# POTASH NUTRITION OF TAPIOCA
## (*Manihot esculenta* Crantz.)

BY

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# DECLARATION

I hereby declare that this thesis entitled "Potash nutrition of tapioca (*Manihot esculenta* Crantz.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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16th September, 1982.

# CERTIFICATE

Certified that this thesis, entitled "Potash nutrition of tapioca (Manihot esculenta Crantz.)" is a record of research work done independently by Sri. V. Muraleedharan Nair under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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# CONTENTS

| | | Page No. |
|---|---|---|
| INTRODUCTION | ... | 1 |
| REVIEW OF LITERATURE | ... | 5 |
| MATERIALS AND METHODS | ... | 34 |
| RESULTS | ... | 55 |
| DISCUSSION | ... | 124 |
| SUMMARY | ... | 169 |
| REFERENCES | ... | i - xvii |
| APPENDICES | ... | I - III |

## LIST OF TABLES

| Table No. | | Page No. |
|---|---|---|
| 1. | Soil characteristics of experimental fields | 36 |
| 2. | Schedule of the time of application of nitrogen and potassium | 43 |
| 3a. | Effect of treatments on the height of plants (cm) during various growth stages at Vellayani | 56 |
| 3b. | Effect of treatments on the height of plants (cm) during various growth stages at Kayamkulam | 57 |
| 4a. | Effect of treatments on the number of nodes per plant during various growth stages at Vellayani | 59 |
| 4b. | Effect of treatments on the number of nodes per plant during various growth stages at Kayamkulam | 60 |
| 5a. | Effect of treatments on the number of functional leaves per plant during various growth stages at Vellayani | 62 |
| 5b. | Effect of treatments on the number of functional leaves per plant during various growth stages at Kayamkulam | 63 |
| 6a. | Effect of treatments on the leaf area index during various growth stages at Vellayani | 65 |
| 6b. | Effect of treatments on the leaf area index during various growth stages at Kayamkulam | 66 |
| 7. | Effect of treatments on the tuber number and tuber weight per plant | 68 |
| 8. | Effect of treatments on length and girth of tubers | 72 |

| Table No. | | Page No. |
|---|---|---|
| 9. | Effect of treatments on utilization index and top yield | 74 |
| 10. | Effect of treatments on tuber yield (pooled) of tapioca (t/ha) at Vellayani | 77 |
| 11. | Effect of treatments on tuber yield (pooled) of tapioca (t/ha) at Kayamkulam | 78 |
| 12. | Effect of treatments on starch content and starch yield | 82 |
| 13. | Effect of treatments on crude protein and HCN content of tubers | 85 |
| 14. | Mean scores obtained in the organoleptic test of Tapioca tubers at Vellayani and Kayamkulam | 88 |
| 15. | Effect of treatments on the leaf drymatter production (g/plant) during various growth stages at Vellayani | 90-91 |
| 16. | Effect of treatments on the stem drymatter production (g/plant) during various growth stages at Vellayani | 93-94 |
| 17. | Effect of treatments on root dry matter production (g/plant) during various growth stages at Vellayani | 95-96 |
| 18. | Effect of treatments on the drymatter production at harvest in Kayamkulam | 98 |
| 19. | Effect of treatments on tuber bulking rate (g/day/plant) during various growth stages at Vellayani | 101 |
| 20. | Effect of treatments on net assimilation rate (mg/d$_m$2/day) during various growth stages at Vellayani | 103 |
| 21. | Effect of$_2$treatments on crop growth rate (g/m$^2$/day) during various growth stages at Vellayani | 105 |

| Table No. | | Page No. |
|---|---|---|
| 22. | Effect of treatments on the plant uptake of nitrogen (kg/ha) during various growth stagesat Vellayani | 107-108 |
| 23. | Effect of treatments on the plant uptake of potassium (kg/ha) during various growth stages at Vellayani | 110-111 |
| 24. | Effect of treatments on the plant uptake (at harvest) of nitrogen and potassium (kg/ha) at Kayamkulam | 113 |
| 25. | Effect of treatments on the available nitrogen and potassium contents (kg/ha) of soil after each crop | 114 |
| 26a. | Correlation matrix - simple correlation among tuber yield and yield components (Vellayani) | 117 |
| 26b. | Correlation matrix - simple correlation among tuber yield and yield components (Kayamkulam) | 118 |
| 27. | Correlation matrix - simple correlation among uptake of nitrogen and potassium and tuber yield at Vellayani and Kayamkulam. | 120 |
| 28a. | Direct effects, indirect effects and correlation coefficients of yield components on yield at Vellayani. | 121 |
| 28b. | Direct effects, indirect effects and correlation coefficients of yield components on yield at Kayamkulam | 122 |
| 29a. | Economics of fertilizer application at Vellayani | 167 |
| 29b. | Economics of fertilizer application at Kayamkulam | 168 |

## LIST OF ILLUSTRATIONS

| Fig. No. | | Between pages |
|---|---|---|
| 1. | Weather conditions during the crop periods at Vellayani | 35-36 |
| 2. | Weather conditions during the crop periods at the Rice Re~~a~~search Station, Kayamkulam | 35-36 |
| 3. | Layout plan - confounded factorial experiment at Vellayani | 38-39 |
| 4. | Layout plan - confounded factorial experiment at Kayamkulam | 38-39 |
| 5. | Effect of treatments on tuber number at Vellayani and Kayamkulam | 68-69 |
| 6. | Effect of treatments on mean tuber weight at Vellayani and Kayamkulam. | 69-70 |
| 7. | Effect of treatments on tuber yield at Vellayani and Kayamkulam | 78-79 |
| 8. | Effect of treatments on starch yield at Vellayani and Kayamkulam | 83-84 |
| 9. | Effect of nitrogen and potassium on HCN content of tuber at Vellayani and Kayamkulam | 85-86 |
| 10. | Path coefficient analysis of yield components on yield at Vellayani | 121-122 |
| 11. | Path coefficient analysis of yield components on yield at Kayamkulam | 122-123 |
| 12. | Effect of nitrogen and potassium on total drymatter production at Vellayani (mean of 1978 and 1979) | 139-140 |

# Introduction

# INTRODUCTION

Carbohydrate is the largest single component of human diet and the main source of energy. Tapioca, an important source of carbohydrate, is rapidly emerging as a crop of considerable importance in India. It is the most popular subsidiary food crop of the middle and lower income group of the people of the densely populated state of Kerala. Tapioca is grown over an area of 2.43 lakh hectares in Kerala which accounts for about 80 per cent of the total area of the crop in India. But the per hectare yield of the crop is very low(16.77 t/ha) as compared to the yield (100 t/ha) obtained in countries like Australia (Allen, 1980). Now a days tapioca is used largely for making industrial starches and forms an important constituent of the feed concentrates for cattle. Therefore, there is not only need, but also much scope for further augmenting the yield of tapioca in our country. Eventhough it is a hardy crop which grows better than many other crops under sub optimal soil conditions, its productivity can undoubtedly be raised by the use of improved varieties and better agrotechniques. With the introduction of high yielding fertilizer responsive varieties, it has become necessary to develop fertilizer techniques, optimising the dose and improving the efficiency of fertilizers. With the escalating cost of commercial fertilizers in recent years there is need for a judicious use of these materials. This is especially true in the case of potassium, which is imported from other countries. By proper timing of potassium application there is considerable scope for economising this nutrient.

Tapioca requires a fairly good amount of nutrients for high yields. Several investigators have reported that this crop responds excellently to applications of potassium. In many soils potassium is the main element limiting yields of tapioca (CIAT, 1975). There is widespread deficiency of potassium in Kerala soils. The deficiency is particularly marked in the laterite and coastal sandy soils. The review of available literature on tapioca indicates that responses of this crop to nitrogen and potassium is inconsistent and erratic. This may probably be due to the improper timing of application without having a clear idea about the crop requirement for the nutrients at the various growth stages. Hence application of nitrogen and potassium in split dose may supply adequate nutrients throughout the crop period, especially at stages of peak requirements.

Application of potassium has considerable influence on the quality attributes. Likewise; the effect of split application of potassium on quality has not been studied in detail. Several workers have reported that potassium in conjunction with nitrogen not only increases the yield but also improves the quality. Hence an investigation on this aspect was considered useful.

Reports on the optimum quantity and time of application of nitrogen and potassium for tapioca are few and far between. The potassium requirement of a crop and the need for fertilizer potassium may differ widely according to soil and climatic conditions. Tapioca is cultivated mainly in the red and laterite soils of the state. There is considerable scope for the extensive cultivation of this crop in the sandy tracts of Onattukara where tapioca with fish forms a popular diet of the people.

There is scanty information on the response of 'Sree Sahya', a high yielding variety of tapioca to the application of potassium especially under the different agroclimatic conditions of the state. It was therefore, thought worthwhile to take up the present study.

The objectives of the present investigation were to elicit information on the following aspects of 'Sree Sahya' variety of tapioca grown in two different agroclimatic conditions of the State.

(i) to assess the influence of different levels and time of application of potassium in conjunction with nitrogen on growth parameters and yield components of tapioca in the red loam soils of Vellayani and the sandy loam soils of Kayamkulam;

(ii) to findout the influence of quantity and time of application of potassium in conjunction with nitrogen on yield and quality of tapioca in the two different soil types of Kerala;

(iii) to determine the optimum quantity of nitrogen and potassium for the variety in the two different agroclimatic conditions;

(iv) to estimate the plant uptake of nitrogen and potassium in the various growth stages of the crop grown in the red loam soils of Vellayani;

(v) to work out the economics of tapioca cultivation under different levels of fertilization with nitrogen and potassium in the two different agroclimatic conditions of the state.

# Review of literature

# 2. REVIEW OF LITERATURE

The present investigation deals with the effect of potassium nutrition in conjunction with nitrogen on the growth, yield and quality of a high yielding hybrid variety of tapioca (H-2304) raised in two different agroclimatic conditions of Kerala State. The available literature on the effect of quantity and time of application of nitrogen and potassium alone and in combination on the growth, productivity and quality of tapioca are reviewed below. Wherever sufficient information are lacking, relevant literature in other tuber crops are also reviewed.

## 2.1 Nutrient removal by tapioca

Tapioca removes large amount of nutrients from the soil especially K and N, in each harvest. Preliminary studies conducted at the Central Tuber Crops Research Institute, Trivandrum revealed that a tapioca crop with 30 tonnes of tuber yield removes from a hectare of soil 180-200 kg nitrogen, 15-22 kg phosphorus and 140-160 kg potash. According to Kanapathy (1974), on a per crop basis, tapioca removes more nutrients than most other tropical crops. Howeler (1976), reviewing the literature, showed that tapioca absorbed potassium and nitrogen in large quantities. On an average, the crop removes per tonne of roots about 2.3 kg nitrogen, 0.5 kg phosphorus and 4.1 kg potassium when only the roots are removed from the soil (Howeler, 1980).

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).

## 2.2 Nitrogen

Eventhough nitrogen is essential for the proper growth and yield of tapioca, high rates of application of this nutrient results in excessive top growth at the expense of root growth.

### 2.2.1. Effect of nitrogen on growth characters

Krochmal and Samuels (1967) noticed severe reduction in plant height and weight of tapioca in a tank culture study when nitrogen was omitted from the nutrient solution.

At 30, 60 and 90 days after planting there was no significant difference 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.

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

Eventhough high rates of nitrogen increased leaf growth it was found to decrease root growth (CIAT, 1975).

Increases in plant height, leaf area, leaf area duration and leaf size by incremental doses of nitrogen was observed by Ngongi (1976). But high total plant fresh weight was obtained at low levels of nitrogen.

Pillai and George (1978a) noticed increases in plant height and weight due to higher levels of nitrogen in M-4 variety of tapioca. But, Muthukrishnan (1980) could not find significant differences in foliage weight due to different rates of nitrogen.

Several workers reported enhancement of leaf area and leaf number due to higher doses of nitrogen in colocasia (Premraj et al., 1980 and Mohandas and Sethumadhavan, 1980).

### 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 in the quantity of nitrogen decreased the tuber number in both varieties of tapioca (M-4 and H-105) tried in the experiment.

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

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 both the tuber number and average size of tubers were increased with increase in the levels of nitrogen in all the varieties tried.

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

Natarajan (1975) did not get 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.

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) tried.

### 2.2.3 Effect of nitrogen on yield

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

Nakviroj et al. (1971), on the basis of multilocation trials condluded that 50-100 kg N/ha in combination with 100 kg $P_2O_5$ and 50 kg $K_2O$/ha was suitable for high root production in tapioca.

Gomes et al. (1973) reported from Brazil that nitrogen fertilization had no effect on yield of tapioca. But, in Colombia, Howler (1976) observed yield increases upto 200 kg N/ha.

Kumar et al. (1976) noticed significant yield increases by the application of nitrogen alone or in combination with phosphorus and potash.

A local cultivar gave the maximum yield at 60 kg N/ha, whereas the highest yield of an improved cultivar could be obtained only by the application of nitrogen at 120 kg/ha. (Obigbesan and Fayemi, 1976). They also observed that high rates of nitrogen (150 kg/ha) tended to reduce yield.

Saraswat and Chattiar (1976) got the highest tuber yield of 33.4 tonnes/ha with a nitrogen application at 150 kg/ha.

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

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

Yield reduction at higher rates of nitrogen application was reported by CIAT (1978). Yield depressions in tapioca to the extent of 11-14 per cent at 150 kg N/ha as compared to 50 kg N/ha was observed by Muthuswamy and Chiranjivi Rao (1979).

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

Kang and Wilson (1980) reported that cassava has only a lower nitrogen requirement.

### 2.2.4 Effect of nitrogen on quality

#### 2.2.4.1 Drymatter content

Varying levels of nitrogen did not produce any difference in the dry matter content of tuber (Vijayan and Aiyer, 1969).

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

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

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

2.2.4.2 Starch content

Many workers have reported the beneficial effect of nitrogen nutrition in increasing the tuber starch content of tapioca (Mandal et al., 1971; Natarajan, 1975 and Pillai and George, 1978c).

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

Hukkeri (1968) recorded increases in crude protein content of potato tubers with higher doses of nitrogen application.

Nair and Kumar (1975) did not find significant influence of nitrogen on the protein content of tubers of <u>Dioscorea alata</u>.

Crude protein content of the 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, 1978c)

In Colocasia, nitrogen fertilization brought about significant increases in crude protein content of tubers and the maximum content was noticed with 120 kg N/ha (Mohandas and Sethumadhavan, 1980). But Premraj et al. (1980) could not get any increases of protein content by nitrogen nutrition in colocasia.

### 2.2.4.4 HCN content

Indira et al. (1972) reported that application of nitrogen and phosphorus alone 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).

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 levels of nitrogen (Prema et al., 1975).

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

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 (30) of soft textured tubers as against a lower percentage (12 - 19) 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).

2.2.5 Effect of nitrogen on nutrient uptake

Mohankumar and Nair (1969) noticed increase 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 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_. (1979b) due to nitrogen nutrition. But petiole potassium showed a linear response to applied nitrogen.

## 2.3 Potassium

Tapioca requires adequate supply of potassium for the synthesis and translocation of starch. According to Sereeponk (1977), the primary factor limiting cassava production was potassium. Potash deficiency will 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.

Malavolta et al. (1955), in a sand culture experiment to study the physiological basis for the nutrition of cassava, found that when potassium was omitted from the nutrients, the weight of shoots increased while that of roots dropped.

In sweet potato, Fujise and Tsuno (1967), observed low values of leaf area index in high potassium plot as compared to control. Net assimilation rate of high potassium plot was 20 to 30 per cent higher than control. They opined that potassium contributes to the higher photosynthetic activity of leaves.

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

Several investigators could not get significant responses to levels of potassium on such growth characters as plant height, number of leaves and top yield (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.

Ramanujam (1982) observed increases in plant height, node number, leaf size and leaf area index by potassium fertilization 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 drymatter production.

### 2.3.2 Effect of potassium on yield components

Mandal and Mohankumar (1972a) noticed no differences in the number of tubers by the application of low levels of potash ranging from 40 to 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).

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 <u>et</u> <u>al</u>., 1976).

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.

Asokan and Sreedharan (1977) found the maximum number of tubers at 75 kg $K_2O$/ha. But the length and girth of tubers were unaffected by the levels of potassium tried.

Verma and Grewal (1979) reported increases in tuber size of potato with higher doses of potassium.

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

### 2.3.3 Effect of potassium on yield

On the basis of the results of experiments in cultivators' fields in Kerala, Chadha (1958) reported that the mean response due to doses of potash varied from 19 to 43 per cent for 80 kg/ha and 23 to 75 per cent for 160 kg/ha.

Significant yield increases in potato upto 133 kg $K_2O$/ha was observed by Hukkeri (1968). Mohankumar and Nair (1969) noted progressive yield increases in tapioca upto 150 kg $K_2O$/ha.

Potassium fertilizer improved root yield significantly only when the available potassium of soil was less than 40 ppm (Anon., 1969).

Yield depressions in cassava have been reported at high rates of potash application by Kumar *et al.* (1971) and CIAT (1974). Similar yield reduction by higher rates of potassium application was observed in other tuber crops like *Dioscorea esculenta* (Mandal *et al.*, 1969) and *Dioscorea alata* (Nair and Kumar, 1975).

Pushpadas and Aiyer (1976) secured maximum tuber yield of a hybrid variety of tapioca, H-105 with 250 kg $K_2O$/ha. Rajendran *et al.* (1976) reported that 100 kg $K_2O$/ha is the optimum dose and higher rates resulted in luxury consumption.

Field trials conducted with potato for two seasons, by Shukla and Singh (1976) revealed that yield and grade of tubers were improved with higher levels of potassium nutrition. The most profitable rate of potassium was found to be 222 kg $K_2O$/ha.

In a trial to study potassium tolerance of cassava cultivars by application of 0 and 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. (1978b) studied the growth response of cassava to different rates of potassium fertilizer 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.

In an experiment to study the effect of different levels and time of application of potassium in a hybrid variety of tapioca, H-97, Asokan and Sreedharan (1977) noticed maximum tuber yield at 112.5 kg $K_2O$/ha. Mathura Rai et al. (1980) recorded significant yield increases upto 120 kg/ha of $K_2O$ in sweet potato. Higher levels of potassium could not produce significant yield increases in tapioca (Ramaswamy and Muthukrishnan, 1980).

Non significant yield increases by the application of potassium from 60 to 120 kg $K_2O$/ha were noticed in the red sandy loam soils of north Malabar (Asokan et al., 1980).

Ramanujam (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 to 16 per cent over control.

Nair and Kumar (1982a) 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 in $K_0$ treatment.

### 2.3.4 Effect of potassium on quality

#### 2.3.4.1 Drymatter content

Obigbesan (1973) observed increases in tuber drymatter content with higher rates of potassium application. Obigbesan and Agboola (1973) also reported similar results.

While Pushpadas and Aiyer (1976) noticed the highest percentage of drymatter with potassium nutrition of 125 kg $K_2O$/ha, Asokan and Sreedharan (1980) obtained maximum values of drymatter with 75 kg/ha of potash application.

#### 2.3.4.2 Starch Content

Jacob and Uexküll (1966) reported low values of tuber starch content when the soil potassium level was low.

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.

Linear increases in starch yield with higher rates of potassium application upto 200 kg $K_2O$/ha were reported by CIAT (1979). But Nair and Kumar (1982) noticed only a slight increase in starch content by potassium fertilization.

### 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).

Protein content of sweet potato tuber was found to increase when 50 kg $K_2O$/ha was used (Muthuswamy and Krishnamoorthy 1976).

### 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).

Ramanujam (1982) also 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 cyanide 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 control.

Nair and Kumar (1982b), 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 definite decrease in the HCN content.

### 2.3.4.5 Cooking quality

Kurian *et al*. (1973) reported that by the application of wood ash alone or a mixture of cowdung and wood ash, 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).

### 2.3.4.6 Effect of potassium on nutrient uptake

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

Percentage of nitrogen and potassium in petioles of colocasia was increased with potassium fertilization (Ramon and Donald, 1967).

Kumar et al. (1971) also observed a similar increase in potassium uptake by higher doses of potash.

Ngongi et al.(1976) observed severe sulphur deficiency in tapioca due to high rates of application of potassium chloride. Spear et al. (1978) showed that high concentrations of potassium in solution reduced the uptake of calcium and magnesium by Cassava.

Increase in potassium uptake by potato tubers due to higher levels of applied potassium was reported by Verma and Grewal (1979).

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

## 2.4 Effect of potassium application in combination with nitrogen

Cassava required high levels of nutrients especially nitrogen and potassium to obtain maximum yields. It was also well established that potassium was effective only in the presence of nitrogen. But the crop is sensitive to over fertilization, which causes excessive top growth and little root growth. The use of large amounts of inorganic fertilizers may also lead to serious nutritional imbalances on low fertility soils. The yield and quality of tubers depend both on the level of individual nutrients and their relative quantities. The nitrogen-potassium ratio is especially important in cassava nutrition.

Chadha (1958) noticed highly significant interaction between doses of nitrogen and potassium in increasing the tuber yield of tapioca. He also opined that the productivity due to one of these nutrients was highly limited by the amount of the other with which it was combined. The data also revealed that maximum tuber yields can be obtained by the application of nitrogen and potassium in a ratio of 1:1.75.

Highest tuber yields in sweet potato was obtained by the application of nitrogen and potassium in the ratio of 1:2 (George Samuels, 1967). He observed that when soil potassium levels were low, high rates of applied nitrogen could induce potassium deficiencies and thereby limit root yields. Increasing potassium levels in the presence of high rates of nitrogen could offset the harmful effect of nitrogen on root yields.

De Geus (1967) reported that a NPK ratio of 1:1:2 is the optimum for cassava. In the presence of high rates of nitrogen, high level of potassium application gave a significant yield increase over low potassium level (Krochmaland Samuels, 1967). It was also seen that high levels of potassium did not influence tuber weight when nitrogen levels were lowered.

Mohan Kumar and Nair (1969) obtained the highest tuber yield of 33 t/ha with 100 kg each of nitrogen and potassium as compared to only 17.7 t/ha in control.

Mandal and Singh (1970) recorded tuber yield increases of hybrid variety of tapioca H-97 by the combined application of nitrogen and potash.

By the application of 150 kg/ha of nitrogen and 100 kg/ha of potash, Mohankumar and Hrishi (1973) observed the largest number of tubers in a cassava hybrid, H-226. But the tuber size was maximum in the treatment with nitrogen and potash each applied at 150 kg/ha level.

Nair and Mohankumar (1975) found in Dioscorea alata, that by the application of nitrogen at the rate of 120 kg/ha and potash at the rate of 80 kg/ha the tuber yield could be maximised.

A study of N x K interaction, with levels of 0, 100 and 200 kg/ha nitrogen and 0, 150 and 300 kg/ha potash, (CIAT, 1975) showed that cassava responded to nitrogen only in the presence of potassium and that this response was positive only upto 100 kg/ha nitrogen, whereas the application of 200 kg/ha nitrogen resulted in a negative response. There were positive responses to the application of 150 kg/ha potash, both in the absence and presence of nitrogen.

In the central Tuber Crops Research Institute, Trivandrum, Rajendran et al. (1976). Obtained a tuber yield of 28.2 t/ha with the application of nitrogen and potash at 100 kg/ha each. Further increases in the levels of nutrients caused yield reductions. But with increasing doses of nitrogen and potassium there was progressive increase in the uptake of potassium.

An investigation with four cassava varieties including H-2304 to ascertain the response to yield and quality to different combination of nitrogen and potassium during October season, Nair (1976) got significant yield increases 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) reported decreasing trend in the values of harvest index of tapioca by nitrogen and potassium applications.

The highest tuber yields were obtained by Prabhakar and Nair (1977) in cassava hybrids tried with a NK combination of 100 kg/ha each. Maximum tuber number was also noticed in this treatment combination. Dry matter, starch and HCN contents remained unaltered due to fertilizer levels.

NK combinations did not reveal any consistent effect on cooking characteristics of tuber.

In a multilocation trial, Sitiboot *et al*. (1978a) could get marked effect of nitrogen and potassium in increasing fresh root yields only at one location.

Sharma *et al*. (1978) observed in potato that the drymatter yield and total content of nutrients in the plant were almost doubled by the combined application of nitrogen, phosphorus and potassium.

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

Many fertilizer trials in Colombia and Brazil showed no clear effect of nitrogen and potassium on root yields of cassava (Edward *et al*., 1980).

In colocasia, the highest tuber yield was noticed by the application of nitrogen and potash at 120 kg/ha each (Premraj *et al*., 1980). Tuber size was increased by higher levels of nitrogen and potassium. Treatment with low level of nitrogen and high rate of potassium produced the highest starch content. The maximum uptake of nitrogen and potassium were observed at the highest level of application of nitrogen and potassium respectively.

Asokan (1981) did not observe any response for the cassava hybrid, H-1687 to higher doses of nitrogen and potassium in the sandy clay loam soils of Trichur. A significant reduction in tuber yield of the hybrid was noticed by raising the rate of applied potash upto 180 kg/ha.

Drymatter content of tuber was not affected by the different levels of nutrients (Sheela, 1981).

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.

Nair and Mohan Kumar (1982) found that by the application of nitrogen and potash at the rate of 60 kg and 90 kg/ha respectively, the maximum tuber yield was obtained in a promising sweet potato hybrid H-269. NK combinations did not show any effect on tuber number.

### 2.5 Influence of time of application of nitrogen and potassium.

De Geus (1967) opined that split application of nitrogen and potassium gave the best results in cassava. Mandal *et al*. (1971) obtained high yields in cassava by the application of nitrogen at 100 kg/ha in two splits, half as basal dressing and the other half two months after planting.

In an experiment, Kumar et al. (1971) noticed that the application of 100kg potash in two splits of half as basal and half one month after planting gave the highest tuber yield, starch and dry matter content than potassium applied entirely as basal or entire dose one or two months after planting or in two equal split doses at one month and two months after planting.

Mandal and Mohan Kumar (1972a) could not observe any significant difference in yield of cassava hybrid H-165 by split application of nitrogen or potassium.

In an experiment to assess the relative efficiency of various methods of potassium application on the uptake and translocation of major nutrients by potato varieties, Shukla and Girirao (1974) observed that application of potassium in splits enhanced the rate of absorption of nitrogen and potassium.

Nunes et al. (1974) noticed that split application of potassium did not influence the yield of cassava.

Rodriguez (1975) studied the effect of different levels of N, $P_2O_5$ and $K_2O$, as well as the fractionation of 100 kg of nitrogen. One single application of nitrogen at planting resulted in better yields compared to application in two doses.

Howeler (1976) found that application of 25 per cent nitrogen at 50 days, 25 per cent at 85 days, and 50 per cent at 120 days after planting with a nitrogen level of 200 kg/ha, resulted in better yields than a total application at 60 days.

Another trial on nitrogen levels (0, 50, 75, 100 and 150 kg/ha), applied as urea at the time of planting or fractionated at 30, 120 and 150 days after planting, showed a negative response to the higher doses when applied all at planting. The best fractionation was 50 per cent of nitrogen at 30 days, 25 per cent at 120 days and 25 per cent at 150 days after planting (CIAT, 1976).

Sitiboot et al. (1976), in a study to find out the best time of application of nitrogenous fertilizers to cassava, did not find any marked difference among the times of application of N in tuber yield.

Shukla and Singh (1977) opined that fractionated application of potassium was quite advantageous over full basal or full foliar application in potato. Split application of half to soil and half as foliar with a high level of potassium of 180 kg $K_2O$/ha gave the maximum accumulation of drymatter and starch in tubers and the largest uptake of potassium.

CIAT (1978) could not find any significant difference between application as a single basal dose or in splits of either N or K fertilizers in cassava.

On light soils, especially under high rainfall conditions potassium leaches readily and a fractionated application may be advisable. A fractionated application of one-third dose at planting, One-third at 30 days and one-third at 90 days was found better than any other method or time of application (CIAT, 1979). Highest starch yield was obtained with fractionated application of 100 kg $K_2O$/ha.

In a field experiment at Vellayani to study the effect of different levels and time of application of potassium in conjunction with farm yard manure on the productivity of cassava hybrid H-97, Asokan and Sreedharan (1980) found that two split application of 112.5 kg $K_2O$/ha had given the highest tuber yield (39.1 t/ha) followed by three split application of 75 kg $K_2O$/ha. Thus three split applications had given better response at lower levels of potassium than two splits. Yield reduction was seen at higher levels of potassium when applied in three splits.

An experiment on levels, methods and times of application of potassium was carried out with four potassium levels (40, 80, 120 and 160 kg $K_2O$/ha) applied as muriate of potash, four methods, and three times of application. It was revealed that fractionation of potassium had no beneficial effect (Gomes and Howeler, 1980).

## 2.6 Effect of nitrogen and potassium on soil nutrient content

Rajendran et al.(1971) observed that application of nitrogen at and above 100 kg/ha resulted in an increase in soil available nitrogen ranging between 16 to 74 kg/ha.

With increasing dose of potash application above 100 kg/ha, the amount of available potassium in the soil after the crop increases, thereby suggesting the possibility of a small residual effect due to high rates of potassium application (Kumar et al., 1971).

From the studies on the nutrient uptake of sweet potato, Rajendran et al. (1972) reported that application of potash either at 75 kg or 100 kg/ha increases soil available nutrient after the crop. In case of nitrogen 75 kg/ha level of application is not sufficient to maintain soil fertility but application of 100 kg is just sufficient to effect a marginal increase of the available nutrients in soil.

Mohankumar and Maini (1977), in an experiment to study the effect of molybdenum and nitrogen on the yield and quality of cassava had shown that application of increasing doses of nitrogen slightly increased the available nitrogen status of soil

## 2.7 Correlation studies

Muthukrishnan et al. (1973) reported that tuber yield of cassava was positively correlated with tuber length and girth and with height and number of nodes per plant. But the yield was found negatively correlated with leaf area.

Williams (1974) concluded that high yield was associated with high tuber weight rather than with tuber number.

In sweet potato, Lowe and Wilson (1975) observed significant negative correlation between tuber number and mean tuber weight.

CIAT (1975) found that root drymatter production was highly correlated with total drymatter production. Rajendran et al. (1976) noticed that irrespective of the nutrients, uptake of both nitrogen and potassium by cassava tubers was positively correleated with tuber yield.

Holmes and Wilson (1976) noted significant negative correlation between tuber number and mean tuber weight.

High positive correlation between cassava root yields and total plant fresh weight was observed by Ngongi (1976). They also observed positive correlations between root yields, leaf area index, leaf area dufation and total drymatter production per hectare.

Mean root weight showed strong positive correlation with root yield (Biradar et al., 1978). Pillai and George (1978b) found positive correlation between tuber yield and number of tubers per plant, while Okeke et al. (1979a) noticed positive correlation between tuber weight and tuber yield and negative correlation between tuber yield and tuber number.

Ramanujam and Indira (1980) found that plant height, node number and stem thickness have no relationship with tuber yield. Tuber number and mean tuber weight are important factors for tuber yield.

From the review it is evident that nutrient requirements in various soil types of different climatic conditions are highly variable. The beneficial effect of potassium is felt more clearly when it is combined with other nutrients especially nitrogen. Fractionated application is associated with efficient absorption and translocation of nutrients from the soil and foliage. But the proportion of splitting the dose or the time of application of split doses were not thoroughly investigated. Determinations of the optimum rate of fertilization and the proper balance of nutrients are of great importance. These should be based on soil and plant analysis as well as on fertilization trials. Hence the present study was taken up.

# Materials and methods

# 3. MATERIALS AND METHODS

Field investigations were carried out to study the response of tapioca to the quantity and time of application of nitrogen and potassium at the Instructional farm of the College of Agriculture, Vellayani and Rice Research Station, Kayamkulam, consecutively for two years during 1977-79. The details of the materials used and methods adopted in the experiments are given in this chapter.

## 3.1 Location

### (a) Instructional farm, Vellayani

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

### (b) Rice Research Station, Kayamkulam

The Rice Research Station, Kayamkulam is situated at 9.8° north latitude and 76.3° east longitude at an altitude of 3.05 metres above mean sea level.

## 3.2 Climatic conditions

### (a) Vellayani

The mean annual rainfall is 2053 mm. The mean annual maximum and minimum temperatures are 30.4°C and 24.3°C, respectively.

(b) Kayamkulam

The mean annual rainfall is 2416 mm. The mean annual maximum and minimum temperatures are 32.04°C and 23.34°C respectively.

The weather conditions which prevailed during the cropping period at both the locations are shown in the form of chart (Fig.1 and 2) and the relevant meteorological data are given in Appendix I to III.

### 3.3 Soil

(a) Vellayani

The soil of the experimental area was red loam. The soil was low in available nitrogen, and available $K_2O$ and medium in available $P_2O_5$

(b) Kayamkulam

The soil of the experimental area was sandy loam. The soil was low in available nitrogen, and available $K_2O$. and medium in available $P_2O_5$

The data on the mechanical, physical and chemical properties of the soils at both the locations are given in Table 1.

