium application.

Obigbesan and Agboola (1973) also reported similar results.

Pushpadas and Aiyer (1976) noticed the highest percentage of dry matter with potassium nutrition of 125 kg K_2O/ha.

Pillai and George (1978 c) also reported an increase in dry matter content with K application.

Asokan and Sreedharan (1980) obtained maximum values of dry matter with 75 kg/ha of potash application.

Keating and Evenson (1981) observed that application of K increased total dry matter yield upto rates of 400-480 kg K_2O/ha for one variety and 360-440 kg K_2O/ha for another variety.

Nair (1982) also got a significant effect at all growth stages in the root, leaf and stem dry matter production by the application of potash.

2.3.4.2. Starch content

The effect of potassium nutrition in enhancing the starch content of tubers was observed by several workers (Obigbesan and Agboola, 1973; Natarajan, 1975; Muthuswamy and Chiranjivi Rao, 1979 and Muthukrishnan, 1980).

Pushpadas and Aiyer (1976) secured highest starch yield per hectare with 250 kg K_2O/ha.

Pillai and George (1978.c) also reported increase in starch content by application of potassium.

Linear increases in starch yield with higher rates of potassium application upto 200 kg K_2O/ha were reported by CIAT (1979).

Gomes et al. (1980) also reported a favourable increase in starch content by K application.

Nair et al. (1980) noticed that increasing levels of K application resulted in an increase in starch content.

Relationships of soil K and leaf K with cassava yield and starch content were established in a trial conducted on an oxisol at the Malaysian Agricultural Research and Development Institute, Malasia. Results showed that leaf K was a better indicator of starch yield than water soluble soil K. The optimum leaf K for maximum starch yield was 2.11 percentage (Chan and Lee, 1982).

Nair and Kumar (1982 b) noticed only a slight increase in starch content by potassium fertilizers.

2.3.4.3. Crude protein content

Levels of potassium exerted no influence on the crude protein content of tubers (Mandal and Singh, 1970). But Natarajan (1975) noticed significant reduction in crude protein content of tubers by the application of higher levels of potassium.

Similar results were obtained by Pushpadas and Aiyer (1976) and Pillai and George (1978 c).

Asokan and Sreedharan (1980) reported a decrease in crude protein content with K application.

A decrease in crude protein was also reported by Nair (1982) due to potash application.

2.3.4.4. HCN content

Potassium alone or in combination with nitrogen reduced the HCN content of tapioca tubers (Indira et al., 1972).

Appreciable reduction in HCN content of cassava tubers by higher levels of potassium nutrition was reported by Obigbesan (1973) and Natarajan (1975).

Muthuswamy and Rao (1981) also reported a reduction in HCN content by potash application.

Ramanujam (1982) reported reduction in the HCN content of tubers and leaves of tapioca variety H-2304 by potassium nutrition. The lower dose of K_2O (50 kg/ha) was not effective in reducing the HCN concentration. But by the application of potash beyond 100 kg K_2O/ha, the HCN content was reduced by 40 to 76 per cent as compared to the control.

Nair and Kumar (1982 b) studying the effect of different sources and levels of potassium on the yield

and quality of tubers, found that higher levels of potassium application resulted in a decrease in the HCN content.

Nair (1982) also reported a significant decrease in HCN content by different rates of potassium.

2.3.4.6. Cooking quality

Kurian et al. (1973) reported that by the application of woodash alone or a mixture of cowdung and woodash, the quality of tubers was improved by reducing bitterness.

Appreciable improvement in cooking quality as measured by the bitterness of tuber, at a higher rate of potassium nutrition (150 kg K_2O/ha) was observed by Asokan and Sreedharan (1980).

Nair (1982) reported a better cooking quality of tubers at Vellayani and Kayamkulam with potassium application.

2.3.4.7. Effect of potassium on nutrient uptake

Mohankumar and Nair (1969) noticed an increase in potassium uptake by plant parts and a decrease in nitrogen content by potassium fertilization.

Spear et al. (1978) showed that high concentration of potassium in solution reduced the uptake of calcium and magnesium by cassava.

Nair and Kumar (1982 b) found an increase in potassium content of plant parts by higher rates of potassium nutrition.

Chan and Lee (1982) obtained significant correlations between applied K and water soluble soil K and between applied K and leaf K.

From the review made, it could be seen that potassium plays an important role in the growth, yield and quality of tapioca.

2.4. Phosphorus

In the experiments conducted at Central Tuber Crops Research Institute, Trivandrum, in acid laterite soils of low available P content (10-15 kg/ha), cassava responded to P application upto 100 kg P_2O_5/ha beyond which the yield increase was not significant (Anon. 1983).

Gomes et al. (1979) showed that yield of cassava increased significantly with P fertilization.

An experiment was conducted in Brazil to determine the effects of the sources and levels of P fertilization on

cassava. The incremental rates of the nutrient increased P and Mg contents in the limb. It also affected Harvest Index significantly (Souza, 1979).

Correa et al. (1979) found that when 90 kg P_2O_5 was applied per hectare, highest yields were obtained even in the absence of N and K.

The physiologically inferior root system of cassava required a much higher external P concentration than other plant species to achieve 95 per cent of the maximum yield (Jintakanon et al., 1979).

From the review of literature, Gomes (1979) highlighted that although P was required in lower amounts, it was still limiting to the production and suggested that 80-120 kg P_2O_5 would be applied per ha.

Cadavid (1980) obtained a positive response upto 100 kg P_2O_5/ha and less response at 400 kg/ha in an experiment in which four levels of P tried (0, 50, 100 and 400 kg P_2O_5/ha).

Arismendi (1980) found that P was the most limiting nutrient element for root production in cassava followed by N and K.

Gomes and Howeler (1980) also reported the favourable effect of P in increasing the root yield.

An experiment was conducted on a yellow podzolic soil in Australia to evaluate the response of cassava to the band application of different levels of P. The response of P fertilizer treatments was generally small. But root yields at 100 kg P_2O_5/ha were significantly greater than 0 and 50 kg P_2O_5/ha treatments (Hicks and Fukai, 1981).

Moraes et al. (1981) reported an yield increase upto the application of 80 kg P_2O_5/ha.

Studies were carried out in Brazil to determine economic rates of P to cassava crops. The 4 levels of P tried (0, 40, 80 and 120 kg/ha) did not show statistical difference among themselves in canopy yield. Regarding root yield the application of 120 kg P_2O_5/ha gave the highest yield. There was no difference among treatments regarding starch content (Magalhaes, 1981).

Cadavid and Howeler (1982) reported a significant increase in yield with 200 kg P_2O_5/ha without N and K.

Nair and Prabhakar (1984) reported highest yields with 25 kg P_2O_5/ha. P uptake was also highest at this

dose, but the difference between the various levels were not significant.

From the above review it could be seen that tapioca required appreciable quantity of phosphorus for its higher yield, the magnitude of which varied according to situations.

2.5. Combined effect of nitrogen, phosphorus and potassium

Cassava requires higher levels of nitrogen and potassium and small amount of phosphorus to produce maximum yields. But the crop is sensitive to over fertilization, which causes excessive top growth and little root growth. The indiscriminate use of large amount of inorganic fertilizers also leads to serious nutritional imbalances. The yield and quality of tubers depend both on the level of individual nutrients and on their relative quantities.

Studies at C.T.C.R.I., revealed that cassava with a yield of 30 t/ha removed 180 kg N, 22 kg P_2O_5 and 160 kg K_2O/ha (Mohankumar et al., 1984).

Sittibusaya and Kurmarohita (1978) reported that in South East Thailand, after 15 years of continuous unfertilized situation, the yields dropped from an initial

level of 30 t/ha to only 17 t/ha. When the soils were fertilized with 375 kg N, 164 kg P_2O_5 and 312 kg K_2O/ha, yields increased from 22 to 41 t/ha.

Okeke et al. (1982) studied the effect of fertilizer and plant age on distribution of nutrients in Nigerian cassava. They identified the third month from planting as the most sensitive stage for diagnostic sampling when N and P status were best reflected in leaf blades and K in petioles. The largest root tuber yields after 12 months were associated with leaf blade analysis of 5.0 per cent N, 0.4 per cent P and 2.0 per cent K at 3 months after planting.

Acosta and Pinto (1978) obtained highest yields of 21 t/ha with the application of 120-90-60 kg N, P_2O_5 and K_2O/ha.

Sereeponk (1977) studied the effect of different fertilizer formulae on yield and he got the formulae 6-12-12 and 6-6-12 for the higher yields of 2939 kg and 2753 kg/rai.

Goomarohit (1975) reported that analysis of leaves and stems of 5 and 10 months old plants showed good corelation with yield. They found that nutrient uptake was correlated with yield parabolically.

Nakviroj et al. (1971) concluded that 50-100 kg N/ha in combination with 100 kg P_2O_5 and 50 kg K_2O/ha was the most suitable for high root production.

Cotejo junior and Talatala (1978) obtained optimum yield at 90:60:60 NPK level/ha.

Cock (1979) studied the crop growth rate in tapioca. They found that root growth rate increased upto LAI 3-3.5, then declined.

Gomes et al. (1979) opined that a better response of P was noticed in the presence of N and K.

Obigbesan and Fritz (1980) reported a plant nutrient uptake of the whole cassava plant with dry matter yield of 10.5 t of tops and 12.4 t of roots/ha amounts to 145, 98 and 569 kg of N, P_2O_5 and K_2O/ha respectively.

Ramaswamy and Muthukrishnan (1980) did not get any significant difference due to different fertilizer treatments on three varieties of tapioca at the Tamil Nadu Agricultural University.

Field trials were carried out in soils of low fertility to investigate the behaviour of four cassava varieties treated with different levels of fertilization. The fertilization rates were 0-0-0, 20-40-30 and 40-80-60 kg

of N, P_2O_5, K_2O/ha. Regarding root yields the results showed significant difference among varieties. A positive linear effect of fertilization was also noticed (Lorenzi et al., 1980).

Lorenzi et al. (1981) got greatest dry matter accumulation between 120-180 days after sprouting with an average of 105 kg/ha/day.

Nair (1982) reported that 125 kg N and 125 kg K_2O/ha gave the maximum tuber yield at Vellayani, Trivandrum. At Kayamkulam where the soil was sandy loam the combination of 125 kg N and 200 kg K_2O/ha applied in three splits resulted in highest tuber yield.

Cadavid and Howeler (1982) obtained optimum yield with a combination of 100-200-150 kg N, P_2O_5 and K_2O/ha in Latin America.

Sushama et al. (1982) reported a significant positive correlation between leaf area and root yield.

Economic analysis indicated that cassava grown in a soil treated with N, P_2O_5, K_2O at 60-45-120 gave significantly higher net returns (Ramos and Mojica, 1982).

Howeler (1983) suggested the critical levels for N, P_2O_5 and K_2O in leaves as 4.7 per cent 0.3 per cent and

1.0 per cent at 3-4 months of age.

Results on yield trials of five experiments in Columbia showed that treatments consisting of 60-90-60 kg N, P_2O_5 and K_2O gave better yield (Cepedav and Acostar, 1983).

It was well established that potassium was effective only in the presence of nitrogen.

A study of N x K interaction, with levels of 0, 100 and 200 kg/ha nitrogen and 0, 150 and 300 kg/ha of potash (CIAT, 1975) showed that cassava responded to nitrogen only in the presence of potassium and this response was positive only upto 100 kg/ha nitrogen where as the application of 200 kg/ha of nitrogen resulted in a negetive response. From an investigation with four cassava varieties including H-2304 to ascertain the response to different combinations of nitrogen and potassium, Nair (1976) got significant yield increase with the application of nitrogen at 100 kg/ha and potash at 150 kg/ha. Highest tuber number was noted in the treatment with nitrogen and potash at 75 kg and 225 kg/ha respectively. HCN and starch contents of tuber were unaffected by NK combinations.

CIAT (1977) recorded a decreasing trend in the values of harvest index of tapioca by nitrogen and potassium applications.

In a multilocation trial, Ramanathan et al. (1980) reported significant tuber yield increases due to different levels of nitrogen and potassium at Bhavanisagar only. The highest tuber yield was obtained by a combined application of nitrogen and potash at 80 kg and 120 kg/ha respectively. Starch content was maximum in this NK combination. At Coimbatore, the tuber yield was not influenced by fertilizer levels.

Indira (1982) reported decreases in HCN content of cassava tubers by the application of nitrogen and potassium. But differences in crude protein content was not significant due to treatments.

The above review indicated that there would be a proper nutritional balance among nitrogen, phosphoric acid and potash for the efficient utilization of the different nutrients by the tapioca plant. Determination of the optimum rate of fertilization and the proper balance of nutrients are of great importance. For short duration tapioca varieties the nutritional studies are lacking.

MATERIALS AND METHODS

The present investigation was undertaken to select a suitable early maturing variety of tapioca for the uplands of Kuttanad and to work out a fertilizer dose suitable for the variety. The details of the materials used and methods adopted in the experiment are given in this chapter.

3.1. Materials

3.1.1. Experimental site

The experiment was carried out in the Regional Agricultural Research Station, Kumarakom, Kottayam. The crop was raised on the bunds which represent the upland conditions of Kuttanad. The station is located at 9° 30' N latitude and at an altitude of 0.6 metres below MSL.

3.1.2. Soil

The soil type of the experimental area is reclaimed alluvial. The results of analysis of the soil before starting the experiment are given below.

A. Mechanical composition

Coarse sand	-	8.5 per cent
Fine sand	-	34.9 ,,
Silt	-	20.6 ,,
Clay	-	30.6 ,,
Organic matter	-	5.4 ,,

B. Chemical composition

pH	-	4.7
Total nitrogen	-	0.168 per cent
Available P_2O_5	-	0.0031 ,,
Available K_2O	-	0.0711 ,,

3.1.3. Season

The experiment was conducted during the period from 20-10-1984 to 23-4-1985. The season represents the main season of the region for the crop and the second main planting season in the State.

3.1.4. Weather conditions

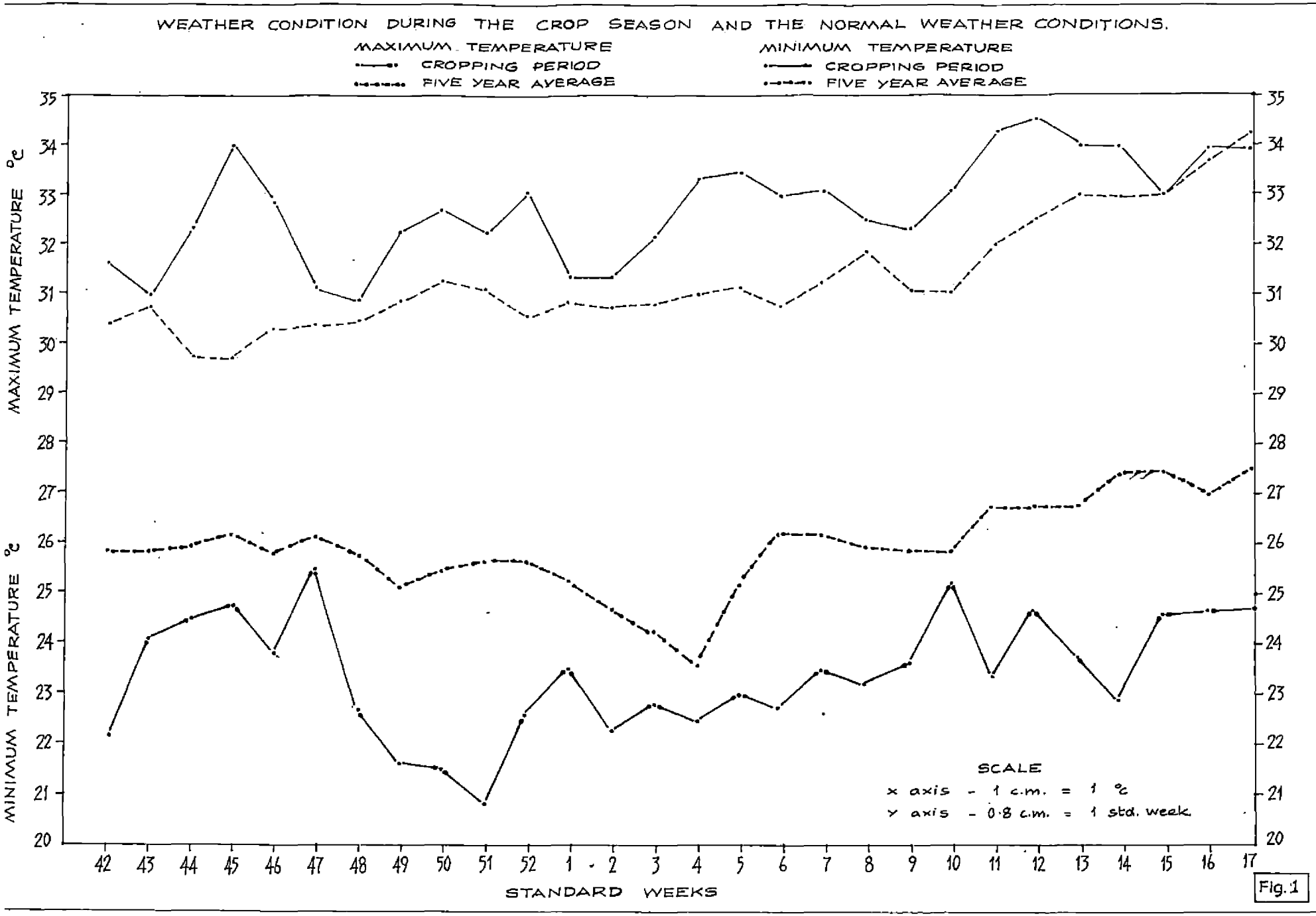
The meteorological parameters such as maximum and minimum temperature, rainfall and relative humidity during the entire crop period were recorded from the meteorological observatory of the R.A.R.S., Kumarakom.

The average weekly values as well as the average values for the past five years were worked out and presented in Appendix I and in Figure 1 and 2.

The weekly average for maximum temperature during the cropping period ranged between 34.57°C and 30.71°C and the minimum between 25.64°C and 20.93°C. The weekly average maximum temperature was highest during 19-3-1985 to 25-3-1985 (Standard week 12) and the weekly average for the minimum temperature was lowest during the period from 17-12-1984 to 23-12-1984 (Standard week 51). There was no appreciable variation between the values recorded for the cropping period and the average values of the corresponding period for the past five years.

During the cropping period there was 530.40 mm rainfall distributed over 26 days and the pattern of rainfall was more or less similar to that of the past five years. However, quantity of rainfall received during the cropping season was slightly higher than the average for the corresponding period (450.25 mm).

The relative humidity during the cropping period ranged between 82.0 per cent and 61.0 per cent without much variation from the mean for the past five years.


WEATHER CONDITION DURING THE CROP SEASON AND THE NORMAL WEATHER CONDITIONS.
MAXIMUM TEMPERATURE
CROPPING PERIOD
FIVE YEAR AVERAGE
MINIMUM TEMPERATURE
CROPPING PERIOD
FIVE YEAR AVERAGE
MAXIMUM TEMPERATURE °C
MINIMUM TEMPERATURE °C
35
34
33
32
31
30
29
28
27
26
25
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22
21
20
42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
STANDARD WEEKS
SCALE
x axis - 1 c.m. = 1 °c
y axis - 0·8 c.m. = 1 std. week.