### 3.4 Cropping history of the field

Field numbers 1 and 2 of Vellayani were under bulk crops of pineapple without fertilizers whereas

FIG 1. WEATHER CONDITIONS DURING THE CROP PERIODS AT VELLAYANI

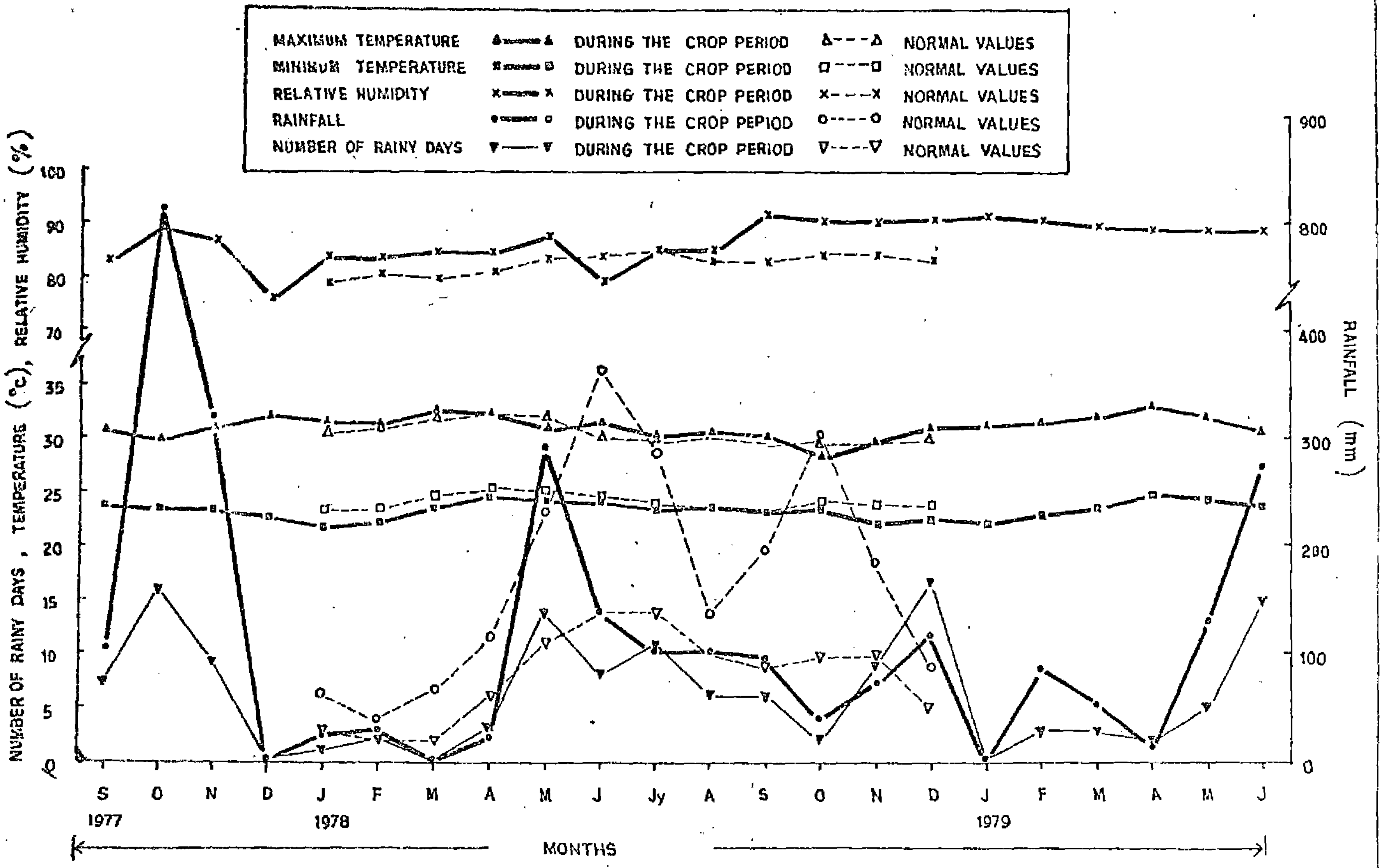


FIG 2. WEATHER CONDITIONS DURING THE CROP PERIODS AT THE RICE RESEARCH STATION, KAYAMKULAM

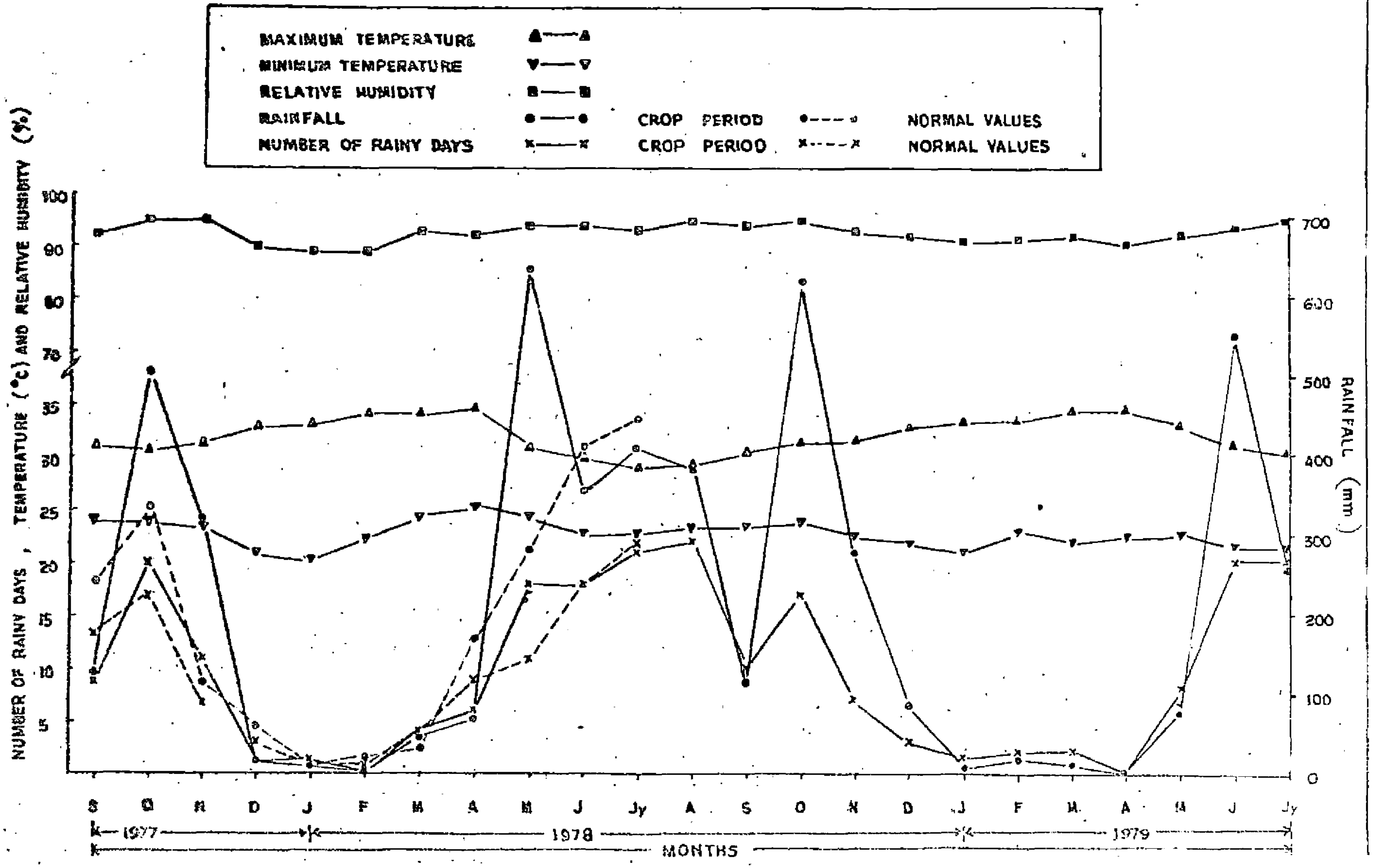


Table 1. Soil characteristics of experimental fields

| Sl.No. | Constituent | Vellayani |  | Kayamkulam |  |
|---|---|---|---|---|---|
|  |  | Field No.1 (1977-'78) | Field No.2 (1978-'79) | Field No.1 (1977-'78) | Field No.2 (1978-'79) |
| A | Mechanical composition |  |  |  |  |
| 1. | Clay | 14.90 | 15.10 | 5.92 | 6.10 |
| 2. | Silt | 19.85 | 20.20 | 6.14 | 5.95 |
| 3. | Fine sand | 20.10 | 19.30 | 30.80 | 30.30 |
| 4. | Coarse sand | 44.80 | 45.20 | 56.10 | 56.50 |
| B | Physical properties |  |  |  |  |
| 1. | Field capacity (per cent) | 16.00 | 15.90 | 13.82 | 14.33 |
| 2. | Permanent wilting point (per cent) | 4.25 | 4.30 | 3.90 | 3.95 |
| C | Chemical composition |  |  |  |  |
| 1. | Total nitrogen (per cent) | 0.46 | 0.42 | 0.045 | 0.052 |
| 2. | Available nitrogen (kg/ha) | 260.20 | 220.40 | 135.27 | 146.28 |
| 3. | Available $P_2O_5$ (kg/ha) | 46.00 | 38.00 | 32.00 | 40.00 |
| 4. | Available $K_2O$ (kg/ha) | 66.70 | 58.25 | 46.55 | 41.40 |
| 5. | pH (1:2.5 water suspension) | 4.90 | 5.30 | 5.10 | 4.70 |
| 6. | Organic Carbon (per cent) | 0.53 | 0.58 | 0.45 | 0.42 |
| 7. | Cation exchange capacity (m.e/100 g soil) | 6.20 | 6.53 | 3.82 | 4.10 |

field numbers 1 and 2 of Kayamkulam were lying fallow during the past one year.

### 3.5 Crop and variety

A tapioca variety, Sree Sahya (H.2304) released from the Central Tuber Crops Research Institute, Sreekaryam during 1977 was selected for the study.

Sree Sahya was derived by controlled hybridizations involving elite selections of germplasm collection of C.T.C.R.I and a popular variety M4. It has a field duration of about ten months.

### 3.6 Season

At both the locations the crops were planted during the second main planting season of the crop in the state namely September - October, during both the years.

### 3.7 Preparation of field

The land was once tractor ploughed and then dug using mammotties at both the locations during the two seasons. Clod crushing and levelling were done. The plots were marked with pegs and bunds were formed. Then the plot area was levelled and mounds were prepared.

### 3.8 Design and layout

The experiment was laid out as a $3^3$ partially confounded factorial design with two replications, confounding NKS in replication 1 and $NKS^2$ in replication 2. An absolute control, being the complete absence of nitrogen and potassium was attached to each block. (Fig. 3 and 4)

Number of blocks per replication : 3

Number of plots per block : 9 treatments + 1 Absolute control

Total number of treatments per replication : 27 treatments + 3 Absolute control

### 3.8.1 Treatments

Factorial combinations of three levels of nitrogen, three levels of potassium and three times of application of nitrogen and potassium constituted the treatments.

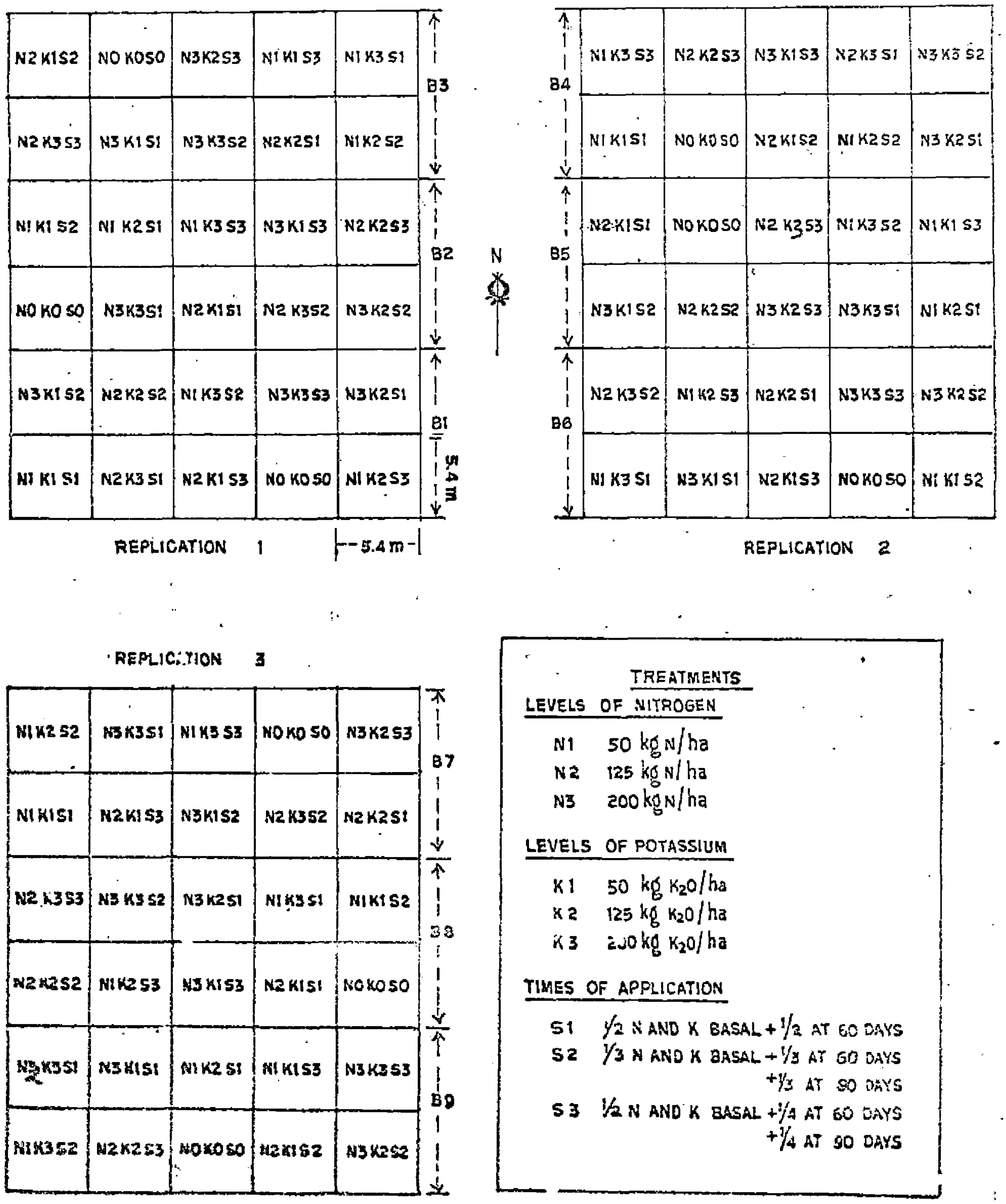
(i) Levels of nitrogen

$N_1$ - 50 kg N/ha
$N_2$ - 125 kg N/ha
$N_3$ - 200 kg N/ha

(ii) Levels of potassium

$K_1$ - 50 kg $K_2O$/ha
$K_2$ - 125 kg $K_2O$/ha
$K_3$ - 200 kg $K_2O$/ha

FIG 3. LAYOUT PLAN - CONFOUNDED FACTORIAL EXPERIMENT AT VELLAYANI



| | | | | |
|---|---|---|---|---|
| N2 K1 S2 | NO KO SO | N3 K2 S3 | N1 K1 S3 | N1 K3 S1 |
| N2 K3 S3 | N3 K1 S1 | N3 K3 S2 | N2 K2 S1 | N1 K2 S2 |
| N1 K1 S2 | N1 K2 S1 | N1 K3 S3 | N3 K1 S3 | N2 K2 S3 |
| NO KO SO | N3 K3 S1 | N2 K1 S1 | N2 K3 S2 | N3 K2 S2 |
| N3 K1 S2 | N2 K2 S2 | N1 K3 S2 | N3 K3 S3 | N3 K2 S1 |
| N1 K1 S1 | N2 K3 S1 | N2 K1 S3 | NO KO SO | N1 K2 S3 |

REPLICATION 1

| | | | | |
|---|---|---|---|---|
| N1 K3 S3 | N2 K2 S3 | N3 K1 S3 | N2 K3 S1 | N3 K3 S2 |
| N1 K1 S1 | NO KO SO | N2 K1 S2 | N1 K2 S2 | N3 K2 S1 |
| N2 K1 S1 | NO KO SO | N2 K3 S3 | N1 K3 S2 | N1 K1 S3 |
| N3 K1 S2 | N2 K2 S2 | N3 K2 S3 | N3 K3 S1 | N1 K2 S1 |
| N2 K3 S2 | N1 K2 S3 | N2 K2 S1 | N3 K3 S3 | N3 K2 S2 |
| N1 K3 S1 | N3 K1 S1 | N2 K1 S3 | NO KO SO | N1 K1 S2 |

REPLICATION 2

REPLICATION 3

| | | | | |
|---|---|---|---|---|
| N1 K2 S2 | N3 K3 S1 | N1 K3 S3 | NO KO SO | N3 K2 S3 |
| N1 K1 S1 | N2 K1 S3 | N3 K1 S2 | N2 K3 S2 | N2 K2 S1 |
| N2 K3 S3 | N3 K3 S2 | N3 K2 S1 | N1 K3 S1 | N1 K1 S2 |
| N2 K2 S2 | N1 K2 S3 | N3 K1 S3 | N2 K1 S1 | NO KO SO |
| N2 K3 S1 | N3 K1 S1 | N1 K2 S1 | N1 K1 S3 | N3 K3 S3 |
| N1 K3 S2 | N2 K2 S3 | NO KO SO | N2 K1 S2 | N3 K2 S2 |

TREATMENTS

LEVELS OF NITROGEN

| | |
|---|---|
| N1 | 50 kg N/ha |
| N2 | 125 kg N/ha |
| N3 | 200 kg N/ha |

LEVELS OF POTASSIUM

| | |
|---|---|
| K1 | 50 kg $K_2O$/ha |
| K2 | 125 kg $K_2O$/ha |
| K3 | 200 kg $K_2O$/ha |

TIMES OF APPLICATION

| | |
|---|---|
| S1 | 1/2 N AND K BASAL + 1/2 AT 60 DAYS |
| S2 | 1/3 N AND K BASAL + 1/3 AT 60 DAYS<br>+ 1/3 AT 90 DAYS |
| S3 | 1/2 N AND K BASAL + 1/4 AT 60 DAYS<br>+ 1/4 AT 90 DAYS |

FIG 4. LAYOUT PLAN - CONFOUNDED FACTORIAL EXPERIMENT AT KAYAMKULAM

**REPLICATION 1**

| | | | | | |
|---|---|---|---|---|---|
| N1 K1 S1 | N2 K3 S1 | N0 K0 S0 | N3 K3 S1 | N2 K3 S3 | N3 K1 S1 |
| N2 K1 S3 | N0 K0 S0 | N2 K1 S1 | N2 K3 S2 | N3 K3 S2 | N2 K2 S1 |
| N1 K2 S3 | N3 K2 S1 | N3 K2 S2 | N2 K2 S3 | N1 K2 S2 | N1 K3 S1 |
| N3 K3 S3 | N1 K3 S2 | N3 K1 S3 | N1 K1 S3 | N1 K1 S3 | N3 K2 S3 |
| N2 K2 S2 | N3 K1 S2 | N1 K2 S1 | N1 K1 S2 | N0 K0 S0 | N2 K1 S2 |

← B1 → ← B2 → ← B3 →

**REPLICATION 2**

← 5.4 m →

| | | | | | |
|---|---|---|---|---|---|
| N1 K1 S1 | N0 K0 S0 | N3 K1 S2 | N2 K2 S2 | N1 K3 S1 | N3 K1 S1 |
| N2 K1 S2 | N1 K2 S2 | N3 K2 S3 | N3 K3 S1 | N2 K1 S3 | N0 K0 S0 |
| N3 K2 S1 | N3 K3 S2 | N1 K2 S1 | N1 K1 S3 | N1 K1 S2 | N3 K2 S2 |
| N2 K3 S1 | N3 K1 S3 | N1 K3 S2 | N2 K3 S3 | N3 K3 S3 | N2 K2 S1 |
| N2 K2 S3 | N1 K3 S3 | N0 K0 S0 | N2 K1 S1 | N1 K2 S3 | N2 K3 S2 |

↑ 5.4 m ↓

← B4 → ← B5 → ← B6 →

**TREATMENTS**

**LEVELS OF NITROGEN**

| | |
|---|---|
| N1 | 50 kg/ha |
| N2 | 125 kg N/ha |
| N3 | 200 kg N/ha |

**LEVELS OF POTASSIUM**

| | |
|---|---|
| K1 | 50 kg $K_2O$/ha |
| K2 | 125 kg $K_2O$/ha |
| K3 | 200 kg $K_2O$/ha |

**TIMES OF APPLICATION**

| | |
|---|---|
| S1 | ½ N AND K BASAL + ½ AT 60 DAYS |
| S2 | ⅓ N AND K BASAL + ⅓ AT 60 DAYS + ⅓ AT 90 DAYS |
| S3 | ½ N AND K BASAL + ¼ AT 60 DAYS + ¼ AT 90 DAYS |

(iii) Time of application of N and K

$S_1$ - ½ basal + half sixty days after planting

$S_2$ - 1/3 basal + 1/3 sixty days after planting + 1/3 ninety days after planting

$S_3$ - ½ basal + ¼ sixty days after planting + ¼ ninety days after planting.

3.8.2 Treatment combinations

1. $N_1K_1S_1$
2. $N_1K_1S_2$
3. $N_1K_1S_3$
4. $N_1K_2S_1$
5. $N_1K_2S_2$
6. $N_1K_2S_3$
7. $N_1K_3S_1$
8. $N_1K_3S_2$
9. $N_1K_3S_3$
10. $N_2K_1S_1$
11. $N_2K_1S_2$
12. $N_2K_1S_3$
13. $N_2K_2S_1$
14. $N_2K_2S_2$
15. $N_2K_2S_3$
16. $N_2K_3S_1$
17. $N_2K_3S_2$
18. $N_2K_3S_3$
19. $N_3K_1S_1$
20. $N_3K_1S_2$
21. $N_3K_1S_3$
22. $N_3K_2S_1$
23. $N_3K_2S_2$
24. $N_3K_2S_3$
25. $N_3K_3S_1$
26. $N_3K_3S_2$
27. $N_3K_3S_3$

A third replication with the same treatment combinations was laid out at Vellayani during both the seasons for plant removal at thirty day intervals. $NK^2S$ was confounded in this replication. Plant removal was intended to study the drymatter production and uptake of nitrogen and potassium at various growth stages.

### 3.8.3 Plot size and spacing

| | | |
|---|---|---|
| Plot size | - | 5.4 x 5.4 M (gross) |
| | - | 3.6 x 3.6 M (net) |
| Spacing | - | 90 x 90 cm |

## 3.9 Planting

### 3.9.1 Cutting of setts

Healthy stems were cut into setts of 20 cm. length after discarding about 10 cm. from the lower mature end and about 25 - 30 cm. from the upper immature portion of the stems.

### 3.9.2 Planting of setts

Pits followed by mounds were taken in the plots at the spacing given above for planting setts at Vellayani. Planting in pits was adopted at Kayamkulam. One sett per pit or mound was planted vertically at a depth not exceeding 6 cm.

## 3.10 Fertilizers

### 3.10.1 Nitrogen

Nitrogen was supplied as urea analysing 46.0 per cent nitrogen and the calculated amounts of nitrogen were given as per treatment schedule.

### 3.10.2 Phosphorus

Phosphorus was given as super phosphate containing 16.0 per cent $P_2O_5$ uniformly to all plots at the rate of 100 kg $P_2O_5$/ha as basal dressing.

### 3.10.3 Potassium

Potassium was given as muriate of potash which contains 60.0 per cent $K_2O$ and the calculated amounts of potassium were given as per treatment schedule. Schedule of the time of application of nitrogen and potassium to the various treatments are shown in Table 2.

### 3.10.4 Lime

Lime was applied at the rate of 1 t/ha unformly to all plots at both locations alongwith the digging of the field.

### 3.11 After cultivation

Germination of setts was satisfactory during both the seasons at both the locations. Ungerminated setts were removed and replanted by fresh setts ten days after planting. After retaining two healthy sprouts, all other shoots were removed after about thirty days. Plant protection measures were given in time as per the KAU package of practices. Weeding and earthing up were done as per the schedule given below:

Schedule of cultural operations

| Year | Cultural operation | Vellayani | Kayamkulam |
|---|---|---|---|
| 1977-'78 | 1. first weeding and earthing up | 3.10.1977 | 29.10.1977 |
| | 2. second weeding and earthing up | 4.11.1977 | 27.11.1977 |
| | 3. third weeding and earthing up | 4.12.1977 | 27.12.1977 |
| 1978-'79 | 1. first weeding and earthing up | 27.9.1978 | 24.10.1978 |
| | 2. second weeding and earthing up | 31.10.1978 | 19.11.1978 |
| | 3. third weeding and earthing up | 30.11.1978 | 19.12.1978 |

Table 2. Schedule of the time of application of nitrogen and potassium

| Year | | Vellayani | | | Kayamkulam | | |
|---|---|---|---|---|---|---|---|
| 1977-'78 | | Date of planting: 5-9-1977 | | | Date of planting: 28-9-1977 | | |
| | | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| | Basal dressing | 5.9.1977 | 5.9.1977 | 5.9.1977 | 28.9.1977 | 28.9.1977 | 28.9.1977 |
| | First topdressing | 4.11.'77 | 4.11.'77 | 4.11.'77 | 27.11.'77 | 27.11.'77 | 27.11.'77 |
| | Second topdressing | - | 4.12.'77 | 4.12.'77 | - | 27.12.'77 | 27.12.'77 |
| 1978-'79 | | Date of planting: 1-9-1978 | | | Date of planting: 20-9-1978 | | |
| | | $S_1$ | $S_2$ | $S_3$ | $S_1$ | $S_2$ | $S_3$ |
| | Basal dressing | 1.9.1978 | 1.9.1978 | 1.9.1978 | 20.9.1978 | 20.9.1978 | 20.9.1978 |
| | First topdressing | 31.10.'78 | 31.10.'78 | 31.10.'78 | 19.11.'78 | 19.11.'78 | 19.11.'78 |
| | Second topdressing | - | 30.11.'78 | 30.11.'78 | - | 19.12.'78 | 19.12.'78 |

### 3.12 Harvest

The crops were harvested ten months after planting. The plants selected for biometric observations were harvested on the previous day of harvest and necessary observations were recorded. The dates of harvests are shown below:

| Year | Dates of harvest | |
|---|---|---|
| | Vellayani | Kayamkulam |
| 1977-'78 | 8.7.1978 | 2.8.1978 |
| 1978-'79 | 30.6.1979 | 22.7.1979 |

### 3.13 Biometric observations

#### 3.13.1 Pre-harvest observations

Three plants were selected from each plot at random in the first and second replications at both locations and were tagged. The following observations were made on these plants, recorded and mean values worked out at intervals of 30 days from planting to harvest.

##### 3.13.1.1 Plant height

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

### 3.13.1.2 Number of nodes per plant

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

### 3.13.1.3 Number of functional leaves per plant

The number of fully opened leaves or functional leaves was counted from the base to the tip of the stem on both the shoots

### 3.13.1.4 Leaf area index

The leaf area was calculated using linear measurement method suggested by Ramnujam and Indira (1978). The leaf area index was worked out by the following formula suggested by Watson (1947).

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

### 3.13.2 Post harvest observations

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

### 3.13.2.1 Number of tubers per plant

The tubers from the observational plants were separated and counted.

### 3.13.2.2 Tuber weight

The mean tuber weight was worked out by dividing the fresh tuber weight of sample plant by the number of tubers. This was expressed in grams.

### 3.13.2.3 Length of tuber

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

### 3.13.2.4 Girth of tuber

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

### 3.13.2.5 Utilization index (U.I)

The ratio of the root weight to top weight (stem and leaves), which is an important yield determinant of tapioca (Obigbesan, 1973) was calculated for each treatment in both the replications.

### 3.13.3 Top yield

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

### 3.13.4 Tuber yield

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

### 3.13.5 Quality attributes

### 3.13.5.1 Starch content

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

### 3.13.5.2 Starch yield

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

### 3.13.5.3 Hydrocyanic acid content

HCN content of fresh tuber samples were estimated colorimetrically by Sodium picrate method (Indira and Sinha, 1969).

### 3.13.5.4 Crude protein content

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

### 3.13.5.5 Cooking quality

The cooking quality of the tuber was assessed by judging the bitterness. The sensory method of analysis by a tastepannel was used in differentiating cooking quality (Jellinck, 1964). Since the sensitivity in taste discrimination test is likely to be affected by increasing the number of samples, only combinations of the extreme levels of nitrogen and potassium were tested for cooking quality (Prema et al. 1975).

Fresh tubers from plots receiving combinations of the two extreme levels of nitrogen and potassium were combined over two replications. A random sample of about 3 kg fresh tubers was selected from the four treatment combinations $N_1K_1$, $N_1K_3$, $N_3K_1$ and $N_3K_3$. These samples were used for quality evaluation test.

The sample tubers were derinded, cut into pieces of 5 to 8 cm length, washed clean and cooked in four different earthen pots for 30 minutes till the flesh was soft. The members of the taste panel were served with samples in random order. The taste was assessed on a discrete scale. The best taste was described as sweet and was allotted a score of 2. The other scores in the decreasing order of taste were watery sweet (1), starchy (0) bitter (-1) and watery bitter (-2).

### 3.13.6 Growth analysis

#### 3.13.6.1 Drymatter production and distribution

Sample harvests at 30 day intervals from planting were done in the third replication at Vellayani during both seasons to study the drymatter production at various growth stages. At each harvest one plant was carefully pulled out, the roots separated and washed and the tops separated into leaves and stems. Each part was weighed fresh and subsamples were taken and dried in the oven at 80°C to constant weight and the dry weights of the various plant parts were determined and recorded.

#### 3.13.6.2 Tuber bulking rate (B.R.)

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth. It is expressed in g/day/plant (dry weight).

$$B.R. = \frac{W_2 - W_1}{T_2 - T_1}$$

where $W_2$ = Dry weight of tuber at time $T_2$

$W_1$ = Dry weight of tuber at time $T_1$

#### 3.13.6.3 Net assimilation rate (NAR)

The rate of increase in dry weight per unit leaf area per unit time, was worked out during both the seasons at Vellayani from the data on third replication, using the following formula of Williams (1946).

$$\text{NAR} = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)}$$

Where $L_1$ and $W_1$ are the leaf area and dry weight of the plant at time $t_1$, and $L_2$ and $W_2$ are the leaf area and dry weight of the plant at time $t_2$. This was expressed in $mg/dm^2/day$.

### 3.13.6.4 Crop growth rate (CGR)

It is the absolute growth rate per unit area grown. This was calculated by the formula of Watson(1958).

$$\text{CGR} = \text{NAR} \times \text{LAI}$$

This was expressed as $g/m^2/day$

## 3.14 Chemical analysis

### 3.14.1 Plant analysis

The plant samples uprooted at 30 day intervals from the third replication at Vellayani were separated into leaf, stem and root and then dry weight determined as mentioned earlier. Nitrogen and potassium contents of the different plant parts were analysed during the various growth stages. At Kayamkulam, the plant analysis for nitrogen and potassium was done only at harvest.

The plant parts used for drymatter determination were ground separately into fine powder using an electric grinder for chemical analysis.

### 3.14.1.1 Nitrogen

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

### 3.14.1.2 Potassium

Potassium was determined flamephotometrically using a systronics flame photometer.

### 3.14.2 Uptake studies

Uptake of nitrogen and potassium at intervals of 30 days was estimated from the sample plants uprooted from the third replication at Vellayani for drymatter determinations. At Kayamkulam, uptake of nitrogen and potassium was computed only at harvest stage.

### 3.14.2.1 Uptake of nitrogen

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

### 3.14.2.2 Uptake of potassium

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

### 3.14.3 Soil analysis

At both locations, the soil in each field was analysed for the various physico-chemical properties before commencement of the experiment. Plotwise analysis of soil samples for available nitrogen and potassium was done at both locations soon after the harvest of each field experiment. For this purpose, soil samples from individual plots of third replication were used at Vellayani whereas the soil samples from all plots of the two replications were used at Kayamkulam.

#### 3.14.3.1 Collection of soil sample

A representative soil sample of the field obtained by mixing the soil samples collected from the different parts of the field, was used for initial analysis.

For the collection of soil sample for final analysis, each plot was divided into four equal parts. From each part one soil sample was collected. The four samples thus obtained from each plot were mixed together thoroughly and a representative sample was taken. This composite sample was air dried and then powdered and sieved through a 2 mm sieve.

#### 3.14.3.2 Analytical methods

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

3.14.3.2.1 Mechanical analysis

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

3.14.3.2.2 Soil pH

The pH was determined with Elico pH meter (Jackson, 1967).

3.14.3.2.3 Organic carbon

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

3.14.3.2.4 Total nitrogen

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

3.14.3.2.5 Available nitrogen

It was estimated by the Alkaline permangamate method of Subbiah and Asija (1956).

3.14.3.2.6 Available phosphorus

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

3.14.3.2.7 Available potassium

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

### 3.14.3.2.8 Total cation exchange capacity

Cation exchange capacity was determined by using normal neutral ammonium acetate and potassium chloride (Piper, 1950).

## 3.15 Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance for partially confounded $3^3$ factorial experiment 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 all statistical analysis wherever F-test was significant. The critical difference values have not been given wherever F-test was not significant. In general, the results and discussion are based at probability level of 0.05.

The correlation studies between the yield attributes and their intercorrelations were also determined. Path analysis was studied as per the procedure given by Wright (1921) and Li (1956).

Response curves were worked out between the levels of nutrients applied and crop yields. The statistical analysis of the data was carried out by the micro 2200 Hindustan Computer at the College of Agriculture, Vellayani.

# *Results*

# 4. RESULTS

The results of the investigations conducted under two different agroclimatic conditions of the state to study the effect of graded doses of potassium in combination with nitrogen at different times of application on the growth characters, yield components and tuber yield of tapioca during 1978 and 1979 are presented below. The results obtained at Vellayani under each aspect of study are given first followed by the results obtained at Kayamkulam.

## 4.1 Growth characters

Results of growth characters are presented at intervals of sixty days as the differences observed at thirty day intervals were not considerable.

### 4.1.1 Plant height

The data on plant height at different stages of crop growth at Vellayani and Kayamkulam during 1978 and 1979 are presented in Tables 3a and 3b.

It is seen from the Tables that the levels of nitrogen exhibited significant differences in plant height at various growth stages during both years at Vellayani. The tallest plants were produced at the $N_3$ level during both years. The influence of nitrogen on

Table 3 a. Effect of treatments on the height of plants (cm) during various growth stages at Vellayani.

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 36.87 | 31.28 | 34.07 | 91.65 | 86.45 | 89.06 | 115.63 | 110.95 | 113.29 | 139.19 | 136.72 | 137.95 | 172.58 | 188.79 | 180.69 |
| $N_2$ | 33.14 | 31.49 | 32.31 | 101.19 | 99.66 | 100.42 | 126.28 | 125.20 | 125.74 | 149.49 | 149.88 | 149.68 | 187.97 | 207.05 | 197.51 |
| $N_3$ | 30.89 | 37.78 | 34.33 | 110.15 | 107.36 | 108.75 | 134.69 | 132.18 | 133.41 | 161.41 | 159.11 | 160.26 | 194.69 | 209.95 | 202.32 |
| SE | 1.67 | 1.47 | | 1.55 | 1.76 | | 1.66 | 2.08 | | 2.40 | 1.88 | | 3.13 | 3.09 | |
| CD | NS | 4.28 | | 4.52 | 5.12 | | 4.83 | 6.04 | | 6.97 | 5.47 | | 9.11 | 8.97 | |
| $K_1$ | 33.90 | 31.91 | 32.90 | 95.92 | 91.54 | 93.73 | 121.77 | 117.70 | 119.73 | 149.05 | 146.51 | 147.78 | 186.55 | 197.92 | 192.24 |
| $K_2$ | 32.74 | 33.70 | 33.22 | 102.83 | 99.75 | 101.29 | 126.64 | 122.99 | 124.81 | 149.50 | 150.21 | 149.85 | 186.78 | 203.84 | 195.31 |
| $K_3$ | 34.26 | 34.93 | 34.59 | 104.25 | 102.20 | 103.22 | 128.18 | 127.65 | 127.91 | 151.54 | 149.00 | 150.27 | 181.91 | 204.03 | 192.97 |
| SE | 1.67 | 1.47 | | 1.85 | 1.76 | | 1.66 | 2.08 | | 2.40 | 1.88 | | 3.13 | 3.09 | |
| CD | NS | NS | | 4.52 | 5.12 | | 4.83 | 6.04 | | NS | NS | | NS | NS | |
| $S_1$ | 31.06 | 34.24 | 32.65 | 104.84 | 99.23 | 102.03 | 130.17 | 125.60 | 127.88 | 154.23 | 151.64 | 152.93 | 187.73 | 203.82 | 195.78 |
| $S_2$ | 36.21 | 32.40 | 34.30 | 97.26 | 97.57 | 97.41 | 124.08 | 120.89 | 122.48 | 148.24 | 146.49 | 147.36 | 184.62 | 198.70 | 191.66 |
| $S_3$ | 33.63 | 33.91 | 33.77 | 100.90 | 96.70 | 98.80 | 122.34 | 121.83 | 122.08 | 147.62 | 148.59 | 148.10 | 182.89 | 203.26 | 193.08 |
| SE | 1.67 | 1.47 | | 1.55 | 1.76 | | 1.66 | 2.08 | | 2.40 | 1.88 | | 3.13 | 3.09 | |
| CD | NS | NS | | 4.52 | NS | | 4.83 | NS | | NS | NS | | NS | NS | |
| A.C | 28.08 | 26.40 | 27.24 | 63.55 | 58.25 | 60.90 | 88.05 | 81.92 | 84.98 | 105.66 | 106.88 | 106.27 | 136.74 | 146.41 | 141.58 |
| T Vs A.C | NS | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

Table 3b. Effect of treatments on the height of plants (cm) during various growth stages at Kayamkulam.

| Treat-ments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 33.02 | 46.25 | 39.63 | 68.04 | 80.27 | 74.65 | 103.73 | 109.80 | 106.76 | 142.57 | 152.50 | 147.53 | 199.52 | 217.23 | 208.38 |
| $N_2$ | 30.58 | 42.97 | 36.77 | 66.10 | 80.76 | 73.43 | 104.05 | 107.97 | 106.01 | 133.81 | 153.58 | 143.69 | 191.98 | 216.92 | 204.45 |
| $N_3$ | 30.28 | 48.31 | 39.29 | 62.95 | 84.92 | 73.93 | 103.02 | 124.98 | 114.00 | 142.36 | 170.37 | 156.36 | 197.90 | 231.38 | 214.64 |
| SE | 1.89 | 1.93 | | 1.84 | 1.93 | | 2.69 | 2.72 | | 2.66 | 3.13 | | 2.85 | 3.13 | |
| CD | NS | NS | | NS | NS | | NS | 7.91 | | 7.72 | 9.09 | | NS | 9.10 | |
| $K_1$ | 31.18 | 42.55 | 36.86 | 67.45 | 86.76 | 77.10 | 101.11 | 113.49 | 107.30 | 138.60 | 161.69 | 150.14 | 197.47 | 224.04 | 210.76 |
| $K_2$ | 30.92 | 44.81 | 37.86 | 62.13 | 75.35 | 68.74 | 105.95 | 111.77 | 108.86 | 149.13 | 151.62 | 150.37 | 203.46 | 218.14 | 210.80 |
| $K_3$ | 31.77 | 51.17 | 41.47 | 68.49 | 83.84 | 76.16 | 103.75 | 117.49 | 110.62 | 131.02 | 163.15 | 147.08 | 188.49 | 233.35 | 205.92 |
| SE | 1.89 | 1.93 | | 1.84 | 1.93 | | 2.69 | 2.72 | | 2.66 | 3.13 | | 2.85 | 3.13 | |
| CD | NS | 5.63 | | 5.36 | 5.62 | | NS | NS | | 7.72 | 9.09 | | 8.30 | NS | |
| $S_1$ | 29.55 | 44.52 | 37.03 | 64.09 | 77.93 | 71.01 | 103.92 | 110.53 | 107.22 | 140.88 | 156.25 | 148.56 | 192.44 | 218.53 | 205.49 |
| $S_2$ | 33.47 | 47.38 | 40.42 | 71.42 | 85.51 | 78.46 | 103.69 | 115.64 | 109.66 | 137.78 | 159.38 | 148.58 | 193.49 | 222.97 | 208.23 |
| $S_3$ | 30.85 | 46.65 | 38.75 | 62.57 | 82.50 | 72.53 | 103.19 | 116.59 | 109.89 | 140.09 | 160.84 | 150.46 | 203.48 | 224.03 | 213.75 |
| SE | 1.89 | 1.93 | | 1.84 | 1.93 | | 2.69 | 2.72 | | 2.66 | 3.13 | | 2.85 | 3.13 | |
| CD | NS | NS | | 5.36 | 5.62 | | NS | NS | | NS | NS | | 8.30 | NS | |
| A.C. | 30.31 | 36.73 | 33.52 | 55.07 | 66.02 | 60.54 | 107.92 | 93.55 | 100.73 | 141.53 | 136.67 | 139.10 | 188.60 | 169.52 | 179.06 |
| T Vs A.C | NS | Sig** | | Sig** | Sig** | | NS | Sig** | | NS | Sig** | | NS | Sig** | |

A.C - Absolute Control T - Treatment NS- Not significant * Significant at 5% level
** Significant at 1% level.

plant height was significant during the various growth stages at Kayamkulam also with $N_3$ producing the tallest plants.

The different rates of potassium also showed significant differences in plant height during various growth stages at both locations. Eventhough treatment $K_3$ resulted in maximum plant height during the earlier stages it was on par with $K_2$. But in the harvest stage treatment $K_2$ produced the tallest plants.

The effect of time of application was not significant in most of the stages during both years at both locations. However, treatment $S_1$ produced the tallest plants at Vellayani.

### 4.1.2 Number of nodes

The data pertaining to the number of nodes at the various stages of growth of the crop at Vellayani and Kayamkulam during 1978 and 1979 are given in Tables 4a and 4b.

The data at Vellayani show that the levels of nitrogen produced significant differences in the number of nodes at the various growth stages. The highest dose of nitrogen gave the maximum number of nodes at all stages. At Kayamkulam also, the treatment $N_3$ showed the

Table 4a. Effect of treatments on the number of nodes per plant during various growth stages at Vellayani

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 41.67 | 29.69 | 35.68 | 66.65 | 115.35 | 91.00 | 143.63 | 160.38 | 152.00 | 199.81 | 210.08 | 164.94 | 234.98 | 305.30 | 270.14 |
| $N_2$ | 40.13 | 30.43 | 35.28 | 75.86 | 120.58 | 98.22 | 140.62 | 157.13 | 148.87 | 192.18 | 217.54 | 204.86 | 238.81 | 315.04 | 276.93 |
| $N_3$ | 42.87 | 41.93 | 42.40 | 74.97 | 130.87 | 102.92 | 157.99 | 169.78 | 163.88 | 212.17 | 230.39 | 221.12 | 253.60 | 317.66 | 285.63 |
| SE | 5.56 | 1.48 | | 2.48 | 4.36 | | 4.90 | 5.03 | | 6.29 | 7.78 | | 7.19 | 7.06 | |
| CD | NS | 4.31 | | 7.20 | NS | | 14.24 | NS | | NS | NS | | NS | NS | |
| $K_1$ | 47.56 | 31.14 | 39.35 | 75.29 | 124.54 | 99.41 | 151.36 | 167.74 | 159.55 | 209.72 | 221.62 | 215.67 | 248.34 | 308.19 | 278.27 |
| $K_2$ | 37.52 | 32.59 | 35.05 | 68.89 | 126.89 | 97.89 | 145.38 | 164.16 | 154.77 | 199.76 | 219.73 | 209.74 | 244.90 | 312.46 | 278.68 |
| $K_3$ | 39.59 | 38.32 | 38.95 | 74.31 | 115.37 | 94.84 | 145.51 | 155.40 | 150.45 | 194.68 | 216.67 | 205.67 | 234.15 | 317.35 | 275.75 |
| SE | 5.56 | 148 | | 2.48 | 4.36 | | 4.90 | 5.03 | | 6.29 | 7.78 | | 7.19 | 7.06 | |
| CD | NS | 4.31 | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 38.53 | 35.67 | 37.10 | 74.25 | 121.76 | 98.00 | 152.52 | 163.66 | 158.09 | 203.35 | 222.81 | 213.08 | 245.18 | 319.37 | 282.28 |
| $S_2$ | 38.00 | 34.02 | 36.01 | 71.96 | 123.02 | 97.49 | 145.46 | 164.36 | 154.91 | 203.71 | 219.90 | 211.80 | 247.41 | 312.32 | 279.87 |
| $S_3$ | 48.13 | 32.36 | 40.24 | 71.28 | 122.02 | 96.65 | 144.27 | 159.27 | 151.77 | 197.11 | 215.31 | 206.21 | 234.81 | 306.31 | 270.56 |
| SE | 5.56 | 1.48 | | 2.48 | 4.36 | | 4.90 | 5.03 | | 6.29 | 7.78 | | 7.19 | 7.06 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 30.30 | 30.47 | 30.38 | 68.48 | 99.80 | 84.14 | 137.80 | 116.03 | 126.91 | 172.02 | 163.37 | 167.69 | 202.95 | 200.55 | 201.75 |
| T Vs A.C | NS | NS | | NS | Sig** | | NS | Sig** | | Sig* | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level

** Significant at 1% level.

Table 4b. Effect of treatments on the number of nodes per plant during various growth stages at Kayamkulam.

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 32.55 | 47.21 | 39.88 | 73.26 | 103.53 | 88.39 | 110.75 | 119.19 | 114.97 | 170.13 | 182.58 | 176.35 | 194.50 | 259.69 | 227.09 |
| $N_2$ | 34.76 | 41.57 | 38.16 | 65.82 | 102.01 | 83.91 | 111.79 | 130.15 | 120.97 | 180.58 | 211.44 | 196.01 | 202.48 | 290.42 | 246.45 |
| $N_3$ | 34.24 | 48.05 | 41.14 | 65.67 | 99.20 | 82.43 | 110.03 | 124.08 | 117.05 | 168.08 | 212.60 | 190.34 | 220.47 | 292.96 | 256.72 |
| SE | 1.40 | 2.06 | | 1.32 | 3.78 | | 2.45 | 3.54 | | 5.02 | 6.71 | | 4.03 | 9.23 | |
| CD | NS | NS | | 3.83 | NS | | NS | NS | | NS | 19.48 | | 11.70 | 26.80 | |
| $K_1$ | 32.69 | 45.55 | 39.12 | 69.72 | 107.01 | 88.36 | 112.77 | 128.64 | 120.70 | 170.78 | 206.39 | 188.58 | 208.38 | 282.03 | 245.21 |
| $K_2$ | 34.64 | 44.81 | 39.72 | 64.94 | 95.98 | 80.46 | 109.57 | 120.89 | 115.23 | 174.63 | 199.79 | 187.21 | 204.87 | 275.45 | 240.16 |
| $K_3$ | 34.22 | 46.47 | 40.34 | 70.08 | 101.74 | 85.91 | 110.22 | 123.88 | 117.05 | 173.38 | 200.44 | 186.91 | 204.21 | 285.60 | 244.91 |
| SE | 1.40 | 2.06 | | 1.32 | 3.78 | | 2.45 | 3.54 | | 5.02 | 6.71 | | 4.03 | 9.23 | |
| CD | NS | NS | | 3.83 | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 35.56 | 46.53 | 41.04 | 66.67 | 99.05 | 82.86 | 109.24 | 125.66 | 117.45 | 177.69 | 200.83 | 189.26 | 191.90 | 278.16 | 235.03 |
| $S_2$ | 31.04 | 43.21 | 37.12 | 72.88 | 108.51 | 90.69 | 111.18 | 129.20 | 129.19 | 168.96 | 199.38 | 184.17 | 212.27 | 275.68 | 243.98 |
| $S_3$ | 34.96 | 47.08 | 41.02 | 65.19 | 97.18 | 81.18 | 112.14 | 118.57 | 115.35 | 172.14 | 206.41 | 189.27 | 213.28 | 289.24 | 251.26 |
| SE | 1.40 | 2.06 | | 1.32 | 3.78 | | 2.45 | 3.54 | | 5.02 | 6.71 | | 4.03 | 9.23 | |
| CD | NS | NS | | 3.83 | NS | | NS | NS | | NS | NS | | 11.70 | NS | |
| A.C | 34.23 | 31.75 | 32.99 | 58.60 | 74.52 | 66.56 | 101.28 | 94.65 | 97.96 | 139.58 | 160.23 | 149.90 | 164.48 | 202.17 | 183.33 |
| T Vs A.C | NS | Sig** | | Sig** | Sig** | | Sig* | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level

** Significant at 1% level.

highest number of nodes at harvest stage.

The different rates of potassium did not exert significant influence in this growth character during both years at both locations.

The effect of time of application was also not significant in the two locations.

### 4.1.3 Number of functional leaves

The mean number of functional leaves per plant during the various stages at Vellayani and Kayamkulam during both years are shown in Tables 5a and 5b.

The results show that the effect of nitrogen on the number of functional leaves was significant at various growth stages during both years at Vellayani. The number of functional leaves was maximum at $N_3$ at the different stages of growth. Treatment $N_2$ produced the highest number of functional leaves during the early stages of growth at Kayamkulam. In the later stages treatment $N_3$ gave the maximum number of functional leaves though on par with $N_2$.

The influence of potassium on the number of functional leaves was not significant at Vellayani or Kayamkulam during 1978 and 1979.

Table 5a. Effect of treatments on the number of functional leaves per plant during various growth stages at Vellayani.

| Treat-ments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 24.81 | 23.03 | 23.92 | 34.67 | 38.27 | 36.47 | 38.12 | 53.01 | 45.56 | 47.02 | 57.68 | 52.35 | 38.48 | 57.73 | 48.11 |
| $N_2$ | 26.85 | 22.47 | 24.66 | 37.14 | 36.94 | 37.04 | 37.95 | 55.69 | 46.82 | 43.36 | 60.42 | 51.89 | 36.93 | 60.12 | 48.53 |
| $N_3$ | 28.52 | 25.18 | 26.85 | 36.56 | 41.34 | 38.95 | 37.57 | 60.63 | 49.10 | 49.89 | 56.98 | 53.43 | 40.32 | 58.86 | 49.59 |
| SE | 0.79 | 1.33 | | 0.90 | 1.96 | | 0.98 | 1.54 | | 1.71 | 1.25 | | 1.19 | 2.22 | |
| CD | 2.32 | NS | | NS | NS | | NS | 4.49 | | 4.98 | NS | | NS | NS | |
| $K_1$ | 26.43 | 22.77 | 24.60 | 35.63 | 39.39 | 37.51 | 36.98 | 56.71 | 46.84 | 45.97 | 59.40 | 52.68 | 39.08 | 59.79 | 49.44 |
| $K_2$ | 26.53 | 23.62 | 25.07 | 35.41 | 37.82 | 36.61 | 38.02 | 54.27 | 46.14 | 47.20 | 57.66 | 52.43 | 38.75 | 58.50 | 48.63 |
| $K_3$ | 27.22 | 24.29 | 25.75 | 37.33 | 39.34 | 38.33 | 38.63 | 58.34 | 48.48 | 47.10 | 58.02 | 52.56 | 37.91 | 58.40 | 48.16 |
| SE | 0.79 | 1.33 | | 0.90 | 1.96 | | 0.98 | 1.54 | | 1.71 | 1.25 | | 1.19 | 2.22 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 27.70 | 23.87 | 25.78 | 36.32 | 39.91 | 38.06 | 37.36 | 56.80 | 47.08 | 47.73 | 56.74 | 52.23 | 40.13 | 60.21 | 50.17 |
| $S_2$ | 26.42 | 22.62 | 24.52 | 36.73 | 37.42 | 37.07 | 37.33 | 56.36 | 46.84 | 47.93 | 59.87 | 53.90 | 38.73 | 62.01 | 50.37 |
| $S_3$ | 26.06 | 24.19 | 25.12 | 35.32 | 39.22 | 37.27 | 38.96 | 56.16 | 47.56 | 44.61 | 58.47 | 51.54 | 36.88 | 54.48 | 45.68 |
| SE | 0.79 | 1.33 | | 0.90 | 1.96 | | 0.98 | 1.54 | | 1.71 | 1.25 | | 1.19 | 2.22 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 18.97 | 18.33 | 18.65 | 28.90 | 32.00 | 30.45 | 31.42 | 44.90 | 38.16 | 36.52 | 39.72 | 38.12 | 30.28 | 42.07 | 36.18 |
| T Vs A.C. | Sig** | Sig* | | Sig** | NS | | Sig** | Sig** | | Sig** | Sig** | | Sig* | Sig** | |

A.C. - Absolute control T - Treatment NS - Not significant * Significant at 5% level

** Significant at 1% level.

Table 5 b. Effect of treatments on the number of functional leaves per plant during various growth stages at Kayamkulam.

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 22.63 | 29.42 | 26.02 | 45.08 | 41.49 | 43.28 | 35.45 | 46.06 | 40.75 | 44.73 | 54.96 | 49.84 | 57.29 | 61.54 | 59.42 |
| $N_2$ | 22.74 | 25.86 | 24.30 | 38.02 | 54.48 | 46.25 | 36.78 | 51.66 | 44.22 | 48.49 | 65.33 | 56.91 | 56.41 | 67.64 | 62.03 |
| $N_3$ | 22.46 | 25.17 | 23.81 | 38.57 | 53.59 | 46.08 | 38.00 | 49.77 | 43.88 | 50.86 | 64.05 | 57.45 | 60.64 | 64.45 | 62.55 |
| SE | 0.88 | 0.97 | | 1.29 | 3.13 | | 0.91 | 1.26 | | 1.23 | 1.75 | | 1.15 | 1.25 | |
| CD | NS | 2.83 | | 3.76 | 9.09 | | NS | 3.67 | | 3.60 | 5.06 | | 3.36 | 3.63 | |
| $K_1$ | 22.56 | 28.27 | 25.41 | 40.33 | 50.98 | 45.65 | 37.59 | 48.27 | 42.93 | 50.53 | 59.96 | 55.24 | 58.98 | 64.80 | 61.89 |
| $K_2$ | 22.19 | 25.61 | 23.90 | 37.37 | 48.98 | 43.17 | 34.04 | 49.72 | 41.88 | 48.29 | 62.29 | 54.79 | 57.36 | 65.67 | 61.51 |
| $K_3$ | 23.09 | 26.57 | 24.83 | 43.97 | 49.60 | 46.78 | 38.60 | 49.49 | 44.04 | 47.27 | 61.08 | 54.17 | 58.00 | 63.16 | 60.58 |
| SE | 0.88 | 0.97 | | 1.29 | 3.13 | | 0.91 | 1.26 | | 1.23 | 1.75 | | 1.15 | 1.25 | |
| CD | NS | NS | | 3.76 | NS | | 2.67 | NS | | NS | NS | | NS | NS | |
| $S_1$ | 23.88 | 27.31 | 25.59 | 39.43 | 52.62 | 46.02 | 36.17 | 47.69 | 41.93 | 48.53 | 59.58 | 54.05 | 58.53 | 63.31 | 60.92 |
| $S_2$ | 21.83 | 26.43 | 24.13 | 45.20 | 46.12 | 45.66 | 39.72 | 48.80 | 44.26 | 48.67 | 60.59 | 54.63 | 58.96 | 63.92 | 61.44 |
| $S_3$ | 22.12 | 26.71 | 24.41 | 37.03 | 50.83 | 43.93 | 34.34 | 50.98 | 42.66 | 46.89 | 64.16 | 55.52 | 56.86 | 66.41 | 61.64 |
| SE | 0.88 | 0.97 | | 1.29 | 3.13 | | 0.91 | 1.26 | | 1.23 | 1.75 | | 1.15 | 1.25 | |
| CD | NS | NS | | 3.76 | NS | | 2.67 | NS | | NS | NS | | NS | NS | |
| A.C | 20.63 | 16.85 | 18.74 | 30.50 | 28.85 | 29.67 | 24.90 | 34.35 | 29.62 | 32.37 | 55.02 | 43.69 | 44.73 | 54.83 | 49.78 |
| T Vs A.C | NS | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig* | NS | | Sig** | Sig** | |

A.C - Absolute control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

Similarly, the time of application had no effect in the number of functional leaves at Vellayani or Kayamkulam during both years.

### 4.1.4 Leaf area index

The results of the effect of treatments on leaf area index during the different growth stages in both years at Vellayani and Kayamkulam are presented in Tables 6a and 6b.

The increase in nitrogen levels increased the leaf area index upto the $N_3$ level during early and later stages of growth at Vellayani. Significant difference in leaf area index due to nitrogen nutrition was observed at Kayamkulam with the maximum obtained at the $N_2$ level at all stages of growth.

The different rates of applied potassium were not influential in producing significant variations in LAI during different growth stages at Vellayani and Kayamkulam. But the treatment $K_2$ produced the highest LAI values in the later stages of growth at Vellayani and at all stages at Kayamkulam though the differences were not significant.

Time of application also did not reveal significant influence on LAI in the different growth stages during both years at both locations.

Table 6a. Effect of treatments on the leaf area index during various growth stages at Vellayani.

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 1.17 | 1.07 | 1.12 | 2.03 | 2.06 | 2.04 | 2.10 | 2.05 | 2.07 | 1.70 | 1.93 | 1.81 | 1.62 | 1.79 | 1.70 |
| $N_2$ | 1.13 | 1.01 | 1.07 | 2.15 | 2.04 | 2.09 | 2.20 | 2.10 | 2.15 | 1.63 | 1.95 | 1.79 | 1.51 | 1.88 | 1.69 |
| $N_3$ | 1.12 | 1.13 | 1.12 | 2.20 | 2.12 | 2.16 | 2.16 | 2.05 | 2.10 | 1.77 | 1.86 | 1.81 | 1.66 | 1.80 | 1.73 |
| SE | 0.03 | 0.03 | | 0.03 | 0.05 | | 0.03 | 0.03 | | 0.03 | 0.02 | | 0.02 | 0.02 | |
| CD | NS | NS | | 0.09 | NS | | 0.09 | NS | | 0.09 | 0.07 | | 0.06 | 0.05 | |
| $K_1$ | 1.14 | 1.03 | 1.08 | 2.08 | 2.10 | 2.09 | 2.10 | 2.09 | 2.09 | 1.73 | 1.90 | 1.81 | 1.61 | 1.80 | 1.70 |
| $K_2$ | 1.13 | 1.07 | 1.10 | 2.14 | 1.99 | 2.06 | 2.23 | 2.06 | 2.14 | 1.68 | 1.94 | 1.81 | 1.59 | 1.85 | 1.72 |
| $K_3$ | 1.16 | 1.11 | 1.13 | 2.15 | 2.12 | 2.13 | 2.13 | 2.05 | 2.09 | 1.70 | 1.89 | 1.79 | 1.60 | 1.82 | 1.71 |
| SE | 0.03 | 0.03 | | 0.03 | 0.05 | | 0.03 | 0.03 | | 0.03 | 0.02 | | 0.02 | 0.02 | |
| CD | NS | NS | | NS | NS | | 0.09 | NS | | NS | NS | | NS | NS | |
| $S_1$ | 1.15 | 1.09 | 1.12 | 2.12 | 2.07 | 2.09 | 2.12 | 2.08 | 2.10 | 1.75 | 1.94 | 1.84 | 1.65 | 1.86 | 1.75 |
| $S_2$ | 1.12 | 1.05 | 1.08 | 2.14 | 2.06 | 2.10 | 2.16 | 2.07 | 2.11 | 1.68 | 1.90 | 1.79 | 1.58 | 1.82 | 1.71 |
| $S_3$ | 1.17 | 1.07 | 1.12 | 2.11 | 2.08 | 2.09 | 2.17 | 2.05 | 2.11 | 1.67 | 1.90 | 1.78 | 1.57 | 1.80 | 1.68 |
| SE | 0.03 | 0.03 | | 0.03 | 0.05 | | 0.03 | 0.03 | | 0.03 | 0.02 | | 0.02 | 0.02 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | 0.06 | 0.05 | |
| A.C. | 1.03 | 0.93 | 0.98 | 1.84 | 1.88 | 1.86 | 1.88 | 1.86 | 1.87 | 1.35 | 1.67 | 1.51 | 1.24 | 1.65 | 1.44 |
| T. Vs. A.C. | Sig* | Sig* | | Sig** | NS | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C. - Absolute Control T - Treatment NS - Not significant * Significant at 5% level

** Significant at 1% level.

Table 6b. Effect of treatments on the leaf area index during various growth stages at Kayamkulam.

| Treatments | 60 days | | | 120 days | | | 180 days | | | 240 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.97 | 1.01 | 0.99 | 2.12 | 1.93 | 2.02 | 1.58 | 1.99 | 1.78 | 1.89 | 2.21 | 2.05 | 1.98 | 2.39 | 2.18 |
| $N_2$ | 1.03 | 1.10 | 1.06 | 1.99 | 2.14 | 2.06 | 1.56 | 1.98 | 1.77 | 1.90 | 2.42 | 2.16 | 1.94 | 2.54 | 2.24 |
| $N_3$ | 1.02 | 1.03 | 1.02 | 1.97 | 2.12 | 2.04 | 1.62 | 1.91 | 1.76 | 1.96 | 2.26 | 2.11 | 2.03 | 2.40 | 2.21 |
| SE | 0.02 | 0.03 | | 0.03 | 0.06 | | 0.02 | 0.03 | | 0.03 | 0.03 | | 0.02 | 0.03 | |
| CD | NS | NS | | 0.07 | 0.18 | | 0.05 | NS | | NS | 0.10 | | NS | 0.09 | |
| $K_1$ | 1.00 | 1.07 | 1.03 | 1.98 | 2.14 | 2.06 | 1.60 | 1.96 | 1.78 | 1.99 | 2.26 | 2.12 | 1.98 | 2.38 | 2.18 |
| $K_2$ | 0.98 | 1.08 | 1.03 | 1.99 | 2.12 | 2.05 | 1.57 | 1.98 | 1.77 | 1.92 | 2.33 | 2.12 | 1.99 | 2.52 | 2.25 |
| $K_3$ | 1.04 | 1.00 | 1.02 | 2.10 | 1.93 | 2.01 | 1.59 | 1.94 | 1.76 | 1.86 | 2.31 | 2.08 | 1.98 | 2.43 | 2.20 |
| SE | 0.02 | 0.03 | | 0.03 | 0.06 | | 0.02 | 0.03 | | 0.03 | 0.03 | | 0.02 | 0.03 | |
| CD | NS | NS | | 0.07 | 0.18 | | NS | NS | | 0.07 | NS | | NS | 0.09 | |
| $S_1$ | 1.01 | 1.05 | 1.03 | 2.00 | 2.05 | 2.02 | 1.59 | 1.91 | 1.75 | 1.94 | 2.25 | 2.09 | 1.98 | 2.40 | 2.19 |
| $S_2$ | 1.03 | 1.09 | 1.06 | 2.12 | 2.02 | 2.07 | 1.63 | 1.96 | 1.79 | 1.95 | 2.28 | 2.11 | 2.00 | 2.43 | 2.21 |
| $S_3$ | 0.99 | 1.00 | 0.99 | 1.96 | 2.12 | 2.04 | 1.54 | 2.03 | 1.78 | 1.88 | 2.37 | 2.12 | 1.96 | 2.49 | 2.22 |
| SE | 0.02 | 0.03 | | 0.03 | 0.06 | | 0.02 | 0.03 | | 0.03 | 0.03 | | 0.02 | 0.03 | |
| CD | NS | NS | | 0.07 | NS | | 0.05 | NS | | NS | 0.10 | | NS | NS | |
| A.C. | 0.93 | 0.98 | 0.95 | 1.55 | 1.58 | 1.56 | 1.31 | 1.69 | 1.50 | 1.48 | 2.17 | 1.82 | 1.64 | 1.95 | 1.79 |
| T. Vs. A.C. | NS | NS | | Sig** | Sig** | | Sig** | Sig** | | Sig* | NS | | Sig** | Sig** | |

A.C. - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

## 4.2 Yield components and yield

### 4.2.1 Number of tubers

The data on the mean number of tubers per plant at harvest in 1978 and 1979 at Vellayani and Kayamkulam are shown in Table 7. and illustrated graphically in Fig.5.

It is evident from the data that the nitrogen levels increased the tuber number at Vellayani upto the highest level during the first year showing significant difference between $N_1$ and $N_2$ levels. During the second year the tuber number increased significantly upto the $N_2$ level and at $N_3$ it registered a significant reduction. At Kayamkulam, the tuber number increased by raising the level of nitrogen from $N_1$ to $N_2$ in the first year. But a significant decrease in tuber number was observed at the $N_3$ level. The effect of nitrogen was not significant during the second year.

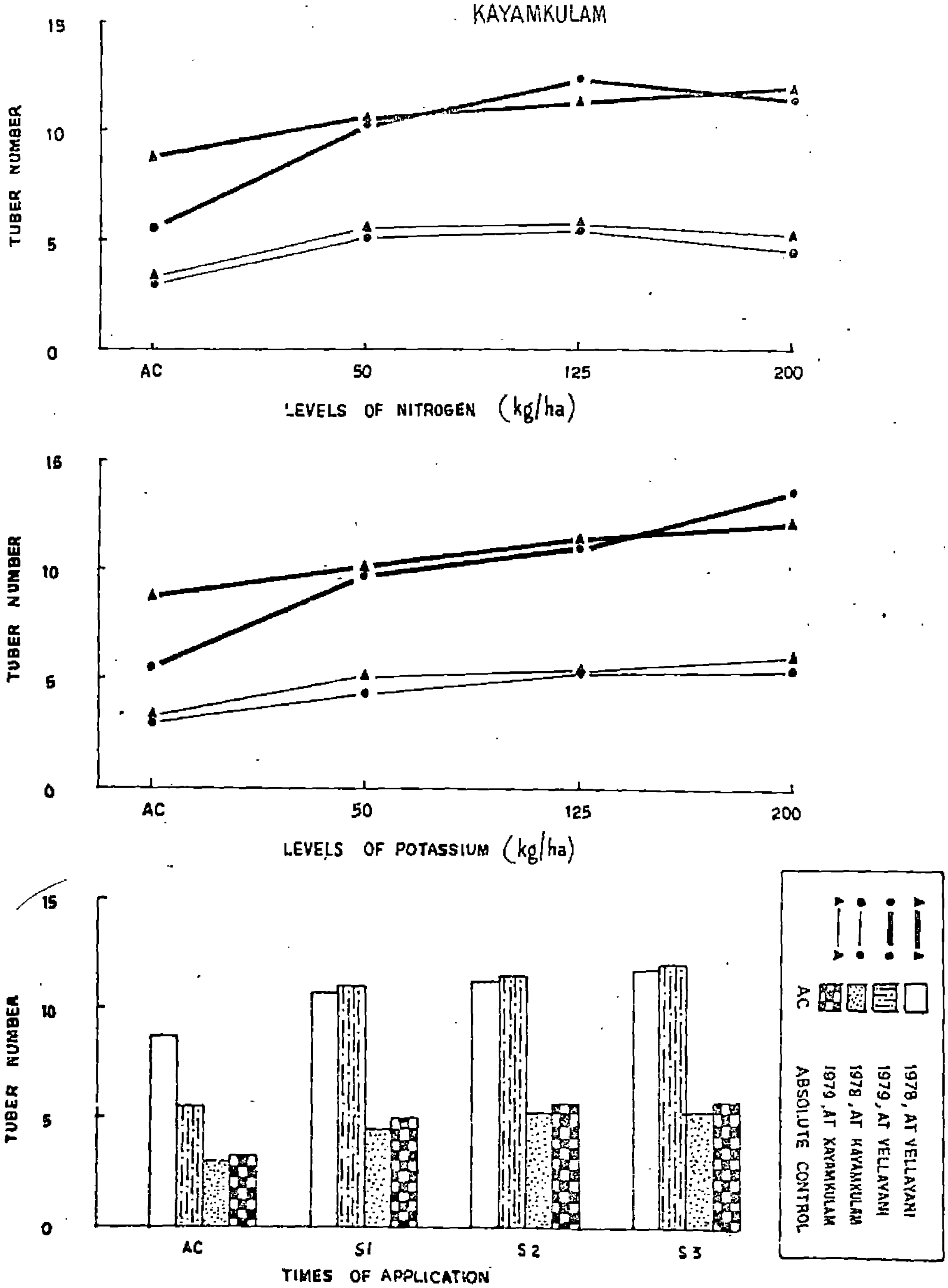
Different rates of applied potassium increased the tuber number at both locations. Tuber number was maximum at the $K_3$ level. During the first year treatment $K_3$ was on par with $K_2$, both being significantly superior to $K_1$. Treatment $K_3$ produced significantly higher number of tubers than $K_2$ and $K_1$ at both locations during the second year.

Table 7. Effect of treatments on tuber number and tuber weight per plant.

| Treatments | Vellayani | | | | | | Kayamkulam | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tuber number | | | Tuber weight (g) | | | Tuber number | | | Tuber weight (g) | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 10.57 | 10.39 | 10.46 | 152.00 | 159.94 | 155.97 | 5.08 | 5.57 | 5.32 | 189.94 | 197.94 | 193.94 |
| $N_2$ | 11.27 | 12.41 | 11.82 | 162.22 | 193.06 | 177.64 | 5.46 | 5.54 | 5.49 | 212.83 | 225.16 | 219.00 |
| $N_3$ | 11.81 | 11.61 | 11.71 | 149.17 | 166.28 | 157.72 | 4.57 | 5.12 | 4.85 | 202.78 | 216.89 | 209.83 |
| SE | 0.24 | 0.26 | | 4.64 | 3.33 | | 0.19 | 0.22 | | 3.32 | 2.33 | |
| CD | 0.69 | 0.77 | | NS | 9.69 | | 0.56 | NS | | 9.64 | 6.78 | |
| $K_1$ | 10.03 | 9.83 | 9.93 | 152.00 | 148.06 | 150.03 | 4.38 | 5.05 | 4.72 | 176.33 | 179.28 | 177.81 |
| $K_2$ | 11.58 | 11.12 | 11.33 | 161.06 | 178.00 | 169.53 | 5.35 | 5.22 | 5.29 | 200.67 | 212.11 | 206.39 |
| $K_3$ | 12.03 | 13.47 | 12.73 | 150.33 | 193.22 | 171.78 | 5.37 | 5.96 | 5.66 | 228.56 | 248.61 | 238.58 |
| SE | 0.24 | 0.26 | | 4.64 | 3.33 | | 0.19 | 0.22 | | 3.32 | 2.33 | |
| CD | 0.69 | 0.77 | | NS | 9.69 | | 0.56 | 0.65 | | 9.64 | 6.78 | |
| $S_1$ | 10.68 | 10.97 | 10.80 | 150.72 | 159.44 | 155.08 | 4.64 | 4.99 | 4.82 | 193.33 | 202.22 | 197.78 |
| $S_2$ | 11.23 | 11.47 | 11.35 | 155.72 | 176.00 | 165.86 | 5.20 | 5.53 | 5.42 | 205.22 | 214.56 | 209.89 |
| $S_3$ | 11.73 | 11.98 | 11.84 | 156.94 | 183.83 | 170.39 | 5.16 | 5.70 | 5.43 | 207.00 | 223.22 | 215.11 |
| SE | 0.24 | 0.26 | | 4.64 | 3.33 | | 0.19 | 0.22 | | 3.32 | 2.33 | |
| CD | 0.69 | 0.77 | | NS | 9.69 | | NS | NS | | 9.64 | 6.78 | |
| A.C. | 8.66 | 5.53 | 7.09 | 133.00 | 134.66 | 123.83 | 3.01 | 3.21 | 3.11 | 152.33 | 158.16 | 155.24 |
| T Vs A.C | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig* | Sig** | |

A.C - Absolute control    T - Treatment    NS - Not significant    * Significant at 5% level
** Significant at 1% level.

FIG 5. EFFECT OF TREATMENTS ON TUBER NUMBER AT VELLAYANI AND KAYAMKULAM



As regards the time of application, treatment $S_3$ resulted in the maximum number of tubers at Vellayani and was significantly superior to $S_1$ but on par with $S_2$ during both years. At Kayamkulam, the highest tuber number was noticed in the treatment $S_2$ during the first year and in $S_3$ during the second year, though the differences were not significant.