Fig. 1

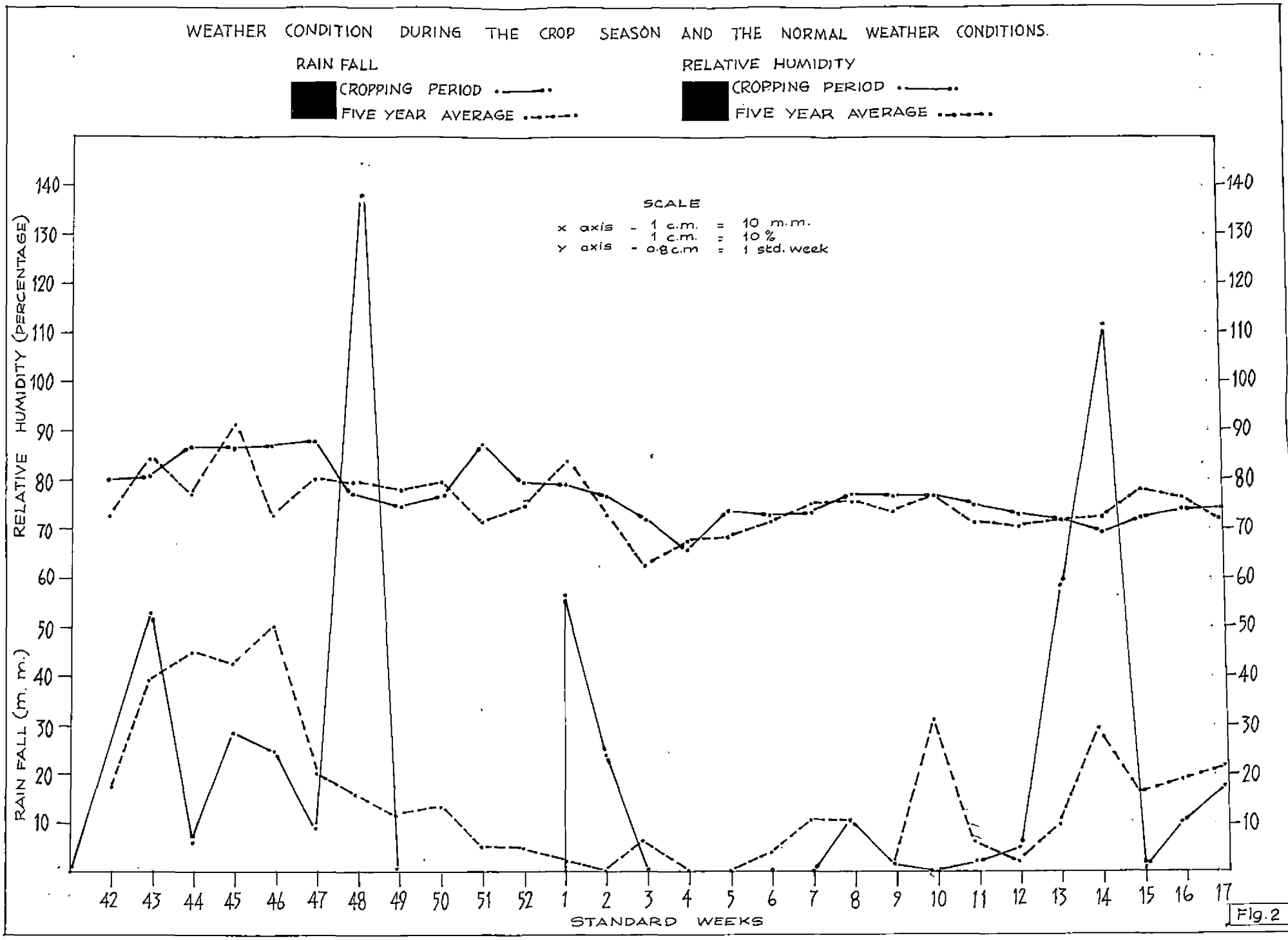

WEATHER CONDITION DURING THE CROP SEASON AND THE NORMAL WEATHER CONDITIONS.
RAIN FALL
CROPPING PERIOD
FIVE YEAR AVERAGE
RELATIVE HUMIDITY
CROPPING PERIOD
FIVE YEAR AVERAGE
SCALE
x axis - 1 c.m. = 10 m.m.
1 c.m. = 10 %
y axis - 0.8 c.m = 1 std. week
RELATIVE HUMIDITY (PERCENTAGE)
RAIN FALL (m. m.)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
42 43 44 45 46 47 48 49 50 51 52 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
STANDARD WEEKS

Fig. 2

In general, the cropping season was favourable for the satisfactory growth of the crop.

3.1.5. Cropping history

The experimental area was lying fallow for the previous one year and before that the area was under fodder grasses uniformly.

3.1.6. Planting materials

Three cultivars of tapioca were used for the experiment namely Thottakolli, Kaduthuruthy local and Sree Sahya. Thottakolli which has been reported to be a short duration variety is extensively cultivated in Chalakudy area of Trichur District and harvested usually within six months after planting. It is a non-branching variety with moderate yields. Kaduthuruthy local is popularly cultivated in Kaduthuruthy, Kuravilangad, Arpookara areas of Kottayam District. It is a tall growing non-branching variety harvested usually within six months after planting. The third variety used was Sree Sahya (H-2304) released by C.T.C.R.I. during 1977.

The planting materials of the two local varieties were collected from the respective farmer's field and Sree Sahya from C.T.C.R.I., Trivandrum.

3.1.7.Fertilizers and manures

Urea analysing 46.00 per cent N, superphosphate analysing 16 per cent P_2O_5, muriate of potash analysing 60.00 per cent K_2O and farm yard manure analysing 0.46 per cent N, 0.30 per cent P_2O_5 and 0.27 per cent K_2O were used for the trial.

3.2.Methods

3.2.1.Design and layout

The experiment was laid out in factorial Randomised Block Design with three replications. The lay out plan of the experiment is given in Figure 2.

Treatments

The trial was conducted with three varieties and five fertilizer combinations.

Varieties : 3

V_1 - Thottakolli

V_2 - Kaduthuruthy local

V_3 - Sree Sahya

LAYOUT PLAN

REPLICATION - I

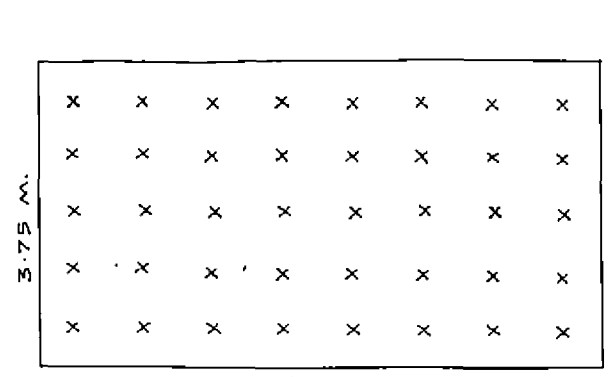
V_1L_1	V_3L_5	V_2L_1	V_2L_3	V_1L_5	V_2L_5	V_3L_2	V_3L_1	V_2L_4	V_1L_2	V_1L_3	V_3L_4	V_2L_2	V_1L_4	V_3L_3

REPLICATION - II

V_1L_2	V_3L_3	V_2L_2	V_1L_4	V_2L_5	V_2L_4	V_1L_3	V_3L_5	V_3L_1	V_1L_1	V_2L_1	V_3L_2	V_1L_5	V_3L_4	V_2L_3

REPLICATION - III

V_3L_1	V_2L_4	V_2L_5	V_1L_4	V_2L_1	V_2L_3	V_1L_5	V_3L_4	V_1L_2	V_2L_2	V_3L_5	V_1L_3	V_3L_3	V_3L_2	V_1V_2



SINGLE PLOT ENLARGED

DESIGN - FACTORAL R.B.D.

TREATMENTS

VARIETIES

V_1 - THOTTAKOLLI

V_2 - KADUTHURUTHY LOCAL

V_3 - SREE SAHYA

FERTILIZER COMBINATION

	N	P_2O_5	K_2O	
L_1	30	30	30	Kg./ha.
L_2	30	30	45	"
L_3	50	50	50	"
L_4	50	50	75	"
L_5	50	50	100	"

Fig. 3

Fertilizer combinations : 5

	N	P_2O_5	K_2O
L_1	30	30	30 kg/ha
L_2	30	30	45 ,,
L_3	50	50	50 ,,
L_4	50	50	75 ,,
L_5	50	50	100 ,,

Treatment combinations

(1) V_1L_1	(6) V_2L_1	(11) V_3L_1
(2) V_1L_2	(7) V_2L_2	(12) V_3L_2
(3) V_1L_3	(8) V_2L_3	(13) V_3L_3
(4) V_1L_4	(9) V_2L_4	(14) V_3L_4
(5) V_1L_5	(10) V_2L_5	(15) V_3L_5

Number of replications : 3

Total number of plots : 45

Spacing : 75 x 75 cm

Number of boarder rows : one row all around the plot.

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Plot size

Plot size (gross)	:	6 m x 3.75 m
Plot size (net)	:	3.75 m x 2.25 m
Total number of plants/ plot (gross)		40
Number of plants used for destructive sampling		3
Total number of plants/ plot (net)		15

3.2.2. Details of cultivation

Land preparation

The experimental area was dug twice, stubbles were removed, clods were broken and the field was laid out into blocks and plots. Mounds were raised at a distance of 75 cm in both ways.

Manuring

A uniform basal dose of 12.50 t/ha of farm yard manure was applied and well incorporated into the soil uniformly before taking mounds.

Fertilizer application

The different nutrients as per the treatments were applied in the form of urea, superphosphate and muriate of

potash respectively. Fertilizer application was done as per package of practices recommendations P full basal, N and K in three equal split doses.

Planting

Planting of tapioca was done on 20-10-1984. Tapioca setts of 20 cm length were planted on the top of the mounds.

After cultivation

Germination of setts was good. Excess sprouts were removed after retaining two healthy and vigorous shoots per sett.

The first earthing up and first top dressing of fertilizers were given on 20-12-1984. Second top dressing of fertilizer was given on 20-1-1985.

General condition of the crop

The general condition of the crop was satisfactory throughout the period of growth.

Harvest

Tapioca was harvested on 23-4-1985, six months after planting.

3.2.3.Observations recorded

Sampling technique for biometric studies

Four plants were selected at random from each plot for taking the detailed biometric observations at different stages. Averages of the observations were subjected to statistical analysis.

Observations on growth characters

Height of the plant

Cumulative height of the shoot of each plant was measured from the base of the sprouts to the top of the unopened bud at bimonthly intervals starting from the second month after planting to harvest.

Number of leaves per plant

The total number of leaves were recorded by counting the number of fully opened leaves as well as the leaf scars from the base to the tip of the shoot. The observation was recorded at bimonthly intervals from 60 days after planting to harvest.

Leaf area index

The leaf area was calculated using linear measurement method suggested by Ramanujam and Indira (1978).

The leaf area index was worked out by the following formula suggested by Watson (1947).

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

Observations on yield and yield attributes

Post harvest observations

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

Total number of roots per plant

The total number of roots including productive and unproductive ones was recorded at the time of harvest.

Number of tubers per plant

The total number of fully developed tubers from the observation plants was recorded and average per plant worked out.

Percentage of productive roots

The percentage of productive roots in each plant was worked out using the number of tubers per plant and the total number of roots per plant.

Length of tubers

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

Girth of tubers

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

Rind to flesh ratio

A random sample of fresh tubers was taken from each plot. The tubers were peeled and the rind weight and flesh weight were found out separately. From this, the rind to flesh ratio was worked out.

Tuber yield

Tuber yield per plot was recorded at the time of harvest after removing the soil adhering to the tubers. This value was expressed in tonnes of tubers per hectare.

Top yield

After removing the tubers, the total weight of the

stem and leaves was recorded per net plot and converted into tonnes per hectare.

Utilisation index

According to Obigbesan (1973) this is an important yield determinant factor and is the ratio of the tuber weight to the top weight (stem and leaves). This was found out from the observations recorded in tuber weight and top weight of the observational plants.

Observations on quality attributes

Dry matter content of tuber flesh

Uniform quantity of fresh tuber flesh was taken from each plot and chopped into small pieces and dried to constant weight in an air oven. The weight of dry matter expressed as percentage of the fresh weight gave the dry matter content of tuber flesh (A.O.A.C., 1969).

Starch content of tubers

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

Crude protein content of tubers

The total nitrogen of oven dried samples from each plot was estimated using Modified micro-kjeldahl method

(Jackson, 1967). To get the crude protein content of the tuber, the nitrogen values were multiplied by the factor 6.25 (A.O.A.C., 1969).

Hydrocyanic acid content of tubers

The HCN content of fresh tubers was estimated by the colorimetric method of Indira and Sinha (1969) and expressed in µg per g of fresh tuber.

Cooking quality

Cooking quality of the tuber was assessed by judging the bitterness and plumpiness. The sensory method of analysis by a taste pannel was used in differentiating cooking quality (Jellinck, 1964).

Since the sensitivity in taste determination test is likely to be affected by increasing the number of samples, only three treatments (three varieties) were tested for cooking quality (Prema et al., 1975).

Fresh tubers of the above treatments were combined over replications. A random sample of about three kg of fresh tubers was taken from each of the treatments. These samples were used for the cooking quality test. The samples were derinded cut into pieces of about five cm

long, washed and cooked in three earthern pots giving uniform time.

Members of the taste pannel were served with the samples. Taste was assessed on a discrete scale. The best taste was described as sweet and a score of two was used. The other scores in the decreasing order of taste were watery sweet (1), starchy (0), bitter (-1) and watery bitter (-2).

3.2.4. Plant analysis

Samples collected for chemical studies were dried at 80°C ± 5, ground in a willey mill and used for chemical analysis. Nitrogen, phosphorus and potassium contents of tuber, stem and leaves were separately analysed.

Nitrogen content

The total nitrogen content of the sample was determined by the modified micro-kjeldahl method (Jackson, 1967).

Phosphorus content

Phosphorus content was determined by Vanado-molybdo-phosphoric yellow colour method (Jackson, 1967).

Potassium content

Potassium content was determined by flamephotometry using 'EEL' Flamephotometer.

3.2.5. Uptake studies

The total uptake of nitrogen, phosphorus and potassium at sixty days interval were calculated based on the content of these nutrients in the tuber, stem and leaves and multiplying their corresponding dry weights.

3.2.6. Soil analysis

Mechanical composition of the soil before starting the experiment was determined by the International pipette method.

The total nitrogen, available phosphorus and available potassium content of a composite soil sample collected blockwise prior to the experiment and soil samples collected from individual plots after the experiment were analysed.

Total nitrogen was determined by Modified micro-kjeldahl method, available phosphorus by Bray's method and available potassium by Ammonium acetate method (Jackson, 1967).

Organic matter was calculated by finding out the organic carbon by Walkley and Black's wet oxidation method as described by Jackson (1967).

3.2.7. Economics of cultivation

Cost benefit ratio was worked out by calculating actual cost of cultivation and the price of produce harvested.

3.2.8. Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for factorial R.B.D. and significance was tested by F test (Cochran and Cox, 1965). The standard error of means and least significant difference (Critical difference) have been provided for testing the inference wherever 'F' test was significant.

The statistical analysis of the data was carried out in the Versa INS Keltron Computor at the College of Agriculture, Vellayani.

RESULTS

4. RESULTS

An experiment to study the response of three varieties of short duration tapioca to five levels of fertilizer combinations was conducted at the Regional Agricultural Research Station, Kumarakom during 1984-85. Observations on various biometric characters, yield and quality were recorded. The data on various observations were statistically analysed and the results are presented in this chapter. The corresponding analysis of variance tables are given in the appendices II to VIII.

4.1. Growth characters

4.1.1. Height of the plant

The height of the plant was recorded at sixty days interval upto 180 days after planting. The mean values are presented in Tables 1 (a) to 1 (c) and the analysis of variance in Appendix II.

Sixty days after planting

There was significant difference in plant height due to the varieties. The variety V_3 (Sree Sahya) was superior to V_2 (Kaduthuruthy local) which in turn was superior to V_1 (Thottakolli).

Table 1 (a)

Height of plant in cm (60 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	46.50	52.00	52.66	53.66	65.50	54.07
V_2	65.50	67.50	72.25	81.47	84.46	74.23
V_3	112.25	121.50	125.08	127.83	129.50	123.23
Mean	74.75	80.33	83.33	87.63	93.15	

C.D. at 0.05 level for comparing varieties = 1.589

C.D. at 0.05 level for comparing fertilizer levels = 2.051

C.D. at 0.05 level for comparing interaction = 3.552

Table 1 (b)

Height of plant in cm (120 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	78.33	86.63	93.25	96.28	102.41	91.38
V_2	104.78	108.50	120.41	121.91	125.43	116.21
V_3	145.11	148.48	149.93	153.66	170.70	153.58
Mean	109.41	114.53	121.20	123.95	132.85	

C.D. at 0.05 level for comparing varieties = 1.109

C.D. at 0.05 level for comparing fertilizer levels = 1.432

C.D. at 0.05 level for comparing interaction = 2.479

Table 1 (c)

Height of plant in cm (180 days after planting - harvest)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	173.41	186.33	191.05	203.50	204.08	191.67
V_2	183.25	187.08	204.00	206.41	208.83	197.91
V_3	201.38	204.60	208.16	211.50	216.61	208.45
Mean	186.01	192.67	201.07	207.13	209.84	

C.D. at 0.05 level for comparing varieties = 1.728

C.D. at 0.05 level for comparing fertilizer levels = 2.231

C.D. at 0.05 level for comparing interaction = 3.864

Regarding different fertility levels also, there were significant differences in plant height. The highest plant height was recorded by L_5 which was significantly superior to all other levels. The lowest plant height was recorded by the lowest level (L_1) of fertilizer application.

The interaction effect was also found to be significant. The treatment combination V_3L_5 recorded the maximum plant height while V_1L_1 recorded the lowest. For the variety V_1, the levels L_1, L_2 and L_3 were on par and for the variety V_2, L_1 and L_2 were on par. For the variety V_3, L_3, L_4 and L_5 were on par.

One hundred and twenty days after planting

There was significant difference in plant height due to varieties. The variety V_3 (Sree Sahya) was superior to V_2 (Kaduthuruthy local) which in turn was superior to V_1 (Thottakolli).

The different fertility levels also resulted in significant difference in plant height. The level L_5 produced maximum plant height while L_1 produced the lowest.

The interaction effect was also found significant. The treatment combination V_3L_5 produced maximum plant height while V_1L_1 the lowest. For the variety V_1, all the levels

differed significantly. For the variety V_2, L_2 and L_3, L_3 and L_4 were on par. For the variety V_3 also all the levels differed significantly.

One hundred and eighty days after planting

At this stage also there was significant difference in plant height due to the varieties. The variety V_3 (Sree Sahya) produced the maximum plant height and V_1 produced the lowest.