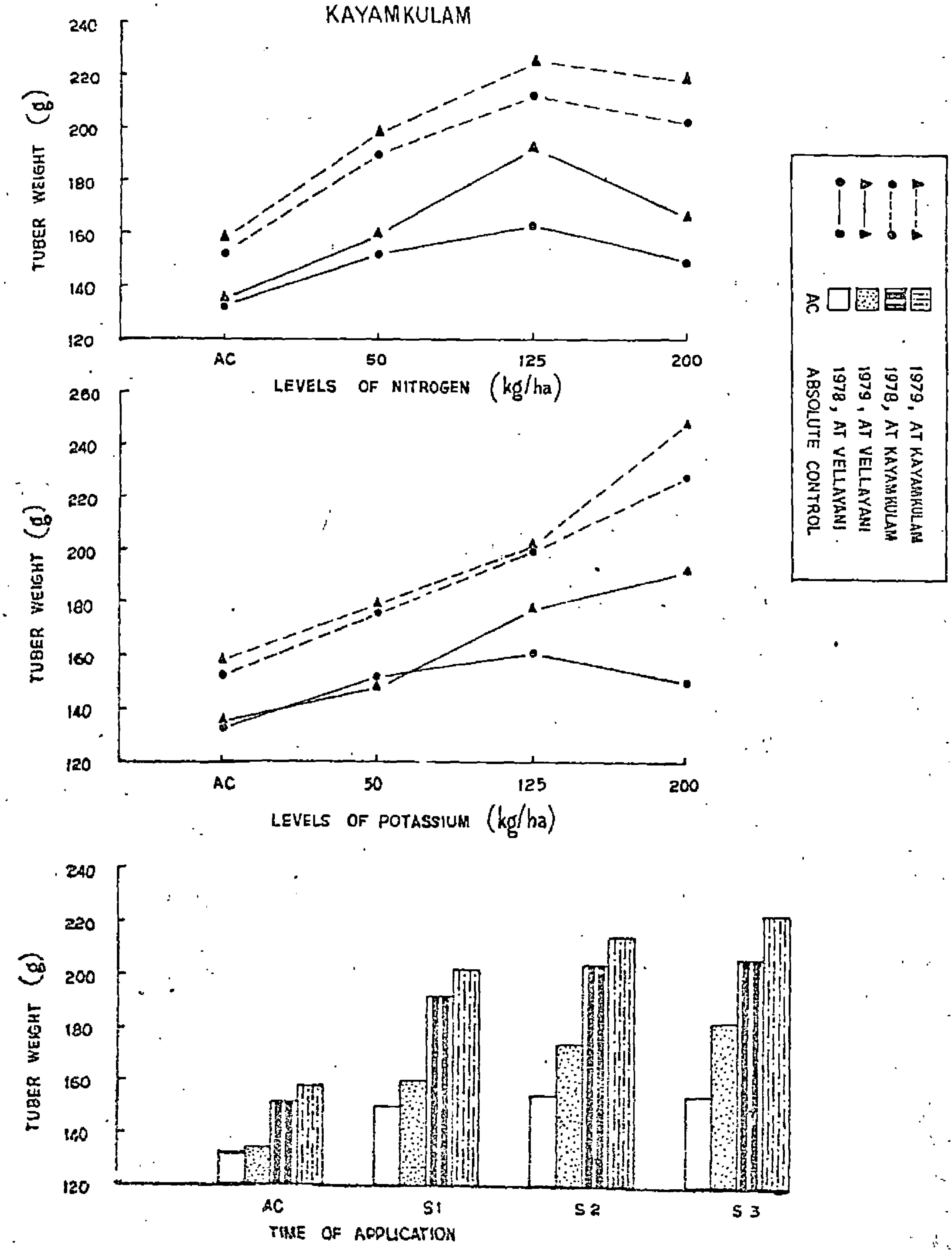
An examination of the data on tuber number at both locations revealed that the number at Vellayani was almost double that obtained at Kayamkulam.

### 4.2.2 Tuber weight

The data on mean tuber weight at harvest during 1978 and 1979 at Vellayani and Kayamkulam are given in Table 7 and illustrated graphically in Fig.6.

The data clearly show increases in tuber weight due to nitrogen nutrition at Vellayani. Tuber weight increased upto the $N_2$ level during both years and the difference was significant during the second year. At the $N_3$ level, tuber weight decreased significantly during the second year. At Kayamkulam the effect of nitrogen was significant during both years. The trend of variation in tuber weight due to nitrogen nutrition was similar to that at Vellayani.

FIG 6. EFFECT OF TREATMENTS ON MEAN TUBER WEIGHT AT VELLAYANI AND KAYAMKULAM



Incremental doses of potassium increased tuber weight significantly upto the highest level ($K_3$) during the second year of the study at Vellayani. But the differences were not significant during the first year. The mean tuber weight increased significantly during both years at Kayamkulam by higher rates of potassium application with a maximum noticed at the $K_3$ level. Treatment $K_3$ was significantly higher than $K_2$ which in turn was superior to $K_1$.

Time of application was significant in this respect during the second yearat Vellayani. Treatment $S_3$ gave the maximum tuber weight which was significantly higher than $S_1$ only. Tuber weight was maximum in treatment $S_3$ during the first year also eventhough the differences were not significant. Similarly, during both years treatment $S_3$ resulted in the highest tuber weight at Kayamkulam. Treatments $S_2$ and $S_3$ were on par during the first year which in turn was superior to $S_1$. But in the second year, treatment $S_3$ was significantly higher than $S_2$ and $S_1$.

The data on mean tuber weight show that the values at Kayamkulam were much higher than those obtained at Vellayani and were to the tune of about 25 per cent

### 4.2.3 Length of tuber

The data pertaining to the length of tuber at harvest during both years at Vellayani and Kayamkulam are given in Table 8.

Though tuber length increased significantly with higher doses of nitrogen application during the first year at Vellayani, the effect of nitrogen was not significant during the second year. Tuber length at Kayamkulam was not affected by nitrogen levels during both years.

The levels of potassium did not influence this component during either year at the two locations.

Time of application had no significant effect on tuber length at Vellayani during either 1978 or 1979. The effect was not significant during the first year at Kayamkulam though it showed a significant difference during the second year.

### 4.2.4 Girth of tuber

The data on the girth of tuber at harvest during both years at the two locations are presented in Table 8.

The data reveal that the girth of tuber did not differ significantly between the levels of nitrogen during both years at Vellayani. The influence of nitrogen was significant only during the first year at Kayamkulam.

Table 8. Effect of treatments on length and girth of tubers

| Treat-ments | Vellayani | | | | | | Kayamkulam | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length of tuber (cm) | | | Girth of tuber(cm) | | | Length of tuber(cm) | | | Girth of tuber (cm) | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 31.83 | 33.86 | 32.85 | 9.86 | 10.09 | 9.98 | 25.71 | 25.68 | 25.69 | 18.89 | 13.54 | 16.21 |
| $N_2$ | 33.94 | 33.77 | 33.86 | 10.49 | 10.57 | 10.53 | 24.61 | 26.45 | 25.53 | 14.15 | 13.56 | 13.86 |
| $N_3$ | 35.00 | 32.85 | 33.93 | 9.77 | 9.83 | 9.80 | 25.87 | 26.24 | 26.06 | 13.28 | 12.42 | 12.85 |
| SE | 0.81 | 1.17 | | 0.29 | 0.36 | | 1.10 | 1.12 | | 0.67 | 0.65 | |
| CD | 2.35 | NS | | NS | NS | | NS | NS | | 1.95 | NS | |
| $K_1$ | 33.12 | 33.08 | 33.10 | 9.49 | 9.81 | 9.65 | 24.73 | 24.48 | 24.60 | 15.40 | 12.91 | 14.15 |
| $K_2$ | 32.84 | 32.48 | 32.66 | 10.38 | 10.10 | 10.24 | 24.69 | 27.14 | 25.92 | 15.63 | 12.72 | 14.18 |
| $K_3$ | 34.82 | 34.92 | 34.87 | 10.24 | 10.58 | 10.41 | 26.77 | 26.75 | 26.76 | 15.29 | 13.89 | 14.59 |
| SE | 0.81 | 1.17 | | 0.29 | 0.36 | | 1.10 | 1.12 | | 0.67 | 0.65 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 34.26 | 32.41 | 33.34 | 10.62 | 9.82 | 9.72 | 26.04 | 28.78 | 27.41 | 15.30 | 12.66 | 13.98 |
| $S_2$ | 33.16 | 34.29 | 33.72 | 10.19 | 10.06 | 10.12 | 26.32 | 24.81 | 25.56 | 15.01 | 12.74 | 13.88 |
| $S_3$ | 33.36 | 33.78 | 33.57 | 10.31 | 10.61 | 10.46 | 23.82 | 24.78 | 24.30 | 16.02 | 14.11 | 15.06 |
| SE | 0.81 | 1.17 | | 0.29 | 0.36 | | 1.10 | 1.12 | | 0.67 | 0.65 | |
| CD | NS | NS | | NS | NS | | NS | 3.26 | | NS | NS | |
| A.C | 32.90 | 34.55 | 33.72 | 9.41 | 9.68 | 9.54 | 26.60 | 25.35 | 25.97 | 12.05 | 12.31 | 12.18 |
| T Vs A.C. | NS | NS | | NS | NS | | NS | NS | | Sig* | NS | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level

The effect of potassium was not significant during both years at Vellayani. The influence of potassium at Kayamkulam was also similar in this aspect.

Tuber girth variations due to different times of application of nutrients were also not significant at Vellayani and Kayamkulam.

### 4.2.5 Utilization index

The results of treatment effects on utilization index at Vellayani and Kayamkulam during the two years are given in Table 9.

The utilization index was not affected significantly by nitrogen levels during the first year at Vellayani. But it increased upto the $N_2$ level and decreased thereafter during the second year. An increasing trend in utilization index by the higher doses of nitrogen was noticed upto the $N_2$ level during both years at Kayamkulam, treatments $N_1$ and $N_2$ being on par during the second year. But at the $N_3$ level the value decreased significantly during both years.

At Vellayani the effect of potassium was not significant in this yield component during both the years. But at the highest level of potassium application utilization index was also a maximum. Utilization index

Table 9. Effect of treatments on Utilization index and top yield

| Treatments | Vellayani | | | | | | Kayamkulam | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Utilization index | | | Topyield (t/ha) | | | Utilization index | | | Topyield (t/ha) | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 1.96 | 2.16 | 2.06 | 11.27 | 9.50 | 10.09 | 1.23 | 1.36 | 1.30 | 12.44 | 11.82 | 12.13 |
| $N_2$ | 1.66 | 2.26 | 1.96 | 14.00 | 12.13 | 12.70 | 1.52 | 1.51 | 1.53 | 12.42 | 17.33 | 14.87 |
| $N_3$ | 1.60 | 1.80 | 1.70 | 14.97 | 15.70 | 14.91 | 1.30 | 1.19 | 1.25 | 15.20 | 18.73 | 16.96 |
| SE | 0.10 | 0.06 | | 0.61 | 0.54 | | 0.05 | 0.08 | | 0.55 | 0.60 | |
| CD | NS | 0.19 | | 1.78 | 1.58 | | 0.17 | 0.25 | | 1.61 | 1.75 | |
| $K_1$ | 1.76 | 2.13 | 1.95 | 12.51 | 10.75 | 11.63 | 1.10 | 1.17 | 1.14 | 14.06 | 17.36 | 15.71 |
| $K_2$ | 1.63 | 1.95 | 1.79 | 14.73 | 12.90 | 13.81 | 1.44 | 1.43 | 1.44 | 13.07 | 15.87 | 14.47 |
| $K_3$ | 1.82 | 2.14 | 1.98 | 13.00 | 13.67 | 13.33 | 1.52 | 1.47 | 1.50 | 12.94 | 14.66 | 13.80 |
| SE | 0.10 | 0.06 | | 0.61 | 0.54 | | 0.05 | 0.08 | | 0.55 | 0.60 | |
| CD | NS | NS | | 1.78 | 1.58 | | 0.17 | 0.25 | | NS | 1.75 | |
| $S_1$ | 1.72 | 1.94 | 1.83 | 12.82 | 12.20 | 12.16 | 1.21 | 1.24 | 1.23 | 12.24 | 15.63 | 13.93 |
| $S_2$ | 1.73 | 2.15 | 1.94 | 13.63 | 12.84 | 12.87 | 1.39 | 1.43 | 1.41 | 13.84 | 16.65 | 15.24 |
| $S_3$ | 1.76 | 2.14 | 1.95 | 13.80 | 12.28 | 12.68 | 1.47 | 1.41 | 1.44 | 13.85 | 15.59 | 14.79 |
| SE | 0.10 | 0.06 | | 0.61 | 0.54 | | 0.05 | 0.08 | | 0.55 | 0.60 | |
| CD | NS | 0.19 | | NS | NS | | 0.17 | NS | | NS | NS | |
| A.C | 1.70 | 1.41 | 1.55 | 7.44 | 7.69 | 7.56 | 1.24 | 1.01 | 1.12 | 6.90 | 7.16 | 7.03 |
| T. Vs. A.C | Sig** | Sig** | | Sig** | Sig** | | NS | Sig* | | Sig** | Sig** | |

A.C. - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

increased significantly during both years at Kayamkulam due to potassium nutrition with the maximum observed in treatment $K_3$.

Time of application was also significant in this respect during the second year at Vellayani wherein treatments $S_2$ and $S_3$ were on par. Treatment $S_3$ produced the highest utilization index during the first year eventhough the differences were not significant. During the first year, at Kayamkulam the utilization index was significantly higher in treatment $S_3$ as compared to $S_1$. Treatments $S_2$ and $S_3$ were on par. Utilization index was higher in treatments $S_2$ and $S_3$ as compared to $S_1$ during the second year eventhough the differences were not significant.

### 4.2.6 Top yield

The data on top yield during 1978 and 1979 at both locations are presented in Table 9.

The data reveal that top yield increased by nitrogen nutrition during both years at Vellayani. While the increase was significant only upto the $N_2$ level during the first year it exhibited significant increase upto the highest level during the second year. An increasing trend in top yield by nitrogen nutrition was observed at Kayamkulam also during both years. The top yield was the highest in the treatment $N_3$.

Top yield increased significantly by potassium nutrition during both years at Vellayani. During the first year treatment $K_2$ resulted in the highest top yield which was significantly higher than in treatment $K_1$ and it decreased in $K_3$. But during the second year though treatment $K_3$ gave the highest yield of top portion it was on par with $K_2$. During both years treatment $K_3$ produced the minimum top yields at Kayamkulam and the effect of potassium levels was significant only during the second year.

The effect of time of application was not significant in top yield during both years either at Vellayani or at Kayamkulam.

### 4.2.7 Tuber yield

The data on tuber yield of tapioca as influenced by the fertilizer levels, time of application and their interaction during 1978 and 1979 at Vellayani and Kayamkulam are presented in Tables 10 and 11 and illustrated graphically in Fig. 7.and 8.

The statistical analysis of the tuber yield data for different years at each location did not show any significant difference. Hence pooled analysis of the data averaged over the years was done and presented.

Table 10. Effect of treatments on tuber yield (pooled) of tapioca (t/ha) at Vellayani

| Treatments | $N_1$ | $N_2$ | $N_3$ | $S_1$ | $S_2$ | $S_3$ | Mean |
|---|---|---|---|---|---|---|---|
| $K_1$ | 16.67 | 17.83 | 17.26 | 17.20 | 16.89 | 17.65 | 17.25 |
| $K_2$ | 19.77 | 27.35 | 21.12 | 20.57 | 21.94 | 25.72 | 22.75 |
| $K_3$ | 22.67 | 25.90 | 24.01 | 21.01 | 24.53 | 27.05 | 24.20 |
| $S_1$ | 18.63 | 19.90 | 20.25 | | | | 19.59 |
| $S_2$ | 19.27 | 22.92 | 21.17 | | | | 21.12 |
| $S_3$ | 21.20 | 28.24 | 20.98 | | | | 23.47 |
| Mean | 19.70 | 23.68 | 20.80 | | | | 21.39 |

Absolute control 9.40

Absolute Control Vs treatments Sig$^{**}$

| Source | S.E. | C.D. (P=0.05) |
|---|---|---|
| Marginal means | 0.73 | 2.12 |
| Two factor means | 1.23 | 3.56 |

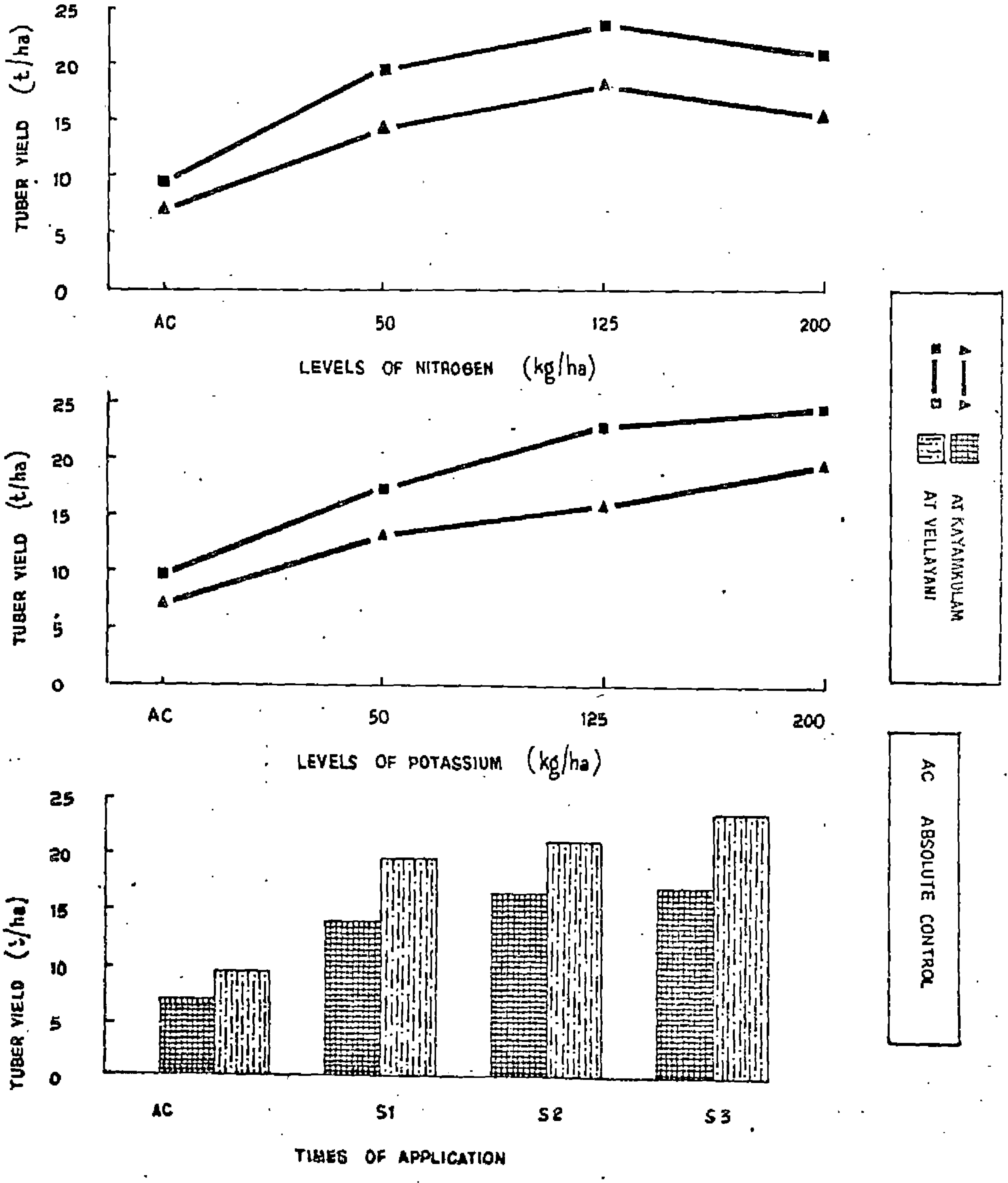
Table 11. Effect of treatments on tuber yield (pooled) of tapioca (t/ha) at Kayamkulam

| Treatments | $N_1$ | $N_2$ | $N_3$ | $S_1$ | $S_2$ | $S_3$ | Mean |
|---|---|---|---|---|---|---|---|
| $K_1$ | 10.67 | 12.55 | 15.24 | 11.33 | 14.97 | 12.15 | 12.82 |
| $K_2$ | 13.91 | 18.45 | 14.51 | 14.06 | 16.04 | 16.78 | 15.63 |
| $K_3$ | 18.29 | 23.26 | 16.52 | 16.65 | 18.40 | 23.02 | 19.36 |
| $S_1$ | 12.50 | 14.49 | 15.06 | | | | 14.02 |
| $S_2$ | 14.35 | 18.53 | 16.53 | | | | 16.47 |
| $S_3$ | 16.04 | 21.25 | 14.65 | | | | 17.31 |
| Mean | 14.29 | 18.09 | 15.42 | | | | 15.93 |

| | |
|---|---|
| Absolute control | 6.80 |
| Absolute control Vs Treatments | Sig** |

| Source | S.E. | C.D. (P=0.05) |
|---|---|---|
| Marginal means | 0.55 | 1.60 |
| Two factor means | 0.95 | 2.77 |

FIG 7. EFFECT OF TREATMENTS ON TUBER YIELD AT VELLAYANI AND KAYAMKULAM



Nitrogen exerted significant effect on tuber yield at Vellayani. By increasing the dose of applied nitrogen from 50 kg/ha ($N_1$) to 125 kg/ha ($N_2$) the yield increased significantly by about 3.98 t/ha. But by a further increase to 200 kg N/ha ($N_3$) the yield decreased significantly to the extent of 2.88 t/ha as compared to that at $N_2$ (125 kg/ha). At Kayamkulam also the response to nitrogen fertilization showed a similar trend. The yield increase by the application of 125 kg N/ha was 3.8 t/ha. The yield reduction observed at the highest level of nitrogen application (200 kg N/ha) was 2.67 t/ha.

Application of potassium increased tuber yields upto the highest level at both locations. The significant yield increase noticed by the application of 125 kg $K_2O$/ha at Vellayani was 5.5 t/ha. Eventhough the yield increased by the application of 200 kg $K_2O$/ha to the tune of about 1.45 t it was not significantly higher than the yield obtained at 125 kg $K_2O$/ha. The trend of yield increase by potassium application was similar at Kayamkulam, significant differences being noticed at each level. The yield increase by the application of $K_2O$ at 125 kg/ha as compared to 50 kg/ha was 2.81 t/ha. But increase was 3.73 t/ha when the level of application of $K_2O$ was increased from 125 kg/ha to 200 kg/ha.

Similarly, the effect of time of application was also significant at both locations. At Vellayani, treatment $S_3$ was significantly superior to $S_2$ and $S_1$ with a yield increase of 3.88 t/ha at $S_3$ as compared to $S_1$. At Kayamkulam also the tuber yield was maximum in treatment $S_3$ but was on par with $S_2$. The yield difference between $S_1$ and $S_3$ was 3.29 t/ha.

N x K interaction was also significant at both places. The treatment combination $N_2K_2$ produced the highest tuber yield which was on par with $N_2$ $K_3$ and $N_3$ $K_3$ but significantly superior to all the others. The tuber yield obtained at $N_2$ $K_3$ was significantly higher than all other NK combinations at Kayamkulam.

Likewise N x S interaction was also significant for tuber yield at Vellayani and Kayamkulam. The combination $N_2$ $S_3$ produced the highest tuber yield which was significantly superior to all others. At Kayamkulam, treatment $N_2$ $S_3$ gave the highest tuber yield but it was on par with $N_2$ $S_2$ and significantly higher than all the others.

It is evident from the data that K x S interaction was also significant for tuber yield at both locations. The highest yield noticed in the combination $K_3$ $S_3$

was on par with $K_2S_3$ and $K_3S_2$ at Vellayani. The tuber yield for the combination $K_3S_3$ was significantly higher than that of all other KS bombinations at Kayamkulam.

### 4.3 Quality attributes

#### 4.3.1 Starch content

The data on starch content of tuber as affected by the various treatments during 1978 and 1979 at Vellayani and Kayamkulam are presented in Table 12.

The percentage of starch in the tuber was increased by nitrogen nutrition only upto the $N_2$ level at both locations. A significant increase in the percentage of starch was observed upto the $N_2$ level at Vellayani and Kayamkulam. Starch content registered a decrease at the $N_3$ level during both years at Vellayani and it was significant during the second year. At Kayamkulam a significant decrease in starch content was noticed at the $N_3$ level during the first year. Though the trend of variation in starch content was similar during the second year also the effect of nitrogen was not significant.

A progressive increase in starch content with incremental doses of potassium was observed during both years at Vellayani with the maximum at $K_3$. However, significant differences between all levels were noticed

Table 12. Effect of treatments on starch content and starch yield

| Treatments | Vellayani | | | | | | Kayamkulam | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Starch content (%) | | | Starch yield(t/ha) | | | Starch content (%) | | | Starch yield(t/ha) | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 28.13 | 28.16 | 28.14 | 5.77 | 5.32 | 5.54 | 28.07 | 28.18 | 28.12 | 4.00 | 4.06 | 4.03 |
| $N_2$ | 28.76 | 29.52 | 29.14 | 6.35 | 7.51 | 6.93 | 28.96 | 28.76 | 28.86 | 4.80 | 5.69 | 5.24 |
| $N_3$ | 28.37 | 28.45 | 28.41 | 5.82 | 5.99 | 5.90 | 28.30 | 28.56 | 28.43 | 3.99 | 4.75 | 4.37 |
| SE | 0.15 | 0.25 | | 0.15 | 0.21 | | 0.22 | 0.23 | | 0.17 | 0.19 | |
| CD | 0.44 | 0.74 | | 0.45 | 0.61 | | 0.65 | NS | | 0.50 | 0.57 | |
| $K_1$ | 27.59 | 28.02 | 27.80 | 5.04 | 4.52 | 4.78 | 28.02 | 27.78 | 27.90 | 3.15 | 3.97 | 3.56 |
| $K_2$ | 28.19 | 28.94 | 28.56 | 6.16 | 6.87 | 6.51 | 28.86 | 28.72 | 28.79 | 4.41 | 4.58 | 4.49 |
| $K_3$ | 29.47 | 29.17 | 29.32 | 6.74 | 7.43 | 7.08 | 28.45 | 29.00 | 28.72 | 5.22 | 5.95 | 5.58 |
| SE | 0.15 | 0.25 | | 0.15 | 0.21 | | 0.22 | 0.23 | | 0.17 | 0.19 | |
| CD | 0.44 | 0.74 | | 0.45 | 0.61 | | 0.65 | 0.67 | | 0.50 | 0.57 | |
| $S_1$ | 28.27 | 28.50 | 28.38 | 5.69 | 5.42 | 5.55 | 28.49 | 28.43 | 28.46 | 3.53 | 4.44 | 3.98 |
| $S_2$ | 28.39 | 28.62 | 28.50 | 5.85 | 6.21 | 6.03 | 28.43 | 28.22 | 28.32 | 4.29 | 5.03 | 4.66 |
| $S_3$ | 28.59 | 28.99 | 28.79 | 6.40 | 7.20 | 6.80 | 28.41 | 28.86 | 28.63 | 4.96 | 5.05 | 5.00 |
| SE | 0.15 | 0.25 | | 0.15 | 0.21 | | 0.22 | 0.23 | | 0.17 | 0.19 | |
| CD | NS | NS | | 0.45 | 0.61 | | NS | NS | | 0.50 | 0.57 | |
| A.C. | 26.91 | 27.48 | 27.19 | 2.42 | 2.66 | 2.54 | 27.51 | 27.21 | 27.36 | 1.98 | 1.71 | 1.84 |
| T. Vs A.C. | Sig** | Sig** | | Sig** | Sig** | | NS | Sig** | | Sig** | Sig** | |

A.C. - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

during the first year and between treatments $K_1$ and $K_2$ only during the second year. The highest starch content was observed at the $K_3$ level during the second year at Kayamkulam but significant difference was found only between treatments $K_1$ and $K_2$. During the first year, eventhough treatment $K_2$ gave the highest starch content it was on par with $K_3$.

The effect of time of application was not significant for this quality attribute during both years at Vellayani and Kayamkulam. However, treatment $S_3$ resulted in the highest starch content of tuber during both years at Vellayani.

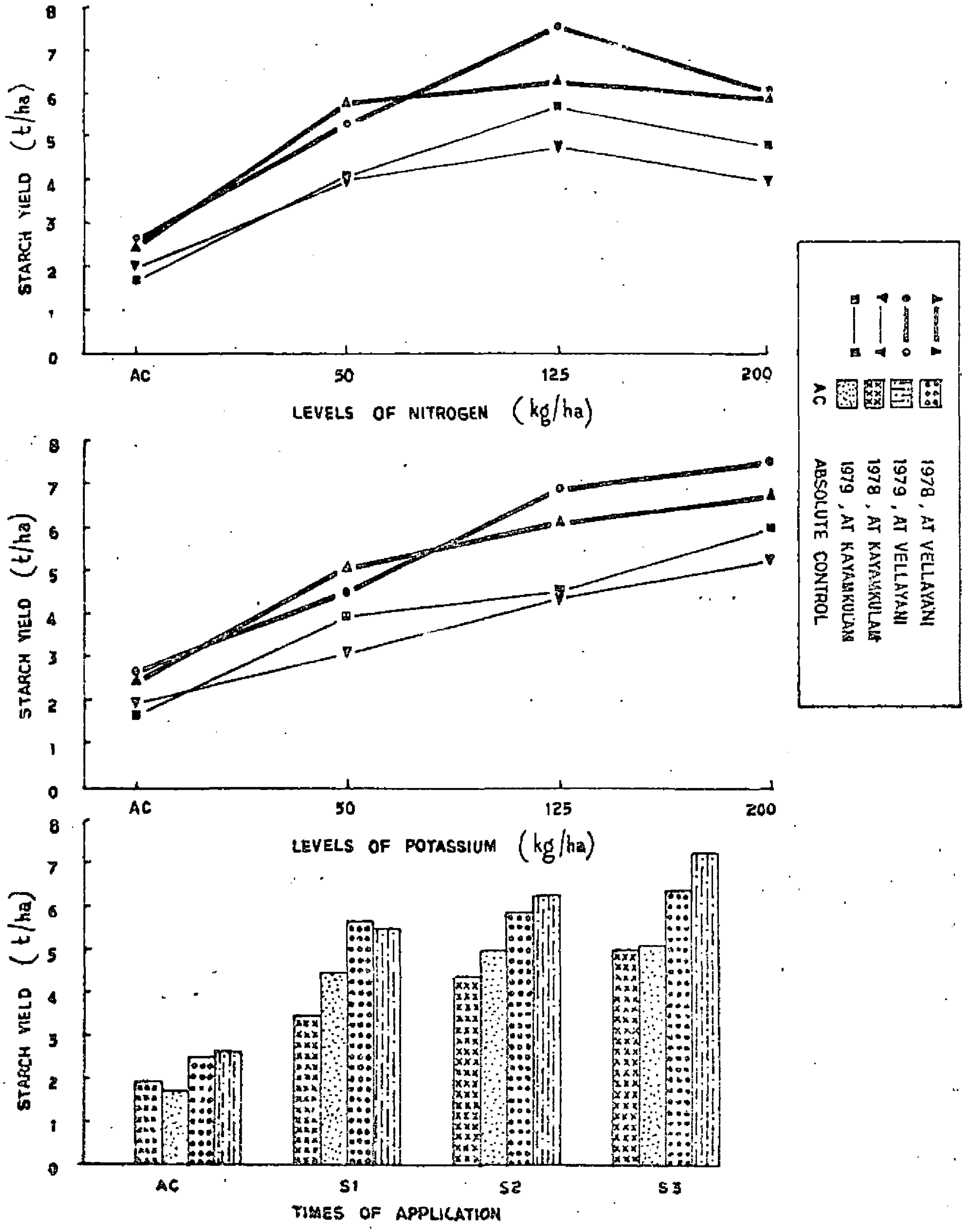
### 4.3.2 Starch yield

The data on starch yield computed during 1978 and 1979 at both locations are given in Table 12 and illustrated graphically in Fig.8.

The data at both locations reveal increases in starch yield by the application of higher levels of nitrogen. Starch yield increased significantly by the application of nitrogen at the $N_2$ level at both places in the two years. Similarly, it registered a significant decrease at the $N_3$ level at both locations.

The different rates of applied potassium also significantly influenced this quality attribute during

FIG 8. EFFECT OF TREATMENTS ON STARCH YIELD AT VELLAYANI AND KAYAMKULAM



both years at Vellayani and Kayamkulam. Significant increases in starch yield were obtained upto the highest level of potassium application ($K_3$) during the first year at Vellayani. But during the second year, eventhough the yield increase was observed upto the $K_3$ level, significant difference was noticed only upto the $K_2$ level. The starch yield increased significantly upto the highest level during both years at Kayamkulam.

The influence of time of application was also significant for starch yield at both locations. At Vellayani, treatment $S_3$ recorded the maximum starch yields during both years which was significantly superior to treatments $S_2$ and $S_1$. Starch yields were the highest at the $S_3$ level during both years at Kayamkulam. Treatment $S_3$ was significantly superior to $S_2$ and $S_1$ during the first year while in the second year it was on par with $S_2$.

### 4.3.3 HCN content

The data pertaining to the HCN content of tubers as influenced by treatments during both years at Vellayani and Kayamkulam are given in Table 13 and illustrated graphically in Fig.9.

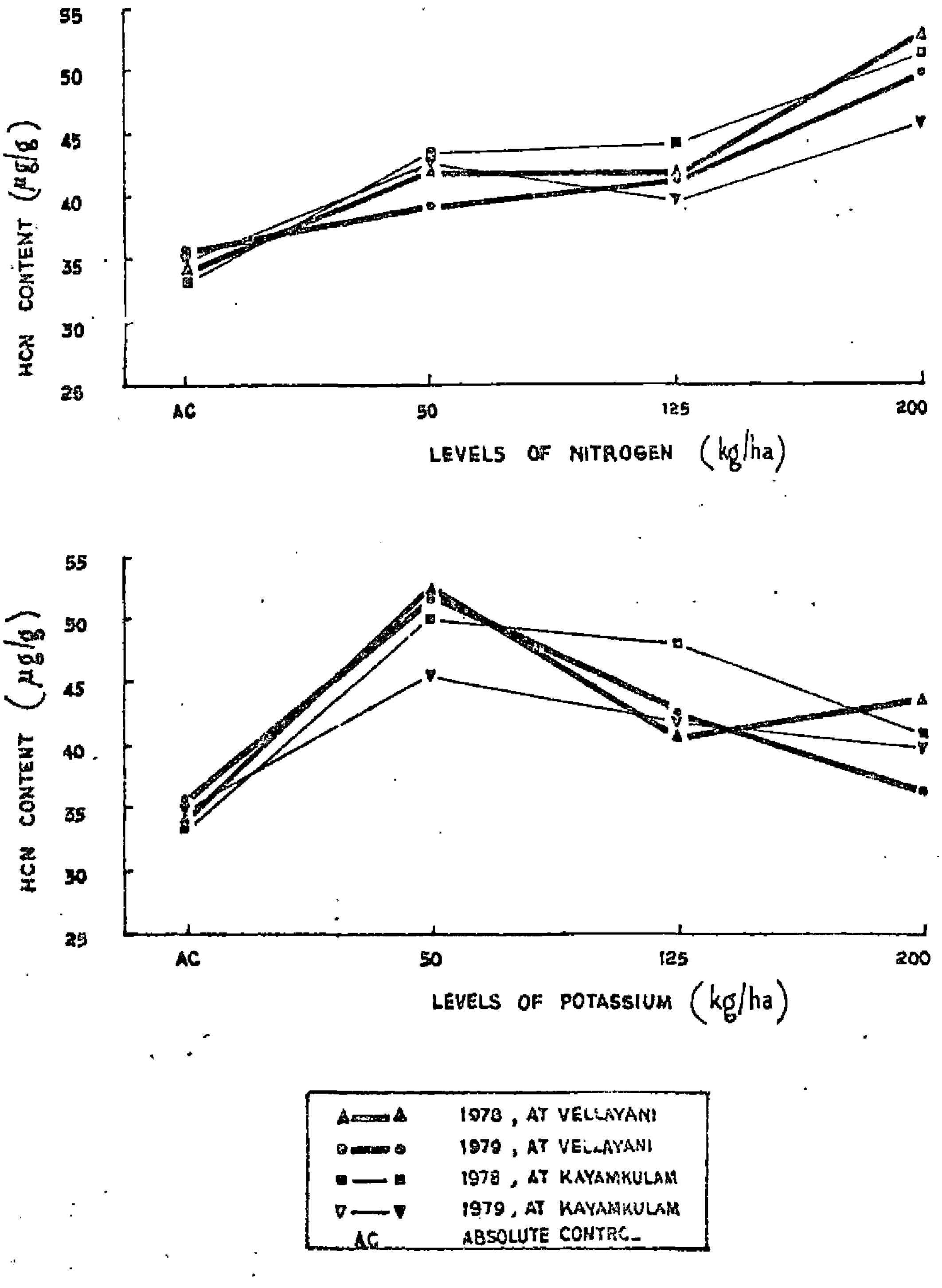
At both locations, the HCN content increased with higher levels of nitrogen application. At Vellayani, the $N_3$ level produced the highest HCN content which was

Table 13. Effect of treatments on crude protein and HCN content of tubers

| Treatments | Vellayani | | | | | | Kayamkulam | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crude protein(%) | | | HCN content (ug/g) | | | Crude protein (%) | | | HCN content (ug/g) | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 1.80 | 1.84 | 1.82 | 41.89 | 39.22 | 40.55 | 1.94 | 1.92 | 1.93 | 43.56 | 42.78 | 43.17 |
| $N_2$ | 2.02 | 2.05 | 2.03 | 41.78 | 41.67 | 41.72 | 2.08 | 2.00 | 2.04 | 44.44 | 39.50 | 41.97 |
| $N_3$ | 2.21 | 2.14 | 2.17 | 52.56 | 49.72 | 51.14 | 2.18 | 2.17 | 2.17 | 51.44 | 45.67 | 48.55 |
| SE | 0.04 | 0.03 | | 2.36 | 1.88 | | 0.03 | 0.02 | | 1.92 | 1.50 | |
| CD | 0.11 | 0.09 | | 6.85 | 5.48 | | 0.09 | 0.08 | | 5.59 | 4.36 | |
| $K_1$ | 2.07 | 2.05 | 2.06 | 52.33 | 51.67 | 52.00 | 2.10 | 2.07 | 2.08 | 50.00 | 45.44 | 47.72 |
| $K_2$ | 1.99 | 2.01 | 2.00 | 40.28 | 42.56 | 41.42 | 2.07 | 2.04 | 2.05 | 47.78 | 42.06 | 44.92 |
| $K_3$ | 1.96 | 1.97 | 1.96 | 43.61 | 36.39 | 40.00 | 2.02 | 1.99 | 2.00 | 41.67 | 41.44 | 41.05 |
| SE | 0.04 | 0.03 | | 2.36 | 1.88 | | 0.03 | 0.02 | | 1.92 | 1.50 | |
| CD | NS | NS | | 6.85 | 5.48 | | NS | NS | | 5.59 | NS | |
| $S_1$ | 1.98 | 1.98 | 1.98 | 46.94 | 43.72 | 45.33 | 2.02 | 2.01 | 2.01 | 44.89 | 42.50 | 43.69 |
| $S_2$ | 2.01 | 1.99 | 2.00 | 44.89 | 43.28 | 44.30 | 2.09 | 2.09 | 2.09 | 44.72 | 42.50 | 43.61 |
| $S_3$ | 2.03 | 2.04 | 2.03 | 44.38 | 43.61 | 43.99 | 2.09 | 2.05 | 2.07 | 49.83 | 42.94 | 46.38 |
| SE | 0.04 | 0.03 | | 2.36 | 1.88 | | 0.03 | 0.02 | | 1.92 | 1.50 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 1.54 | 1.73 | 1.63 | 34.00 | 35.67 | 34.83 | 1.79 | 1.83 | 1.81 | 33.50 | 35.00 | 34.25 |
| T Vs A.C | NS | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

FIG 9. EFFECT OF NITROGEN AND POTASSIUM ON HCN CONTENT OF TUBER AT VELLAYANI AND KAYAMKULAM



significantly higher than treatments $N_2$ and $N_1$. At Kayamkulam the HCN content was maximum at $N_3$ during the first year which was significantly higher than treatments $N_2$ and $N_1$. During the second year also the maximum HCN content was observed for treatment $N_3$.

Potassium application at higher levels led to a reduction in HCN content in the two locations. The lowest HCN content was observed at the highest level of potassium application at Vellayani and Kayamkulam. It was significatnly lesser than that obtained at the $K_1$ level during the two years at Vellayani and in the first year at Kayamkulam. The effect of potassium was not significant during the second year at Kayamkulam.

The effect of time of application on the HCN content of tuber was not significant in the two locations.

### 4.3.4 Crude protein

The data on the crude protein content of tubers during 1978 and 1979 at Vellayani and Kayamkulam are presented in Table 13.

The different levels of applied nitrogen increased the crude protein content at both locations. With increasing levels of nitrogen, crude protein increased significantly upto the highest level during the first year at Vellayani.

During the second year also it increased upto the $N_3$ level but treatment $N_2$ was on par with $N_3$. At Kayamkulam also the crude protein content increased significantly with incremental doses of nitrogen, the maximum being noticed at the $N_3$ level during both years.

Potassium did not exert any significant influence on this quality attribute at either of the locations. However, a decreasing trend in crude protein content with increasing levels of potassium application was observed at the two stations.

Crude protein content of tubers was not affected significantly by the time of application during both years at Vellayani or at Kayamkulam.

### 4.3.5 Cooking quality

The mean scores obtained in the organoleptic test are given in Table 14.

It can be seen from the data that application of potassium resulted in better cooking quality of tubers at both locations, though not significantly. But the cooking quality of tubers was reduced by higher levels of nitrogen nutrition. However, the application of potassium alongwith nitrogen reduced to some extent this bad effect of nitrogen at higher rates.

Table 14. Mean scores obtained in the organoleptic test of Tapioca tubers at Vellayani and Kayamkulam.

| Treatments | Vellayani | | | Kayamkulam | | |
|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ $K_1$ | 1.27 | 0.90 | 1.08 | 1.00 | 1.18 | 1.09 |
| $N_1K_3$ | 1.45 | 1.36 | 1.40 | 1.45 | 1.27 | 1.36 |
| $N_3$ $K_1$ | 0.90 | 0.73 | 0.81 | 0.81 | 0.72 | 0.76 |
| $N_3$ $K_3$ | 1.00 | 0.82 | 0.91 | 1.09 | 0.90 | 0.99 |
| S.E | 0.69 | 0.78 | | 0.83 | 0.79 | |
| C.D | NS | NS | | NS | NS | |

## 4.4 Growth analysis

As already mentioned earlier the investigation on this aspect was carried out only at Vellayani during the different growth stages. At Kayamkulam only the dry matter production at harvest (top and tuber) was determined during the two years.

### 4.4.1 Dry matter production and distribution

### 4.4.1.1 Leaf dry matter (Vellayani)

The data on leaf drymatter during the various growth stages in 1978 and 1979 are given in Table 15. The data reveal that the leaf drymatter increased by nitrogen nutrition though not significantly during the various growth stages. The dry matter values were higher at the $N_2$ level during the early stages of crop growth. But in the later stages treatment $N_3$ produced the maximum leaf dry matter content.

The different rates of potassium did not have any significant effect on leaf dry matter production during the various growth stages. But the leaf dry matter was a maximum at the $K_2$ level from 60 to 120 days after planting.

Similarly the leaf dry matter production was not influenced significantly by the time of application.

Table 15. Effect of treatments on the leaf drymatter production (g/plant) during various growth stages at Vellayani.

| Treat-ments | 30 days | | | 60 days | | | 90 days | | | 120 days | | | 150 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.78 | 0.88 | 0.83 | 44.90 | 64.53 | 54.71 | 62.57 | 72.32 | 67.44 | 47.18 | 56.67 | 51.92 | 41.75 | 46.77 | 44. |
| $N_2$ | 1.01 | 1.17 | 1.09 | 48.28 | 75.96 | 62.12 | 60.31 | 80.56 | 70.43 | 42.86 | 65.84 | 54.35 | 49.02 | 63.22 | 56. |
| $N_3$ | 0.95 | 1.24 | 1.09 | 44.89 | 62.38 | 53.63 | 60.54 | 63.03 | 61.78 | 48.80 | 56.20 | 52.50 | 55.64 | 57.52 | 56. |
| SE | 0.08 | 0.12 | | 6.32 | 4.55 | | 6.91 | 6.43 | | 5.09 | 8.12 | | 6.34 | 7.34 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $K_1$ | 0.62 | 1.21 | 0.91 | 43.67 | 60.81 | 52.24 | 50.38 | 66.54 | 58.46 | 37.50 | 54.16 | 45.83 | 47.12 | 46.38 | 46.7 |
| $K_2$ | 1.22 | 1.01 | 1.11 | 49.16 | 73.34 | 61.25 | 67.57 | 78.84 | 73.20 | 50.23 | 65.46 | 57.84 | 51.88 | 62.64 | 57.2 |
| $K_3$ | 0.90 | 1.07 | 0.98 | 45.24 | 68.71 | 56.97 | 65.48 | 70.52 | 68.00 | 51.10 | 59.09 | 25.09 | 47.42 | 58.49 | 52.9 |
| SE | 0.08 | 0.12 | | 6.32 | 4.55 | | 6.91 | 6.43 | | 5.09 | 8.12 | | 6.34 | 7.34 | |
| CD | 0.27 | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 1.00 | 1.10 | 1.05 | 49.94 | 78.73 | 64.33 | 70.56 | 68.36 | 69.46 | 52.04 | 53.98 | 53.01 | 51.46 | 52.07 | 51.76 |
| $S_2$ | 0.84 | 1.13 | 0.98 | 47.83 | 61.82 | 54.82 | 56.11 | 72.26 | 64.18 | 45.53 | 56.87 | 51.20 | 48.38 | 53.24 | 50.81 |
| $S_3$ | 0.90 | 1.06 | 0.98 | 40.29 | 62.31 | 51.30 | 56.74 | 75.30 | 66.00 | 41.25 | 67.86 | 54.55 | 46.57 | 62.20 | 54.38 |
| SE | 0.08 | 0.12 | | 6.32 | 4.55 | | 6.91 | 6.43 | | 5.09 | 8.12 | | 6.34 | 7.34 | |
| CD | NS | NS | | NS | 14.85 | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 0.48 | 0.60 | 0.54 | 18.53 | 40.27 | 29.40 | 27.73 | 51.57 | 39.65 | 17.63 | 33.13 | 25.38 | 18.13 | 38.00 | 28.06 |
| T Vs A.C | Sig** | Sig* | | Sig* | Sig** | | Sig* | NS | | Sig** | NS | | Sig* | NS | |

A.C - Absolute Control T - Treatment NS - Not Significant * Significant at 5% level
** Significant at 1% level.

Table 15. Continued.

| Treat-ments | 180 days | | | 210 days | | | 240 days | | | 270 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 54.98 | 67.27 | 61.12 | 54.31 | 67.00 | 60.65 | 50.61 | 50.68 | 50.64 | 25.97 | 38.66 | 32.31 | 21.36 | 34.19 | 27.77 |
| $N_2$ | 54.94 | 83.02 | 68.98 | 52.07 | 67.48 | 59.77 | 38.13 | 72.93 | 55.53 | 19.81 | 47.41 | 33.61 | 42.49 | 47.46 | 44.97 |
| $N_3$ | 67.27 | 83.42 | 75.34 | 67.04 | 79.53 | 73.28 | 57.64 | 77.67 | 67.65 | 33.73 | 45.21 | 39.47 | 45.80 | 59.57 | 52.68 |
| SE | 4.76 | 7.27 | | 6.42 | 6.38 | | 5.14 | 8.70 | | 4.86 | 4.65 | | 3.12 | 6.51 | |
| CD | NS | NS | | NS | NS | | 16.78 | NS | | NS | NS | | 10.19 | NS | |
| $K_1$ | 63.84 | 65.88 | 64.86 | 68.28 | 60.34 | 64.31 | 65.06 | 68.79 | 66.92 | 27.43 | 38.43 | 32.93 | 42.32 | 39.11 | 41.20 |
| $K_2$ | 58.43 | 86.39 | 72.41 | 55.79 | 70.78 | 63.28 | 45.03 | 56.12 | 50.57 | 31.68 | 38.66 | 35.17 | 32.15 | 46.16 | 39.15 |
| $K_3$ | 54.92 | 81.44 | 68.18 | 49.36 | 82.89 | 66.12 | 36.30 | 76.37 | 56.33 | 20.40 | 54.20 | 37.30 | 34.18 | 55.94 | 45.06 |
| SE | 4.76 | 7.27 | | 6.42 | 6.38 | | 5.14 | 8.70 | | 4.86 | 4.65 | | 3.12 | 6.51 | |
| CD | NS | NS | | NS | NS | | 16.78 | NS | | NS | NS | | NS | NS | |
| $S_1$ | 61.91 | 75.07 | 68.49 | 67.55 | 70.46 | 69.00 | 51.39 | 70.16 | 60.93 | 30.78 | 38.67 | 34.72 | 40.50 | 45.17 | 42.83 |
| $S_2$ | 57.29 | 77.18 | 67.23 | 51.78 | 66.52 | 59.15 | 52.23 | 67.54 | 59.88 | 26.87 | 48.02 | 37.44 | 31.14 | 44.44 | 37.79 |
| $S_3$ | 58.00 | 81.46 | 69.73 | 54.07 | 77.03 | 65.55 | 42.77 | 63.57 | 53.17 | 21.86 | 44.60 | 33.23 | 38.01 | 51.60 | 44.80 |
| SE | 4.76 | 7.27 | | 6.42 | 6.38 | | 5.14 | 8.70 | | 4.86 | 4.65 | | 3.12 | 6.51 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 24.67 | 50.13 | 37.40 | 27.53 | 35.23 | 31.38 | 27.90 | 27.10 | 27.50 | 8.30 | 22.93 | 15.61 | 10.60 | 22.83 | 16.71 |
| T Vs A.C | Sig** | NS | | Sig* | Sig** | | Sig* | Sig* | | Sig* | Sig* | | Sig** | NS | |

A.C - Absolute Control T - Treatment NS - Not significant Sig* Significant at 5% level
** Significant at 1% level.

The leaf dry matter increased considerably after 30 days and attained high values at 90 days. The leaf dry matter tended to decline considerably after 180 days.

### 4.4.1.2 Stem dry matter (Vellayani)

The data on stem dry matter contents at the different growth stages during the two years are given in Table 16.

The influence of nitrogen and stem dry matter was not significant at the various growth stages. Treatment $N_2$ showed the highest stem dry matter content during the period 90 to 180 days. But in the later stages of growth treatment $N_3$ produced the highest stem dry matter contents.

The effect of potassium on stem dry matter production was not significant during the different stages of growth. From 180 days onwards treatment $K_2$ resulted in higher stem dry matter content as compared to treatments$K_1$ and $K_3$.

The influence of time of application was not significant during both the years.

### 4.4.1.3 Root dry matter (Vellayani)

The data on root dry matter at the different growth stages during 1978 and 1979 are presented in Table 17.

Table 16. Effect of treatments on the stem dry matter production (g/plant) during various growth stages of Vellayani.

| Treatments | 30 days | | | 60 days | | | 90 days | | | 120 days | | | 150 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.64 | 0.65 | 0.64 | 21.79 | 14.38 | 18.08 | 44.98 | 47.74 | 46.36 | 59.12 | 62.72 | 60.92 | 98.42 | 90.98 | 94.70 |
| $N_2$ | 0.69 | 0.76 | 0.72 | 20.27 | 23.20 | 21.73 | 55.07 | 64.04 | 59.55 | 64.42 | 76.34 | 70.38 | 107.89 | 108.87 | 108.38 |
| $N_3$ | 0.81 | 0.72 | 0.77 | 25.96 | 18.93 | 22.44 | 44.70 | 46.94 | 45.82 | 59.24 | 57.64 | 58.44 | 90 .61 | 86.09 | 88.35 |
| SE | 0.05 | 0.05 | | 2.03 | 1.34 | | 6.37 | 7.65 | | 5.34 | 6.90 | | 9.07 | 12.91 | |
| CD | NS | NS | | NS | 4.38 | | NS | NS | | NS | NS | | NS | NS | |
| $K_1$ | 0.51 | 0.69 | 0.60 | 15.97 | 13.44 | 14.70 | 35.27 | 48.59 | 41.93 | 54.80 | 49.38 | 52.09 | 86.85 | 76.89 | 81.87 |
| $K_2$ | 0.82 | 0.69 | 0.75 | 21.84 | 23.01 | 22.42 | 57.88 | 54.61 | 56.24 | 69.02 | 70.74 | 69.88 | 104.08 | 100.37 | 102.22 |
| $K_3$ | 0.82 | 0.75 | 0.78 | 30.21 | 20.06 | 25.13 | 51.60 | 55.53 | 53.56 | 58.96 | 76.59 | 67.77 | 105.99 | 108.68 | 107.33 |
| SE | 0.05 | 0.05 | | 2.03 | 1.34 | | 6.37 | 7.65 | | 5.34 | 6.90 | | 9.07 | 12.91 | |
| CD | 0.17 | NS | | 6.62 | 4.38 | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 0.74 | 0.76 | 0.75 | 21.76 | 22.42 | 22.09 | 44.68 | 53.86 | 49.27 | 60.84 | 63.50 | 62.17 | 96.00 | 86.34 | 91.17 |
| $S_2$ | 0.71 | 0.67 | 0.73 | 21.19 | 16.46 | 21.80 | 44.47 | 52.63 | 49.16 | 60.74 | 60.52 | 60.63 | 96.91 | 94.51 | 95.71 |
| $S_3$ | 0.70 | 0.69 | 0.69 | 25.06 | 17.63 | 21.34 | 55.58 | 52.24 | 54.10 | 61.20 | 72.69 | 66.94 | 104.01 | 105.08 | 104.54 |
| SE | 0.05 | 0.05 | | 2.03 | 1.34 | | 6.37 | 7.65 | | 5.34 | 6.90 | | 9.07 | 12.91 | |
| CD | NS | NS | | NS | 4.38 | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 0.38 | 0.52 | 0.45 | 11.80 | 12.27 | 12.03 | 27.70 | 22.20 | 24.95 | 36.53 | 31.50 | 34.01 | 52.53 | 64.37 | 58.45 |
| T Vs A.C. | Sig** | NS | | Sig** | Sig* | | NS | Sig* | | Sig* | Sig* | | Sig* | NS | |

A.C - Absolute Control  T - Treatment  NS - Not significant  * Significant at 5% level
** Significant at 1% level.

Table 16. Continued.

| Treatments | 180 days | | | 210 days | | | 240 days | | | 270 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 108.48 | 100.16 | 104.32 | 144.50 | 135.20 | 139.85 | 196.78 | 198.09 | 197.43 | 191.90 | 187.04 | 189.47 | 191.52 | 262.34 | 226.93 |
| $N_2$ | 123.20 | 106.33 | 114.76 | 241.89 | 157.68 | 149.78 | 214.52 | 235.91 | 225.21 | 211.97 | 285.70 | 248.83 | 249.65 | 330.86 | 290.25 |
| $N_3$ | 113.50 | 95.00 | 104.25 | 157.27 | 169.62 | 163.44 | 194.29 | 254.33 | 224.31 | 204.14 | 352.07 | 278.10 | 237.26 | 422.18 | 329.72 |
| SE | 8.22 | 15.35 | | 9.01 | 31.90 | | 9.09 | 41.16 | | 8.57 | 26.22 | | 13.26 | 26.04 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | 85.50 | | 43.24 | 84.94 | |
| $K_1$ | 103.83 | 84.30 | 94.06 | 134.94 | 122.07 | 128.50 | 183.30 | 181.21 | 182.25 | 185.91 | 203.73 | 194.82 | 201.74 | 286.02 | 243.88 |
| $K_2$ | 122.93 | 110.38 | 116.65 | 158.10 | 189.23 | 173.66 | 221.18 | 247.93 | 234.55 | 206.61 | 328.28 | 267.44 | 230.10 | 370.46 | 305.28 |
| $K_3$ | 118.41 | 106.81 | 112.61 | 150.62 | 151.20 | 150.91 | 201.11 | 259.19 | 230.15 | 215.49 | 292.80 | 254.14 | 244.60 | 348.90 | 297.75 |
| SE | 8.22 | 15.35 | | 9.01 | 31.90 | | 9.09 | 41.16 | | 8.57 | 26.22 | | 13.26 | 26.04 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | 85.50 | | NS | NS | |
| $S_1$ | 103.41 | 83.42 | 93.41 | 138.91 | 152.63 | 145.77 | 202.88 | 225.34 | 214.11 | 188.57 | 262.11 | 225.34 | 221.27 | 316.86 | 269.06 |
| $S_2$ | 123.17 | 97.10 | 110.13 | 258.07 | 140.11 | 149.09 | 207.27 | 205.57 | 204.92 | 197.13 | 250.68 | 223.90 | 218.64 | 360.78 | 289.71 |
| $S_3$ | 118.60 | 120.97 | 119.78 | 146.68 | 169.76 | 158.22 | 198.44 | 257.42 | 227.93 | 222.31 | 312.02 | 267.16 | 238.53 | 337.74 | 288.13 |
| SE | 8.22 | 15.35 | | 9.01 | 31.90 | | 9.09 | 41.16 | | 8.57 | 26.22 | | 13.26 | 26.04 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 66.10 | 78.73 | 72.41 | 79.56 | 201.63 | 140.59 | 92.73 | 246.90 | 169.81 | 107.86 | 174.87 | 141.35 | 130.66 | 200.67 | 165.66 |
| T Vs A.C | Sig** | NS | | Sig** | NS | | Sig** | NS | | Sig** | NS | | Sig** | Sig* | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

Table 17. Effect of treatments on root dry matter production (g/plant) during various growth stages at Vellayani

| Treat-ments | 30 days | | | 60 days | | | 90 days | | | 120 days | | | 150 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.18 | 0.49 | 0.33 | 8.26 | 10.33 | 9.29 | 78.48 | 69.52 | 74.00 | 157.70 | 172.53 | 165.11 | 223.11 | 262.04 | 242.57 |
| $N_2$ | 0.21 | 0.58 | 0.39 | 14.63 | 15.52 | 15.07 | 87.63 | 96.52 | 92.07 | 161.45 | 213.78 | 187.61 | 223.07 | 333.64 | 278.35 |
| $N_3$ | 0.39 | 0.60 | 0.49 | 9.67 | 21.08 | 15.37 | 75.71 | 91.71 | 83.71 | 148.00 | 160.57 | 154.28 | 202.16 | 252.63 | 227.39 |
| SE | 0.01 | 0.04 | | 1.01 | 1.65 | | 9.74 | 10.82 | | 14.32 | 18.63 | | 22.47 | 25.04 | |
| CD | 0.06 | NS | | 3.30 | 5.39 | | NS | NS | | NS | NS | | NS | NS | |
| $K_1$ | 0.13 | 0.44 | 0.28 | 9.64 | 9.83 | 9.73 | 58.50 | 45.33 | 51.91 | 124.62 | 133.90 | 129.26 | 189.28 | 210.70 | 199.99 |
| $K_2$ | 0.26 | 0.53 | 0.39 | 12.54 | 15.69 | 14.12 | 92.62 | 104.83 | 98.72 | 171.76 | 200.94 | 186.35 | 231.24 | 311.84 | 271.54 |
| $K_3$ | 0.38 | 0.71 | 0.54 | 10.37 | 21.41 | 15.89 | 90.71 | 107.59 | 99.15 | 170.78 | 212.03 | 191.40 | 227.82 | 325.78 | 276.80 |
| SE | 0.01 | 0.04 | | 1.01 | 1.65 | | 9.74 | 10.82 | | 14.32 | 18.63 | | 22.47 | 25.04 | |
| CD | 0.06 | 0.16 | | NS | 5.39 | | NS | 35.29 | | NS | 60.78 | | NS | 81.65 | |
| $S_1$ | 0.28 | 0.49 | 0.38 | 11.14 | 19.84 | 15.49 | 82.02 | 86.38 | 84.20 | 158.94 | 164.83 | 161.88 | 214.31 | 251.58 | 232.94 |
| $S_2$ | 0.25 | 0.61 | 0.43 | 10.56 | 12.97 | 11.76 | 72.89 | 76.17 | 74.53 | 142.45 | 169.79 | 156.12 | 210.97 | 267.13 | 239.05 |
| $S_3$ | 0.24 | 0.57 | 0.43 | 10.84 | 14.12 | 12.48 | 86.92 | 95.20 | 91.06 | 165.76 | 212.26 | 189.01 | 223.05 | 329.61 | 276.33 |
| SE | 0.01 | 0.04 | | 1.01 | 1.65 | | 9.74 | 10.82 | | 14.32 | 18.63 | | 22.47 | 25.04 | |
| CD | NS | NS | | NS | 5.39 | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 0.11 | 0.29 | 0.20 | 3.70 | 6.70 | 5.20 | 27.43 | 53.13 | 40.23 | 46.30 | 84.27 | 65.28 | 55.63 | 100.27 | 77.95 |
| T Vs. A.C. | Sig** | Sig** | | Sig** | Sig** | | Sig** | NS | | Sig** | Sig* | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

Table 17. Continued

| Treatments | 180 days | | | 210 days | | | 240 days | | | 270 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 302.93 | 334.08 | 318.50 | 398.35 | 439.94 | 419.14 | 486.67 | 526.60 | 506.63 | 534.33 | 587.13 | 560.73 | 679.12 | 652.52 | 665.82 |
| $N_2$ | 291.36 | 420.41 | 355.88 | 422.22 | 550.88 | 486.55 | 516.40 | 664.13 | 590.26 | 554.70 | 747.34 | 651.02 | 701.64 | 856.46 | 779.05 |
| $N_3$ | 280.60 | 338.03 | 299.31 | 405.04 | 429.67 | 417.35 | 540.36 | 520.28 | 530.32 | 578.63 | 577.71 | 578.17 | 671.28 | 704.42 | 687.85 |
| SE | 29.27 | 26.65 | | 31.58 | 21.78 | | 25.97 | 24.61 | | 26.87 | 29.95 | | 32.12 | 20.95 | |
| CD | NS | NS | | NS | 71.09 | | NS | 80.26 | | NS | 97.69 | | NS | 68.33 | |
| $K_1$ | 246.71 | 274.74 | 260.72 | 339.83 | 352.91 | 346.37 | 429.05 | 414.34 | 421.69 | 465.13 | 458.46 | 461.79 | 580.19 | 522.34 | 551.26 |
| $K_2$ | 315.60 | 388.30 | 351.95 | 436.87 | 520.23 | 478.55 | 536.98 | 638.40 | 587.69 | 578.17 | 671.11 | 624.64 | 698.58 | 777.78 | 738.18 |
| $K_3$ | 312.57 | 409.48 | 361.02 | 448.92 | 547.34 | 498.13 | 577.37 | 658.27 | 617.82 | 624.36 | 782.62 | 703.49 | 773.26 | 913.27 | 843.26 |
| SE | 29.27 | 26.65 | | 31.58 | 21.78 | | 25.97 | 24.61 | | 26.87 | 29.95 | | 32.12 | 20.95 | |
| CD | NS | 86.91 | | NS | 71.09 | | 84.69 | 80.26 | | 87.63 | 97.69 | | 104.77 | 68.33 | |
| $S_1$ | 294.64 | 318.79 | 306.71 | 397.02 | 419.30 | 408.16 | 508.18 | 490.80 | 499.49 | 552.84 | 553.19 | 553.01 | 647.43 | 666.90 | 657.16 |
| $S_2$ | 289.60 | 343.68 | 316.64 | 413.70 | 477.60 | 445.65 | 496.91 | 572.39 | 534.65 | 533.28 | 647.54 | 590.41 | 672.93 | 734.57 | 703.75 |
| $S_3$ | 290.64 | 400.06 | 350.35 | 414.90 | 523.59 | 469.24 | 538.32 | 647.82 | 593.07 | 581.54 | 711.46 | 646.50 | 731.68 | 811.93 | 771.80 |
| SE | 29.27 | 26.65 | | 31.58 | 21.78 | | 25.97 | 24.61 | | 26.87 | 29.95 | | 32.12 | 20.95 | |
| CD | NS | NS | | NS | 71.09 | | NS | 80.26 | | NS | 97.69 | | NS | 68.33 | |
| A.C | 93.87 | 136.23 | 115.05 | 148.33 | 123.43 | 135.88 | 207.96 | 143.10 | 175.53 | 247.40 | 236.56 | 241.98 | 289.87 | 340.20 | 315.03 |
| T Vs A.C | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

The data reveal the significant influence of nitrogen in root dry matter only during the later stages of crop growth during the second year. The highest root dry matter was observed in treatment $N_2$ at all stages of growth and it was significant in the later stages during the second year. The root dry matter content showed a decreasing trend at $N_3$.

The effect of potassium was significant at all growth stages during the second year and from 240 days onwards during the first year. The root dry matter was the highest in treatment $K_3$.

Time of application did not show significant influence on root dry matter during the first year. But during the second year it exhibited significant difference from 210 days onwards. However, during both years treatment $S_3$ gave the highest root dry matter yield.

Root dry matter increased considerably from 90 days after planting. It had almost doubled at the stage of 240 days as compared to that at 150 days.

### 4.4.1.4 Tuber dry matter (Kayamkulam)

The data pertaining to the tuber dry matter production at harvest during the two years are presented in Table 18.

Table 18. Effect of treatments on the dry matter production at harvest in Kayamkulam

| Treatments | Tuber dry matter (t/ha) | | | Top dry matter (t/ha) | | |
|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 5.59 | 5.61 | 5.60 | 5.63 | 5.47 | 5.55 |
| $N_2$ | 6.61 | 7.81 | 7.21 | 5.87 | 8.20 | 7.03 |
| $N_3$ | 5.67 | 6.69 | 6.18 | 6.96 | 8.73 | 7.84 |
| SE | 0.22 | 0.28 | | 0.23 | 0.28 | |
| CD | 0.66 | 0.81 | | 0.66 | 0.85 | |
| $K_1$ | 4.34 | 5.45 | 4.89 | 6.25 | 7.68 | 6.96 |
| $K_2$ | 6.11 | 6.38 | 6.24 | 5.93 | 7.46 | 6.69 |
| $K_3$ | 7.43 | 8.27 | 7.85 | 6.25 | 7.27 | 6.76 |
| SE | 0.22 | 0.28 | | 0.23 | 0.28 | |
| CD | 0.66 | 0.81 | | NS | NS | |
| $S_1$ | 4.95 | 6.13 | 5.54 | 5.61 | 7.24 | 6.42 |
| $S_2$ | 6.02 | 7.11 | 6.56 | 6.31 | 7.84 | 7.07 |
| $S_3$ | 6.91 | 6.87 | 6.89 | 6.54 | 7.32 | 6.93 |
| SE | 0.22 | 0.28 | | 0.23 | 0.28 | |
| CD | 0.66 | NS | | 0.66 | NS | |
| A.C. | 2.86 | 2.43 | 2.64 | 3.05 | 3.37 | 3.21 |
| T Vs A.C. | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

Tuber dry matter increased significantly by nitrogen nutrition during the two years. By raising the level of nitrogen from treatment $N_1$ to $N_2$ tuber dry matter registered a significant increase. But it got reduced significantly at the $N_3$ level during 1978 as well as in 1979.

Potassium significantly increased the tuber dry matter upto the highest level during both years. Treatment $K_3$ resulted in the maximum value.

As regards the time of application, significant difference was obtained during the first year only, with the highest tuber dry matter noticed for treatment $S_3$. But during the second year the effect was not significant.

### 4.4.1.5 Top dry matter (Kayamkulam)

The data on top dry matter at harvest during 1978 and 1979 are presented in Table 18.

Top dry matter increased with incremental doses of nitrogen the maximum being obtained at the $N_3$ level during both years. During the first year the dry matter in treatment $N_3$ was significantly higher than $N_2$ and $N_1$ while in the second year treatments $N_2$ and $N_3$ were on par.

The different levels of potassium did not produce any significant difference in top dry matter during either of the years.

The effect of time of application was significant in this respect only during the first year. The highest top dry matter observed in treatment $S_3$ was on par with that of $S_2$ and significantly higher than in $S_1$.

### 4.4.2 Tuber bulking rate

The data on tuber bulking rate at various growth phases during 1978 and 1979 at Vellayani are given in Table 19.

The data show the significant influence of nitrogen on tuber bulking at various growth phases. Nitrogen nutrition increased tuber bulking rate upto the $N_2$ level. Treatment $N_2$ showed the maximum tuber bulking rates at all phases. By a further increase in the rate of nitrogen application bulking rate decreased. It showed only a slight increase in the second phase at the lowest level of nitrogen application ($N_1$) and declined thereafter. But at the higher levels it exhibited marked increase in the second phase and then declined in the third phase.

The effect of potassium was also significant in this aspect during the different phases. The tuber bulking rate increased with increases in the rate of potassium and the maximum value was observed at the highest level ($K_3$). A progressive decrease in tuber bulking rate from the first to third phase was observed at the lowest

Table 19. Effect of treatments on tuber bulking rate (g/day/plant) during various growth stages at Vellayani

| Treat-ments | Ist Phase (90-150 days) | | | IInd Phase (150-210 days) | | | IIIrd Phase (210-270 days) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 2.29 | 3.20 | 2.74 | 2.91 | 2.96 | 2.94 | 2.26 | 2.45 | 2.35 |
| $N_2$ | 2.26 | 4.05 | 3.15 | 3.31 | 4.06 | 3.69 | 2.20 | 3.27 | 2.73 |
| $N_3$ | 2.10 | 2.67 | 2.38 | 3.37 | 2.94 | 3.16 | 2.89 | 2.46 | 2.67 |
| SE | 0.24 | 0.28 | | 0.23 | 0.23 | | 0.20 | 0.26 | |
| CD | NS | 0.93 | | NS | 0.78 | | NS | NS | |
| $K_1$ | 2.17 | 2.86 | 2.51 | 2.50 | 2.36 | 2.43 | 2.08 | 1.75 | 1.91 |
| $K_2$ | 2.19 | 3.44 | 2.81 | 3.42 | 3.91 | 3.67 | 2.35 | 2.51 | 2.43 |
| $K_3$ | 2.28 | 3.63 | 2.95 | 3.69 | 3.68 | 3.68 | 2.92 | 3.91 | 3.41 |
| SE | 0.24 | 0.28 | | 0.23 | 0.23 | | 0.20 | 0.26 | |
| CD | NS | NS | | 0.76 | 0.78 | | NS | 0.85 | |
| $S_1$ | 2.09 | 2.95 | 2.52 | 3.04 | 2.79 | 2.91 | 2.59 | 2.22 | 2.41 |
| $S_2$ | 2.29 | 3.17 | 2.73 | 3.37 | 3.94 | 3.66 | 1.98 | 2.82 | 2.40 |
| $S_3$ | 2.27 | 3.85 | 3.06 | 3.19 | 3.23 | 3.21 | 2.77 | 3.05 | 2.91 |
| SE | 0.24 | 0.28 | | 0.23 | 0.23 | | 0.20 | 0.26 | |
| CD | NS | NS | | NS | 0.78 | | NS | NS | |
| A.C. | 0.47 | 0.78 | 0.63 | 1.54 | 0.38 | 0.96 | 1.64 | 1.88 | 1.76 |
| T. Vs. A.C. | Sig** | Sig** | | Sig** | Sig** | | NS | NS | |

A.C. - Absolute control T - Treatment NS - Not significant ** Significant at 1% level.

level of potassium nutrition ($K_1$). But at the $K_2$ level the rate increased considerably in the second phase and then showed a decrease at the third phase. But at the highest level ($K_3$) the increase observed at the second phase was not as much as that at $K_2$.