The five fertility levels also recorded significant differences in plant height. The level L_5 produced maximum plant height and L_1 the lowest.

The interaction effects were also significant. V_3L_5 produced the maximum plant height and V_1L_1 produced the lowest. For the variety V_1, all the levels significantly differed each other. For the variety V_2, L_3, L_4 and L_5 were on par. For V_3, L_1 and L_2, L_3 and L_4 were also on par.

4.1.2. Number of leaves per plant

The data on the number of leaves per plant recorded at sixty days interval were subjected to statistical analysis. The mean values are presented in Tables 2 (a) to 2 (c) and the analysis of variance in Appendix II.

Sixty days after planting

There was significant difference in leaf number due to varieties. Variety V_3 (Sree Sahya) produced the highest leaf number and V_1 produced the lowest.

The different fertilizer levels also produced significant difference in leaf number. But the levels L_1 and L_2, L_3 and L_4 and L_4 and L_5 were on par. There was a reduction in leaf number at the L_5 level though it was not statistically different from L_4 which recorded the maximum.

The interactions were also significant. V_3L_5 produced maximum number of leaves and V_1L_1 produced the minimum. For the variety V_1, all the levels did not differ significantly while for V_2, L_1 and L_2 were on par. So also was the case for L_3, L_4 and L_5. For V_3, L_1 and L_2, L_4 and L_5 were also on par.

One hundred and twenty days after planting

There was significant difference in leaf number due to varieties. The variety V_2 (Kaduthuruthy local) produced the highest leaf number followed by V_1 and V_3.

The fertilizer levels also produced significant difference in leaf number. The level L_1 produced the lowest leaf number and L_5 the highest.

Table 2 (a)

Number of leaves (sixty days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	50.00	50.00	53.50	56.66	55.16	53.11
V_2	52.00	54.33	61.66	61.91	58.75	57.73
V_3	53.00	56.91	57.75	63.41	63.50	58.91
Mean	51.75	53.75	57.63	60.66	59.13	

C.D. at 0.05 level for comparing varieties = 2.578

C.D. at 0.05 level for comparing fertilizer levels= 3.328

C.D. at 0.05 level for comparing interaction = 5.764

Table 2 (b)

Number of leaves (120 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	92.58	104.33	108.50	111.33	119.41	107.23
V_2	103.16	110.16	114.33	123.66	128.50	115.96
V_3	92.00	93.25	102.16	106.00	112.08	102.15
Mean	96.00	104.25	108.33	113.66	120.00	

C.D. at 0.05 level for comparing varieties = 1.215

C.D. at 0.05 level for comparing fertilizer levels= 1.569

C.D. at 0.05 level for comparing interaction = 2.717

Table 2 (c)

Number of leaves (180 days after planting - harvest)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	164.66	170.33	179.00	183.33	186.66	176.80
V_2	171.33	175.91	180.66	183.33	186.83	179.61
V_3	151.33	166.83	170.33	176.33	179.66	168.90
Mean	162.44	171.02	176.66	181.00	184.38	

C.D. at 0.05 level for comparing varieties = 1.556

C.D. at 0.05 level for comparing fertilizer levels = 2.008

C.D. at 0.05 level for comparing interaction = 3.478

The interaction effects were also significant. V_2L_5 produced the highest number of leaves and V_1L_1 produced the lowest number.

One hundred and eighty days after planting

Varieties produced significant effect on the leaf number. Variety V_2 (Kaduthuruthy local) produced highest leaf number and V_1 (Thottakolli) produced the lowest.

The different fertilizer levels also recorded significant effect on the leaf production. L_1 produced the lowest level and L_5 the highest.

The interaction effects were also significant. V_3L_1 produced the lowest leaf number while V_2L_5 produced the highest. For all the varieties L_4 and L_5 were on par.

4.1.3. Leaf Area index

The leaf area index was calculated at sixty days interval. The mean values are presented in Tables 3 (a) to 3 (c). The analysis of variance is given in Appendix II.

Sixty days after planting

There was significant effect on leaf area index due to varieties. V_2 produced highest leaf area index followed by V_3 and V_1.

The different fertilizer levels also produced significant effect on leaf area index. There was a reduction in leaf area index at L_5 level for V_1 and V_2.

The interaction effects were also significant. V_3L_1 produced the lowest leaf area index and V_2L_4 produced the highest.

One hundred and twenty days after planting

There was significant effect on leaf area index due to varieties. Variety V_2 (Kaduthuruthy local) produced the highest leaf area followed by V_1 and V_3.

The different fertilizer levels also resulted in significant differences in leaf area index. The treatments L_1 and L_2 were on par. Again, L_3, L_4 and L_5 were also on par.

The interaction effects were not significant.

One hundred and eighty days after planting

At this stage also, the effects due to varieties and levels of fertilizers were similar to that of the previous stage. However, the interaction effects were significant at this stage. A slight reduction in leaf area index was observed for the varieties V_1 and V_2 at L_5 level.

Table 3 (a)

Leaf Area Index (60 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	1.166	1.176	1.370	1.580	1.470	1.352
V_2	1.280	1.296	1.480	1.690	1.530	1.455
V_3	1.213	1.253	1.490	1.523	1.590	1.414
Mean	1.220	1.242	1.446	1.597	1.530	

C.D. at 0.05 level for comparing varieties = 0.0071

C.D. at 0.05 level for comparing fertilizer levels = 0.0092

C.D. at 0.05 level for comparing interaction = 0.0160

Table 3 (b)

Leaf Area Index (120 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	1.786	1.800	2.023	2.083	2.026	1.944
V_2	1.943	1.953	2.080	2.180	2.126	2.056
V_3	1.686	1.686	2.003	2.066	2.090	1.906
Mean	1.805	1.813	2.035	2.110	2.081	

C.D. at 0.05 level for comparing varieties = 0.0618

C.D. at 0.05 level for comparing fertilizer levels = 0.0798

S.E. for interaction effects = 0.0477

Table 3 (c)

Leaf Area Index (180 days after planting)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	1.896	1.923	2.083	2.186	2.173	2.052
V_2	2.113	2.120	2.226	2.246	2.236	2.188
V_3	1.783	1.790	2.090	2.156	2.183	2.000
Mean	1.931	1.944	2.133	2.196	2.197	

C.D. at 0.05 level for comparing varieties = 0.0385

C.D. at 0.05 level for comparing fertilizer levels = 0.0497

C.D. at 0.05 level for comparing interaction = 0.0860

4.2. Yield attributes

4.2.1. Total number of roots

Total number of roots produced was counted at harvest. The mean values are presented in Table 4 and the analysis of variance in Appendix III.

The varieties differed significantly in the total number of roots. Sree Sahya produced the highest number of roots per plant.

The different fertilizer levels also imparted significant effect on the total number of roots. The level L_1 produced the lowest number and L_5 the highest number.

The interaction effects were also significant. V_1L_1 produced the lowest number and V_3L_5 the highest. For the variety V_1, L_1 and L_2 and also L_3 and L_4 were on par. For the variety V_2, L_3, L_4 and L_5 were on par. For V_3, L_1 and L_2, L_2 and L_3, L_3 and L_4 and L_4 and L_5 were on par.

4.2.2. Total number of productive roots

The total number of productive roots were counted and analysed. The mean values are presented in Table 5 and the analysis of variance in Appendix III.

Table 4

Total number of roots per plant

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	12.00	13.33	17.00	17.66	19.00	15.80
V_2	13.00	14.66	18.33	19.00	19.33	16.86
V_3	15.66	16.33	17.66	19.00	20.00	17.73
Mean	13.55	14.77	17.66	18.55	19.44	

C.D. at 0.05 level for comparing varieties = 0.6445

C.D. at 0.05 level for comparing fertilizer levels = 0.8320

C.D. at 0.05 level for comparing interaction = 1.4412

Table 5

Total number of productive roots per plant

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	6.00	6.33	9.33	9.66	11.00	8.46
V_2	6.00	6.66	9.66	10.33	11.00	8.73
V_3	5.33	6.00	6.00	8.00	9.33	6.93
Mean	5.77	6.33	8.33	9.33	10.44	

C.D. at 0.05 level for comparing varieties = 0.5715

C.D. at 0.05 level for comparing fertilizer levels = 0.7378

C.D. at 0.05 level for comparing interaction = 1.278

There was significant difference due to varieties. Varieties V_1 and V_2 were on par. V_3 was significantly inferior to the other two varieties.

The effects due to different fertilizer levels were also significant. The level L_1 produced the lowest number of productive roots while L_5 the highest.

The interaction effects were also significant. V_3L_1 produced the lowest number of productive roots and V_1L_5 and V_2L_5 produced the highest. For the variety V_1, L_1 and L_2 and L_3 and L_4 were on par. For the variety V_2, L_1 and L_2 and L_4 and L_5 were on par and for V_3, L_1, L_2 and L_3 were on par.

4.2.3. Percentage of productive roots

The mean values are given in Table 6. The varieties differed significantly. V_1 gave the highest percentage while V_3 gave the lowest value. V_1 and V_2 were on par and were significantly superior to V_3 for this character.

The effects due to different fertilizer levels were also differed significantly. L_5 gave the highest value which was significantly superior to L_1, L_2 and L_3. The interaction effects were not significant.

Table 6

Percentage of productive roots

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	50.68	47.60	55.02	54.79	58.08	53.23
V_2	46.73	45.55	52.80	54.48	56.83	51.28
V_3	34.02	36.76	33.98	41.99	46.58	38.66
Mean	43.81	43.30	47.27	50.42	53.83	

C.D. at 0.05 level for comparing varieties = 4.178

C.D. at 0.05 level for comparing fertilizer levels = 5.394

S.E. for interaction = 3.226

4.2.4.Length of tuber

The mean values on length of tuber are presented in Table 7 and the analysis of variance in Appendix III.

The varieties differed significantly in the length of tubers. The length of the tuber was high in V_3 (Sree Sahya) and low in V_2 (Kaduthuruthy local).

The fertilizer levels also resulted in significant differences in length of tuber. L_1 recorded the maximum length. But L_2 and L_3, and L_4 and L_5 were on par.

The interaction effects were also significant. For all the varieties maximum length was observed in L_1 level.

4.2.5.Girth of tuber

The mean values are given in Table 8 and the analysis of variance in Appendix III.

There was significant difference in the girth of tubers due to varieties. Variety V_2 produced tubers of maximum girth and V_3 the lowest.

Girth of tuber differed significantly due to fertilizer levels. The L_5 treatment recorded the maximum girth while L_1 the minimum and it was significantly inferior to all other levels. The levels L_2 and L_3, and L_3 and L_4 were on par.

Table 7

Length of tuber (cm)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	30.22	24.39	23.33	30.10	28.87	27.38
V_2	25.24	23.40	22.48	21.73	24.40	23.45
V_3	36.63	33.85	35.50	34.83	34.73	35.11
Mean	30.70	27.21	27.10	28.88	29.33	

C.D. at 0.05 level for comparing varieties = 1.259

C.D. at 0.05 level for comparing fertilizer levels = 1.625

C.D. at 0.05 level for comparing interaction = 2.815

Table 8

Girth of tuber (cm)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	11.44	12.56	12.72	12.97	13.58	12.65
V_2	11.48	13.41	14.03	14.56	15.41	13.77
V_3	9.97	10.27	10.27	11.02	11.32	10.57
Mean	10.96	12.08	12.34	12.85	13.43	

C.D. at 0.05 level for comparing varieties = 0.4447

C.D. at 0.05 level for comparing fertilizer levels = 0.5741

C.D. at 0.05 level for comparing interaction = 0.9944

The effects due to interactions were also significant. The treatment combination V_3L_5 recorded the maximum girth while V_3L_1 the minimum. For V_1, L_2, L_3 and L_4 were on par. For V_2, L_3 and L_4 and for V_3, L_2, L_3 and L_4 were on par.

4.2.6. Utilization index

The mean values of utilization index are presented in Table 9 and the analysis of variance in Appendix III.

The different varieties differed significantly. The variety V_3 (Sree Sahya) exhibited highest utilization index followed by V_2 and V_1.

Significant effects were also observed due to the different fertilizer levels. The highest utilization index was noticed with lowest level ie. L_1. There was a decrease in utilization index to the increase in the fertilizer levels.

The interaction effects were not significant.

4.2.7. Rind to flesh Ratio

The analysis of variance is presented in the Appendix III and the mean values are given in Table 10.

Table 9

Utilization Index

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	1.983	1.836	1.726	1.590	1.586	1.744
V_2	2.123	1.830	1.796	1.750	1.700	1.840
V_3	2.193	2.160	1.736	1.890	1.876	1.971
Mean	2.100	1.942	1.753	1.743	1.721	

C.D. at 0.05 level for comparing varieties = 0.0871

C.D. at 0.05 level for comparing fertilizer levels = 0.1125

S.E. for comparing interaction = 0.0672

Table 10

Rind to flesh ratio

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.2233	0.2267	0.2376	0.2200	0.2267	0.2266
V_2	0.2433	0.2200	0.2100	0.2200	0.2467	0.2280
V_3	0.2700	0.2733	0.2700	0.2733	0.2976	0.2766
Mean	0.2456	0.2400	0.2389	0.2378	0.2567	

C.D. at 0.05 level for comparing varieties = 0.0132

S.E. for fertilizer levels = 0.0058

S.E. for interactions = 0.0102

There was significant difference due to varieties. V_3 recorded the highest ratio which was significantly different from the other two varieties.

The different fertilizer levels did not make any significant influence on this character.

The interaction effects were also not significant.

4.2.8.Top yield

Table 11 shows the mean values of the top yield and the Appendix IV furnishes the corresponding analysis of variance.

There was significant effect due to varieties. Variety V_1 (Thottakolli) produced highest top yield and V_3 (Sree Sahya) the lowest.

The different fertilizer doses also imparted significant effect. The lowest top yield was observed in the L_1 level and highest in the L_5 level.

The interaction effects were also significant. The combination V_3L_1 produced the lowest top yield and V_1L_5 produced the highest top yield.

4.3.Tuber yield

The mean values on tuber yield are presented in Table 12 and the analysis of variance in Appendix IV.

Table 11

Top yield (kg/plot)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	8.460	9.393	14.453	15.830	18.166	13.260
V_2	7.576	10.003	14.673	15.206	15.863	12.664
V_3	6.263	7.086	9.973	11.093	11.943	9.272
Mean	7.433	8.827	13.033	14.043	15.324	

C.D. at 0.05 level for comparing varieties = 0.1987

C.D. at 0.05 level for comparing fertilizer levels = 0.2566

C.D. at 0.05 level for comparing interaction = 0.4445

Table 12

Tuber yield in kg/plot

(The figures in brackets show the tuber yield in tonnes/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	16.820 (19.93)	17.294 (20.50)	25.068 (29.71)	25.279 (29.96)	28.868 (34.21)	22.666 (26.86)
V_2	16.103 (19.09)	18.354 (21.75)	26.442 (31.34)	26.661 (31.60)	26.925 (31.91)	22.897 (27.18)
V_3	13.770 (16.32)	15.340 (18.18)	17.434 (20.66)	21.007 (24.90)	22.624 (26.81)	18.035 (21.37)
Mean	15.564 (18.45)	16.996 (20.14)	22.981 (27.24)	24.316 (28.82)	26.139 (30.98)	

C.D. at 0.05 level for comparing varieties = 0.8614 (1.02)

C.D. at 0.05 level for comparing fertilizer levels = 1.112 (1.32)

C.D. at 0.05 level for comparing interaction = 1.926 (2.28)

There was significant difference in yield due to the varieties. V_3 was significantly inferior to the other two varieties. But varieties V_1 and V_2 were on par. V_2 (Kaduthuruthy local) recorded the highest tuber yield.

The effects due to N P K combinations also differed significantly. The lowest tuber yield was observed in the L_1 level and highest in the L_5 level.

The interaction effects were also significant. V_3L_1 produced the lowest tuber yield while V_1L_5 produced the highest tuber yield. For the variety V_1 (Thottakolli) L_1 and L_2, and L_3 and L_4 were on par. For the variety V_2, L_3, L_4 and L_5 were on par and for V_3, L_4 and L_5 were on par.

4.4. Quality attributes

4.4.1. Starch content of tubers at harvest

The mean values are presented in Table 13 and the analysis of variance in Appendix IV.

The varieties differed significantly in the starch content of tubers. The highest starch content was in V_3 (Sree Sahya) which was on par with V_2 (Kaduthuruthy local) and the lowest was in V_1 (Thottakolli).

Table 13

Starch content of tuber at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	21.73	21.83	23.34	25.06	25.57	23.50
V_2	22.37	23.51	25.75	26.31	26.29	24.85
V_3	22.98	24.42	25.75	26.52	27.31	25.39
Mean	22.36	23.25	24.95	25.96	26.39	

C.D. at 0.05 level for comparing varieties = 0.9213

C.D. at 0.05 level for comparing fertilizer levels = 1.189

S.E.for interaction effects = 0.7113

The fertilizer levels also had significant effect on the starch content of tuber. The highest starch content was observed in the L_5 level and lowest in L_1 level. But L_1 and L_2, and L_3 and L_4 were on par.

The interaction effects were not significant.

4.4.2. HCN content of tubers at harvest (µg/g)

The mean values are presented in Table 14 and the analysis of variance in Appendix IV.

There was significant difference in the HCN content due to varieties. The lowest HCN content was in V_1 (Thottakolli) and highest in V_2 (Kaduthuruthy local).

The effects due to fertilizer levels were also significant. The lowest HCN content was in the L_5 level and the highest in L_2 level.

The effects due to interaction were also significant. V_3L_5 combination recorded the lowest HCN content while V_3L_2 the highest.

4.4.3. Crude Protein content of tubers

The mean values are presented in Table 15 and the analysis of variance in Appendix IV.

The varieties differed significantly in the crude protein content of tubers. The highest crude protein

content was in V_2 which was significantly superior to the other two varieties which were on par.

The effects due to fertilizer levels were also significant. The highest content of crude protein was in L_5 level and the lowest in L_1 level. However, L_1 and L_2 were on par.

The interaction effects were also significant. The V_2L_1 combination had the lowest value and V_2L_4 the highest. For V_1, L_1 and L_2 were on par. For V_2, L_1 and L_2, and L_4 and L_5 were on par and for V_3 also L_1 and L_2 were on par.

4.4.4. Cooking quality

The mean scores obtained in the organoleptic test are given in Table 16.

Since the sensitivity in taste determination test is likely to be affected by increasing the number of samples, only three treatments (Three varieties) were tested for cooking quality.

It could be seen from the Table that the variety V_1 (Thottakolli) recorded the highest score followed by V_2 (Kaduthuruthy local).

Table 14

HCN content of tuber (µg/g) at harvest

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	39.07	40.78	42.46	38.89	38.37	39.91
V_2	41.14	42.25	42.60	42.27	39.71	41.59
V_3	42.98	43.14	40.73	39.27	36.74	40.55
Mean	41.06	42.05	41.93	40.14	38.27	

C.D. at 0.05 level for comparing varieties = 0.9667

C.D. at 0.05 level for comparing fertilizer levels = 1.248

C.D. at 0.05 level for comparing interaction = 2.162

Table 15

Crude protein content of tubers at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	1.75	1.72	1.97	2.10	2.21	1.95
V_2	1.64	1.68	2.20	2.27	2.27	2.01
V_3	1.77	1.77	1.97	2.04	2.16	1.94
Mean	1.72	1.72	2.05	2.13	2.21	

C.D. at 0.05 level for comparing varieties = 0.0263

C.D. at 0.05 level for comparing fertilizer levels = 0.0339

C.D. at 0.05 level for comparing interaction = 0.0588

Table 16

Mean scores obtained in the organoleptic test of tapioca tubers (mean of five tests)

Varieties	Mean score
V_1	2.0
V_2	1.8
V_3	1.4

4.5. Dry Matter Production

4.5.1. Leaf

Dry matter production of leaf was calculated at sixty days interval and the mean values are presented in Tables 17 (a) to 17 (c). The analysis of variance is presented in Appendix V.

Sixty days after planting

The mean values are presented in Table 17 (a).

The varieties differed significantly in the leaf dry matter production. The variety V_3 (Sree Sahya) produced the highest leaf dry matter.

The fertilizer levels tried also resulted in significant differences in the leaf dry matter production. The highest leaf dry matter production was with L_5, but it was on par with L_4. The lowest level of fertilizers resulted the lowest dry matter production at this stage.

The interactions were not significant.

One hundred and twenty days after planting

The mean values are presented in Table 17 (b) and analysis of variance in Appendix V.

At this stage also the varieties differed significantly. The variety V_2 (Kaduthuruthy local) produced the highest leaf dry matter.

The different fertilizer levels also produced significant effect. But the level L_1 and L_2 were on par and all other levels differed significantly.

The interactions were not significant.

One hundred and eighty days after planting

The mean values are presented in Table 17 (c) and the analysis of variance in Appendix V.

There was significant effect due to varieties. Variety V_2 (Kaduthuruthy local) produced highest leaf dry matter at the harvest stage while V_1 and V_3 were on par and inferior to V_2.

The different fertilizer levels also produced significant effect. The highest leaf dry matter production was observed with L_5 level and lowest by the L_1 level.

The interaction effects were also significant. V_1L_1 produced the lowest leaf dry matter while V_2L_5 produced the highest.

Table 17 (a)

Leaf dry matter production (60 days) (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	35.916	38.083	44.166	44.533	46.000	41.750
V_2	35.833	38.666	44.916	47.416	48.916	43.150
V_3	39.566	40.500	45.833	47.333	49.333	44.513
Mean	37.105	39.083	44.972	46.444	48.083	

C.D. at 0.05 level for comparing varieties = 1.373

C.D. at 0.05 level for comparing fertilizer levels = 1.773

S.E. for interaction = 1.061

Table 17 (b)

Leaf dry matter production (120 days) (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	68.733	70.666	74.300	76.566	78.666	73.786
V_2	71.100	71.966	78.166	80.850	82.117	76.840
V_3	71.616	72.766	76.150	76.893	78.633	75.212
Mean	70.483	71.800	76.205	78.103	79.805	

C.D. at 0.05 level for comparing varieties = 1.049

C.D. at 0.05 level for comparing fertilizer levels = 1.354

S.E. for interaction = 0.8099

Table 17 (c)

Leaf dry matter production (180 days - Harvest) (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	84.203	85.716	88.246	92.376	101.913	90.491
V_2	85.036	86.956	92.140	94.096	105.283	92.702
V_3	84.213	86.713	89.890	92.446	100.936	90.839
Mean	84.484	86.462	90.092	92.973	102.711	

C.D. at 0.05 level for comparing varieties = 0.3966

C.D. at 0.05 level for comparing fertilizer levels = 0.5120

C.D. at 0.05 level for comparing interaction = 0.8868

4.5.2. Stem

Dry matter production of stem at 60 days interval was calculated and presented in Tables 18 (a) to 18 (c) and the analysis of variance in Appendix V.

Sixty days after planting

The mean values are presented in Table 18 (a) and the analysis of variance in Appendix V.

There was significant effect due to varieties. The variety V_2 recorded the maximum dry matter production which was significantly superior to V_1. However, the varieties V_1 and V_3, and V_2 and V_3 were on par.

Different fertilizer levels also imparted significant effect on stem dry matter production. L_1 produced the lowest and L_5 the highest dry matter. But L_2 and L_3, L_3 and L_4, and L_4 and L_5 were on par.

Interactions were not significant.

One hundred and twenty days after planting

Table 18 (b) presents the mean values of stem dry matter production at the 120^{th} day after planting and the analysis of variance in Appendix V.

Table 18 (a)

Dry matter production (stem) 60 days after planting (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	24.616	27.583	28.510	31.516	30.983	28.642
V_2	24.750	29.667	33.900	36.600	41.000	33.183
V_3	25.500	28.250	31.533	33.200	36.100	30.916
Mean	24.955	28.500	31.314	33.772	36.027	

C.D. at 0.05 level for comparing varieties = 3.213

C.D. at 0.05 level for comparing fertilizer levels = 4.148

S.E. for interaction = 2.481

Table 18 (b)

Dry matter production (stem) 120 days after planting (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	95.400	96.086	100.466	101.416	104.466	99.567
V_2	96.233	100.316	102.250	103.583	104.350	101.346
V_3	95.950	97.750	102.233	103.850	106.050	101.166
Mean	95.861	98.051	101.650	102.950	104.955	

C.D. at 0.05 level for comparing fertilizer levels = 2.230

S.E. for comparing varieties = 0.5967

S.E. for comparing interaction = 1.334

Table 18 (c)

Dry matter production (stem) 180 days after planting - harvest (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	121.340	125.010	132.357	137.000	139.123	130.966
V_2	123.297	126.246	139.287	141.993	148.680	135.900
V_3	121.703	124.786	131.336	137.543	146.520	132.378
Mean	122.113	125.348	134.326	138.845	144.775	

C.D. at 0.05 level for comparing varieties = 0.4511

C.D. at 0.05 level for comparing fertilizer levels = 0.5823

C.D. at 0.05 level for comparing interaction = 1.009

There was no significant effect due to varieties at this stage. However, V_2 recorded the maximum followed by V_3 and the minimum was recorded by V_1.

There was significant effect due to the different fertilizer levels tried. The highest stem dry matter production was obtained at the L_5 level. But L_1 and L_2, L_3 and L_4, and L_4 and L_5 were on par.

The interaction effects were not significant.

One hundred and eighty days after planting

The mean values are presented in Table 18 (c) and analysis of variance in Appendix V.

The varieties differed significantly in the stem dry matter production. Variety V_2 (Kaduthuruthy local) produced the highest stem dry matter and V_1 (Thottakolli) the lowest.

The fertilizer levels tried also had significant effect on this character. The highest stem dry matter production was recorded at L_5 level.

The interactions were also significant. The combination of V_1L_1 produced the lowest stem dry matter whereas V_2L_5 produced the highest.

4.5.3. Root

Dry matter production of root was calculated at sixty

days interval and subjected to statistical analysis and the mean values are presented in Tables 19 (a) to 19 (c) and analysis of variance in Appendix V.

Sixty days after planting

The mean values are presented in Table 19 (a) and the analysis of variance in Appendix V.

There was no significant effect due to varieties.

The different fertilizer levels tried resulted in significant effects on the root dry matter production. The level L_5 produced the highest root dry matter. But there was no significant difference between L_2 and L_3, L_3 and L_4, and L_4 and L_5.

The interaction effects were not significant.

One hundred and twenty days after planting

The Table 19 (b) presents the mean values and the Appendix V the analysis of variance.

There was significant difference in the root dry matter production due to varieties. The variety V_2 recorded the maximum and was superior to others. The varieties V_1 and V_3 were on par.

The fertilizer levels also had significant effect. The L_5 level resulted in the highest root dry matter production.

Table 19 (a)

Dry matter production (root) (at 60 days after planting) (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	9.393	10.973	13.623	14.170	14.790	12.590
V_2	10.243	11.083	13.750	14.316	15.853	13.049
V_3	9.553	13.290	11.486	11.753	13.590	11.934
Mean	9.730	11.7822	12.9533	13.4133	14.744	

C.D. at 0.05 level for comparing fertilizer level = 1.407

S.E. for comparing varieties = 0.3760

S.E. for comparing interaction = 0.8411

Table 19 (b)

Dry matter production (root) at 120 days after planting (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	178.136	184.876	193.450	206.203	209.250	194.383
V_2	186.116	191.256	199.913	206.586	216.193	200.013
V_3	185.160	189.563	196.603	202.570	205.386	195.856
Mean	183.137	188.565	196.655	205.120	210.276	

C.D. at 0.05 level for comparing varieties = 3.275

C.D. at 0.05 level for comparing fertilizer levels = 4.228

S.E. for comparing interaction = 2.528

Table 19 (c)

Dry matter production (root) at 180 days after planting - harvest (g/plant)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	354.460	359.566	457.416	461.916	475.046	421.681
V_2	352.926	360.180	466.913	486.636	492.670	431.865
V_3	249.203	256.410	323.046	431.466	448.513	341.728
Mean	318.863	325.385	415.792	460.006	472.076	

C.D. at 0.05 level for comparing varieties = 2.910

C.D. at 0.05 level for comparing fertilizer levels = 3.757

C.D. at 0.05 level for comparing interaction = 6.508

The interaction effects were not significant.

One hundred and eighty days after planting

The mean values are presented in Table 19 (c) and analysis of variance in Appendix V.

The varieties differed significantly in the root dry matter production. The variety V_2 produced the highest root dry matter and V_3 the lowest.

The different fertilizer levels also produced significant effect. The level L_5 produced highest root dry matter and L_1 the lowest.

The interactions were also significant. The combination V_3L_1 produced the lowest root dry matter while V_2L_5 the highest.

4.8. Dry matter production (tuber) at harvest

The mean values on dry matter production of tuber are given in Table 20 and the analysis of variance in Appendix VI.

The varieties differed significantly in the tuber dry matter production. The lowest tuber dry matter production was in V_3 (Sree Sahya) which was significantly inferior to the other varieties. The highest dry matter production was in V_2 (Kaduthuruthy local) which was significantly superior to V_1.

The effects due to the five fertilizer levels tried were also significant. The highest dry matter production was in the L_5 level and the lowest in L_1 level.

The interaction effects were also significant. The combination V_3L_1 recorded the lowest tuber dry matter production while V_2L_5 the highest.

4.9. Dry matter production (top) at harvest

The mean values are presented in Table 21 and the analysis of variance in Appendix VI.

The three varieties were significantly different in the top dry matter production, the lowest being in V_1 and the highest in V_3.

The fertilizer levels tried also had significant effect. The lowest value was recorded in L_1 level and the highest in L_5 level.

The interaction effects were significant. The highest top dry matter production was in V_2L_5 combination and the lowest in V_1L_1 combination.

Table 20

Dry matter production (tuber) kg/ha at harvest

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	6301.00	6392.00	8132.00	8211.33	8444.66	7496.20
V_2	6273.66	6402.66	8300.33	8650.66	8758.66	7677.20
V_3	4475.33	4557.66	5742.66	7670.00	7973.00	6083.73
Mean	5683.33	5784.11	7391.66	8177.33	8392.11	

C.D. at 0.05 level for comparing varieties = 55.018

C.D. at 0.05 level for comparing fertilizer levels = 71.027

C.D. at 0.05 level for comparing interaction = 123.023

Table 21

Dry matter production (top) kg/ha at harvest

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	3653.66	3745.66	3921.33	4075.66	4284.33	3936.13
V_2	3703.00	3790.00	4113.00	4197.66	4515.66	4063.86
V_3	3660.66	3757.00	3932.33	4088.33	4398.00	3967.26
Mean	3672.44	3764.22	3988.68	4120.55	4399.33	

C.D. at 0.05 level for comparing varieties = 10.300

C.D. at 0.05 level for comparing fertilizer levels = 13.298

C.D. at 0.05 level for comparing interaction = 23.032

4.7. Plant Analysis

4.7.1. Nitrogen content at harvest

(a) Leaf

The mean values are presented in Table 22 (a) and analysis of variance in Appendix VII.

The varieties differed significantly in the nitrogen content of leaf. Highest nitrogen content in leaf was observed in variety V_1 (Thottakolli) and the lowest in V_2 (Koduthuruthy local).

The fertilizer levels also resulted in significant differences in the nitrogen content. The highest content was in L_5 and the lowest in L_1 level.

Eventhough the interaction effects were significant, for the variety V_1, L_1 and L_2, and L_3 and L_4 were on par and for V_2, L_3 and L_4 were on par.

(b) Stem

Table 22 (b) presents the mean values and Appendix VII the analysis of variance.

There was significant difference in the nitrogen content of stem due to varieties. The variety V_3 recorded

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the highest values which were significantly superior to V_1 and V_2 and the latter two were on par.

The effects due to different fertilizer levels were also significantly different. The lowest N content was observed in L_1 level and the highest in L_5 level.

The interaction effects were also significant. For the variety V_2 and V_3, L_1 and L_2, L_3 and L_4 were on par. The combination V_3L_5 recorded the highest N content in the stem.

(c) Tuber

The mean values are presented in Table 22 (c) and the analysis of variance in Appendix VII.

Varieties differed significantly in the nitrogen content of tuber. Varieties V_1 and V_3 were on par while V_3 recorded the highest nitrogen content in tuber.

The five fertilizer levels also got significant effects on the nitrogen content of tuber. While L_1 and L_2 were on par, the highest nitrogen content was observed in L_5.

The interactions were also significant. For the all the varieties L_1 and L_2 were on par.

Table 22 (a)

Nitrogen content (%) of leaf at harvest

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	3.506	3.506	3.863	3.860	3.836	3.714
V_2	3.420	3.453	3.623	3.623	3.673	3.558
V_3	3.613	3.633	3.696	3.736	3.753	3.686
Mean	3.513	3.531	3.727	3.740	3.754	

C.D. at 0.05 level for comparing varieties = 0.00848

C.D. at 0.05 level for comparing fertilizer levels = 0.0109

C.D. at 0.05 level for comparing interaction = 0.0189

Table 22 (b)

Nitrogen content of stem at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.506	0.520	0.526	0.556	0.563	0.534
V_2	0.516	0.513	0.533	0.553	0.556	0.534
V_3	0.563	0.570	0.583	0.580	0.593	0.578
Mean	0.528	0.534	0.547	0.563	0.571	

C.D. at 0.05 level for comparing varieties = 0.00434

C.D. at 0.05 level for comparing fertilizer levels = 0.00560

C.D. at 0.05 level for comparing interaction = 0.00970

Table 22 (c)

Nitrogen content of tuber at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.280	0.276	0.316	0.336	0.353	0.312
V_2	0.263	0.270	0.353	0.363	0.363	0.322
V_3	0.283	0.283	0.316	0.326	0.346	0.311
Mean	0.275	0.276	0.328	0.342	0.354	

C.D. at 0.05 level for comparing varieties = 0.00414

C.D. at 0.05 level for comparing fertilizer levels = 0.0054

C.D. at 0.05 level for comparing interaction = 0.00928

4.7.2. Phosphorus content at harvest

(a) Leaf

The mean values are presented in Table 23 (a) and the analysis of variance in Appendix VII.

There was significant difference in the phosphorus content of leaf due to varieties. Variety V_3 (Sree Sahya) recorded the highest phosphorus content and V_1 (Thottakolli) the lowest.

The five fertilizer levels tried also had significant effects in the phosphorus content of leaf. The L_5 level recorded the maximum values, but was on par with L_4.

The interaction effects were also significant. The lowest phosphorus content was in the V_1L_1 combination and the highest in V_3L_4 combination. For the variety V_1, L_3, L_4 and L_5 were on par. For V_2, L_1 and L_2 were on par. For the variety V_3, the different levels did not result in any significant difference.

(b) Stem

The mean values are presented in Table 23 (b) and the analysis of variance in Appendix VII.

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Table 23 (a)

Phosphorus content of leaves at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.396	0.416	0.453	0.453	0.460	0.436
V_2	0.446	0.460	0.446	0.470	0.483	0.461
V_3	0.486	0.480	0.490	0.496	0.493	0.489
Mean	0.443	0.452	0.463	0.473	0.478	

C.D. at 0.05 level for comparing varieties = 0.0071

C.D. at 0.05 level for comparing fertilizer levels = 0.0092

C.D. at 0.05 level for comparing interaction = 0.0159

Table 23 (b)

Phosphorus content of stem at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.210	0.213	0.223	0.223	0.240	0.222
V_2	0.230	0.240	0.246	0.253	0.266	0.247
V_3	0.240	0.233	0.253	0.260	0.266	0.250
Mean	0.226	0.228	0.241	0.245	0.257	

C.D. at 0.05 level for comparing varieties = 0.0046

C.D. at 0.05 level for comparing fertilizer levels = 0.0059

S.E. for comparing interaction = 0.00352

Table 23 (c)

Phosphorus content of tuber at harvest(%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.090	0.083	0.103	0.106	0.090	0.094
V_2	0.116	0.123	0.123	0.120	0.130	0.122
V_3	0.113	0.110	0.130	0.120	0.133	0.121
Mean	0.106	0.105	0.118	0.115	0.117	

C.D. at 0.05 level for comparing varieties = 0.0059

C.D. at 0.05 level for comparing fertilizer levels = 0.0075

C.D. at 0.05 level for comparing interaction = 0.0130

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The three varieties differed significantly in the phosphorus content of the stem. The lowest content was observed in V_1 which was significantly inferior to the other varieties. The highest values were given by V_3.

The different fertilizer levels also imparted significant difference in the phosphorus content eventhough L_1 and L_2, and L_3 and L_4 were on par.

The interaction effects were not significant.

(c) Tuber

The mean values are presented in Table 23 (c) and the analysis of variance in Appendix VII.

There was significant difference in the phosphorus content of tubers due to varieties. The variety V_2 recorded the highest value. However, varieties V_2 and V_3 were on par.

The different fertilizer levels also had significant effect on this character. Maximum P content was in L_3. However, L_1 and L_2 were on par. Same was the case with L_3, L_4 and L_5.

The interaction effects were also significant. The lowest phosphorus content was observed in the V_1L_2 while the highest in V_2L_3 combination. For the variety V_1, L_1

and L_2 and L_3 and L_4 were on par. For the variety V_2, L_2, L_3 and L_4 were on par. For the variety V_3, L_1 and L_2, and L_3 and L_4 were also on par.

4.7.3. Potassium content at harvest

(a) Leaf

The mean values are presented in Table 24 (a) and the analysis of variance in Appendix VII.

The varieties did not differ significantly in the potassium content.

But the fertilizer levels tried resulted in significant effects. The higher two levels recorded higher K content in the leaves which were on par. The levels L_1 and L_2 were also on par. The highest potassium content was observed in the L_5 level.

The interactions were also significant. The combination V_1L_5 recorded the highest K content while V_1L_1 the lowest.

(b) Stem

The mean values are presented in Table 24 (b) and the analysis of variance in Appendix VII.

The varieties differed significantly in the potassium content of the stem. The highest was in V_1 and the lowest in V_2.