Time of application showed significant influence only in the second growth phase. Treatment $S_3$ resulted in the highest values of tuber bulking rates in the first and third phases. However, the bulking rates in all treatments were higher in the first and second phases and the lowest in the third phase.

### 4.4.3 Net assimilation rate (NAR)

The mean values of NAR obtained during the two years at Vellayani during the various growth phases are presented in Table 20.

The net assimilation rate did not differ significantly between nitrogen levels. The values were the highest at the $N_2$ level during the active tuberization phases (first, second and third phases). Treatment $N_3$ resulted in the lowest values of NAR. At the later stages of tuber development (sixth phase) also treatment $N_2$ produced the highest NAR value.

Potassium also did not influence the assimilation rate at any of the growth stages. But the NAR values tended to increase with increasing levels of potassium application

Table 20. Effect of treatments on Net assimilation rate (mg/dm$^2$/day) during various growth stages at Vellayani

| Treaments | Ist phase (60 - 90 days) | | | IInd phase (90 - 120 days) | | | IIIrd phase (120 - 150 days) | | | IVthe phase (150 - 180 days) | | | Vth phase (180 - 210 days) | | | VIth phase (210-240 days) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 33.20 | 30.60 | 31.40 | 18.00 | 22.60 | 20.30 | 19.20 | 19.20 | 19.20 | 19.60 | 19.10 | 19.35 | 28.80 | 30.50 | 29.65 | 32.70 | 29.90 | 31.30 |
| $N_2$ | 34.10 | 39.50 | 36.80 | 13.80 | 26.10 | 19.95 | 20.10 | 27.50 | 23.80 | 16.70 | 18.60 | 17.65 | 29.30 | 35.60 | 32.45 | 35.90 | 43.80 | 39.85 |
| $N_3$ | 28.90 | 29.60 | 29.25 | 15.40 | 16.00 | 15.70 | 16.50 | 21.30 | 18.90 | 21.30 | 17.80 | 19.55 | 34.20 | 40.30 | 37.25 | 36.70 | 40.80 | 38.75 |
| SE | 4.07 | 5.15 | | 1.84 | 3.33 | | 2.22 | 3.09 | | 2.16 | 2.00 | | 1.78 | 4.82 | | 3.33 | 3.67 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $K_1$ | 22.10 | 23.40 | 22.75 | 16.00 | 16.70 | 16.35 | 20.00 | 16.80 | 18.40 | 17.50 | 15.80 | 16.65 | 27.40 | 23.80 | 25.60 | 31.20 | 29.30 | 30.25 |
| $K_2$ | 38.60 | 39.10 | 38.85 | 15.60 | 22.80 | 19.20 | 16.90 | 25.70 | 21.30 | 20.30 | 20.80 | 20.55 | 31.20 | 42.30 | 36.75 | 35.50 | 36.20 | 35.85 |
| $K_3$ | 35.50 | 37.20 | 36.35 | 15.50 | 25.30 | 20.40 | 18.90 | 25.50 | 22.20 | 19.80 | 18.80 | 19.30 | 33.70 | 40.30 | 37.00 | 38.60 | 49.10 | 43.85 |
| SE | 4.07 | 5.15 | | 1.84 | 3.33 | | 2.22 | 3.09 | | 2.16 | 2.00 | | 1.78 | 4.82 | | 3.33 | 3.67 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| $S_1$ | 32.60 | 26.20 | 29.40 | 15.60 | 16.10 | 15.85 | 19.30 | 19.40 | 19.35 | 18.80 | 15.70 | 17.25 | 29.60 | 35.30 | 32.45 | 36.20 | 32.40 | 34.30 |
| $S_2$ | 28.00 | 34.20 | 31.10 | 16.40 | 19.50 | 17.95 | 19.00 | 22.60 | 20.80 | 21.30 | 19.10 | 20.20 | 31.70 | 36.60 | 34.15 | 30.40 | 37.20 | 33.80 |
| $S_3$ | 35.60 | 39.30 | 37.45 | 15.20 | 29.30 | 22.25 | 17.50 | 26.10 | 21.80 | 17.50 | 20.80 | 19.15 | 31.00 | 34.60 | 32.80 | 38.70 | 45.00 | 41.85 |
| SE | 4.07 | 5.15 | | 1.84 | 3.33 | | 2.22 | 3.09 | | 2.16 | 2.00 | | 1.78 | 4.82 | | 3.33 | 3.67 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 16.80 | 21.80 | 19.30 | 4.60 | 5.50 | 5.05 | 5.60 | 10.50 | 8.05 | 12.70 | 12.50 | 12.60 | 17.30 | 22.90 | 20.10 | 23.20 | 14.40 | 18.80 |
| T Vs A.C | NS | NS | | Sig** | Sig* | | Sig* | NS | | NS | NS | | Sig** | NS | | NS | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level ** Significant at 1% level.

upto the $K_3$ level, though the effect was not significant.

The effect of time of application was not significant in this aspect during the two years.

### 4.4.4 Crop growth rate (CGR)

Mean values of CGR recorded during various growth phases at Vellayani during the two years are shown in Table 21.

The effect of nitrogen on CGR was not significant at any of the growth phases. Treatment $N_2$ showed the highest values of CGR at the active tuberization stage and at the later stages of tuber development (sixth phase).

The levels of potassium have not significantly influenced CGR during both years. However, CGR values were higher at the $K_2$ level as compared to the other levels in the different stages of tuber development. Eventhough the values at $K_2$ and $K_3$ were almost equal at all phases, treatment $K_1$ was markedly inferior to the former two.

CGR values at the different phases were not significantly influenced by the time of application. But treatment $S_3$ gave higher values of CGR at the early as well as the later stages of tuber development.

Table 21. Effect of treatments on crop growth rate (g/m$^2$/day) during various growth stages at Vellayani

| Treatments | Ist phase (60-90 days) | | | IInd phase (90-120 days) | | | IIIrd phase (120-150 days) | | | IVth phase (150-180 days) | | | Vth phase (180-210 days) | | | VIth phase (210-240 days) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 4.56 | 4.12 | 4.34 | 3.20 | 4.20 | 3.70 | 4.08 | 4.43 | 4.25 | 4.23 | 4.17 | 4.20 | 5.37 | 5.77 | 5.57 | 5.62 | 5.47 | 5.54 |
| $N_2$ | 4.92 | 5.03 | 4.97 | 2.70 | 4.72 | 3.71 | 4.57 | 6.15 | 5.36 | 3.67 | 4.27 | 3.97 | 6.02 | 6.83 | 6.42 | 6.28 | 8.09 | 7.18 |
| $N_3$ | 4.12 | 4.08 | 4.10 | 3.08 | 2.98 | 3.03 | 3.79 | 5.00 | 4.39 | 4.63 | 4.11 | 4.37 | 6.90 | 7.49 | 7.19 | 6.69 | 7.12 | 6.90 |
| SE | 0.60 | 0.70 | | 0.39 | 0.56 | | 0.70 | 0.65 | | 0.48 | 0.40 | | 0.40 | 0.94 | | 0.57 | 0.62 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | 2.02 | |
| $K_1$ | 3.07 | 3.13 | 3.10 | 2.99 | 3.16 | 3.07 | 4.37 | 3.96 | 4.16 | 3.74 | 3.73 | 3.73 | 5.28 | 4.53 | 4.90 | 5.52 | 5.30 | 5.41 |
| $K_2$ | 5.52 | 5.02 | 5.27 | 2.99 | 4.05 | 3.52 | 3.95 | 5.65 | 4.80 | 4.50 | 4.52 | 4.51 | 6.32 | 8.02 | 7.17 | 6.26 | 6.66 | 6.46 |
| $K_3$ | 5.01 | 5.07 | 5.04 | 3.00 | 4.68 | 3.84 | 4.12 | 5.96 | 5.04 | 4.30 | 4.30 | 4.30 | 6.70 | 7.55 | 7.12 | 6.81 | 8.73 | 7.77 |
| SE | 0.60 | 0.70 | | 0.39 | 0.56 | | 0.70 | 0.65 | | 0.48 | 0.40 | | 0.40 | 0.94 | | 0.57 | 0.62 | |
| CD | 1.95 | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | 2.02 | |
| $S_1$ | 4.70 | 3.43 | 4.06 | 3.06 | 3.02 | 3.04 | 3.69 | 4.42 | 4.05 | 4.03 | 3.58 | 3.80 | 5.89 | 6.76 | 6.32 | 6.53 | 5.91 | 6.22 |
| $S_2$ | 3.85 | 4.51 | 4.18 | 3.09 | 3.53 | 3.31 | 4.41 | 5.24 | 4.82 | 4.67 | 4.23 | 4.45 | 6.30 | 6.83 | 6.56 | 5.33 | 6.62 | 5.97 |
| $S_3$ | 5.05 | 5.28 | 5.16 | 2.83 | 5.34 | 4.08 | 4.33 | 5.92 | 5.12 | 3.84 | 4.74 | 4.29 | 6.10 | 6.49 | 6.29 | 6.73 | 8.15 | 7.44 |
| SE | 0.60 | 0.70 | | 0.39 | 0.56 | | 0.70 | 0.65 | | 0.48 | 0.40 | | 0.40 | 0.94 | | 0.57 | 0.62 | |
| CD | NS | NS | | NS | 1.85 | | NS | NS | | NS | NS | | NS | NS | | NS | 2.02 | |
| A.C | 1.90 | 2.50 | 2.20 | 0.72 | 0.90 | 0.81 | 1.06 | 2.20 | 1.63 | 2.39 | 2.56 | 2.47 | 2.90 | 3.91 | 3.40 | 3.00 | 2.33 | 2.66 |
| T Vs A.C | Sig* | NS | | Sig* | Sig* | | Sig* | Sig* | | NS | NS | | Sig** | NS | | Sig* | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level

** Significant at 1% level.

## 4.5 Nutrient uptake

### 4.5.1 Nitrogen (Vellayani)

The data on the plant uptake of nitrogen at the various growth stages during 1978 and 1979 are given in Table 22.

The data clearly show the significant effect of nitrogen in respect of the uptake of this nutrient at various stages during the two years. Plant uptake of nitrogen increased with increases in nitrogen application upto the highest level. It was on par with $N_2$ and significantly higher than $N_1$ at the various growth stages.

The plant uptake of nitrogen was not influenced significantly at different growth stages by the levels of potassium. However, an increasing trend in the uptake of nitrogen at higher levels of potassium application was observed upto the $K_2$ level in the early stages and at harvest. A reduction in the uptake of nitrogen was noticed at the $K_3$ level.

Nitrogen uptake was not influenced significantly by the different times of fertilizer application. However, the uptake of nitrogen in treatment $S_2$ and $S_3$ were higher than in treatment $S_1$ during the later stages of growth.

Plant uptake of nitrogen increased progressively upto 240 days and decreased thereafter.

Table 22. Effect of treatments on the plant uptake of nitrogen (kg/ha) during various growth stages at Vellayani

| Treatments | 30 days | | | 60 days | | | 90 days | | | 120 days | | | 150 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.14 | 0.15 | 0.14 | 18.93 | 23.78 | 21.35 | 34.40 | 28.40 | 31.40 | 41.60 | 43.25 | 42.42 | 49.94 | 61.66 | 55.80 |
| $N_2$ | 0.21 | 0.24 | 0.22 | 24.92 | 25.97 | 25.44 | 49.05 | 39.71 | 44.38 | 67.20 | 54.23 | 60.71 | 88.42 | 95.68 | 92.05 |
| $N_3$ | 0.26 | 0.29 | 0.27 | 25.25 | 30.40 | 27.82 | 43.86 | 46.33 | 45.09 | 59.04 | 69.37 | 64.20 | 75.07 | 104.83 | 89.95 |
| SE | 0.02 | 0.03 | | 1.94 | 2.10 | | 3.01 | 1.73 | | 5.38 | 2.66 | | 6.78 | 2.84 | |
| CD | 0.07 | 0.10 | | NS | NS | | 9.82 | 5.67 | | 17.55 | 8.67 | | 22.10 | 9.26 | |
| $K_1$ | 0.24 | 0.24 | 0.24 | 20.61 | 25.87 | 23.24 | 37.30 | 36.24 | 36.77 | 48.70 | 55.16 | 51.93 | 59.87 | 86.12 | 72.99 |
| $K_2$ | 0.19 | 0.23 | 0.21 | 26.33 | 29.83 | 28.08 | 47.46 | 44.30 | 45.88 | 60.19 | 57.22 | 58.70 | 78.06 | 91.75 | 84.90 |
| $K_3$ | 0.18 | 0.22 | 0.20 | 22.16 | 24.44 | 23.30 | 42.55 | 33.92 | 38.23 | 58.93 | 54.47 | 56.70 | 75.49 | 84.30 | 79.89 |
| SE | 0.02 | 0.03 | | 1.94 | 2.10 | | 3.01 | 1.73 | | 5.38 | 2.66 | | 6.78 | 2.84 | |
| CD | NS | NS | | NS | NS | | 9.82 | 5.67 | | NS | NS | | NS | NS | |
| $S_1$ | 0.19 | 0.20 | 0.19 | 25.87 | 32.52 | 29.19 | 41.60 | 44.17 | 42.88 | 52.28 | 55.89 | 54.08 | 65.28 | 85.78 | 75.53 |
| $S_2$ | 0.22 | 0.27 | 0.24 | 20.44 | 24.71 | 22.57 | 41.54 | 36.51 | 39.02 | 53.60 | 52.27 | 52.93 | 69.68 | 85.94 | 77.81 |
| $S_3$ | 0.20 | 0.21 | 0.20 | 22.79 | 22.92 | 22.85 | 44.18 | 33.78 | 38.98 | 61.95 | 58.68 | 60.31 | 78.47 | 90.44 | 84.45 |
| SE | 0.02 | 0.03 | | 1.94 | 2.10 | | 3.01 | 1.73 | | 5.38 | 2.66 | | 6.78 | 2.84 | |
| CD | NS | NS | | NS | 6.87 | | NS | 5.67 | | NS | NS | | NS | NS | |
| A.C. | 0.08 | 0.05 | 0.06 | 6.68 | 11.68 | 9.18 | 18.19 | 19.09 | 18.64 | 18.27 | 19.20 | 18.73 | 23.37 | 27.64 | 25.50 |
| T Vs A.C. | Sig* | Sig* | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant * Significant at 5% level
** Significant at 1% level.

Table 22. Continued

| Treatments | 180 days | | | 210 days | | | 240 days | | | 270 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 58.29 | 73.65 | 65.97 | 61.20 | 75.99 | 68.59 | 58.47 | 80.76 | 69.61 | 54.11 | 77.82 | 65.96 | 53.52 | 68.98 | 61.23 |
| $N_2$ | 95.94 | 106.02 | 100.98 | 95.55 | 103.46 | 99.50 | 102.74 | 114.27 | 108.50 | 84.95 | 108.05 | 96.50 | 81.35 | 86.27 | 83.81 |
| $N_3$ | 88.25 | 110.28 | 99.26 | 97.33 | 112.64 | 104.98 | 109.12 | 121.62 | 115.37 | 94.98 | 110.25 | 102.61 | 86.36 | 100.45 | 93.40 |
| SE | 6.07 | 6.00 | | 5.75 | 5.45 | | 7.47 | 6.36 | | 4.18 | 5.11 | | 3.34 | 4.67 | |
| CD | 19.80 | 19.56 | | 18.75 | 17.77 | | 24.38 | 20.76 | | 13.63 | 16.68 | | 10.89 | 15.24 | |
| $K_1$ | 68.12 | 93.35 | 80.73 | 70.99 | 92.97 | 81.98 | 79.23 | 104.05 | 91.64 | 62.90 | 95.15 | 79.02 | 62.03 | 78.77 | 70.40 |
| $K_2$ | 89.55 | 99.31 | 94.43 | 93.90 | 96.84 | 95.37 | 92.04 | 106.34 | 99.19 | 83.30 | 102.42 | 92.86 | 79.40 | 93.23 | 86.31 |
| $K_3$ | 84.82 | 97.31 | 91.06 | 89.18 | 102.28 | 95.73 | 99.06 | 106.25 | 102.65 | 87.85 | 98.54 | 93.19 | 79.80 | 83.67 | 81.73 |
| SE | 6.07 | 6.00 | | 5.75 | 5.45 | | 7.47 | 6.36 | | 4.18 | 5.11 | | 3.34 | 4.67 | |
| CD | 19.80 | NS | | 18.75 | NS | | NS | NS | | 13.63 | NS | | 10.89 | NS | |
| $S_1$ | 72.75 | 90.92 | 81.83 | 80.20 | 93.91 | 87.05 | 86.78 | 100.60 | 93.69 | 71.66 | 94.86 | 83.31 | 67.77 | 81.44 | 74.60 |
| $S_2$ | 79.30 | 96.22 | 87.76 | 81.82 | 94.08 | 87.95 | 86.89 | 102.44 | 94.66 | 76.58 | 95.42 | 86.00 | 75.11 | 84.32 | 79.71 |
| $S_3$ | 90.44 | 102.83 | 96.63 | 92.07 | 104.10 | 98.08 | 96.65 | 113.59 | 105.12 | 85.32 | 105.82 | 95.57 | 78.35 | 89.91 | 84.13 |
| SE | 6.07 | 6.00 | | 5.75 | 5.45 | | 7.47 | 6.36 | | 4.18 | 5.11 | | 3.34 | 4.67 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 26.75 | 24.69 | 25.72 | 25.10 | 37.22 | 31.16 | 27.28 | 58.64 | 42.96 | 22.63 | 60.02 | 41.32 | 24.65 | 45.18 | 34.91 |
| T Vs A.C. | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not Significant ** Significant at 1% level.

### 4.5.2 Potassium (Vellayani)

The data on the plant uptake of potassium at different growth stages in 1978 and 1979 are presented in Table 23.

The data reveal the significant influence of nitrogen nutrition on the uptake of potassium during the different growth stages. The uptake of potassium increased upto the $N_2$ level beyond which it tended to decrease.

Different levels of potassium influenced the plant uptake of this element significantly, the highest level recording the maximum uptake during both years.

Time of application was not significant in this aspect during both years. But treatment $S_3$ resulted in the higher values of potassium uptake as compared to treatment $S_2$ and $S_1$.

A progressive increase was noticed in the uptake of potassium upto 240 days followed by a decrease thereafter.

### 4.5.3 Nitrogen (Kayamkulam)

The data on the uptake of nitrogen at harvest during the two years are given in Table 24.

Plant uptake of nitrogen increased significantly with the higher rates of application of this element and the maximum was observed at the $N_3$ level.

Table 23. Effect of treatments on the plant uptake of potassium (kg/ha) during various growth stages at Vellayani.

| Treat-ments | 30 days | | | 60 days | | | 90 days | | | 120 days | | | 150 days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 0.26 | 0.22 | 0.24 | 20.44 | 27.57 | 24.01 | 36.49 | 47.14 | 41.81 | 45.10 | 58.00 | 51.05 | 58.35 | 75.63 | 66.99 |
| $N_2$ | 0.25 | 0.25 | 0.25 | 35.68 | 40.16 | 37.92 | 53.07 | 67.22 | 60.14 | 67.26 | 81.67 | 74.46 | 85.39 | 116.11 | 100.75 |
| $N_3$ | 0.32 | 0.28 | 0.30 | 30.62 | 37.05 | 33.83 | 50.00 | 63.05 | 56.52 | 66.13 | 73.36 | 69.74 | 86.45 | 109.88 | 98.16 |
| SE | 0.01 | 0.01 | | 1.52 | 2.06 | | 3.64 | 4.84 | | 3.62 | 7.12 | | 5.07 | 8.98 | |
| CD | 0.05 | NS | | 4.97 | 6.75 | | 11.90 | 15.80 | | 11.83 | NS | | 16.54 | 29.29 | |
| $K_1$ | 0.25 | 0.26 | 0.25 | 22.74 | 29.61 | 26.17 | 32.28 | 46.21 | 39.24 | 41.82 | 52.48 | 47.15 | 57.23 | 73.47 | 65.35 |
| $K_2$ | 0.29 | 0.23 | 0.26 | 30.19 | 37.08 | 33.63 | 51.33 | 65.63 | 58.48 | 63.06 | 76.55 | 69.80 | 81.14 | 109.42 | 95.28 |
| $K_3$ | 0.30 | 0.26 | 0.28 | 33.80 | 38.09 | 35.94 | 55.96 | 65.58 | 60.77 | 73.60 | 83.00 | 78.30 | 91.81 | 118.74 | 105.27 |
| SE | 0.01 | 0.01 | | 1.52 | 2.06 | | 3.64 | 4.84 | | 3.62 | 7.12 | | 5.07 | 8.98 | |
| CD | NS | NS | | 4.97 | 6.75 | | 11.90 | 15.80 | | 11.83 | 23.21 | | 16.54 | 29.29 | |
| $S_1$ | 0.30 | 0.26 | 0.29 | 31.31 | 41.05 | 36.18 | 45.23 | 57.94 | 51.58 | 57.50 | 64.81 | 61.15 | 74.26 | 90.02 | 82.14 |
| $S_2$ | 0.27 | 0.25 | 0.25 | 27.66 | 31.57 | 29.61 | 43.98 | 57.87 | 50.92 | 55.22 | 67.03 | 61.12 | 71.93 | 98.71 | 85.32 |
| $S_3$ | 0.25 | 0.24 | 0.24 | 27.76 | 32.15 | 29.95 | 50.35 | 61.61 | 55.98 | 65.77 | 80.19 | 72.98 | 83.99 | 112.89 | 98.44 |
| SE | 0.01 | 0.01 | | 1.52 | 2.06 | | 3.64 | 4.84 | | 3.62 | 7.12 | | 5.07 | 8.98 | |
| CD | 0.05 | NS | | NS | 6.75 | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 0.08 | 0.11 | 0.09 | 12.21 | 14.89 | 13.55 | 21.89 | 23.78 | 22.83 | 21.52 | 22.43 | 21.97 | 24.53 | 29.21 | 26.87 |
| T Vs A.C. | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control  T - Treatment  NS - Not significant  Sig** Significant at 1% level.

Table 23. Continued.

| Treatments | 180 days | | | 210 days | | | 240 days | | | 270 days | | | At harvest | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 70.88 | 84.54 | 77.71 | 86.43 | 100.24 | 93.33 | 89.79 | 114.84 | 102.31 | 76.58 | 104.02 | 90.30 | 75.38 | 102.49 | 88.93 |
| $N_2$ | 100.21 | 121.72 | 110.96 | 122.87 | 137.12 | 129.99 | 120.26 | 150.80 | 135.53 | 114.58 | 148.27 | 131.42 | 107.16 | 137.40 | 122.28 |
| $N_3$ | 105.14 | 117.02 | 111.08 | 122.35 | 130.31 | 126.33 | 120.67 | 144.15 | 132.41 | 109.68 | 142.81 | 126.24 | 107.28 | 136.60 | 120.44 |
| SE | 4.94 | 8.53 | | 4.32 | 7.18 | | 4.82 | 6.80 | | 6.52 | 4.89 | | 6.36 | 4.30 | |
| CD | 16.12 | 27.82 | | 14.09 | 23.41 | | 15.73 | 22.19 | | 21.27 | 15.94 | | 20.74 | 14.04 | |
| $K_1$ | 70.47 | 82.48 | 76.47 | 90.57 | 93.86 | 92.21 | 92.21 | 110.78 | 101.49 | 91.43 | 103.58 | 97.50 | 83.76 | 100.69 | 92.22 |
| $K_2$ | 98.21 | 115.82 | 107.01 | 115.90 | 132.81 | 124.35 | 113.20 | 142.93 | 128.06 | 96.72 | 135.76 | 116.24 | 95.13 | 127.68 | 111.40 |
| $K_3$ | 107.55 | 124.99 | 116.27 | 125.17 | 141.00 | 133.08 | 125.32 | 156.08 | 140.70 | 112.68 | 155.75 | 134.21 | 107.94 | 148.12 | 128.03 |
| SE | 4.94 | 8.53 | | 4.32 | 7.18 | | 4.82 | 6.80 | | 6.52 | 4.89 | | 6.36 | 4.30 | |
| CD | 16.12 | 27.82 | | 14.09 | 23.41 | | 15.73 | 22.19 | | NS | 15.94 | | 20.74 | 14.04 | |
| $S_1$ | 87.78 | 95.78 | 91.78 | 104.72 | 112.40 | 108.56 | 106.06 | 128.57 | 117.31 | 97.85 | 122.30 | 110.07 | 95.55 | 118.64 | 107.09 |
| $S_2$ | 88.82 | 107.76 | 98.29 | 107.37 | 123.08 | 115.25 | 108.97 | 135.45 | 122.21 | 100.86 | 132.10 | 116.48 | 94.49 | 123.82 | 109.15 |
| $S_3$ | 99.62 | 119.74 | 109.68 | 118.56 | 132.19 | 125.37 | 115.69 | 145.78 | 130.73 | 102.14 | 137.69 | 121.41 | 96.78 | 132.03 | 115.40 |
| SE | 4.94 | 8.53 | | 4.32 | 7.18 | | 4.82 | 6.80 | | 6.52 | 4.89 | | 6.36 | 4.30 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C. | 34.70 | 30.57 | 32.63 | 46.10 | 40.53 | 43.31 | 47.71 | 45.50 | 46.60 | 48.02 | 40.58 | 44.30 | 40.78 | 37.48 | 39.13 |
| T Vs A.C | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute control  T - Treatment  NS - Not significant  ** Significant at 1% level.

The levels of potassium also influenced the nitrogen uptake significantly during the second year. A significant increase was noticed only upto the $K_2$ level, $K_2$ and $K_3$ being on par. The trend was similar during the first year also though the differences were not significant.

The effect of the time of application was significant only during the first year. Treatment $S_3$ was significantly superior to $S_2$ but on par with $S_1$.

### 4.5.4 Potassium (Kayamkulam)

The data on the uptake of potassium at harvest during 1978 and 1979 are presented in Table 24.

The data reveal the significant influence of nitrogen nutrition in ehhancing the uptake of potassium during the second year. Increase in the uptake of potassium was observed only upto the $N_2$ level beyond which it decreased.

Plant uptake of potassium was significantly increased by the application of higher doses of this element upto the highest level ($K_3$).

Time of application did not show any significant influence on the uptake of potassium during the two years.

## 4.6 Soil nutrients

The mean data on the available nitrogen and potassium contents of the soil after each crop at Vellayani and Kayamkulam during the two years are given in Table 25.

Table 24. Effect of treatments on the plant uptake (at harvest) of nitrogen and potassium (kg/ha) at Kayamkulam.

| Treatments | Nitrogen | | | Potassium | | |
|---|---|---|---|---|---|---|
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 45.95 | 58.77 | 52.36 | 93.62 | 91.21 | 92.91 |
| $N_2$ | 65.16 | 84.10 | 74.63 | 96.79 | 105.28 | 101.03 |
| $N_3$ | 91.37 | 108.01 | 99.69 | 101.01 | 102.41 | 102.21 |
| SE | 1.62 | 1.85 | | 2.60 | 2.41 | |
| CD | 4.71 | 5.38 | | NS | 7.00 | |
| $K_1$ | 64.58 | 77,92 | 71.25 | 68.72 | 70.66 | 69.69 |
| $K_2$ | 68.21 | 84.70 | 76.45 | 106.94 | 110.27 | 108.60 |
| $K_3$ | 69.01 | 88.25 | 78.63 | 116.75 | 117.96 | 117.35 |
| SE | 1.62 | 1.85 | | 2.60 | 2.41 | |
| CD | NS | 5.38 | | 7.56 | 7.00 | |
| $S_1$ | 69.69 | 80.86 | 75.27 | 95.65 | 99.44 | 97.54 |
| $S_2$ | 64.00 | 84.40 | 74.20 | 95.88 | 100.09 | 97.98 |
| $S_3$ | 68.80 | 85.62 | 77.21 | 100.88 | 99.37 | 100.12 |
| SE | 1.62 | 1.85 | | 2.60 | 2.41 | |
| CD | 4.71 | NS | | NS | NS | |
| A.C | 15.48 | 17.21 | 16.34 | 26.44 | 37.78 | 32.11 |
| T Vs A.C. | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

Table 25. Effect of treatments on the available nitrogen and potassium contents (kg/ha) of soil after each crop.

| Treatments | Available nitrogen | | | | | | Available potassium | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Vellayani | | | Kayamkulam | | | Vellayani | | | Kayamkulam | | |
| | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean | 1978 | 1979 | Mean |
| $N_1$ | 206.24 | 204.46 | 205.35 | 117.42 | 118.67 | 118.04 | 55.43 | 59.00 | 57.21 | 35.04 | 41.83 | 38.43 |
| $N_2$ | 210.84 | 218.94 | 214.89 | 128.87 | 126.18 | 127.52 | 58.99 | 56.79 | 57.89 | 38.51 | 41.82 | 40.16 |
| $N_3$ | 270.74 | 246.13 | 258.43 | 145.18 | 147.79 | 146.48 | 56.24 | 57.44 | 56.84 | 39.00 | 42.55 | 40.77 |
| SE | 6.14 | 5.09 | | 2.44 | 2.53 | | 3.48 | 3.26 | | 1.43 | 1.77 | |
| CD | 17.84 | 14.78 | | 7.10 | 7.34 | | NS | NS | | NS | NS | |
| $K_1$ | 220.18 | 226.52 | 223.35 | 132.64 | 135.18 | 133.91 | 49.63 | 52.17 | 50.90 | 23.07 | 26.49 | 24.78 |
| $K_2$ | 227.19 | 206.93 | 217.06 | 131.71 | 133.44 | 132.57 | 54.08 | 49.95 | 52.01 | 34.84 | 39.41 | 37.12 |
| $K_3$ | 240.45 | 236.08 | 238.26 | 127.13 | 124.02 | 125.57 | 66.95 | 71.11 | 69.03 | 54.63 | 60.29 | 57.46 |
| SE | 6.14 | 5.09 | | 2.44 | 2.53 | | 3.48 | 3.26 | | 1.43 | 1.77 | |
| CD | 17.84 | 14.78 | | NS | 7.34 | | 10.11 | 9.48 | | 4.16 | 5.15 | |
| $S_1$ | 231.95 | 225.57 | 228.76 | 129.63 | 129.90 | 129.76 | 59.40 | 56.68 | 58.04 | 37.04 | 41.93 | 39.48 |
| $S_2$ | 230.00 | 221.95 | 225.97 | 131.88 | 132.27 | 132.07 | 58.69 | 58.13 | 58.41 | 39.56 | 44.20 | 41.88 |
| $S_3$ | 225.87 | 222.00 | 223.93 | 129.96 | 130.46 | 130.21 | 52.57 | 58.43 | 55.50 | 35.95 | 40.07 | 38.01 |
| SE | 6.14 | 5.09 | | 2.44 | 2.53 | | 3.48 | 3.26 | | 1.43 | 1.77 | |
| CD | NS | NS | | NS | NS | | NS | NS | | NS | NS | |
| A.C | 142.98 | 174.81 | 158.89 | 107.51 | 108.68 | 108.09 | 33.02 | 32.67 | 32.84 | 22.89 | 19.16 | 21.02 |
| T Vs A.C | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | | Sig** | Sig** | |

A.C - Absolute Control T - Treatment NS - Not significant ** Significant at 1% level.

| | Before first crop | | Before second crop | |
|---|---|---|---|---|
| | Vellayani | Kayamkulam | Vellayani | Kayamkulam |
| 1. Available soil nitrogen (kg/ha) | 260.20 | 135.27 | 220.40 | 146.28 |
| 2. Available soil potassium | 66.70 | 41 .40 | 58.25 | 46.55 |

### 4.6.1 Available nitrogen

It is seen from the data that with enhancement in the rate of nitrogen application the available nitrogen content of the soil increased significantly both at Vellayani and Kayamkulam. The highest value observed in treatment $N_3$ was significantly higher than those at $N_2$ and $N_1$

The effect of potassium levels in increasing the available nitrogen content of soil was significant during both years at Vellayani. The highest available nitrogen content of soil obtained at the $K_3$ level was significantly higher than in treatments $K_2$ during the second year. But the maximum obtained at $K_3$ was on par with $K_2$ in the first year. Significant influence of potassium on this soil character was observed only during the second year at Kayamkulam wherein a decreasing trend in available soil nitrogen content with increasing dose of potassium was observed. The trend was similar in the first year also though the differences were not significant.

Available nitrogen content of soil was not affected by the time of application at the two locations.

### 4.6.2 Available potassium

The available potassium content of soil did not show any difference between nitrogen levels at the two locations.

But the effect of potassium application was significant in this soil character at Vellayani and Kayamkulam. Significant increases in the available potassium content of soil with incremental doses of potassium application were observed at both locations, the highest value being noticed in treatment $K_3$.

The influence of time of application was not significant in this regard in the two locations.

## 4.7 Correlation studies

### 4.7.1 Correlation between yield components and yield

Simple correlations were worked out between yield components like number of tubers, mean tuber weight, length of tuber, girth of tuber and utilization index with yield for 1978 and 1979 at Vellayani and Kayamkulam. The correlation matrices are presented in Tables 26 a and 26 b.

It could be seen from the data that the characters such as number of tubers, mean tuber weight and girth of tuber were positively correlated with yield during the two years at Vellayani. Utilization index was also positively correlated with yield at Vellayani during 1979. At Kayamkulam, significant positive correlation between yield and yield components such as tuber number, mean tuber weight and utilization index was noticed during the two years. Girth of tuber also showed significant positive correlation with

Table 26 a. Correlation matrix - Simple correlation among tuber yield and yield components (Vellayani)

1978

| | Tuber yield | Number of tubers | Tuber weight | Length of tuber | Girth of tuber | Utilization index |
|---|---|---|---|---|---|---|
| Tuber yield | 1 | 0.5450* | 0.5884* | 0.1400 | 0.4669* | 0.0936 |
| Number of tubers | - | 1 | -0.1004 | 0.3623* | 0.3442* | 0.0270 |
| Tuber weight | - | - | 1 | -0.1263 | 0.4269* | 0.1038 |
| Length of tuber | - | - | - | 1 | 0.2707* | -0.0110 |
| Girth of tuber | - | - | - | - | 1 | 0.1294 |
| Utilization index | - | - | - | - | - | 1 |
| 1979 | | | | | | |
| Tuber yield | 1 | 0.7258* | 0.7563* | 0.1146 | 0.2837* | 0.3393* |
| Number of tubers | - | 1 | 0.5444* | 0.1174 | 0.2250 | 0.3624* |
| Tuber weight | - | - | 1 | 0.0106 | 0.2745* | 0.1826 |
| Length of tuber | - | - | - | 1 | 0.1024 | 0.0885 |
| Girth of tuber | - | - | - | - | 1 | 0.0909 |
| Utilization index | - | - | - | - | - | 1 |

* Significant at 5% level.