The five fertilizer levels tried also gave significant effects on K content of stem. The highest K content was recorded in the L_5 level and lowest in L_1 level.

The interaction effects were also significant. The combination V_2L_1 recorded the lowest K content while V_1L_5 recorded the highest.

(c) Tuber

The mean values are presented in Table 24 (c) and the analysis of variance in Appendix VII.

The three varieties differed significantly in the potassium content of tuber, the lowest in V_2 and highest in V_1.

The five fertilizer levels also resulted in significant effects. The lowest content of K was in L_1 and the highest in L_5 level.

The interaction effects were also significant. The combination V_3L_1 recorded the lowest and V_1L_5 the highest.

Table 24 (a)

Potassium content of leaf at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.800	0.833	0.900	1.233	1.333	1.020
V_2	0.860	0.903	0.996	1.233	1.300	1.058
V_3	0.930	0.933	1.033	1.166	1.200	1.052
Mean	0.863	0.890	0.976	1.211	1.277	

C.D. at 0.05 level for comparing fertilizer levels = 0.0596

C.D. at 0.05 level for comparing interaction = 0.1032

S.E. for varieties = 0.0356

Table 24 (b)

Potassium content of stem at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.513	0.516	0.596	0.596	0.616	0.568
V_2	0.450	0.466	0.510	0.523	0.540	0.498
V_3	0.516	0.516	0.543	0.556	0.560	0.538
Mean	0.493	0.500	0.550	0.558	0.572	

C.D. at 0.05 level for comparing varieties = 0.0068

C.D. at 0.05 level for comparing fertilizer levels = 0.0089

C.D. at 0.05 level for comparing interaction = 0.0153

Table 24 (c)

Potassium content of tuber at harvest (%)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	0.683	0.683	0.713	0.743	0.753	0.715
V_2	0.593	0.596	0.663	0.703	0.730	0.657
V_3	0.580	0.596	0.640	0.733	0.750	0.660
Mean	0.618	0.625	0.672	0.726	0.744	

C.D. at 0.05 level for comparing varieties = 0.0104

C.D. at 0.05 level for comparing fertilizer levels = 0.0135

C.D. at 0.05 level for comparing interaction = 0.0233

4.6. Uptake studies

4.6.1. Nitrogen uptake

The nitrogen uptakes at sixty days intervals were studied and the data were statistically analysed. The mean values are given in Tables 25 (a) to 25 (c) and analysis of variance in Appendix VIII.

Uptake at sixty days after planting

The mean values are presented in Table 25 (a) and the analysis of variance in Appendix VIII.

The varieties differed significantly. Variety V_3 recorded the highest nitrogen uptake at this stage which was significantly superior to other varieties. V_1 recorded the lowest uptake value at this stage.

The different levels of N P K combination tried also had significant effects on the uptake of nitrogen. The highest N uptake was by L_5 level and the lowest by L_1.

The interaction effects were not significant.

Uptake at one hundred and twenty days after planting

The mean values are presented in Table 25 (b) and analysis of variance in Appendix VIII.

There was significant effect due to the varieties. The varieties V_2 and V_3 were on par and significantly superior to V_1.

Table 25 (a)

Uptake of Nitrogen - 60 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	25.65	27.36	32.07	32.46	34.24	30.35
V_2	25.66	27.89	33.03	35.58	37.13	31.86
V_3	28.56	29.78	33.92	35.31	37.53	33.02
Mean	26.62	28.34	33.00	34.45	36.30	

C.D. at 0.05 level for comparing varieties = 0.9489

C.D. at 0.05 level for comparing fertilizer levels = 1.225

S.E. for interaction = 0.7326

Table 25 (b)

Uptake of Nitrogen - 120 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	61.06	63.02	67.07	72.07	75.63	67.77
V_2	62.34	63.99	72.67	75.84	77.62	70.49
V_3	64.81	66.74	71.49	73.28	76.15	70.49
Mean	62.74	64.58	70.41	73.73	76.47	

C.D. at 0.05 level for comparing varieties = 1.128

C.D. at 0.05 level for comparing fertilizer levels = 1.456

C.D. at 0.05 level for comparing interaction = 2.522

Table 25 (c)

Uptake of Nitrogen - 180 days after planting (at harvest)

(kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	81.15	82.67	98.73	105.08	113.27	96.18
V_2	79.60	82.18	101.87	105.00	115.29	96.99
V_3	78.81	81.55	90.87	100.63	110.42	92.45
Mean	79.85	82.13	97.16	103.91	112.99	

C.D. at 0.05 level for comparing varieties = 0.4727

C.D. at 0.05 level for comparing fertilizer levels = 0.6103

C.D. at 0.05 level for comparing interaction = 1.057

The different fertilizer levels also had significant effects on the uptake of nitrogen. The highest uptake was recorded in the L_5 level and lowest in L_1 level.

The interaction effects were also significant. V_1L_1 recorded the lowest value and V_2L_5 the highest. For the variety V_1 and V_3, L_1 and L_2 were on par and for V_2, L_1 and L_2, and L_4 and L_5 were on par.

Uptake at one hundred and eighty days after planting

The mean values are presented in Table 25 (c) and the analysis of variance in Appendix VIII.

There was significant difference due to the varieties. V_2 recorded the highest uptake closely followed by V_1.

The different levels of fertilizers tried also had significant effects. The highest uptake was recorded by L_5 level and the lowest by L_1.

The interaction effects were also significant. V_2L_5 recorded the highest value and V_3L_1 the lowest.

4.6.2. Uptake of Phosphorus

The uptake of phosphorus was studied at sixty days interval and the data were statistically analysed. The mean values are presented in Tables 26 (a) to 26 (c) and the analysis of variance in Appendix VIII.

Uptake at sixty days after planting

The mean values are presented in Table 26 (a) and the analysis of variance in Appendix VIII.

There was significant difference due to the varieties. Variety V_3 (Sree Sahya) recorded the highest uptake at this stage and V_1 the lowest.

The fertilizer levels also differed significantly. The highest uptake was observed with the L_5 level and the lowest with L_1.

The interaction effects were not significant.

Uptake at one hundred and twenty days after planting

The mean values are presented in Table 26(b) and the analysis of variance in Appendix VIII.

The varieties differed significantly. At this stage also the highest uptake was noticed in V_3 (Sree Sahya) closely followed by V_2 (Kaduthuruthy local) and the lowest values were recorded by V_1 (Thottakolli).

Among the different levels of fertilizers tried, L_5 recorded maximum uptake which was significantly different from other levels.

Table 26 (a)

Uptake of phosphorus - 60 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	3.76	4.22	5.12	5.33	5.58	4.80
V_2	4.20	4.80	5.56	5.99	6.57	5.42
V_3	4.79	5.00	5.94	6.34	6.78	5.77
Mean	4.25	4.67	5.54	5.88	6.31	

C.D. at 0.05 level for comparing varieties = 0.1875

C.D. at 0.05 level for comparing fertilizer levels = 0.2421

S.E. for interaction = 0.1448

Table 26 (b)

Uptake of phosphorus - 120 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	11.58	11.83	14.13	14.71	15.39	13.53
V_2	13.51	14.38	15.34	15.92	17.03	15.24
V_3	14.35	14.27	16.00	16.83	17.35	15.76
Mean	13.14	13.49	15.16	15.82	16.59	

C.D. at 0.05 level for comparing varieties = 0.2762

C.D. at 0.05 level for comparing fertilizer levels = 0.3567

C.D. at 0.05 level for comparing interaction = 0.6178

Table 26 (c)

Uptake of phosphorus - 180 days after planting (harvest)

(kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	16.12	16.40	20.76	21.62	21.86	19.35
V_2	19.09	19.53	23.65	24.62	27.47	22.87
V_3	17.48	17.56	21.19	23.71	26.41	21.27
Mean	17.56	17.83	21.86	23.32	25.24	

C.D. at 0.05 level for comparing varieties = 0.5021

C.D. at 0.05 level for comparing fertilizer levels = 0.6482

C.D. at 0.05 level for comparing interaction = 1.123

The interaction effects were also significant. For the variety V_1, L_1 and L_2, and L_3 and L_4 were on par. For the variety V_2, L_3 and L_4 were on par and for the variety V_3, L_1 and L_2 were on par.

Uptake at one hundred and eighty days after planting

The mean values are presented in Table 26 (c) and the analysis of variance in Appendix VIII.

The three varieties differed significantly. Variety V_2 (Kaduthuruthy local) recorded the highest uptake of phosphorus and V_1 the lowest.

The different fertilizer levels tried also had significant effects eventhough the levels L_1 and L_2 were on par.

The interaction effects were also significant. The lowest uptake was observed in V_1L_1 and the highest in V_2L_5. For the variety V_1, L_1 and L_2, and L_4 and L_5 were on par. For V_2, L_1 and L_2, and L_3 and L_4 were on par while for V_3, L_1 and L_2 were on par.

4.6.3. Uptake of Potassium

The uptake of potassium was studied at sixty days interval and the data were statistically analysed.

The mean values are presented in Tables 27 (a) to 27 (c) and the analysis of variance in Appendix VIII.

Uptake at sixty days after planting

There was significant difference in the uptake of K due to varieties. V_2 recorded the highest uptake followed by V_3 and it was significantly superior to V_1.

The different fertilizer levels tried also resulted in significant differences in the uptake of K. The highest uptake was observed with L_5 level and the lowest with L_1 level.

The interaction effects were not significant.

Uptake at one hundred and twenty days after planting

The mean values are presented in Table 27 (b) and the analysis of variance in Appendix VIII.

There was no significant difference among the varieties in the uptake of potassium at this stage.

The effects due to the fertilizer levels were significant. The highest uptake was observed with L_5 level and lowest with L_1 level.

The interaction effects were also significant. V_2L_1 recorded the lowest uptake while V_2L_5 recorded the highest uptake.

Table 27 (a)

Uptake of potassium - 60 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	14.32	15.94	19.43	21.52	23.27	18.90
V_2	14.65	16.81	21.01	24.32	26.71	20.70
V_3	16.36	17.35	20.87	22.44	25.91	20.58
Mean	15.11	16.70	20.44	22.76	25.29	

C.D. at 0.05 level for comparing varieties = 0.7402

C.D. at 0.05 level for comparing fertilizer levels = 0.9557

S.E. for interaction = 0.5715

Table 27 (b)

Uptake of potassium - 120 days after planting (kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	41.01	42.43	47.90	55.02	58.71	49.01
V_2	39.10	41.47	48.38	54.57	58.84	48.47
V_3	40.85	42.95	47.62	53.69	56.23	48.27
Mean	40.32	42.28	47.96	54.43	57.92	

C.D. at 0.05 level for comparing fertilizer levels = 0.9199

C.D. at 0.05 level for comparing interaction = 1.593

S.E. for varieties = 0.2461

Table 27 (c)

Uptake of potassium - 180 days after planting (harvest)

(kg/ha)

	L_1	L_2	L_3	L_4	L_5	Mean
V_1	66.09	67.83	86.15	95.80	103.02	83.78
V_2	60.15	62.62	83.93	94.68	102.54	80.78
V_3	50.77	52.94	67.43	89.02	95.89	71.21
Mean	59.00	61.13	79.17	93.17	100.48	

C.D. at 0.05 level for comparing varieties = 1.526

C.D. at 0.05 level for comparing fertilizer levels = 1.971

C.D. at 0.05 level for comparing interaction = 3.413

Uptake at one hundred and eighty days after planting

The mean values were presented in Table 27 (c) and the analysis of variance in Appendix VIII.

There was significant difference in the uptake of potassium at harvest due to varieties. Variety V_1 (Thottakolli) recorded highest uptake and V_3 (Sree Sahya) the lowest.

The effects due to fertilizer levels differed significantly, the lowest being in L_1 and the highest in L_5.

The interaction effects were also significant, V_3L_1 giving the lowest and V_1L_5 the highest. In all the three varieties L_1 and L_2 levels were on par.

4.7. Economics of cultivation

4.7.1. Cost Benefit ratio

Cost benefit ratio was worked out for the three varieties and for the different combinations. The data are presented in Table 28 (a) and 28 (b).

The highest ratio was observed with Kaduthuruthy local (1.37) closely followed by Thottakolli (1.35) and the lowest with Sree Sahya (1.08).

Regarding the variety-fertilizer combinations, the highest ratio of 1.69 was recorded by Thottakolli at 50:50:100 kg $N:P_2O_5:K_2O$/ha level followed by Kaduthuruthy local (1.58) at 50:50:100. When the latter variety was grown at 50:50:75 nutrient level the ratio was 1.57 and at 50:50:50 it was 1.56. It can be thus concluded that Thottakolli can be economically grown in the uplands of Kuttanad at 50:50:100 kg $N:P_2O_5:K_2O$/ha and Kaduthuruthy local at 50:50:50 kg $N:P_2O_5:K_2O$/ha.

Table 28 (a)

Economics of fertilizer application. Cost benefit ratio for variety - fertilizer combinations.

Sl. No.	Treatments	N P K	Cost of cultivation Rs/ha	Yield t/ha	Value of tuber Rs/ha	Profit (Rs)	Cost benefit ratio
1	V_1L_1	(30:30:30)	9714	19.93	9965	251	1.02
2	V_1L_2	(30:30:45)	9748	20.50	10250	502	1.05
3	V_1L_3	(50:50:50)	9985	29.71	14855	4870	1.48
4	V_1L_4	(50:50:75)	10040	29.96	14980	4940	1.49
5	V_1L_5	(50:50:100)	10095	34.21	17105	7010	1.69
6	V_2L_1	(30:30:30)	9714	19.09	9545	- 169	0.98
7	V_2L_2	(30:30:45)	9748	21.75	10875	1127	1.12
8	V_2L_3	(50:50:50)	9985	31.34	15670	5685	1.56
9	V_2L_4	(50:50:75)	10040	31.60	15800	5760	1.57
10	V_2L_5	(50:50:100)	10095	31.91	15955	5860	1.58
11	V_3L_1	(30:30:30)	9714	16.32	8160	-1554	0.84
12	V_3L_2	(30:30:45)	9748	18.18	9090	- 658	0.93
13	V_3L_3	(50:50:50)	9985	20.66	10330	345	1.03
14	V_3L_4	(50:50:75)	10040	24.90	12450	2410	1.24
15	V_3L_5	(50:50:100)	10095	26.81	13405	3310	1.33

Cost of Nitrogen - Rs.5.25/kg
Cost of Phosphorus - Rs.6.07/kg
Cost of Potash - Rs.2.21/kg
Value of raw tuber - Rs.500/t

Table 28 (b)

Economics of fertilizer application. Cost benefit ratio for the varieties.

	Cost of cultivation	Mean yield t/ha	Value of tubers Rs./ha	Profit (Rs)	Cost benefit ratio
V_1	9916.40	26.86	13430	3513.60	1.35
V_2	9916.40	27.13	13565	3648.60	1.37
V_3	9916.40	21.37	10685	768.60	1.08

DISCUSSION

5. DISCUSSION

The results of the investigation on the N P K combinations on short duration tapioca varieties grown in the uplands of Kuttanad are discussed below.

5.1. Growth characters

5.1.1. Height of the plant

The results showed that plant height was significantly different among the three varieties of tapioca grown at all the three stages of observation. Sree Sahya produced the tallest plants followed by Keduthuruthy local and the shortest height was observed in Thottakolli. This conspicous difference in plant height would be attributed to their varietal character. It was noted that the uptake of N was maximum in Sree Sahya at the early stages (Table 25 a & b) and the increased quantity of N taken during these periods might have been utilised for the rapid growth resulting in increased plant height at these stages.

Significant differences in plant height were observed due to different fertility levels also and the tallest plant height was noticed under the highest level of fertilizer combination namely 50:50:100. The influence

of major nutrients especially nitrogen in increasing the plant height is well known. Similar increases in plant height due to higher levels of nutrients have been reported in tapioca by several workers like Mandal et al. (1975), Natarajan (1975), Ngongi (1976) and Pillai and George (1978 a).

5.1.2. Number of leaves per plant

It was found that there was significant difference in the number of leaves produced by the different varieties. During the 60th day Sree Sahya produced the maximum number of leaves where as at the later stages Kaduthuruthy local recorded the highest number. The growth stage from the 3rd to 8th month is important in tapioca as tuberisation and tuber development occur during this period. The lower number of leaves observed during the later stages in Sree Sahya would have been responsible for the low tuber yield in this variety as is evident from the yield data (Table 12).

As in the case of plant height leaf production was also increased due to higher fertility level. The influence of major nutrients in increasing the vegetative parts including leaves has been reported by several

workers like Ngongi (1976), Pushpadas and Aiyer (1976), Ramaswamy and Muthukrishnan (1980) and Holmes and Wilson (1982).

5.1.3. Leaf Area Index (LAI)

There was significant difference in the leaf area index due to different varieties of tapioca at all the stages of growth. Leaf area index, being the total leaf area by land area, would be influenced by the difference in the number of leaves present in the plant. It has to be noted that number of leaves was maximum in Kaduthuruthy local at the second and third observations which in turn might have contributed for an increased leaf area index in this variety.

The levels of nutrition also showed significant difference in the leaf area index. There was an increasing trend up to L_4 level (50:50:75) in all the stages and the effects of L_4 and L_5 (50:50:100) were on par. The importance of nutrition as a factor in influencing leaf area index has been reported in many crops by different workers. Russel (1973) reported that as the nitrogen supply increased the extra protein produced stimulated the plant leaves to grow larger and hence to

have a larger surface area available for photosynthesis. In this case N, P and K would have caused such an increase in the leaf area index. The results obtained in the present investigation are in conformation with the findings of Ngangi (1976), Pillai and George (1978 b) and Asokan et al. (1980).

5.2. Yield attributes

5.2.1. Total number of roots

Among the three varieties Sree Sahya produced maximum number of roots per plant which was significantly superior to other varieties. The lowest number was recorded by the variety Thottakolli. It is probable that different varieties behave differently in the production of roots.

Increased fertility levels progressively increased the total number of roots per plant. Increasing the amounts of the different nutrient elements upto certain levels might have influenced the plant to produce more number of roots per plant in them.

5.2.2. Number of productive roots

Significant differences were observed among the different varieties on the production of productive roots

in the plant. Thottakolli and Kaduthuruthy local were on par in this character while Sree Sahya registered a significantly lower value. It is thus seen that the different varieties behaved differently.

Increasing the fertility levels progressively increased the number of productive roots in the plant. The lowest level produced the lowest number of productive roots and the highest level of nutrition produced the highest number. In tapioca productive roots (tuber) is considered as an important yield component. Crops such as tubers which are grown for carbohydrates show a higher rate of photosynthesis consequent on increased leaf area obtained by higher levels of nutrition (Russel, 1973). Such increases in leaf area have been observed in the present investigation also (Tables 3 a to 3 c). This might have lead to the production of large number of productive roots in plants supplied with increasing levels of nutrition. Several investigators like Pushpadas and Aiyer (1969), Natarajan (1975) and Mohankumar and Mandal (1977) observed such results earlier.

5.2.3.Percentage of productive roots

From the results it was seen that the varieties differed significantly in this character. The percentage of productive roots was highest in Thottakolli while Sree Sahya gave the lowest value. Though the total root production was maximum in Sree Sahya it was unable to convert a large number of unproductive roots to productive roots where as in the other cases higher percentage of total roots were converted to productive roots.

Different nutritional levels also caused significant differences in the percentage of productive roots. When sufficient amounts of nutrient elements are available in the soil, a good number of roots would be converted into storage roots.

5.2.4.Length of tuber

The length of tuber was high in Sree Sahya and low in Kaduthuruthy local. The length of tuber is more influenced by variety rather than the environmental situations.

The fertilizer levels also influenced the length of tuber significantly. It is interesting to note that the lowest level of nutrition had produced the maximum length of tuber. This might be due to the fact that under

nutrient stress situations, there would be a tendency for the plant roots to go deeper and wider in search of sufficient quantities of nutrients resulting in an increase in the length of tuber at the lowest nutrient level.

5.2.5. Girth of tuber

Significant differences were observed in the girth of tubers among the three varieties. Kaduthuruthy local recorded the highest girth of tuber. This difference in girth can be attributed to be a varietal character.

The influence of different levels of nutrition was also significant. There was progressive increase in girth of tubers due to incremental levels of nutrition. As seen earlier, the incremental levels of nutrition have increased the growth characters in all the varieties resulting in an increased photosynthetic capability in plants. Under such a situation it is probable that more of photosynthates might have been produced in the plant which might have been accumulated in tubers being the main storage organs in tapioca. This might be the possible reason for increased girth of tuber due to increasing levels of nutrition. Similar increase in diameter of tuber was

earlier reported by Mandal and Mohankumar (1972 b) and Acosta and Pinto (1978) due to increased levels of nutrients.

5.2.6. Utilization Index

Highest utilization index was observed in the variety Sree Sahya followed by Kaduthuruthy local. It is to be noted that number of leaves in Sree Sahya at the later stages was low as compared to other varieties. Perhaps this might have contributed to a higher utilization index to this variety.

The different fertility levels also caused significant differences in the utilization index in tapioca varieties. The value was maximum at the lowest level of nutrition. The nutrients given at the lowest levels might have been more efficiently utilized for tuber formation rather than for growth of other vegetative parts resulting in an increased utilization index at the lowest level of nutrients. Decrease in utilization index at higher levels of nutrient application has been earlier reported by CIAT (1977), Ramanathan et al. (1980), Gomes and Howeler (1980), Nair (1982) and Kang and Okeke (1984). At higher

nutrition levels low utilisation index was obtained mainly due to high top yields noticed at these levels.

5.2.7. Rind to flesh Ratio

Among the tapioca varieties Sree Sahya recorded the highest rind to flesh ratio. Thickness of rind in tuber is a varietal character and this variety possesses thick rind of tuber resulting in higher weight and finally a high rind to flesh ratio.

Different levels of nutrients did not show any significant effect on rind to flesh ratio confirming that this would be a varietal character.

5.2.8. Top yield

The data given in Table 11 showed that top yield was highest in Thottakolli and it was the lowest in Sree Sahya. It has been seen that the total number of leaves was comparatively poor in Sree Sahya when compared to other two varieties. This might have resulted in lowest top growth in this variety. The varietal difference in the top growth of tapioca is well known.

Progressive increases in the top yield with incremental doses of nutrients were observed in this trial and the maximum was attained in the L_5

level (50:50:100). The role of the three major nutrients tried in this experiment in increasing the vegetative growth of the plant is well known. Increases in top yield due to higher doses of nutrients especially nitrogen have been reported by CIAT (1975), Kang and Wilson (1980) and Nair (1982). The highest levels of N, P and K tried in the combinations were 50, 50 and 100 kg/ha respectively and upto these maximum levels the growth rate was linear. As the supply of nitrogen increases and when the other nutrients are not acting as limiting factors, more nitrogen reaches the tops and involves in the carbohydrate and protein synthesis leading to increased growth resulting in an enhanced top growth (Russel, 1973).

.3.Tuber Yield

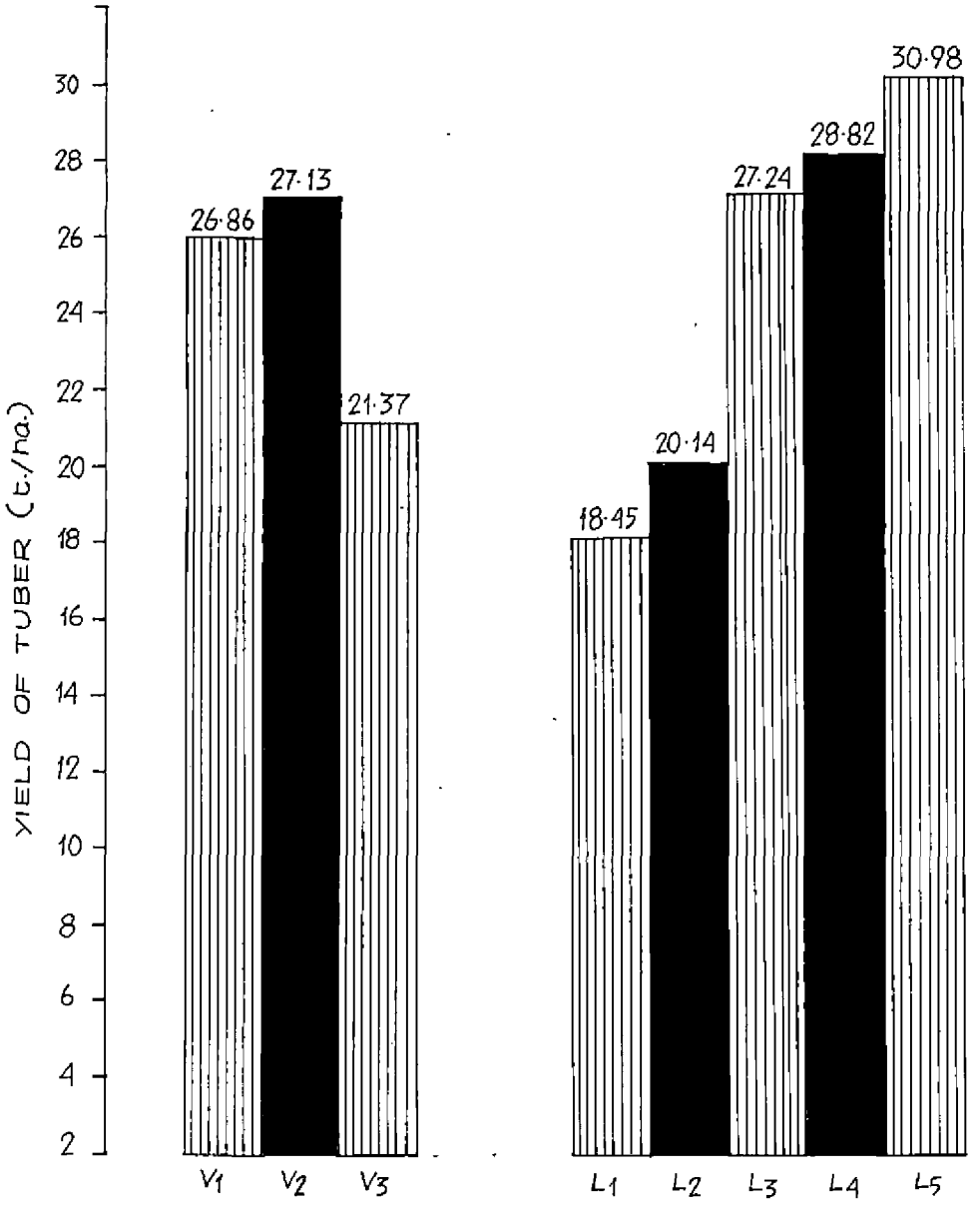
The effect due to varieties in tuber yield was significant. The variety Kaduthuruthy local recorded the highest tuber yield which was significantly superior to Sree Sahya. Sree Sahya, released by CTCRI, has been recognised as a higher yielder. But in the present investigation, it could not produce the highest yield probably because the crop was harvested at the sixth month after planting. Sree Sahya takes about ten months

to manifest its full production potential. The idea in this study is to assess the yielding ability of the varieties at a shorter period, ie. to identify a variety which can yield at appreciably higher rates within the shorter period. Varietal differences in the yielding capacity of tapioca are well known and needs no emphasis.

Tuber yield increased significantly by the incremental levels of nutrition. The highest yield was recorded by the L_5 level and the lowest in L_1 level. Nitrogen and potassium play a vital role in photosynthesis and carbohydrate accumulation in plants. The yield of tapioca depends more upon the extent of assimilation and assimilate accumulation in the roots. Assimilation in turn, depends on the extent of assimilating surface. The influence of the above nutrients in increasing the assimilating surface (leaf area) of plant is well known. Increase in leaf area due to higher levels of nutrients has been observed in the present experiment also (Tables 3 a to 3 c).

The important yield components in tapioca viz., productive roots (number of tubers per plant) and girth of tubers were favourably influenced by higher levels of

YIELD OF TUBER . AS INFLUENCED BY VARIETIES AND FERTILIZER LEVELS.



V_1 - THOTTAKOLLI

V_2 - KADUTHURUTHY LOCAL

V_3 - SREE SAHYA

	N	P_2O_5	K_2O	
L_1 -	30 :	30 :	30	kg./ha.
L_2 -	30 :	30 :	45	"
L_3 -	50 :	50 :	50	"
L_4 -	50 :	50 :	75	"
L_5 -	50 :	50 :	100	"

SCALE

x axis - 1 c.m. = 2 tonnes

Fig.4

nutrients. All these factors either individually or collectively might have contributed substantially to the higher tuber yield observed at the higher levels of nutrient application. Increases in tuber yield due to higher levels of nutrients have already been reported by several workers like Mandal et al. (1971), Mohankumar and Naini (1977), Cadavid and Howeler (1982) and Mohankumar et al. 1984). Thus, the results obtained in the present study are in agreement with the findings of the above workers.

5.4. Quality attributes

5.4.1. Starch content of tubers at harvest

The results show that starch content of tuber varied due to varieties. Sree Sahya had the highest starch content in tuber when compared to other two varieties. Variation in starch content of tuber can be considered mainly as a varietal character.

Increasing the fertilizer doses progressively increased the starch content also. The higher starch content observed at higher nutritional levels may probably be due to the enhanced rate of photosynthetic activity of

leaves which in turn might have resulted in increased starch content of tuber. Increase in starch content of tuber by increased nutrition has been earlier reported by several workers like Mandal et al. (1971), Obigbesan and Agboola (1973), Pillai and George (1978 c) and Nair (1982).

5.4.2. HCN content of tubers at harvest

From the results it is seen that the varieties differed significantly in their HCN content. HCN content of tuber is important as it decides to a large extent the value of tubers for human consumption. Though this is mostly a varietal character, agronomic treatments also play a decided role in changing the HCN content of tuber. The HCN content was significantly reduced when the level of K was increased. This is in conformity with the findings of Indira et al. (1972), Muthuswamy (1981), Nair (1982), Nair and Kumar (1982) and Ramanujam (1982) who found that potassium alone or in combination with nitrogen reduced the HCN of tapioca tubers.

5.4.3. Crude protein content of tubers

The results (Table 15) show that the crude protein content of tuber was significantly different in different

varieties. The variety Kaduthuruthy local recorded the highest crude protein. Varietal difference in crude protein content of tuber in tapioca has been well established and hence needs no discussion.

The different nutrient levels also influenced the protein content of tuber significantly. As the dose of nutrients increased there was a progressive increase in crude protein content also. This was very conspicuous when the dose was changed from 30:30:30 to 50:50:100 kg N P K/ha. The favourable effects of nutrients on protein synthesis are well known. Tapioca is considered as a poor source of protein in human diet. An improvement of this quality to some extent is possible by agronomic manipulations like increased application of nitrogen. Increases in the crude protein content of tuber by incremental doses of nutrients have been reported in different tuber crops by Hukkeri (1968), Pillai and George (1978 c), Mohandas and Sethumadhavan (1980) and Nair (1982). The results obtained in the present investigation are in conformity with the above works.

5.4.4. Cooking quality

From the test conducted it has been seen (Table 16)

that the variety Thottakolli has shown the highest cooking quality followed by Kaduthuruthy local. Cooking quality is mainly a varietal character.

5.5.1. Dry matter production of different plant parts

Leaf dry matter production was significantly different among the varieties. The variety Sree Sahya had the highest leaf dry matter on the 60th day when compared to other two varieties. It was seen that the total number of leaves at the 60th day after planting was maximum in this variety.(Table 2 a). This is probably the reason for high leaf dry matter production in Sree Sahya. However, during the later stages more leaf dry matter production was recorded by Kaduthuruthy local probably because of the higher number of leaves present in the plant during these stages (Tables 2 b and c).

The different fertilizer doses resulted in significant difference in leaf dry matter production. Increasing the levels of fertilizers has substantially increased the rate of growth of the plant resulting in increased number of leaves (Tables 2 a, b and c). This increased number of leaves at higher levels of nutrition might have contributed to increased leaf dry matter production at these stages.

In the case of stem dry matter production also there was significant difference among the varieties. The variety Kaduthuruthy local recorded the highest values during all the stages. Differences in the architecture of the different varieties can be attributed to this differences in stem dry matter production.

The effect of different levels of nutrition was also significant. There was progressive increase in stem dry matter production with increasing levels of nutrition. The pattern of increase was more or less the same at all the stages. The favourable influences of the nutrient elements N, P and K in increasing the photosynthetic activities and thereby increasing the vegetative growth of the plant parts are well known. The accelerated growth of stem at higher nutrient doses resulted in increased stem dry matter at all growth stages.

Regarding the dry matter production in roots the same pattern as seen in stem has been followed among the varieties as well as in the differential doses of fertilizers.

5.5.2. Total dry matter production of tuber at harvest

Varietal differences were significant in the total

dry matter production of tuber. The highest dry matter production was observed in Kaduthuruthy local and the lowest in Sree Sahya. It is to be noted that the tuber yield was highest in this variety and as such the total dry matter production was also higher in this variety.

The effects due to fertilizer levels were also significant. The highest fertility level (50:50:100) recorded the highest dry matter production whereas the dose of 30:30:30, the lowest. Here also the dry matter production was directly related to the tuber yield where it was highest in L_5 and lowest in L_1.

5.5.3. Total dry matter production of top at harvest

The effects due to varieties were significant on the dry matter production of top at harvest. The variety Kaduthuruthy local recorded the highest top dry matter. Stem height continued to be higher in this variety. Further, leaf and stem dry matter productions were also comparatively more in this variety. The cumulative effects of all these components might have resulted in an increased top dry matter production in Kaduthuruthy local.

Fertilizer levels also contributed significantly to top dry matter production, the maximum level of N P K (50:50:100) giving the highest top dry matter. As seen earlier, higher fertilizer doses in general encouraged the vegetative growth and the increased vegetative growth in turn resulted in a higher top dry matter production.

5.6. Plant analysis

5.6.1. Nutrient content in plant parts at harvest

Nitrogen content in leaves was highest in Thottakolli while in stem and tuber it was highest in Sree Sahya. The differences in the nitrogen content observed could be attributed to varietal character. The nitrogen contents were progressively increased in the plant parts with increased fertilizer application.

Phosphorus contents of leaves and stem were significantly high in the variety Sree Sahya while that of tuber, it was in Kaduthuruthy local. It was also observed that the phosphorus contents of plant parts were influenced by the increased nutrients supply especially phosphatic fertilizers.

The data presented on Table 24s revealed that the potassium content of the leaves was not significantly

influenced by varieties, where as in the stem and tuber, there were significant differences. In the case of stem and tuber the potassium content was maximum in Thottakolli.

Different fertilizer doses also influenced the potassium content of leaves, stem and tuber. The increase was conspicuous when potassium application was more, as is evident from the Tables (24 a to c). Probably higher the nutrient element applied to the soil more would be the uptake and contents in the plant parts.

5.7. Nutrient uptake

5.7.1. Nitrogen uptake

Differences were significant in the uptake of nitrogen by different varieties and also at different stages of growth. In the early stage ie. 60 days after planting, maximum uptake was recorded by Sree Sahya while at the later two stages, by Kaduthuruthy local. In the case of Sree Sahya the plant height was maximum at the 60th day indicating that this stage would have demanded for increased uptake of nutrient from the soil. But this variety could not maintain the same growth trend throughout its growth stages. In fact at the time of harvest, the total uptake of nitrogen by this variety was the lowest (Table 25 c)

with a corresponding low tuber yield. In the case of Kaduthuruthy local, the total uptake of N at the later two stage was high with a corresponding higher total dry matter production and tuber yield.

The different doses of nutrients also significantly influenced the uptake of nitrogen by the plant at all the stages. The highest uptake was observed with L_5 level (50:50:100) where as L_1 level (30:30:30) recorded the lowest and this pattern of uptake continued at all the stages of the growth. Increased uptake of N due to increased doses of fertiliser application has been reported by several workers like Mohankumar and Nair (1969) and Pushpadas et al. (1976).

5.7.2. Phosphorus uptake

From the data on the uptake of phosphorus (Tables 26 a to 26 c) it could be seen that phosphorus uptake was maximum in the case of Sree Sahya during the earlier two stages closely followed by Kaduthuruthy local. However, at the harvest stage uptake was more in the case of Kaduthuruthy local followed by Sree Sahya. It was seen earlier that the growth rate of the plant was more in Sree Sahya at the

early stages resulting in higher uptake of the different nutrients. This condition was changed when the growth was advanced and at the harvest stage Kaduthuruthy local recorded the highest value. The tuber yield was also high in the case of Kaduthuruthy local. This increased yield of tuber will be accorded for the increased uptake of nutrients.

5.7.3. Potassium uptake

On the 60th day after planting the uptake of potassium by the plants was significantly influenced by the varieties. The variety Kaduthuruthy local recorded the highest uptake. However, on the 120th day no significant difference could be observed in the uptake of potassium by the different varieties. On the other hand, at harvest, the variety Thottakolli recorded the maximum uptake of potassium. It was seen that potassium contents (Table 24 b and 24 c) of stem and tuber were the highest in Thottakolli at harvest when compared to the other two varieties and probably this high content might have resulted in the increased potassium uptake by this variety inspite of the comparatively lower dry matter production.

As in the case of other two nutrients, the uptake of potassium was also increased at the higher rates of nutrition. The higher doses of nutrient elements increased the total dry matter production which in turn accounted for the increased uptake of potassium. Higher uptake of potassium due to higher doses of nutrient elements has been reported by earlier workers like Chan and Lee (1982) and Nair and Kumar (1982).

SUMMARY

SUMMARY

An investigation was carried out to select a suitable early maturing variety of tapioca and to find out a fertilizer dose suitable for the variety in the uplands of Kuttanad. The experiment was conducted at the Regional Agricultural Research Station, Kumarakom, Kottayam during October 1984 to April 1985 in factorial randomised block design. The varieties tried were Thottakolli, Kaduthuruthy local and Sree Sahya. The fertilizer doses tried were 30:30:30; 30:30:50; 50:50:50; 50:50:75 and 50:50:100 kg N, P_2O_5 and K_2O/ha. The results of the investigation are summarised below.