Table 26 b. Correlation matrix - simple correlation among tuber yield and yield components (Kayamkulam)

| | Tuber yield | Number of tubers | Tuber weight | Length of tuber | Girth of tuber | Utilization index |
|---|---|---|---|---|---|---|
| | | | 1978 | | | |
| Tuber yield | 1 | 0.5606* | 0.7792* | -0.0904 | 0.0988 | 0.5063* |
| Number of tubers | | 1 | 0.4858* | -0.0059 | 0.2179 | 0.2054 |
| Tuber weight | | | 1 | -0.0106 | -0.0456 | 0.5218* |
| Length of tuber | | | | 1 | -0.0771 | 0.0103 |
| Girth of tuber | | | | | 1 | -0.1179 |
| Utilization index | | | | | | 1 |
| | | | 1979 | | | |
| Tuber yield | 1 | 0.7250* | 0.7137* | 0.0969 | 0.3753* | 0.4721* |
| Number of tubers | | 1 | 0.4985* | 0.1274 | 0.3565* | 0.3225* |
| Tuber weight | | | 1 | 0.0089 | 0.2449 | 0.3512* |
| Length of tuber | | | | 1 | 0.0235 | 0.0899 |
| Girth of tuber | | | | | 1 | 0.0112 |
| Utilization index | | | | | | 1 |

* Significant at 5% level.

yield at this location during the second year.

### 4.7.2 Correlation between the uptake of nitrogen and potassium and yield

Simple correlations were worked out between the plant uptake (at harvest) of nitrogen and potassium and the tuber yield at the two locations. The results are presented in Table 27.

The data show significant positive correlation between yield and uptake of nitrogen and potassium at both locations.

### 4.8 Path coefficient analysis of yield components on yield

The path coefficient analysis of the data was carried out by taking the yield as the main dependent character (effect) and the data on yield components such as number of tubers, mean tuber weight, length of tuber, girth of tuber and utilization index as independent characters (causes). The values of the direct and indirect effects on yield and the correlation of various causes among themselves and with yield are presented in Tables 28 a and 28 b. The graph showing the cause and effect relationship taking the five yield components as causes and tuber yield as the effect is illustrated in Fig. 10 and 11.

The direct effect of a particular yield component (cause) with other causes must add upto the correlation of that character with the yield.

Table 27. Correlation matrix - simple correlation among uptake of nitrogen and potassium and tuber yield at Vellayani and Kayamkulam

| | Vellayani | | Kayamkulam | |
|---|---|---|---|---|
| | (Tuber yield) | | (Tuber yield) | |
| | 1978 | 1979 | 1978 | 1979 |
| N | 0.723* | 0.588* | 0.291* | 0.640* |
| K | 0.682* | 0.818* | 0.540* | 0.606* |

* Significant at 5% level

Table 28 a. Direct effects, indirect effects and correlation co-efficients of yield components on yield at Vellayani

- 1978 -

| | Number of tubers (X1) | Weight of tuber (X2) | Length of tuber (X3) | Girth of tuber (X4) | Utilization index (X5) | Correlation with yield -(Y) |
|---|---|---|---|---|---|---|
| $X_1$ | 0.6202 | -0.0668 | 0.0032 | -0.0119 | 0.0003 | 0.5450* |
| $X_2$ | -0.0623 | 0.6653 | -0.0011 | -0.0147 | 0.0013 | 0.5884* |
| $X_3$ | 0.2247 | -0.0840 | 0.0088 | -0.0093 | -0.0001 | 0.1400 |
| $X_4$ | 0.2134 | 0.2840 | 0.0024 | -0.0345 | 0.0016 | 0.4669* |
| $X_5$ | 0.0167 | 0.0691 | -0.0001 | -0.0045 | 0.0124 | 0.0936 |

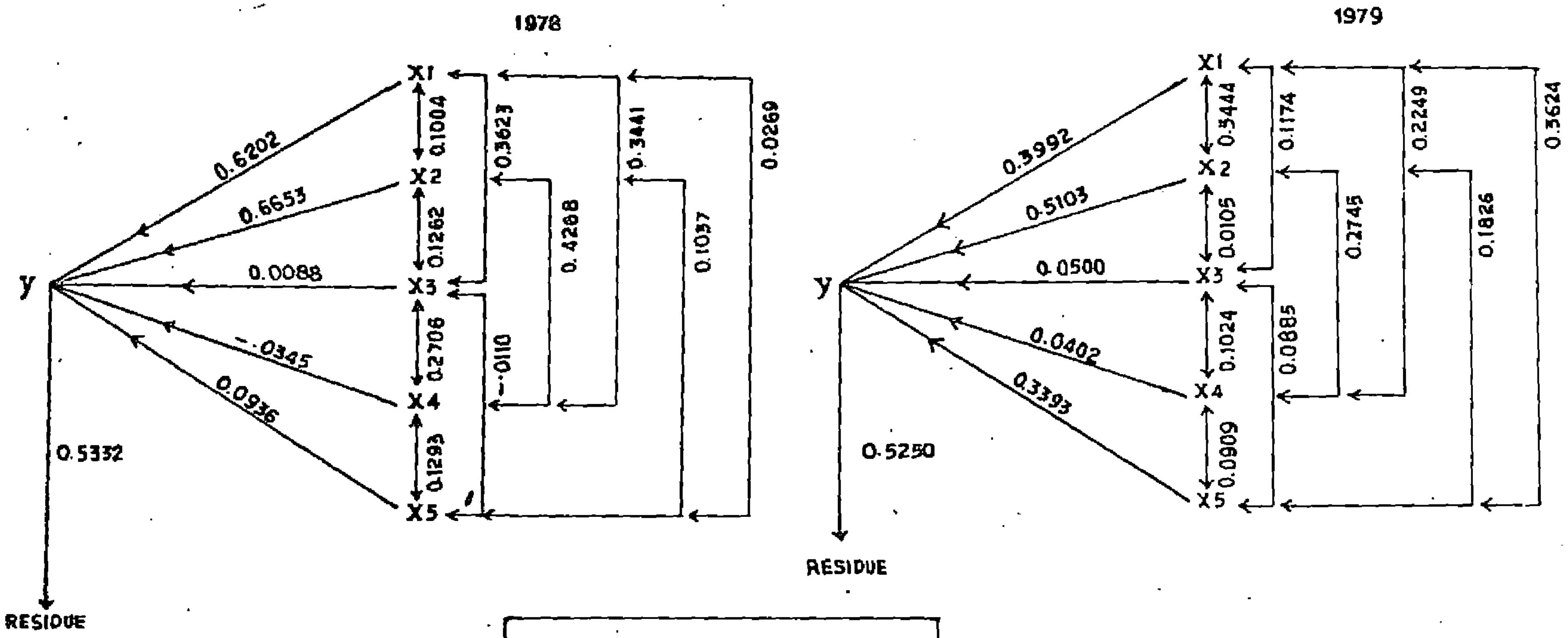
- 1979 -

| | Number of tubers (X1) | Weight of tuber (X2) | Length of tuber (X3) | Girth of tuber (X4) | Utilization index (X5) | Correlation with yield -(Y) |
|---|---|---|---|---|---|---|
| $X_1$ | 0.3992 | 0.2778 | 0.0059 | 0.0090 | 0.0338 | 0.7258* |
| $X_2$ | 0.2173 | 0.5103 | 0.0005 | 0.0110 | 0.0171 | 0.7563* |
| $X_3$ | 0.0469 | 0.0054 | 0.0500 | 0.0041 | 0.0083 | 0.1146 |
| $X_4$ | 0.0898 | 0.1401 | 0.0051 | 0.0402 | 0.0085 | 0.2837* |
| $X_5$ | 0.1447 | 0.0932 | 0.0044 | 0.0037 | 0.0934 | 0.3393* |

Critical value of correlation co-efficient at 5 per cent level = 0.2523

Note: The diagonal values show the direct effect and the off diagonal values indicate the indirect effect.

FIG 10. PATH COEFFICIENT ANALYSIS OF YIELD COMPONENTS ON YIELD AT VELLAYANI



y . YIELD
X 1 . NUMBER OF TUBERS
X 2 . MEAN TUBER WEIGHT
X 3 LENGTH OF TUBER
X 4 GIRTH OF TUBER
X 5 UTILISATION INDEX

Table 28 b. Direct effects, indirect effects and correlation co-efficients of yield components on yield at Kayamkulam

- 1978 -

| | Number of tubers (X1) | Weight of tuber (X2) | Length of tuber (X3) | Girth of tuber (X4) | Utilization index (X5) | Correlation with yield (Y) |
|---|---|---|---|---|---|---|
| $X_1$ | 0.2199 | 0.2864 | 0.0005 | 0.0199 | 0.0339 | 0.5606* |
| $X_2$ | 0.1068 | 0.5895 | 0.0008 | -0.0042 | 0.0862 | 0.7792* |
| $X_3$ | -0.0013 | -0.0063 | -0.0775 | -0.0070 | 0.0017 | -0.0904 |
| $X_4$ | 0.0479 | -0.0269 | 0.0060 | 0.0913 | -0.0195 | 0.0988 |
| $X_5$ | 0.0452 | 0.3076 | -0.0008 | -0.0108 | 0.1651 | 0.5064* |

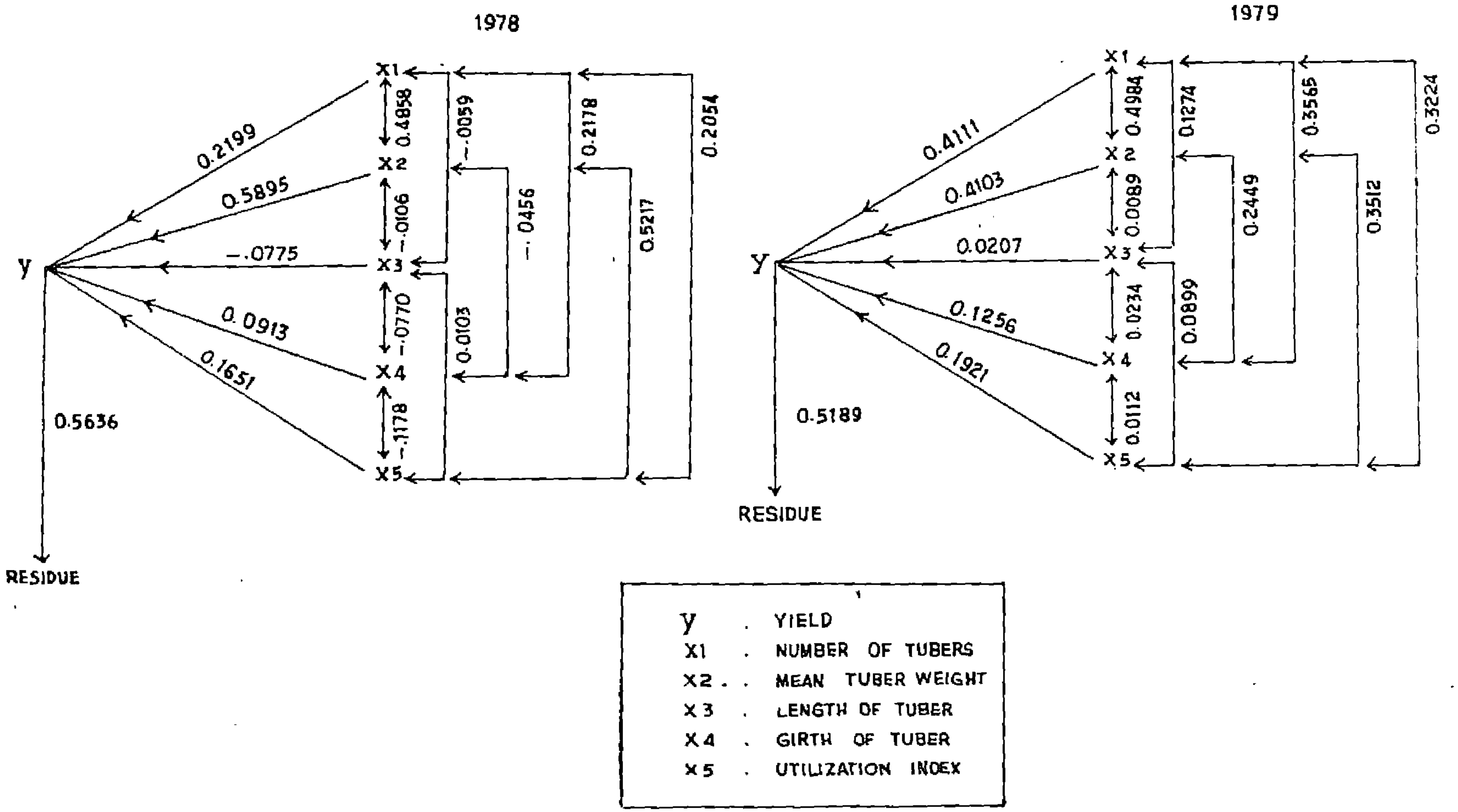
- 1979 -

| | Number of tubers (X1) | Weight of tuber (X2) | Length of tuber (X3) | Girth of tuber (X4) | Utilization index (X5) | Correlation with yield (Y) |
|---|---|---|---|---|---|---|
| $X_1$ | 0.4111 | 0.2045 | 0.0026 | 0.0448 | 0.0620 | 0.7250* |
| $X_2$ | 0.2049 | 0.4103 | 0.0002 | 0.0308 | 0.0675 | 0.7137* |
| $X_3$ | 0.0524 | 0.0036 | 0.0207 | 0.0029 | 0.0173 | 0.0969 |
| $X_4$ | 0.1466 | 0.1005 | 0.0005 | 0.1256 | 0.0022 | 0.3753* |
| $X_5$ | 0.1326 | 0.1441 | 0.0019 | 0.0014 | 0.1921 | 0.4721* |

Critical value of correlation co-efficient at 5 per cent level = 0.2523

Note: The diagonal values show the direct effect and the off diagonal values indicate the indirect effect.

FIG II . PATH COEFFICIENT ANALYSIS OF YIELD COMPONENTS ON YIELD AT KAYAMKULAM



From the 5 sets of direct and indirect effects, it can be seen that the mean tuber weight is having the maximum positive direct effect in the first year at Vellayani than other causes, which was closely followed by the number of tubers. It exhibited a high positive indirect effect also. But the indirect effect shown by number of tubers was the maximum during the first year. The trend of results was similar in the second year also.

The data at Kayamkulam during the first year show that the mean tuber weight had a high positive direct effect which was the maximum and more than double in magnitude as compared to the direct effect of the number of tubers. It showed a positive indirect effect also. The number of tubers exhibited a positive direct effect and the maximum indirect effect. During the second year the direct effects of mean tuber weight and number of tubers were significant and positive with almost of equal magnitude.

However, at both locations the direct and indirect effects of other yield components were much less.

# Discussion

# 5. DISCUSSION

The results of the investigation on the effect of graded levels of potassium in combination with nitrogen at different times of application on the growth characters, yield components and tuber yield of tapioca are discussed below.

## 5.1 Growth characters

### 5.1.1 Plant height

The results at Vellayani and Kayamkulam showed that plant height increased by nitrogen nutrition and the tallest plants were observed at the highest level of nitrogen application (Tables 3a and 3b). Eventhough the vegetative parts are not included as the economic portion of the produce in tapioca, it definitely contributes to tuber production by acting as a photosynthetic factory for the manufacture of starch. Height forms an essential component in the production of leaves which act as the 'source'. The importance of nitrogen in influencing the plant height is to be viewed in this context. It may be particularly seen that the height was enhanced by nitrogen application upto the highest level. The influence of nitrogen on vegetative growth of plants is a well established phenomenon which needs no detailed discussion. Similar increases in plant height due to higher levels of nitrogen application have been reported in tapioca by several earlier workers like Natarajan (1975) Mandal et al. (1975) and Pillai and George (1978a).

The data also show that potassium application increased plant height significantly at the different growth stages. However, significant effect of potassium was observed only upto the $K_2$ level. This shows that application of potassium at a rate of 125 Kg $K_2O$/ha is sufficient for optimum vegetative growth. It is an already established fact that this element has only a lesser influence on vegetative growth characters. Similar results have been reported by earlier workers like Ngongi (1976) and Asokan and Sreedharan (1980) in tapioca.

The application of nutrients in two splits ($S_1$) gave increased plant height as compared to three split applications ($S_2$ and $S_3$) at Vellayani eventhough the effect was not statistically significant. In treatment $S_1$ the entire dose of nutrients was applied within 60 days after planting whereas in the other two treatments it was extended upto 90 days. Plants in treatment $S_1$ thus received the entire dose of nutrients in the active vegetative growth phase itself which would have enabled the plants to utilise the same for increasing the height of plants. But in treatments $S_2$ and $S_3$ the application of nutrients was extended upto

90 days after planting at which stage tuberization had already commenced. Therefore the nutrients supplied during this period have evidently been utilised for tuber formation also resulting in lesser influence on plant height.

### 5.1.2 Number of nodes and functional leaves

The data presented in Tables 4a and 4b show the significant influence of nitrogen on the number of nodes at different growth stages at the two locations. The highest level of nitrogen produced the maximum number of nodes. Similarly the number of functional leaves also differed significantly between levels of nitrogen at Vellayani and Kayamkulam (Tables 5a and 5b) showing the maximum at the $N_3$ level. The influence of nitrogen was significant in most of the growth stages at Kayamkulam also. Number of nodes actually reflects the number of leaves produced and this is a cardinal index for the measurement of vegetative growth of tapioca. Krochmal and Samuels (1967) in a tank culture study have very well demonstrated the influence of nitrogen on the vegetative growth of tapioca wherein a marked increase in the vegetative growth of the crop by higher levels of nitrogen application was noticed. Similar results in colocasia were reported by Premraj _et al_. (1980) and Mohandas and Sethumadhavan (1980). The growth stage from the third to the eighth month is important in tapioca as tuberization and much of the tuber development occur during this period. A higher number of functional leaves observed at both locations during this period at higher levels of nitrogen application might have resulted in more assimilate production for deposition in tuber.

The number of nodes and functional leaves were not influenced significantly either by the levels of potassium or the time of application in most of the growth stages. The lesser influence of potassium on vegetative growth characters has already been discussed.

### 5.1.3 Leaf area index (LAI)

Levels of nitrogen showed significant differences in LAI at various stages during both years at Vellayani and Kayamkulam (Tables 6a and 6b). At Vellayani it was maximum at the $N_3$ level and at Kayamkulam at the $N_2$ level. The importance of nitrogen as a factor in influencing LAI has been reported in many crops. According to Russell (1973) as nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence to have larger surface area available for photosynthesis. For many crops, the amount of leaf area available for photosynthesis is roughly proportional to the amount of nitrogen supplied. Increase in LAI was also due to an increase in leaf number at higher levels of nitrogen as is evident from the data in Tables 5a and 5b. Increases in leaf area due to incremental doses of nitrogen were reported by Ngongi (1976) in tapioca and Premraj et al. (1980) in colocasia.

Leaf area index was not significantly affected by potassium levels or time of application in the two locations. But it was higher at the $K_2$ level as compared to $K_1$ and $K_3$ though the differences were not significant. The beneficial influence of a higher level of potassium in this growth character may be through its indirect effect in increasing the nitrogen availability to plants as is evident from the data in Tables 22 and 24. Ngongi (1976) and Ramanujam (1982) reported increases in leaf area index by potassium nutrition.

## 5.2 Yield components and yield

### 5.2.1 Number of tubers

The data presented in Table 7 reveal the significant influence of nitrogen nutrition in the production of a higher number of tubers in the two locations. In tapioca, tuber number is reckoned as an important yield component. In the present study tuber number increased significantly by nitrogen nutrition and a maximum was obtained at the $N_2$ level (Fig.5). But at the highest rate of nitrogen application ($N_3$) it registered a significant decrease.

Crops such as tubers which are grown for carbohydrates, show a higher rate of photosynthesis consequent on increased leaf area obtained by nitrogen application (Russell, 1973). Such increases in leaf area have been observed in the present investigation also (Tables 6a and 6b). This might have led to the production of a larger number of tubers in plots supplied with nitrogen at the $N_2$ level. Several investigators like Mandal and Mohankumar (1972a) and Natarajan (1975) have observed increases in tuber number of tapioca due to nitrogen nutrition. Similar increases of tuber number in sweet potato were reported by Shanmugavelu et al. (1973). The trend of reduction in the number of tubers noticed at the highest level of nitrogen application may probably be due to the enhanced top growth observed at this level (Table 9). CIAT (1975) reported that in tapioca excessive top growth occurs at the expense of root growth at high rates of nitrogen application. A decrease in tuber number at high rates of nitrogen application was reported by Vijayan and Aiyer (1969).

Application of potassium also enhanced the tuber number at both locations. The increase in tuber number was noticed upto the highest level ($K_3$) unlike in the case of nitrogen. For efficient photosynthetic activity by leaves an adequate supply of potassium is essential. (Russell, 1973). This would explain why higher tuber number was observed in the plots receiving higher rates of potassium. Pushpadas and Aiyer (1969) reported increases in tuber number at higher levels of potassium application in tapioca varieties such as M-4 and H-105. Mandal and Mohankumar (1972a) also obtained similar increases in another high yielding variety of tapioca, H-165.

As regards the time of application, a significantly higher number of tubers was seen in treatment $S_3$ during both years at Vellayani though on par with treatment $S_2$. At Kayamkulam also the trend was similar though the differences were not significant. Split application of nutrients, especially potassium is associated with efficient absorption and translocation of nutrients from the soil and foliage. So a fractionated application of nutrients in three splits in the present study might have given better results in this respect than an application in two splits.

Number of tubers was more at Vellayani than at Kayamkulam. The soil at Vellayani being more compact was not very congenial for increasing the tuber girth as is seen in the results on tuber girth given in Table 8. As the 'sink' has to accommodate the entire 'source' the plant produced more number of tubers. But the soil at Kayamkulam is loose textured and there is provision for increases in tuber girth values (Table 8) and hence resulted in lesser number of tubers.

### 5.2.2 Tuber weight

The data on mean tuber weight given in Table7 and Fig. 6 show that nitrogen influenced the mean tuber weight significantly at both locations. Tuber weight increased significantly by raising the nitrogen application from $N_1$ to $N_2$. But by a further increase of nitrogen application to the $N_3$ level, mean tuber weight registered a significant decrease. The mean tuber weight is another important yield determinant of tapioca. As already discussed, nitrogen has a definite beneficial influence on the photosynthetic activity of leaves. The increased photosynthetic activity induced by nitrogen might have resulted in the production of more assimilates which in turn have been deposited in the tubers, thereby resulting in higher mean tuber weight. Differences in tuber weight occurs mainly due to the differences in the tuber bulking rates. An examination of the data in Table 19 reveal the influence of nitrogen nutrition on tuber bulking. It is clear from the data that the bulking rates were the highest at the $N_2$ level and it tended to decrease at the $N_3$ level. Mandal and Mohankumar (1972b) reported increases in tuber size of tapioca by nitrogen nutrition. A significant increase in the top yield at the highest level of nitrogen application was noticed in this study (Table 9). Consequently, a lesser rate of translocation of assimilates to tubers might have resulted at this level, resulting in low mean tuber weight~~s~~. Ezedinma et al. (1980) have reported that growth and development of stems may severely limit the bulking of storage roots.

The maximum tuber weight was observed at the highest level of potassium application. Tuber bulking is essential for the increase in mean tuber weight. It may be noted that tuber bulking occurs as a result of the accumulation of assimilates synthesised in the leaves of the plants. Potassium has been identified as being necessary for rapid translocation of nutrients at the later stages of tuberization and bulking. The influence of higher levels of potassium in increasing the uptake of nitrogen (Tables 22 and 24) thereby enhancing the area of assimilating surface of plants (Tables 6a and 6b) in the persent study is noteworthy. The production of more assimilates by potassium nutrition might have led to an increase in mean tuber weight. At higher levels of potassium, it may be noted, that vegetative growth did not increase which would have led to wastage of energy. So the plant might have utilized this extra energy for tuber bulking at higher levels. Several earlier workers have reported increases in mean tuberweight due to potassium nutrition in tapioca (Ngongi, 1976; Godfrey and Garber, 1978).

Time of application also showed significant influence on this yield attribute. Tuber weight was maximum in treatment $S_3$ in the two locations though it was on par with treatment $S_2$. This would show the significant superiority of application of nitrogen and potassium in three splits ($S_2$ and $S_3$) over two splits ($S_1$). The beneficial influence of three split applications can very well be seen in the uptake of nutrients also (Tables 22, 23 and 24) wherein the highest uptake of nitrogen and potassium was observed in treatment $S_3$. Hence tuber growth was better and the mean tuber weight higher in this treatment.

The results showed a higher mean tuber weight at Kayamkulam. As already discussed this may be due to the loose nature of the soil at this station which is more conducive for the proper growth and development of tubers.

### 5.2.3 Length and girth of tuber

The data in Table 8 show that the treatment effects on the length and girth of tuber were not significant. The lack of response may probably be due to the fact that these characters are mostly genetic in nature. In this connection, it is worthwhile noting the differences in length and girth of tuber in the two locations. While higher tuber length was observed at Vellayani the girth values were more at Kayamkulam. The quantity of 'source' being limited the 'sink' has to adjust in such a way as to accommodate the entire 'source'. In a loose textured soil like that at Kayamkulam, there is provision for increasing the tubergirth whereas in compact soils as that in Vellayani the length has to be increased so as to accommodate the assimilates. This may probably be the reason for greater tuberlengths observed at Vellayani and higher girth values noted at Kayamkulam.

### 5.2.4 Utilization index

The effect of nitrogen on the utilization index was significant and similar at both locations. (Table 9). Treatment $N_2$ produced the highest utilization index. Yield increases were observed by nitrogen nutrition upto the $N_2$ level in the two locations. But by a further increase in nitrogen application to the $N_3$ level the yield registered a significant decrease (Tables 10 and 11). But it can be seen that top yield increased significantly by nitrogen application and the maximum was observed at the $N_3$ level (Table 9). Hence the utilization index, being the ratio of root weight to top weight, was the highest at the $N_2$ level. The low values of utilization index noticed in treatment $N_1$ was due to the low tuber yields obtained at this level. But the low values at the $N_3$ level was mainly due to the high top yields and low tuber yields noticed at this level. The influence of nitrogen nutrition on this yield character was clearly revealed in the present study wherein at high levels of application of this nutrient, instead of getting an increase in economic yield an enhancement of vegetative growth was observed. CIAT (1977) also reported a decrease in harvest index due to application of nitrogen at higher levels as it stimulated top growth more than root growth.

Application of potassium enhanced the utilization index and the highest value was seen at the $K_3$ level, but the effect was significant only at Kayamkulam. The lack of response at Vellayani may be due to the fact that the increase in root yield by the application of potassium was accompanied by a corresponding increase in top yields. The result at Kayamkulam show that the rate of tuber production per kilogram of potassium was more at the $K_3$ level than at $K_2$. Hence it can be inferred that a major portion of applied potassium at this level has been utilized for tuber production rather than for top growth thereby resulting in a significant response at Kayamkulam.

Treatment $S_3$ showed the highest utilization index at Vellayani and Kayamkulam. But it was significantly superior to treatment $S_1$ and was on par with $S_2$. The data on tuber yield in the two locations show the highest value in treatment $S_3$ which was significantly higher than $S_1$ only. At the sametime, the influence of time of application on top yield was not significant (Table 9) and hence the maximum values were secured at the $S_3$ level. It is evident that application of nutrients in three splits has benefitted the crop in increasing the tuber yield rather than top yield. It may be mentioned in this connection that plant height was more in treatment $S_1$ (Table 3a) than in the other treatments.

### 5.2.5 Top yield

Top yield as given in Table 9 show that it was affected significantly by nitrogen application in the two locations. Progressive increases in top yield with incremental doses of nitrogen was observed and the maximum attained at the $N_3$ level. As the supply of nitrogen increases, more of the nitrogen reaches the tops and uses the carbohydrates for protein synthesis and growth leading to an enhanced rate of top growth (Russell, 1973). Plant height and number of functional leaves which are the contributing factors for top yield were increased by high rates of nitrogen application in the present study (Tables 3a, 3b, 5a and 5b). Hence the top yields also were higher at higher levels of nitrogen application.

Similar increases in top yield due to higher doses of nitrogen application have been reported from CIAT (1975) and also by Kang and Wilson (1980). Top drymatter also followed a similar pattern of variation due to nitrogen nutrition.

Potassium levels also showed significant effect in top yield. But the time of application wass not significant. Significant increase in top yield due to potassium nutrition was noticed only upto the $K_2$ level at Vellayani. This shows the lesser influence of potassium on vegetative growth characters and the sufficiency of a lower dose of this element for getting optimum vegetative growth in tapioca. Moreover, it may also be probable that at higher levels of potassium application more of the potassium would have been utilised for tuber bulking rather than for top growth of the plant. This is evident from the high values of mean tuber weight at Vellayani as discussed earlier (Table 7). Top yield was a minimum at the $K_3$ level at Kayamkulam (Table 9). The soil type at this location was sandy loam which was extremely deficient in available potassium as seen in Table 1. So right from the early stages of tuberization and development most of the applied potassium at higher levels of application might have been utilised for tuber bulking. The maximum tuber yield obtained at the highest level of potassium application (Table 11) justifies this argument.

### 5.2.6 Tuber yield

The data on tuber yield presented in Tables 10 and 11 and Fig.7 show the significant influence of all treatments on tuber yield in the two locations of the study.

Tuber yield increased significantly by nitrogen application. The highest tuber yield was observed by an application of 125 kg N/ha ($N_2$) beyond which it decreased.

Nitrogen is a component of chlorophyll and plays a vital role in the photosynthesis of plants. The yield of cassava depends more upon the extent of assimilation and assimilate accumulation in the roots. Assimilation in turn depends on the extent of the assimilating surface. The influence of nitrogen in increasing the assimilating surface (leaf area) of plant is well-known. Increases in leaf area upto the $N_2$ level was observed in this study also. This aspect is further substantiated by the favourable impact of nitrogen on net assimilation rate and crop growth rate at Vellayani. These physiological attributes registered an increase due to nitrogen nutrition upto the $N_2$ level (Tables 20 and 21).

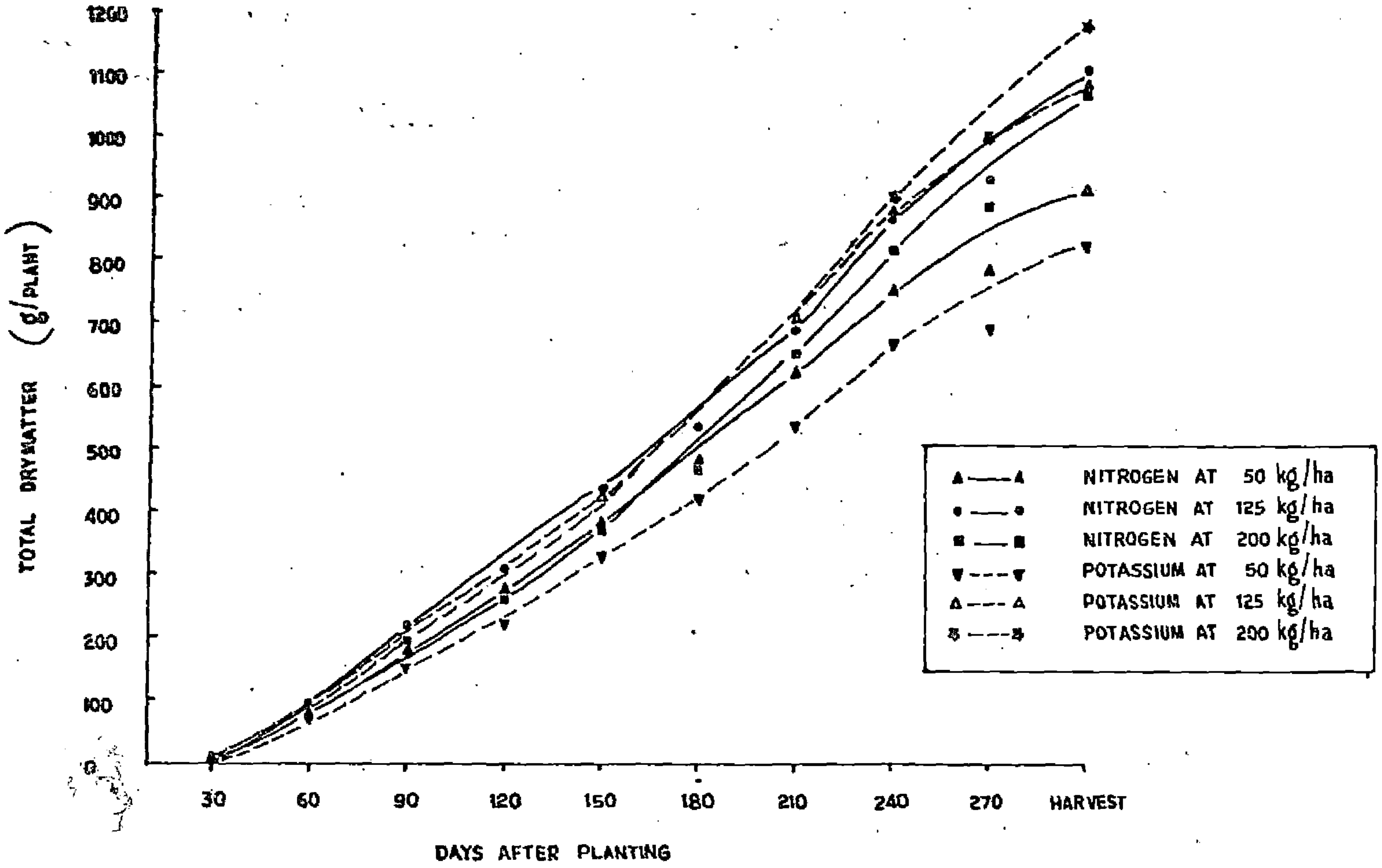
The effect of nitrogen on carbohydrate synthesis is well-known. This hypothesis has been substantiated by the findings of this investigation wherein the dry matter content of tubers was significantly increased by nitrogen nutrition upto the middle level ($N_2$) at both locations (Tables 17 and 18). At Vellayani, total dry matter production was also the maximum at the $N_2$ level (Fig.12). Similarly the tuber bulking rate also showed the highest values at the $N_2$ level (Table 19).

The two important yield components of tapioca namely tuber number and mean tuber weight were seen increased by nitrogen application (Table 7). This result is in accordance with the findings of several other workers like Mandal and Mohan kumar (1972 b) and Natarajan (1975).

The uptake studies conducted further substantiates the role of nitrogen in tuber production. The data in Table 22 show that the nitrogen uptake was more or less in proportion to the tuber production. This was further amplified by the correlation studies (Table 27) which showed a significant positive association between tuber production and nitrogen uptake.

All these factors either individually or in combination might have contributed substantially to the higher tuber yields noticed at the $N_2$ level. Many workers have reported

FIG 12. EFFECT OF NITROGEN AND POTASSIUM ON TOTAL DRYMATTER PRODUCTION AT VELLAYANI (MEAN OF 1978 AND 1979)



yield increases in tapioca by nitrogen application (Mandal and Singh, 1970;Mandal et al., 1971; Mohankumar and Maini, 1977).