1. There was significant difference in plant height due to varieties. The variety Sree Sahya produced the maximum plant height. Among the different fertilizer levels tried L_5 level (50:50:100) recorded the maximum plant height.

2. Variety Kaduthuruthy local was significantly superior in the production of total leaf number. The fertilizer level L_5 produced the highest leaf number in all the three varieties.

3. Highest leaf area index was recorded in the Kaduthuruthy local. Regarding the fertilizer levels, a slight reduction in leaf area index was observed for the varieties Thottakolli and Kaduthuruthy local at L_5 level during the harvest stage.

4. The varieties differed significantly in the production of total number of roots. Sree Sahya produced the highest total number of roots per plant. The highest number of roots was recorded in the L_5 level and the lowest in the L_1 (30:30:30) level.

5. Varieties Thottakolli and Kaduthuruthy local were on par in the production of total number of productive roots. A higher number of productive roots was observed in the L_5 fertility level in all the varieties.

6. The highest percentage of productive roots was noticed in the Thottakolli variety and the lowest in Sree Sahya. Among the different fertilizer levels tried, L_5 level recorded the highest percentage.

7. The length of tuber was maximum in Sree Sahya variety and low in Kaduthuruthy local. The lowest level L_1 recorded the maximum length while all the other levels were on par.

8. The varieties differed significantly in the girth of tubers. The variety Kaduthuruthy local has given the highest girth. The L_5 treatment produced tubers having higher length and all the other levels were on par.

9. The variety Sree Sahya exhibited highest utilization index followed by Kaduthuruthy local and Thottakolli. L_1 level (30:30:30) recorded the highest utilization index.

10. Rind to flesh ratio was significantly different among the varieties. The variety Sree Sahya gave the highest value. The different fertilizer levels did not make any significant influence on this character.

11. Maximum tuber yield was obtained from the variety Kaduthuruthy local (27.13 t/ha) which was on par with Thottakolli (26.86 t/ha). The L_1 level of N P K produced the lowest yield and L_5 the highest yield in all the varieties.

12. Top yield was maximum in Thottakolli and minimum in Sree Sahya. The different fertilizer doses also exerted significant influence on the top yield, L_5 level gave the highest values and L_1 the lowest.

13. The variety Kaduthuruthy local produced the highest leaf, stem and root dry matter. The different fertilizer

levels tried also significantly influenced the leaf, stem and root dry matter production. The 50:50:100 kg/ha level gave the maximum production.

14. Nitrogen uptake was maximum in the Kaduthuruthy local at the time of harvest closely followed by Thottakolli. The highest uptake was recorded in the L_5 level. The above variety also recorded the highest phosphorus uptake while Thottakolli showed the highest potassium uptake.

15. The highest nitrogen content in leaf was noticed in Thottakolli while Sree Sahya recorded the highest nitrogen content in stem and tuber. Regarding the phosphorus content Sree Sahya recorded the highest in leaf and stem while in root Kaduthrutuhy local recorded the highest value. But in the case of potassium content in leaf the varieties did not differ significantly. In stem and root, highest values of potassium were recorded by Thottakolli.

16. Tuber and top dry matter production per hectare was maximum in the variety Kaduthuruthy local. The different fertilizer levels tried were also significant in tuber and top dry matter production.

17. The varieties Sree Sahya and Kaduthuruthy local were on par in starch content. The highest starch content was observed in the 50:50:100 kg/ha fertilizer level and all the other levels were on par.

18. Among the varieties, Thottakolli had the least HCN content in tuber.

19. Regarding the crude protein content, Kaduthuruthy local was significantly superior to others. The highest content of crude protein was in L_5 level.

From the investigation, it was found that Kaduthuruthy local and Thottakolli were the suitable short duration varieties which could be successfully cultivated in the uplands of Kuttanad. Regarding the manurial dose the 50:50:100 kg $N:P_2O_5:K_2O$/ha was the most economical for Thottakolli and 50:50:50 kg $N:P_2O_5:K_2O$/ha for the Kaduthuruthy local.

REFERENCES

REFERENCES

*Acosta, C. and Pinto, J. (1978). Influence of N P K on cassava yields in Northern Colombia. In Instituto Colombiano Agropecuan Programa Nacional de Suelos. Informe de Progreso. 1976-77. Bogota, 1978. pp. 137-138.

*Allen, G.H. (1979). Cassava, a new look at an old crop. Queensland Agric. J. 105(1): 58-71.

Anonymous, (1975). Annual report (1975), Central Tuber Crops Research Institute, Trivandrum.

Anonymous, (1983). Two Decades of Research (1963-1983). Central Tuber Crops Research Institute, Trivandrum.

A.O.A.C. (1969). Official and Tentative Methods of Analysis. Association of Official Agricultural Chemists, Washington, D.C. 10th Edn.

Arismendi, L.G. (1980). Fertilization. Escuela de Ingenieria Agronomica 1980. pp.98-126.

Asher, C.J., Edwards, D.G. and Howeler, R.H. (1980). Nutritional Disorders of Cassava, Dept. of Agriculture, University of Queensland, St. Lucia, Queensland, 1980.

Asokan, P.K. (1981). Fertilizer trial on cassava. Annual report, All India Co-ordinated Project for the Improvement of Tuber Crops (other than potato). College of Horticulture, Vellanikkara, Trichur, 1981.

Asokan, P.K., Neelakantan Potty, N. and Sudhakara, K. (1980). Nutritional studies on cassava in the red sandy loam soil of North Malabar. Proc. of the National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov., 1980. pp.72-74.

Asokan, P.K. and Sreedharan, C. (1977). Influence of levels and time of application of potash on growth, yield and quality of tapioca. J. Root. Crops. 3(2): 1-4.

Asokan, P.K. and Sreedharan, C. (1980). Effect of potash on growth, yield and quality of tapioca variety H-97. Proc. of the National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov., 1980. pp. 78-80.

Barrus, R.S., Mercos, W.C. and Alvim, R. (1978). Sink strength and Cassava productivity. Hort. Science. 13(4) 474-475.

Cedavid, L;L.F. (1980). Use of phosphate rocks in Cassava cultivation. CIAT - Seminarious internos Seric SE - 18-80.

*Cadavid, L;L.F. and Howeler, R.H. (1982). Fertilization in cassava and its long term effect on soil fertility. Suelos Ecuatoriales, 12(1): 59-75.

*Cepedav, R.A. and ACOSTAS, C.E. (1980). Cassava fertilization in soils at the Centro Regional de Investigacion El Carmen in Bolivar. Revista ICA. 18(1): 9-17.

Chan, S.K. and Lee, C.S. (1982). Relationships of tuber yield, starch content and starch yield of cassava with potassium status of fertilizer, soil and leaf. International Symposium on Tropical root and Tuber Crops 5th proc. pp. 461-473.

CIAT (1974) Annual report 1974 Cali, Colombia, CIAT.

CIAT (1975) Annual report 1975 Cali, Colombia, CIAT.

CIAT (1977) Annual report 1977 Cali, Colombia, CIAT.

CIAT (1978) Annual report 1978 Cali, Colombia, CIAT.

CIAT (1979) Annual report 1979 Cali, Colombia, CIAT.

Cochran, W.G. and Cox, G.M. (1965). Experimental designs. Asia Pub. House.

Cock, J.H. (1979). The ideal cassava plant for maximum yield. Crops Science. 19: 271-279.

Correa, H., Tanaka, R.T., Guedes, G.A.A., Andrade, A.M.S. and Rochaby, D.A. (1979). Levels of phosphorus and time of nitrogen and potassium application in cassava cultivation on a red dark latosol. In Congresso Brasileiro de Mandioca. Departmento de Informcaoe Documentaco. pp. 317-323.

*Cotejo junior, F.R. and Talatala, R.L. (1978). The effect of rate and time of fertilizer application on the yield of cassava. Visca Vista. 1(1): 22-23.

Godfrey-Sam-Aggrey, W. and Garber, M.J. (1978). Responses of cassava to potash fertilizers in Sierra Leone. Potash Rev. (1978). Sub. 27, Suite 86, pp.9.

Gomes, J. de C. (1979). Cassava fertilization. Paper presented at Curso Intensivo Nacional de Mandioca-30.

Gomes, J. de C., and Ezeta, F.N. (1982). Potassium nutrition and fertilization of cassava in Brazil (Summary By EDITEC).

Gomes, J. de C. and Howeler, R.H. (1980). Cassava production in low fertility soils. Cassava cultural practices. Proc. of a workshop held in Salvador, Bahia, Brazil, 18-21 March 1980. pp. 93-102, 138-152.

*Gomes, J., de C., Magalhaes, A.F. de J. and Mattos, PLP de (1979). Effect of fertilization on Cassava yields in the State of Bahia. In Congresso Brasilerio de Mandioca Cruzdass Almas BA. pp. 263-277.

Gomes, J., Souza, R.F., Rezende, J. de O. and Lemos, L.M. (1973). Efeitos de NPKS. Micronutrientes e calagem na culture da mandioca IPEAL, Solos, Cruz das Almas, Bahia, Brasil. Boletim Tecnico No. 20: 51-68.

*Goomsrohit, K. (1975). A study of the response of Cassava to high rates of NPK fertilizers. Report of soil field crop fertilizer Bangkok, 1975. pp. 414-451.

Hicks, L.N. and Fukai, S. (1981). The response of cassava to phosphorus fertilizer on a mt. cotton yellow podzolic soil In cassava research programme St.Lucia, Australia, University of Queensland, Dept. of Agriculture, 1981. pp. 66-70.

Holmes, E.B. and Wilson, L.A. (1982). Effect of nitrogen supply on early growth development and nitrate reductase activity in two cassava cultivars. International Symposium on Tropical Root and Tubercrops 5th proc. pp. 487-506.

Howeler, R.H. (1976). La fertilization de la yuca. In curso sobre Production de Yuca. Cali, Colombia, Centro International de Agricultura Tropical (CIAT) pp. 150-162.

Howeler, R.H. (1980). Soil-Related cultural practices for cassava. Cassava cultural practices. Proc. of a workshop held in Salvador, Bahia, Brazil, 18-21 March, 1980. pp. 59-69.

Howeler, R.H. (1983). Plant tissue analysis to diagnose nutritional problems in some tropical crops. Cali. Colombia, Centro International de Agriculture Tropical 28 p. span, 23.

Hukkeri, S.G. (1968). Effect of N, P and K on the yield and quality of potato. Indian J. Agric. Sci. 38(5): 845-849.

Indira, P. (1982). Influence of potash on the HCN content in the bitter and non bitter varieties of cassava. Colloquium on potash Nutrition of Tropical Tuber Crops held at Central Tuber Crops Research Institute, Trivandrum. 21 May 1982. (unpublished).

Indira, P., Nagoon, M.L. and Jose, C.J. (1972). Studies on controlling cyanoglucoside content in cassava - effect of N P K on HCN content of tubers. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1972. pp. 55.

Indira, P. and Sinha, S.K. (1969). Colorimetric method for determination of HCN in tubers and leaves of cassava (Manihot esculenta Crantz). Indian J. agric. Sci. 39(11): 1021-1022.

Jackson, M.L.(1967). Soil Chemical Analysis. Prentice Hall of India Private Ltd. 2nd Edn. New Delhi. 1-498.

*Jellinck, G. (1964). Introduction to and critical review of modern methods of sensory analysis (odxir, taste, and flavour evaluation) with special emphasis on descriptive sensory analysis (Flavour profile method). J. Nutr. Diet. 1: 219-260.

Jintakanon, S., Edwards, D.G. and Asher, C.J. (1979). An anomalous high external phosphorus requirement for young cassava plants in solution culture. Paper presented at the International Symposium on Tropical root crops, 5th, Manila, Philippines. 1979 proc.

Kang, B.t., Okeke, J.E. (1984). Nitrogen and potassium responses of two cassava varieties grown on an Alfisol in Southern Nigeria. In symposium of the International Society for tropical Root Crops, 6th Lima Peru (1983). Proc. Lima International Potato Center. pp. 231-237.

Kang, B.T. and Wilson, G.F. (1980). Effect of Maize plant population and Nitrogen application on Maize - Cassava intercrop. Tropical Root Crops Research Strategies for the 1980s. Proc. of the First Triennial Root crops symposium of the International Society for Tropical Root crops - Africa branch held at Ibdan, Nigeria, 8-12 September, 1980. pp. 133.

Kanwar, J.S. (1974) Assessment of potassium fertilisation in the tropics and sub-tropics of Asia. Proceedings of the tenth congress on the International Potash Institute Institute in Budhapest, Hungary.

Keating, B.A. and Evenson, J.P. (1981). Field response to applied N and K at Red land Bay, S.E. Queensland. In Cassava Research Programme. St. Lucia, Australia, University of Queensland, Department of Agriculture. pp. 63-65.

Kumar, C.R. Mohan, Mandal, R.C. and Magoon, M.L. (1971). Influence of potash on Cassava. Indian J. Agron. 16: 82-84.

Kurian Thomas, Maini, S.B. and Indira, P. (1973). Basal application of cowdung and ash on the quality of cassava tubers. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1973. pp. 18-24.

*Leung, W.T.N., Butrum, R.R. and Chang, F.H. (1972). Proximate composition, mineral and vitamin contents of East Asian Foods. Food Camp. Tab. for use in East Asia. U.S. Govt. Printing Press.

Lorenzi, S.O., Gallo, S.R. and Malavolta, E. (1981). Dry matter and macronutrient accumulation by two Cassava cultivars - Bragantia. 40: 145-156.

Lorenzi, J.O., Monteiro, D.A. and Pereira, A.S. (1980). Effect of 3 levels of NPK on four Cassava varieties - Bragantia-39 : 219-223.

Magalhaes, P.C. (1981). Effect of different levels of 'P' in the presence and absence of 'N' and 'K' in cassava. Maccio-Al-Brasil, Empresa de Pesquisa Agropecurana de Estudo de Alagon. Pesquesa em Andaments No.08.4p.

Magalhaes, P.C., Begazo, J.C.E.O., Pauca, J.Fde. and Defehipo, B. (1980). Effects of levels, time and localization of potassium chloride on some cassava root characteristics. Revista Ceres. 27(151) 215-223.

Mandal, R.C. and Mohankumar, C.R. (1972 a). Effect of different combinations of nitrogen and potassium and time of application on tapioca (H-165). Annual report, Central Tuber Crops Research Institute, Trivandrum, 1972. pp. 32-34.

Mandal, R.C. and Mohankumar, C.R. (1972 b). Testing of different hybrids/selections of various tuber crops for their fertilizer requirements. (1) Effect of varying levels of nitrogen on cassava hybrids. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1972. pp. 28-30.

Mandal, R.C., Nair, G.M. and Kumar, C.R.M. (1975). Effect of farm yard manure and NPK alone and in combination on yield and quality of cassava (H-226). Annual report, Central Tuber Crops Research Institute, 1975. pp. 29-32.

Mandal, R.C. and Singh, K.D. (1970). Testing of different hybrids and selections of various tuber crops at different levels of organic manures and inorganic fertilizers. (b) Response of cassava to different levels of NPK. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1970. pp. 16-17.

Mandal, R.C., Singh, K.D. and Magoon, M.L. (1971). Relative efficacy of different sources, levels and split application of nitrogen in tapioca. Indian J. Agron. 16(4): 449-452.

Maraes, O., de., Mondardo, E., Vizzotto, V.K. and Machado, M.O. (1981). Chemical fertilization and liming on cassava.

Mohandas, P.N. and Sethumadhavan, P. (1980). Effect of graded doses of nitrogen, phosphorus and potash on the quality of Colocasia (Colocasia esculenta var: Thamarakkannan). Proc. of National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov., 1980. pp. 185-188.

Mohankumar, C.R. and Krishi, N. (1973). Testing of promising hybrids of cassava (3) effect of N and K on the yield of cassava varieties. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1973. pp. 20-22.

Mohankumar, B., Kabeerthumma, S. and Nair, P.G. (1984). Soil fertility management of tuber crops. Indian Fmg. 33(12): 35-37.

Mohankumar, B. and Maini, S.B. (1976). Influence of molybdenum and nitrogen on the yield and quality of cassava in acid laterite soil. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1976. pp. 39-40.

Mohankumar, B. and Maini, S.B. (1977). Influence of molybdenum and nitrogen on the yield and quality of cassava in acid laterite soil. Annual report, Central Tuber Crops Research Institute, Trivandrum. pp. 77-78.

Mohankumar, C.R. and Mandal, R.C. (1977). Studies on production economics of high yielding varieties of tapioca to the application of nitrogen. J. R. Crops. 3(2) 63-65. 1977.

Mohankumar, B. and Nair, P.G. (1969). Influence of N and K on yield and nutrient uptake of cassava (H-97). Annual report, Central Tuber Crops Research Institute, Trivandrum (1969). pp. 38-40.

Muthukrishnan, C.R. (1980). Tuber Crop Research in Tamil Nadu - A Resume. Proc. of National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov., 1980. pp.2.

Muthuswamy, P. and Chiranjivi Rao, K. (1979). Influence of nitrogen and potash fertilization on tuber yield and starch production. Potash Rev. (1979). Sub. 27. Suite 91.

Muthuswamy, P. and Rao, K.C. (1981). Influence of nitrogen and potash on the quality of tapioca tuber at different months of growth. Madras Agric. J. 68(3): 169-173.

Nair, G.M. (1976). Effect of N and K on tuber yield and quality of cassava. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1976. pp. 16-22.

Nair, V.M. (1982). Potash nutrition of tapioca (Manihot esculenta Crantz). Thesis submitted to the Kerala Agricultural University for Ph.D. degree.

Nair, P.G. and Kumar, B.M. (1982 a). Potassium fertilization of cassava in acid laterite soil. Colloquium on potash Nutrition of Tropical Tuber Crops held at Central Tuber Crops Research Institute, Trivandrum, 21 May, 1982.

Nair, P.G. and Kumar, B.M. (1982 b). Effect of different sources of potassium on the yield and quality of cassava. Colloquim on potash Nutrition of Tropical Tuber Crops held at Central Tuber Crops Research Institute, Trivandrum, 21 May, 1982.

Nair, P.G., Mohankumar, B. and Rajendran, M. (1980). Effect of different sources of potassium on the yield and quality of cassava. J. R. Crops. 6(2): 21-24.

Nair, P.G. and Mohankumar, B. (1984). Investigations on phosphorus nutrition of cassava in relation to residual effect and uptake. Annual Report 1984. Central Tuber Crops Research Institute. pp. 33-35.

Nair, P.G. and Prabhakar, M. (1984). Investigation on phosphorus nutrition in relation to residual effect and uptake. Annual Report (1983). Central Tuber Crops Research Institute. pp. 28-30.

Nakviroj, P., Kanakoran, P. and Swadeepiboon, S. (1971). A study on the nitrogen uptake of cassava and its fertilizer application. Progress Research report, Ministry of Agriculture, Bangkok, Thailand. pp. 1430-1436.

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

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

Ngongi, A.G.N. , Howeler, R.H. and MaC Donald, H.A. (1976). Effect of potassium and sulphur on growth yield and composition of cassava. Proc. of the Fourth Symposium of the International Society for Tropical Root Crops held at CIAT, Cali, Colombia, 1-7 August 1976. pp. 107-113.

Obigbesan, G.O. (1973). The influence of potassium nutrition on the yield and chemical composition of some tropical root and tuber crops. International potash Institute, Colloquium, tenth, Abidyan, Ivory Coast. pp. 439-451.

Obigbesan, G.O. (1977). Investigations of Nigerian Root and tuber crops: response of cassava cultivars to potassium fertilizer in Western Nigeria. J. Agric. Sci. 89: 23-27.

Obigbesan, G.O. and Agboola, A.A. (1973). An evaluation of the yield and quality of some Nigerian cassava varieties as affected by age. Proc. of the Third International Symposium on Tropical Root Crops held at IITA, Ibadan, nigeria, 2-9 Dec. 1973.

Obigbesan, G.O. and Fayemi, A.A.A. (1976). Investigations on Nigerian Root and Tuber Crops. Influence of nitrogen fertilization on the yield and chemical composition of two cassava cultivars (Manihot esculenta). J. Agric. Sci. 86: 401-406.

Obigbesan, G.O. and Fritz, A. (1980). Nigeria - fertilization of tuber crops in tropical areas. Reportes Agricolas. 1: 7-11 (1980).

Ofori, C.S. (1976). Effect of various nitrogen sources on the yield of cassava (Manihot esculenta Crantz). Ghana J. A. Sci. 9(2): 99-102.

Okeke, J.E., Obigbesan, G.O. and Fayemi, A.A.A. (1979 a). Evaluation of agronomic traits in six Nigerian cassava varieties on representative Ultisol and Alfisol of Southern Nigeria. J. R. Crops. 5(1-2): 25-31.

Okeke, J.D., Obigbesan, G.C., and Kang, B.T. (1979 b). Effect of fertilizer application on nutrient concentration and growth relationships in cassava. J. Root Crops. 5(1-2): 1-7.

Okeke, J.E., Kang, B.T. and Obigbesan, G.O. (1982). Effect of fertilizer and plant age on distribution of nutrients in Nigerian Cassava (Manihot esculenta). Experimental Agriculture. 18(4): 403-411.

Patterson, R., Fukai, S. and Edwards, D.G. (1981). Potassium nutrition of field grown cassava. In cassava Research programme. St.Lucia, Australia, University of Queensland, Department of Agriculture, pp. 94-95.

Pillai, K.G. and George, C.M. (1978 a). Studies on the response of N, P and K in conjunction with Ca on the growth and yield of tapioca (Manihot utilissima pohl). Var. "Malayan-4". Agri. Res. J. Kerala. 16(1): 43-48.

Pillai, K.G. and George, C.M. (1978 b). Studies on the response of N, P and K in conjunction with Ca on the growth and yield of tapioca (Manihot utilissima pohl) Var. "Malayan-4". Agri. Res. J. Kerala. 16(2): 119-124.

Pillai, K.G. and George, C.M. (1978 c). Quality of tubers in tapioca (Manihot utilissima pohl) var. "Malayan-4" as influenced by N, P and K and Ca fertilization. Agri. Res. J. Kerala. 16(2): 166-170.

Piper, C.S. (1950). Soil and plant analysis. Academic Press, New York.

Prabhakar, M. and Nair, G.M. (1977). Testing promising hybrids of cassava for their fertilizer requirement. Annual Report, Central Tuber Crops Research Institute, Trivandrum, 1977. pp. 24-26.

Prema, L., Thomas, E.J. and Aiyer, R.S. (1975). The usefulness of sensory methods of analysis by a taste panel in differentiating the quality of cassava tubers under different manurial treatments. Agri. Res. J. Kerala. 13(2): 141-145.

Pushpadas, M.V. and Aiyer, R.S. (1976). Nutritional studies on casseava. Effect of potassium and calcium on yield and quality of tubers. J. Root Crops. 2(2): 42-71.

Pushpadas, M.V., Vijayan, M.R. and Aiyer, R.S. (1976). Nutritional studies on cassava III Nutrient interrelationships at different stages of growth. J. Root Crops. 2(2): 23-33.

Queiroz, G.M.de (1980). Effect of fertilization with macro nutrients (NPK) on cassava in the State of Ceara. In Empresa de Pesquisa Agropecuariado Ceara. Relatorio anual de Pesquisa, Fitotecnia. Fortaleza-CE. Brasil 1980. pp. 83-96.

Rajendran, N., Kumar, B.M. and Nair, P.G. (1971). Effect of major nutrients on the yield and nutrient uptake of tuber crops (b) Influence of different sources and levels of nitrogen on the yield and nutrient uptake by cassava. Annual report, Central Tuber Crops Research Institute, Trivandrum, 1971. pp. 33-35.

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

Ramanathan, K.M., Francis, J., Honora, Subbiah, S., Appavu, K. and Rajagopal, C.K. (1980). Influence of N and K on the yield and quality of cassava. Proc. of the National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov. 1980. pp. 67-69.

Ramanujam, T. (1982). Effect of potassium on growth, dry matter production, yield and quality of cassava. Colloquim on potash nutrition of Tropical Tuber Crops held at Central Tuber Crops Research Institute, Trivandrum, 21 May 1982.

Ramanujam, J. and Indira (1978). Linear measurement and weight methods for estimation of leaf area in cassava and sweet potato. J. Root Crops. 4(2): 47-50.

Ramaswamy, N. and Muthukrishnan, C.R. (1980). Nutritional requirements of certain cultivars of tapioca. Proc. of the National Seminar on Tuber Crops Production Technology held at Coimbatore, 21-22 Nov. pp. 75-77.

Ramos, B.B., Mojica, P.S. (1982). Productivity of cassava - Manihot esculenta Crantz in a clayey, kaolinitic, isotryper - thermic - paleudult. Philippine Journal of Crop Science. 7(2): 123-127.

Richards, I.R. (1979). Response of tropical crops to fertilizer under farmers conditions - analysis of results of FAO fertilizer programme. Phosphorus in Agriculture. 76: 147-156 (1979).

Runsel, E.W. (1973). Soil conditions and plant growth. Longman group Ltd., London. Tenth Edn. pp. 30-43.

Sheela, K.R. (1981). Nutritional requirement of tapioca based intercropping system. Thesis submitted to the Kerala Agricultural University for M.Sc. (Ag) degree.

Sinha, S.K. (1969). Cyanogenic glucoside production and its possible control in cassava. Indian J. Pl. Physiol. 12: 140-147.

Sitiboot, C., Nakviroj, C. and Uttayopas, P. (1978). Responses to potassium fertilizer of cassava grown on Yasothon and Korat soils. Annual report, Field Crop Division, Ministry of Agriculture, Bangkok, Thailand, 1978. p.58.

Sittibusaya, C. and Kurmarohita, K. (1978). Paper presented at workshop on cassava production and utilization. Khon Kaen, Thailand, 1978.

Souza, A.B. de (1979). Effects of sources and levels of phosphated fertilizers on cassava. Tese Mag. Se. Vicosa. Mg. Brasil Universdale Federal de Vicosa. 36 p.

*Spear, S.N., Edwards, D.G. and Asher, C.J. (1978). Response of cassava, sunflower and maize to potassium concentration in solution III. Interactions between potassium, calcium and magnesium. Field Crops Res. 1: 375-389.

Sreeponk, S. (1977). Study on the effect of different fertilizer formulas on yield of cassava. Research Reports, Faculty of Agriculture, Khon Kaen University, Tailand, 1977. pp. 204-208.

Sushama, P.K., Pillai, G.R., George, T.P. and Mathew, J. (1982). Effect of leaf area on tuber yield of irrigated tapioca. Agri. Res. J. Kerala. 20(1): 95-97.

Vijayan, M.R. and Aiyer, R.S. (1969). Effect of nitrogen and phosphorus on the yield and quality of cassava. Agri. Res. J. Kerala. 7(2): 84-90.

Ward and Pigman. (1970). The Carbohydrates Vol. II. B. Analytical methods of Carbohydrates, Academic Press, New York and Longon. pp. 763.

Watson, D.J. (1947). Comparative physiological studies on the growth and yield of crops. 1. Variation in NAR and LAI between species and varieties and within and between years. Ann. Bot. 11: 41-76.

Watson, D.J. (1947). The physiological basis of variation in yield. Adv. Agron. 4: 101-145. Academic Press INC New York.

* Original not seen.

APPENDICES

APPENDIX I

Weather data during the crop period in comparison with the corresponding average values for the past five years - R.A.R.S., Kumarakom.

Standard weeks	Period From	Period To	Rainfall (mm) Crop period (total)	Rainfall (mm) Past five years average	Average temperature °C Maximum Crop period	Average temperature °C Maximum Average past five years	Average temperature °C Minimum Crop period	Average temperature °C Minimum Average past five years	Average Relative humidity % Crop period	Average Relative humidity % Past five years
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
42	15-10-84	21-10-84	..	17.18	31.43	30.37	22.29	25.99	71.0	78.0
43	22-10-84	28-10-84	51.8	38.48	30.71	30.58	24.14	25.84	82.0	79.2
44	29-10-84	4-11-84	0.6	42.04	32.14	29.65	24.50	25.84	75.5	84.2
45	5-11-84	11-11-84	28.2	41.40	33.86	29.61	24.86	26.26	78.5	83.1
46	12-11-84	18-11-84	24.0	49.78	32.50	30.11	23.86	25.83	71.0	83.0
47	19-11-84	25-11-84	8.2	20.00	31.00	30.30	25.60	26.17	79.0	84.4
48	26-11-84	2-12-84	135.7	16.34	30.93	30.47	22.93	25.79	77.5	75.9
49	3-12-84	9-12-84	..	13.48	32.21	30.80	21.64	25.29	74.0	73.9
50	10-12-84	16-12-84	..	15.30	32.50	31.22	21.57	25.56	76.0	74.5

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
51	17-12-84	23-12-84	..	5.80	32.29	31.03	20.93	25.69	69.0	81.5
52	24-12-84	31-12-84	..	5.68	32.88	30.67	22.56	25.88	72.0	72.9
1	1-1-85	7-1-85	55.3	3.52	31.14	30.91	23.71	25.48	81.0	77.0
2	8-1-85	14-1-85	20.0	..	31.14	30.95	22.29	24.91	71.0	78.2
3	15-1-85	21-1-85	..	8.94	32.29	30.81	22.93	24.44	61.0	76.5
4	22-1-85	28-1-85	..	..	33.14	31.08	22.50	23.78	67.0	71.0
5	29-1-85	4-2-85	..	..	33.36	31.36	23.14	25.58	68.5	66.2
6	5-2-85	11-2-85	..	3.68	32.93	30.96	22.93	26.41	72.0	72.6
7	12-2-85	18-2-85	1.5	10.10	32.93	31.31	23.64	26.48	75.0	74.3
8	19-2-85	25-2-85	11.5	10.50	32.43	31.81	23.36	26.12	76.5	76.0
9	26-2-85	4-3-85	1.4	2.08	32.21	31.16	23.93	26.15	74.0	72.8
10	5-3-85	11-3-85	.	29.36	33.00	31.05	25.64	26.20	76.0	76.3
11	12-3-85	18-3-85	1.5	6.70	34.36	32.09	23.79	27.06	71.0	74.5
12	19-3-85	25-3-85	4.0	2.60	34.57	32.77	25.29	27.18	70.0	74.8
13	26-3-85	1-4-85	5.7	9.76	34.07	33.02	24.14	27.05	71.0	71.0
14	2-4-85	8-4-85	110.6	28.84	34.00	33.04	23.21	27.78	71.0	69.9
15	9-4-85	15-4-85	1.0	16.64	33.50	33.19	25.36	27.88	78.0	72.24
16	16-4-85	22-4-85	..	18.96	34.21	32.97	25.36	27.27	76.5	74.40
17	23-4-85	29-4-85	16.1	22.16	34.07	33.15	25.42	27.61	73.5	74.30

APPENDIX II

Summary of Analysis of variance table

Source	D.F.	Mean sum of squares								
		Height of the plants			Total number of leaves			Leaf Area Index		
		60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.
Replication	2	12.88	0.66	4.44	23.84	2.31	14.63	0.00042	0.0443	0.0320
Treatments	14	2853.69	2330.06	445.07	61.90	326.03	273.85	0.084	0.0747	0.074
V	2	18980.28	14703.22	1078.69	140.88	732.53	462.94	0.040	0.0914	0.1413
L	4	441.88	727.64	891.44	125.34	749.86	675.66	0.259	0.1976	0.1595
V x L	8	27.95	37.98	63.48	10.43	12.48	25.67	0.0066	0.0090	0.0138
Error	28	4.51	2.20	5.34	11.88	2.64	4.33	0.00009	0.0068	0.0026
Total	44									

Appendix III

Summary of analysis of variance table

Source	D.F.	Mean sum of squares						
		Total number of roots	Total number of productive roots	Percentage of productive roots	Length of tuber	Girth of tuber	Utilization index	Rind to flesh ratio
Replication	2	0.267	1.49	104.91	0.174	1.57	0.0015	0.0134
Treatments	14	19.42	12.90	195.05	87.22	8.35	0.1092	0.00210
V	2	14.07	14.16	937.73	527.60	39.70	0.1943	0.0122
L	4	57.24	35.03	179.13	20.65	7.71	0.2437	0.00055
V x L	8	1.84	1.52	17.34	10.41	0.833	0.0207	0.00036
Error	28	0.743	0.584	31.22	2.83	0.354	0.0136	0.00031
Total	44							

Appendix IV

Summary of analysis of variance table

Source	D.F.	Mean sum of squares				
		Top yield	Tuber yield	Starch content	HCN content	Crude protein content
Replication	2	0.0916	0.736	6.44	38.45	0.000061
Treatments	14	41.76	76.03	10.05	11.35	0.1560
V	2	69.44	112.85	14.17	10.75	0.0217
L	4	105.42	195.20	26.20	21.77	0.4852
V x L	8	3.00	7.29	0.539	6.29	0.0249
Error	28	0.0707	1.33	1.52	1.68	0.00124
Total	44					

APPENDIX V

Summary of analysis of variance table

Source	D.F.	Mean sum of squares								
		Dry matter production (gm/plant)								
		Leaf			Stem			Root		
		60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.
Replication	2	91.65	49.44	1.78	99.29	57.09	10.75	0.439	17.63	36.5
Treatments	14	64.33	48.66	135.90	66.07	38.66	248.79	12.12	357.07	20020.54
V	2	28.64	35.00	21.20	77.34	14.39	96.97	4.71	127.69	36552.25
L	4	206.07	144.95	459.72	170.58	122.63	791.20	32.09	1136.81	47662.38
V x L	8	2.39	3.94	2.67	11.00	2.74	15.54	3.99	24.55	2066.69
Error	28	3.37	1.97	0.2812	18.46	5.34	0.3639	2.12	19.18	15.14
Total	44									

APPENDIX VI

Summary of analysis of variance table

Source	D.F.	Mean sum of squares	
		Dry matter production Top (kg/ha) at harvest	Dry matter production tuber (kg/ha) at harvest
Replication	2	3904	16640
Treatments	14	229412.6	6276882
V	2	66528	1.14 E + 07
L	4	756912	1.50 E + 07
V x L	8	6384	645824
Error	28	189.71	5412.57
Total	44		

APPENDIX VII

Summary of analysis of variance table

Source	D.F.	Mean sum of squares								
		Nitrogen content at harvest			Phosphorus content at harvest			Potassium content at harvest		
		leaf	stem	root	leaf	stem	root	leaf	stem	root
Replication	2	0.00034	0.000027	0.0000021	0.00016	0.000079	0.00062	0.0173	0.00059	0.00024
Treatments	14	0.0602	0.0023	0.00398	0.0024	0.00097	0.00073	0.0990	0.0063	0.0117
V	2	0.1038	0.00939	0.00058	0.0107	0.0037	0.0037	0.0065	0.0185	0.0160
L	4	0.1301	0.00295	0.0124	0.0019	0.0015	0.00036	0.323	0.0116	0.0294
V x L	8	0.0143	0.00022	0.000634	0.00063	0.000048	0.00016	0.0181	0.00068	0.00172
Error	28	0.00029	0.000034	0.000030	0.00009	0.000037	0.000060	0.00380	0.000084	0.00019
Total	44									

APPENDIX VIII

Summary of analysis of variance table

Source	D.F.	Mean sum of squares								
		Uptake of Nitrogen			Uptake of phosphorus			Uptake of potassium		
		60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.	60 D.A.P.	120 D.A.P.	180 D.A.P.
Replication	2	41.90	23.46	68.75	1.09	0.8857	2.27	24.12	15.71	8.27
Treatments	14	48.32	97.08	536.57	2.41	8.76	37.36	48.72	149.59	994.86
V	2	26.77	37.05	87.70	3.59	20.44	46.54	15.28	2.23	646.22
L	4	151.86	308.55	1805.84	6.55	19.82	103.19	158.90	516.88	3106.41
V x L	8	1.94	6.35	14.17	5.34	0.3172	2.15	1.98	2.79	26.24
Error	28	1.61	2.27	0.399	6.29	0.1366	0.4508	0.9798	0.9079	4.17
Total	44									

NPK REQUIREMENT OF SHORT DURATION TAPIOCA VARIETIES GROWN IN THE UPLANDS OF KUTTANAD

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was undertaken at the Regional Agricultural Research Station, Kumarakom during 1984-85 to identify a suitable variety of tapioca maturing in about six months and to find out the effect of different fertilizer doses on such varieties in the uplands of Kuttanad. The experiment was laid out in Factorial Randomised Block Design with three replications. The treatments consisted of three varieties namely Thottakolli Kaduthuruthy local and Sree Sahya and five fertilizer levels viz. 30:30:30, 30:30:45, 50:50:50, 50:50:75 and 50:50:100 kg/ha of N P K.

The varieties and fertilizer levels tried showed significant differences in the growth characters of tapioca. In all the three varieties the fertilizer level 50:50:100 recorded maximum plant height, leaf number and leaf area index. The yield and yield attributes were also influenced by the varieties and fertilizer levels. Maximum tuber yield was obtained from the variety Kaduthuruthy local (27.13 t/ha). The variety Thottakolli produced 26.86 t/ha. In all the three varieties, highest tuber yield was observed in the 50:50:100 kg/ha N P K level.

Thottakolli had the lowest HCN content among the varieties. The highest starch content was observed in 50:50:100 kg/ha fertilizer level. The crude protein content was more in Kaduthuruthy local when compared to the other varieties. The variety Kaduthuruthy local produced the highest leaf, stem and root dry matter. Uptake of Nitrogen and phosphorus was maximum in Kaduthuruthy local while the highest potassium uptake was in Thottakolli.

The highest cost benefit ratio of 1.69 was recorded by Thottakolli at 50:50:100 kg N, P_2O_5, K_2O/ha followed by Kaduthuruthy local.

From the investigation, it is found that Kaduthuruthy local and Thottakolli are the short duration varieties suitable for the up lands of Kuttanad. Regarding the manurial dose, the 50:50:100 kg N:P_2O_5:K_2O/ha is the most economical for Thottakolli and 50:50:50 for Kaduthuruthy local.