However, it is worth noting the significant decrease in tuber yield by the application of nitrogen beyond 125 kg N/ha. The vegetative characters like plant height, number of functional leaves and finally the top yield were seen increased upto the highest level of nitrogen ($N_3$) tried in this experiment. The excess vegetative growth produced by nitrogen dressings beyond a certain level might have caused a significant reduction in tuber yield. As nitrogen supply increases, more of the nitrogen reaches the top portion of the plants and uses the carbohydrates for protein synthesis. This leads to excessive growth of the top portion. As a result of the diminished rate of translocation of carbohydrates to roots the growth and development of the underground parts are badly affected (Black, 1973) which is very well reflected in the low tuber bulking rates noticed at this level of nitrogen nutrition. Onwueme (1978) and CIAT(1979) have also reported that high rates of nitrogen application results in luxuriant vegetative growth at the expense of root and tuber growth.

By the application of incremental doses of potassium, tuberyield increased at both locations upto the $K_3$ level.

But it was significant upto the level of 125 kg $K_2O$/ha ($K_2$) at Vellayani and upto 200 kg $K_2O$/ha ($K_3$) at Kayamkulam. The rateof increase in tuber yield at the different doses of potassium was also different at the two locations. The yield increases by the $K_2$ and $K_3$ levels over $K_1$ were 5.5 and 1.45 t/ha, respectively, at Vellayani whereas it was to the tune of 2.81 and 3.73 t/ha respectively at Kayamkulam.

Potassium has been identified as being essential for the normal photosynthetic activity of plants. The increase in leaf area observed in the present study by potassium nutrition upto a certain level is worth mentioning in this context. This might have led to a more efficient photosynthetic activity of plants which were well supplied with potassium resulting in the production of more assimilates. The data on NAR and CGR in the present study (Tables 20 and 21) also reveal the beneficial influence of potassium nutrition on these physiological attributes.

The data on tuber number and mean tuber weight (Table 7) at the two locations show that potassium nutrition had exerted a beneficial influence in improving these two important yield components which in turn have contributed for enhanced tuber yield.

The data given in Tables 17 and 18 show progressive increases in tuber dry matter by incremental doses of potassium with the maximum noticed at the $K_3$ level. Potassium is known to be essential for the synthesis and translocation of starch which is considered as one of the most important physiological activities of root crops. This is corroborated by the high values of tuber bulking rates attained at the $K_3$ level (Table 19). Treatment $K_3$ produced the highest total dry matter at Vellayani (Fig.12).

Potassium application enhanced the plant uptake of nitrogen and potassium (Tables 22, 23 and 24). It can be seen that there was a progressive increase in the uptake of potassium upto the $K_3$ level. This might have favourably influenced the growth and development of tapioca. The influence of potassium uptake on tuber yield can be further seen by the positive correlation observed between these two (Table 27). However in the case of nitrogen uptake the influence was seen only upto the $K_2$ level. Thus the indirect effect of potassium nutrition through an increase in nitrogen uptake was also noticed in this study.

So the combined effects of all these factors must have favourably influenced the increased tuber production at higher levels of potassium nutrition. The beneficial effect of potassium nutrition in enhancing the tuber yield of tapioca was reported by several earlier workers such as Mohan kumar and Nair (1969) and Pushpadas and Aiyer (1976).

The difference in the response to potassium nutrition noticed in the two locations can be attributed to the differences in the agroclimatic conditions of these locations. The extremely porous nature of the soil type with an inherent low potassium status at Kayamkulam (Table 1) might have given a better response to applications of potassium at higher rates at this location. Moreover, the loss of potassium by leaching is also likely to be more at Kayamkulam due to the high annual rainfall conditions prevailing in that locality (Appendix III and Fig. 2). This can also be an added reason for a positive response obtained at Kayamkulam to the highest level of potassium application (200 kg $K_2O$/ha).

At Vellayani, significant response was noticed only upto the $K_2$ level. The soil characteristics were quite different in this locality. The red loam soil of Vellayani has a better retentive capacity of nutrients as compared to the sandy soil of Kayamkulam. The available potassium status was also slightly higher in this soil type. These conditions might have limited the response to potassium upto the $K_2$ level at Vellayani.

Application of nutrients in three splits in the proportion of 50:25:25 ($S_3$) gave a significantly higher tuber yield over the application in two splits ($S_1$) at both locations. The yield in treatment $S_2$was also more than in treatment $S_1$ eventhough it was significantly lower than in treatment $S_3$. According to CIAT (1979) on light soils especially under high rainfall conditions potassium leaches readily and hence a fractionated application may be advisable. It can also be pointed out that split application of nutrients especially potassium is associated with efficient absorption and translocation of nutrients from the soil and foliage. Consequently a higher uptake of nitrogen and potassium has resulted (Tables 22, 23 and 24) which in turn might have favourably influenced the tuber yield. Similarly the data on NAR and CGR (Tables 20 and 21) show the enhanced rate of physiological activity of the plants by the application of nutrients in three splits ($S_3$). The high tuber bulking rate noticed in treatment $S_3$ may be considered as the proof of this. The treatment $S_3$ improved the tuber number and mean tuber weight also substantially. All these have contributed for the higher yield obtained in treatment $S_3$. Howeler (1976) reported that application of nitrogen in three splits resulted in better yields of tapioca. Similarly the beneficial effect of the application of nitrogen and potassium in split doses were reported by many workers (CIAT, 1976; CIAT, 1979 and Asokan and Sreedharan, 1980).

As regards the NK combinations, at Vellayani, the combination $N_2K_2$ gave the maximum yield but was on par with $N_2K_3$ and $N_3K_3$. But at Kayamkulam it was $N_2K_3$ which gave significantly higher tuber yield than others. It is clear from the results already discussed that application of nitrogen at 125 kg/ha ($N_2$) seemed to be sufficient at both locations for getting high yields. In the case of potassium, eventhough yield increase was noticed upto the highest level ($K_3$) at Vellayani, there was no significant difference between the yields obtained at the $K_2$ and $K_3$ levels. But at Kayamkulam, application of potassium at the highest level (100 kg $K_2O$/ha) was required to maintain high yields as it showed significant superiority over treatments $K_2$ and $K_1$.

Regarding the NS interaction, it could be seen that the combination $N_2S_3$ was significantly superior to all others at Vellayani. Hence this combination can be considered ideal for this tract. At Kayamkulam, the combination $N_2S_3$ was on par with $N_2S_2$ and both were significantly higher than all others. But the higher yield secured at $N_2S_3$ showed its superiority over $N_2S_2$ in this locality.

Among the KS combinations, $K_3S_3$ gave the highest tuberyield at Vellayani but was on par with $K_2S_3$ and $K_3S_2$. Since the combination $K_2S_3$ with a lower dose of potassium showed a yield efficiency equal to the higher dose combination this may be considered as the best for this region. At Kayamkulam, as the combination $K_3S_3$ produced the highest tuberyield which was significantly higher than others it can be considered to be suitable for that tract.

On the basis of the above discussions it can be concluded that the combination $N_2K_2S_3$ is the optimum for Vellayani and $N_2K_3S_3$ for Kayamkulam for getting high tuberyields during the season. The relative difference in the agroclimatic conditions in the respective locations might be responsible for this differential response of the same variety.

Path coefficient analysis presented in Tables 28a and 28b shows that tuber number and mean tuberweight were having direct positive effect on tuberyield at Vellayani. Since mean tuberweight had higher values of direct and indirect effects than tuber number it can be considered as the main yield contributing character. The data reveal that at Kayamkulam also the tuber number and mean tuber weight were having direct positive effect on tuber yield.

The direct effect of mean tuberweight was almost double that of the number of tubers during the first year in this location whereas both were almost of equal magnitude during the second year. Moreover, the direct and indirect effects of other yield components were much less in the two locations. From these it can be concluded that increases in tuberyield mainly occurred due to differences in tuberweight and number of tubers. Several workers have reported that tuberweight and tuber number are the most important yield contributing factors in tapioca (Williams, 1974; Pillai and George, 1978b; Ramanujam and Indira, 1980).

## 5.3 Quality attributes

### 5.3.1 Starch content and starch yield

The data on starch content of tubers and starch yield are presented in Table 12.

The results show that starch content increased significantly by nitrogen nutrition upto the $N_2$ level at both places. The higher starch content observed at this level may probably be due to the enhanced rate of photosynthetic activity of leaves which might have resulted from increased leaf area. Coupled with this, the highest tuberyield noticed at the $N_2$ level might have led to the maximum starch yield obtained in treatment $N_2$ (Fig.8). Increase in starch content of tubers by nitrogen nutrition has been reported by several workers like Mandal et al. (1971); Obigbesan and Agboola (1973) and Pillai and George (1978c).

Starch content tended to decrease at the highest level of nitrogen application ($N_3$). As the supply of nitrogen to plants increases, there is a tendency for the carbohydrate content to decrease (Black, 1973). This could be due to an increased production of proteins at this level with a corresponding decrease in the starch content. At higher levels of nitrogen the balance between carbohydrates and protein might have been shifted in favour of protein synthesis resulting in higher percentage of the latter. The present study seems to reveal such a tendency. The reduction in starch yield observed was due to the combined effect of the reduction in starch content and tuberyield at the highest level of nitrogen application.

Starch content and starch yield were increased significantly by potassium nutrition and the maximum values were noticed at the $K_3$ level. The beneficial effect of potassium on this quality trait can be attributed to the well-known role of potassium in carbohydrate synthesis and translocation. CIAT (1979) reported linear increases in starch yield with increasing amount of applied potassium upto a level of 200 kg $K_2O$/ha. The observation in the present investigation is in conformity with the findings of several earlier workers such as Obigbesan (1973), Gomes and Howeler (1980) and Ramanathan et al. (1980).

Though the time of application did not influence starch content significantly, the starch yield differed significantly between the different times of application. Treatment $S_3$ produced the maximum starch yield. In this treatment, the top dressing given in the third month after planting might have been utilised mainly for the synthesis and translocation of starch. Similar observation of the maximum starch content by fractionated application of potassium in three splits was earlier reported by Asokan and Sreedharan (1977). The beneficial effect of split application of potassium in increasing the tuber starch content has been reported by CIAT (1979) also.

### 5.3.2 HCN Content

The results show the significant influence of nitrogen on the HCN content of tuber (Table 13). The HCN content of tuber is important as it decides to a large extent the value of tubers for human consumption. Though it is mostly a varietal character, agronomic manipulation has a decided influence in reducing this hazard and thereby increasing its value for consumption by human beings. Nitrogen nutrition increased the HCN content of tubers in the present invdstigation showing the maximum values at the $N_3$ level (Fig.9). A high level of nitrogen fertilization results in a high level of cyanogenic glucosides in the tuber (Sinha, 1969) which upon hydrolysis releases the poisonous hydrocyanic acid. Several workers have reported increases in the HCN content by nitrogen fertilization (Indira et al. 1972; Mohan kumar and Maini, 1976; Muthukrishnan, 1980).

### 5.3.3 Crude protein

The results (Table 13) reveal the significant influence of nitrogen on this quality attribute. The effect of potassium nutrition and time of application was not significant on this character. Tapioca is considered as a poor source of protein in human diet. An improvement of this quality trait to some extent by nitrogen nutrition is possible. Protein content increased significantly by nitrogen nutrition upto the highest level ($N_3$). The favourable effect of nitrogen nutrition on protein synthesis in relation to carbohydrate accumulation has already been discussed. Increase in crude protein content of tubers of several tuber crops by the application of nitrogen was reported by Hukkeri (1968) in Potato, Pillai and George (1978c) in tapioca and Mohandas and Sethumadhavan (1980) in colocasia.

The influence of potassium on this quality trait was just the reverse of that of nitrogen. The effect of time of application was however not significant. Increasing levels of potassium decreased the HCN content significantly and the lowest value was obtained at the highest level of potassium application. According to Clark (1936) the content of glucosides fell as the drymatter content increased. An increase in root drymatter contents by potassium application observed in the present investigation (Table 17) might have resulted in low HCN at this level. Similar results were reported by many workers like Indira et al. (1972); Obigbesan, (1973) and Ramanujam (1982).

### 5.3.4 Cooking quality

It is observed from the Table 14 that the application of nitrogen and potassium at different levels did not significantly affect the cooking quality of tapioca as measured by the bitterness of tubers. However, a slight reduction in cooking quality of tubers was noted by nitrogen nutrition though the effect was not significant. Similarly the results also show an improvement in cooking quality by potassium nutrition. The data on HCN content which was already discussed show that it increases by higher levels of nitrogen which may be the possible reason for the reduction in cooking quality. Prema et al. (1975) reported such reduction in cooking quality of tubers by higher levels of nitrogen. But at the highest level of potassium nutrition the HCN content was the lowest. Asokan and Sreedharan (1977) also observed an improvement in the cooking quality of tubers by potassium nutrition.

## 5.4 Growth analysis

### 5.4.1 Dry matter production and distribution

Leaf and stem dry matter contents increased with incremental doses of nitrogen though the differences were not statistically significant at the various stages (Tables 15 and 16) at Vellayani. Treatment $N_2$ gave the highest leaf and stem dry matter during the period, 90-180 days. In tapioca, this stage coincides with the stage of maximum leaf production. Leaves are important organs of photosynthesis and assimilate production. Thus the high rates of leaf dry matter observed in treatment $N_2$ at this stage might have produced more assimilates which in turn led to the maximum tuber yield obtained in this treatment at Vellayani. But in the later stages, treatment $N_3$ produced maximum leaf and stem dry matter. Significant increases in top dry matter yield with higher doses of nitrogen were noticed at Kayamkulam (Table 18). This excessive top growth at the highest level of nitrogen have affected the tuber yield unfavourably leading to significantly lower yields at the $N_3$ level.

The root dry matter was maximum in treatment $N_2$ at all stages at Vellayani and it was significantly superior to others in the later stages of growth (Table 17). The effect of nitrogen on tuber dry matter was similar at Kayamkulam also. (Table 18). The high rates of leaf drymatter production observed at the $N_2$ level in the earlier stages of tuberization and development might have produced more photosynthates thereby leading to a higher tuber yield at Vellayani. The highest nitrogen uptake observed during this period in treatment $N_2$ (Table 22) also might have created congenial conditions for higher rates of root dry matter production. This is evident from the high rates of tuber bulking observed in this treatment. Kumar and Maini (1977) reported increases in tuber dry matter contents due to nitrogen applications in H-2304 variety of tapioca. Pillai and George (1978c) also observed similar increases in tuber dry matter contents due to nitrogen nutrition.

The root dry matter decreased at the highest level of nitrogen, in both places. The decrease in root dry matter observed at the $N_3$ level can be attributed to the high rates of protein synthesis occurring at the highest level, as already discussed. Such reduction in root dry matter at the highest level of nitrogen at both locations is in conformity with the findings of Obigbesan and Agboola (1973).

Potassium also increased the leaf and stem dry matter upto a certain level ($K_2$). The effect of potassium on top dry matter was not significant at Kayamkulam. Leaf dry matter was maximum in treatment $K_2$ in the early stages of tuberization and development. Hence it is probable that plants in this treatment might have exhibited more efficient photosynthetic capacity thereby resulting in higher tuber yields in this treatment. It is also clear from the data that potassium applied in excess of the $K_2$ level was not utilised in the production of leaf and stem dry matter. This again revealed the lesser influence of this element on the growth of the vegetative parts.

Root dry matter increased with higher doses of potassium application and was significant for the various stages. The highest root dry matter was noticed in treatment $K_3$ in both locations. It was already seen that leaf area and leaf dry matter increased by potassium nutrition. Which in turn might have contributed towards higher tuber dry matter production. Though the differences in root dry matter contents between treatments $K_2$ and $K_3$ were negligible in the early stages, the difference became marked with treatment $K_3$ showing higher values in the later stages of tuber development. Potassium has been identified as being necessary for rapid translocation of nutrients at the later stages of tuberization and bulking. Obigbesan (1973) observed increases in tuber dry matter contents at higher levels of potassium nutrition. Increase in tuber dry matter content by potassium nutrition upto a level of 200 kg $K_2O$/ha has been reported by CIAT (1980).

The effect of time of application was not significant in leaf and stem dry matter at Vellayani. At Kayamkulam also the effect was not significant during the second year. Root dry matter content was the highest in treatment $S_3$ at Vellayani, though the differences were not significant. At Kayamkulam also treatment $S_3$ produced the highest tuber dry matter. This may probably be due to the better absorption of nutrients in this treatment of three split application as explained earlier in this chapter.

The results of the study at Vellayani also showed that leaf dry matter increased considerably after 30 days, attained peak values on the 90th day, and tended to decline after 180 days. According to Loomis and Rapaport (1976) the leaf area index of most root crops increases slowly after planting and it declines with the onset of storage organ development. The observation in this study also revealed this effect. Hunt _et al_. (1977) reported rapid increases in leaf surface area at first and a decline in later growth stages.

The results showed that root dry matter increased considerably from 90 days after planting. It was almost double at 240 days as compared to that at 150 days. In tapioca, active tuber initiation commences only from the third month onwards. Hence naturally a rapid increase in root dry matter occurs from this stage. The stage of 150 days corresponds to the early tuber development at which time active thickening of storage roots has commenced. In tapioca most of the tuber development will be completed by 240 days which can be considered as the later stages of tuber development. Hence the tuber dry matter content will be much more at this stage as compared to the early stages of tuber development (150 days). CIAT (1973) indicated that the tuber dry matter increases from the third month onwards and proceeds rapidly upto eight months after planting and thereafter slowly for the rest of the growth period.

### 5.4.2 Tuber bulking rate

The results presented in Table 19 reveal the significant influence of nitrogen nutrition on tuber bulking upto the $N_2$ level during the various growth phases. The leaf area was the highest at this level, in the various growth stages which might have resulted in the production of more assimilates as discussed earlier. The highest values of the physiological parameters such as NAR and CGR observed conclusively prove the high rate of photosynthetic activity occurring at this level. The assimilates produced at higher rates at the $N_2$ level might have resulted in the high rates of tuber bulking noticed in the present study. The trend of decline in this character observed from the first to the third phase at the lowest level of nitrogen with only a slight increase in the second phase clearly showed the insufficiency of this amount of nitrogen for the normal physiological activity of the plant. But in the second phase, the tuber bulking rate increased and reached a peak at the $N_2$ level. The low values noted at the $N_3$ level may be due to the excessive shoot growth which occurred at this level as discussed earlier. This conclusively proves the sufficiency of nitrogen at $N_2$ level for maximum rates of tuber bulking.

Application of potassium also increased tuber bulking rates significantly with the highest value obtained at the $K_3$ level. The beneficial influence of potassium in the synthesis and translocation of starch can be attributed to this as explained earlier. It was already seen that potassium at higher rates was mostly used for tuber growth and development.

Tuber bulking rates were the highest in treatment $S_3$. The better absorption and efficient utilization of the nutrients in this treatment may be the reasons for this highest value.

However the tuber bulking rates were higher in the first two phases and tended to declined in the third phase. The peak values were noticed in the second phase. In tapioca, this phase denotes the period of active tuber development and hence the peak values. As the third phase represents the later stages of tuber development where the physiological activity of the plant is a minimum naturally it gave the lowest tuber bulking rates. An increasing trend in tuber bulking rate was observed from the first to the second phase at the highest level of potassium application. Moreover in the third phase also it registered the highest value. It is likely that the leaves remaining on these plants in this treatment still had enough photosynthetic capacity to channel substantial amounts of assimilates towards tuber bulking. These observations are in agreement with the findings of Kang and Wilson (1980) that cassava plants store their excess photosyntheates in roots during the early to the mid part of the crop productive cycle.

### 5.4.3 Net assimilation rate and crop growth rate

Though the levels of nitrogen did not influence NAR and CGR significantly (Tables 20 and 21), the highest values were observed at the $N_2$ level during the first three phases of the maximum physiological activity. Treatment $N_2$ gave higher values in the later stages of tuber development also. The favourable influence of nitrogen application upto a certain level might be due to an increase in the net photosynthetic rate which leads to an increase in all the physiological parameters studied.

In the case of potassium, the highest level gave the maximum values of NAR and CGR especially in the later stages of tuber development though the differences were not significant. Time of application had no significant effect on these characters. Potassium also has exercised a favourable effect in increasing the photosynthetic activity of plants as explained earlier. Moreover it exerted an indirect effect on these characters by increasing the nitrogen availability to plants as is seen in the data on the uptake of nutrients (Tables 22 and 23).

## 5.5 Nutrient uptake

### 5.5.1 Nitrogen and Potassium

The data in Tables 22, 23 and 24 show that plant uptake of nitrogen increased with higher levels of application of this nutrient and the maximum was obtained at the $N_3$ level in both places. But at Vellayani treatments $N_2$ and $N_3$ were on par in this respect. The data on tuber yield at both locations reveal that the yield was the highest at the $N_2$ level thereby showing the efficient utilization of the absorbed nitrogen for tuber production at this level. Eventhough the uptake increased at the $N_3$ level the tuber yield decreased significantly and the top yield registered a marked increase. This clearly shows that by an application of this element in excess of 125 kg N/ha leads to increased top growth at the expense of tuber growth. Increase in the uptake of nitrogen by higher rates of application of the nutrient is an already established fact which needs no further explanation. Pushpadas et al. (1976) has recorded similar observations in tapioca.

The effect of nitrogen levels in increasing the potassium uptake was noticed only upto the $N_2$ level in both places. Rajendran et al. (1976) reported similar results in this crop. At the $N_3$ level the potassium uptake decreased. The decrease in potassium uptake observed at the $N_3$ level in the present study may be due to an imbalance in the nutrient content of soil at the highest level of nitrogen application. This is in conformity with the findings of Okeke et al. (1979b).

The uptake of nitrogen was increased with incremental doses of potassium application in the two locations. Ramon and Donald (1967) observed increases in the content of nitrogen in plant parts of Colocasia by potassium fertilization. But such increase was noticed only upto the $K_2$ level at Vellayani and at $K_3$ level it decreased. This is in conformity with the findings of Mohankumar and Nair (1969) who have reported similar reduction in nitrogen content of tapioca plants by potassium fertilization.

Increase in the plant uptake of potassium by the application of higher rates of this nutrient was observed at both locations and the maximum values were found in treatment $K_3$. This enhanced rate of uptake at higher levels of application was efficiently utilized by the plant for tuber production as is evident from the data on tuber yield (Tables 10 and 11) in the two locations. Kumar *et al.* (1971) observed a similar increase in potassium uptake by higher doses of this element in tapioca. Premraj *et al.* (1980) have reported such increase in colocasia.

The data on the uptake of nitrogen and potassium at the two locations indicate that the application in three splits, with half the dose as basal dressing, one fourth at two months after planting and one fourth at three months after planting ($S_3$) resulted in the maximum uptake of these nutrients. This fractionated application might have resulted in the better availability of nutrients, thereby leading to an efficient absorption by plants. Shukla and Giri rao (1974) and Shukla and Singh (1976) observed enhanced rate of uptake of nitrogen and potassium by split application in Potato.

The plant uptake of nitrogen and potassium gradually increased from 30 days and reached a peak at 240 days and declined thereafter. (Tables 22 and 23) at Vellayani. CIAT (1973) has reported that the rate of dry matter accumulation in the storage roots was rapid between three and eight months and thereafter it reduced until harvest. Naturally plant requirement of nutrients will be high during this period of dry matter accumulation and hence this observation. In the present study, the root dry matter showed an increasing trend even after 240 days without having a corresponding increase in the uptake of nitrogen and potassium. Such increases in the root dry matter might have occurred by the translocation of nutrients from the vegetative parts of the plant.

## 5.6 Soil Nutrients

### 5.6.1 Available nitrogen and potassium

Available nitrogen content of soil increased by the application of higher doses of nitrogen in both locations (Table 25). Such increases in nitrogen status consequent on nitrogen application is a well established fact. Rajendran et al (1971) observed an increase in the available nitrogen content of soil by the application of 100 kg N/ha to tapioca. It was also reported that the dose was just sufficient to effect a marginal increase in the available nutrients of the soil. A slight increase in the available nitrogen content of soil by nitrogen nutrition was reported by Mohankumar and Maini (1977) also.

But eventhough significant differences in the available nitrogen content of soil was noticed between the levels of nitrogen, it was only the highest level of applied nitrogen ($N_3$) which could slightly increase the available nitrogen content of soil, as compared to the initial status. On an average the increase was about 18 kg N/ha at Vellayani and about 6 kg at Kayamkulam.

Available nitrogen content of soil at Vellayani was increased by the application of potassium also. But at Kayamkulam the result obtained was just the reverse. This shows that higher levels of potassium nutrition more of nitrogen also would have been required in this light textured soil for the proper growth and production of the crop. This enhanced rate of uptake of nitrogen by plants at higher levels of potassium application can be attributed for the decreasing trend in the available nitrogen content of soil observed in the investigation.

The results show that the available soil potassium was not significantly influenced by nitrogen application in the two locations. But potassium nutrition significantly increased the available potassium content of soil at both places showing the highest value at the $K_3$ level. Several workers have reported increases in the available potassium content of soil by the application of higher doses of potassium. (Kumar *et al*. 1971 and Rajendran *et al*. 1972). It could be seen that the highest level of potassium resulted in a slight residual effect at both locations. On an average it was about 7 kg/ha of available potassium at Vellayani and 13 kg/ha at Kayamkulam. However the effect of time of application was not significant in respect of available nitrogen and potassium contents of soil at the two locations.

From the foregoing analytical study it was evident that application of nitrogen and potassium at the highest level (200 kg/ha) could only just maintain the initial soil fertility. In other words, this brings out the necessity of organic matter application or a high level of fertilizer application for maintaining soil fertility in cassava cultivation.

## 5.7 Correlation studies

### 5.7.1 Relationship between yield components and yield

The results show that among the characters studied tuber weight was correlated to the maximum extent with tuber yield at Vellayani (Table 26a). The characters such as tuber number and girth of tuber were also correlated with yield in this location. Similarly, the components such as tuber weight, tuber number and utilization index were highly correlated with yield at Kayamkulam (Table 26b). This clearly revealed the importance of these yield components on the tuber yield of tapioca, as reported by several earlier workers (Williams, 1974; Pillai and George, 1978b and Ramanujam and Indira, 1980).

### 5.7.2 Relationship between uptake of nitrogen and potassium and yield

The data given in Table 27 show that the uptake of nitrogen and potassium at harvest stage was highly correlated with yield at Vellayani. At Kayamkulam also the uptake of these nutrients at harvest was highly correlated with tuber yield. Such positive correlation of the uptake of nitrogen and potassium with tuber yield was reported by Rajendran et al. (1976).

## 5.8 Response curves and economics of nitrogen and potassium application

### 5.8.1 Response curve

The linear and quadratic effects of nitrogen and potassium were tested at both locations. Quadratic effect was found significant for nitrogen in both locations and hence quadratic response curves were fitted to determine the optimum and economic optimum levels of nitrogen.

The response curve at

(1) Vellayani

$$Y = 12.59632 + 0.0020964N - 0.000008\ N^2$$

(2) Kayamkulam

$$Y = 5.94666549 + 0.11020\ N - 0.0004187\ N^2$$

| | | Vellayani | Kayamkulam |
|---|---|---|---|
| 1. | Optimum dose of nitrogen (kg/ha) | 130.98 | 131.60 |
| 2. | Economic optimum dose of nitrogen (kg/ha) | 102.50 | 95.26 |

As the linear effect was significant for potassium at both locations optimum level of this nutrient was not worked out.

### 5.8.2 Economics of nitrogen and potassium application

From the results given in Tables 29a and 29b it is clear that at Vellayani the NK combination of 125 kg N and 125 kg $K_2O$/ha resulted in the highest net return (Rs.5625.00). Higher levels of nutrients decreased the net return. But at Kayamkulam the NK combination of 125 kg N and 200 kg $K_2O$/ha gave the maximum net profit (Rs.5453.00)

The increase in net profit by $N_2K_2$ combination over the absolute control was Rs.4652.00 at Vellayani. Similarly the increase in net profit by $N_2K_3$ combination over the absolute control was Rs.4863.00 at Kayamkulam. From this, it can be concluded that application of 125 kg nitrogen and 125 kg potash per hectare was the best at Vellayani and 125 kg nitrogen and 200 kg potash as the most advantageous fertilizer practice at Kayamkulam for this variety of tapioca.

Table 29 a. Economics of fertilizer application at Vellayani

| Sl. No. | Treatments | Cost of cultivation (Rs/ha) | Yield (t/ha) | Value of tuber (Rs/ha) | Profit (Rs/ha) | Gain or loss at different levels of nitrogen and potassium over absolute control (Rs/ha) |
|---|---|---|---|---|---|---|
| 1. | Absolute control | 1847.00 | 9.40 | 2820.00 | 973.00 | - |
| 2. | 50:50 kg N and $K_2O$/ha | 2137.00 | 16.67 | 5001.00 | 2864.00 | 1891.00 |
| 3. | 50:125 kg N and $K_2O$/ha | 2282.00 | 19.77 | 5931.00 | 3649.00 | 2676.00 |
| 4. | 50:200 kg N and $K_2O$/ha | 2400.00 | 22.67 | 6801.00 | 4401.00 | 3428.00 |
| 5. | 125:50 kg N and $K_2O$/ha | 2485.00 | 17.83 | 5349.00 | 2864.00 | 1891.00 |
| 6. | 125:125 kg N and $K_2O$/ha | 2580.00 | 27.35 | 8205.00 | 5625.00 | 4652.00 |
| 7. | 125:200 kg N and $K_2O$/ha | 2719.00 | 25.90 | 7770.00 | 5051.00 | 4078.00 |
| 8. | 200:50 kg N and $K_2O$/ha | 2800.00 | 17.26 | 5178.00 | 2378.00 | 1405.00 |
| 9. | 200:125 kg N and $K_2O$/ha | 2935.00 | 21.12 | 6336.00 | 3401.00 | 2428.00 |
| 10. | 200:200 kg N and $K_2O$/ha | 3052.00 | 24.01 | 7203.00 | 4151.00 | 3178.00 |

Cost of fertilizer N @ Rs.4.00/kg  $P_2O_5$ @ Rs.3.50/kg  $K_2O$/@ Rs.1.40/kg

Value of tapioca tuber Rs. 30/quintal.

Table 29b. Economics of fertilizer application at Kayamkulam.

| Sl. No. | Treatments | Cost of cultivation (Rs/ha) | Yield (t/ha) | Value of tuber (Rs/ha) | Profit (Rs/ha) | Gain or loss at different levels of nitrogen and potassium over absolute control (Rs/ha) |
|---|---|---|---|---|---|---|
| 1. | Absolute control | 1790.00 | 6.80 | 2380.00 | 590.00 | - |
| 2. | 50:50 kg N and $K_2O$/ha | 2085.00 | 10.67 | 3734.50 | 1649.50 | 1059.50 |
| 3. | 50:125 kg N and $K_2O$/ha | 2200.00 | 13.91 | 4868.50 | 2668.50 | 2078.50 |
| 4. | 50:200 kg N and $K_2O$/ha | 2340.00 | 18.29 | 6401.50 | 4061.50 | 3471.50 |
| 5. | 125:50 kg N and $K_2O$/ha | 2410.00 | 12.55 | 4392.50 | 1982.50 | 1392.50 |
| 6. | 125:125 kg N and $K_2O$/ha | 2520.00 | 18.45 | 6457.50 | 3937.50 | 3347.50 |
| 7. | 125:200 kg N and $K_2O$/ha | 2688.00 | 23.26 | 8141.00 | 5453.00 | 4863.00 |
| 8. | 200:50 kg N and $K_2O$/ha | 2730.00 | 15.24 | 5334.00 | 2604.00 | 2014.00 |
| 9. | 200:125 kg N and $K_2O$/ha | 2875.00 | 14.51 | 5078.50 | 2203.50 | 1613.50 |
| 10. | 200:200 kg N and $K_2O$/ha | 2970.00 | 16.52 | 5782.00 | 2812.00 | 2222.00 |

Cost of fertilizer N @ Rs.4.00/kg $P_2O_5$ @ Rs.3.50/kg $K_2O$ @ Rs. 1.40 kg

Value of tapioca tuber Rs. 35/quintal.

# Summary

# 6. SUMMARY

An investigation was undertaken in two different agroclimatic tracts of the state (at Vellayani and Kayamkulam) to assess the performance of tapioca (Var 'Sree Sahya') under different levels of potassium (50, 125 and 200 kg $K_2O$/ha) in conjunction with nitrogen (50,125 and 200 kg N/ha) in three different times of application during the October season of 1978 and 1979. The experiment was conducted in a $3^3$ partially confounded factorial design, confounding NKS in replication I and $NKS^2$ in replication 2. In a third replication at Vellayani $NK^2S$ was confounded. An absolute control, the complete absence of nitrogen and potassium was attached to each block. The results of the investigation are summarised below.

1. The application of 200 kg N/ha resulted in the maximum height of plants. Similarly, 125 kg $K_2O$/ha produced maximum plant heights in the later stages of growth.
2. The node number was a maximum in 200 kg N/ha. The effect of potassium and time of application was not significant.
3. The maximum number of functional leaves was also observed in the treatment receiving 200 kg N/ha.
4. Nitrogen application increased the leaf area and the maximum was observed at 125 kg N/ha.

5. The application of 125 kg N and 200 kg $K_2O$/ha resulted in the maximum number of tubers. Three split application of nutrients was better than application in two splits.

6. By the application of 125 kg N and 200 kg $K_2O$/ha the maximum mean tuber weight was obtained. Three split application gave higher tuber weights than application in two splits.

7. Length and girth of tubers were not influenced appreciably by any of the treatments.

8. The utilization index was a maximum for the application of 125 kg N and 200 kg $K_2O$/ha. Application of nutrients in three splits was better than the two split application.

9. Nitrogen nutrition increased top yield upto the highest level of N(200 kg/ha). Top yield was maximum at 125 kg $K_2O$/ha.

10. The combination of 125 kg N and 125 kg $K_2O$/ha gave the maximum tuber yield at Vellayani. Application of N and K in three splits ($\frac{1}{2}$ as basal, $\frac{1}{4}$ at 60 days and $\frac{1}{4}$ at 90 days) was found to be the best. At Kayamkulam, the combination of 125 kg N and 200 kg $K_2O$/ha applied in three splits ($\frac{1}{2}$ as basal, $\frac{1}{4}$ at 60 days and $\frac{1}{4}$ at 90 days) resulted in the highest tuber yield. At both locations tuber yield decreased at 200 kg N/ha.

11. Starch content of tubers and starch yield per hectare were maximum in the combination of 125 kg N + 200 kg $K_2O$/ha. Three split applications were invariably better than two splits in this respect.

12. Application of nitrogen increased the HCN content of tuber and the maximum was observed for 200 kg N/ha. Similarly potassium nutrition reduced it and the HCN content was minimum in the treatment of 200 kg $K_2O$/ha.

13. Nitrogen application increased crude protein content of tubers and 200 kg N/ha resulted in the maximum value.

14. Cooking quality of tuber was not affected either by nitrogen or potassium levels.

15. The leaf and stem dry matter were the highest at 200 kg N/ha. Leaf dry matter increased in the early stages and tended to decline after 180 days.

16. The root dry matter at Vellayani and at Kayamkulam (harvest) were the highest in the treatment 125 kg N/ha. But it decreased at 200 kg N/ha. Increases in root dry matter at Vellayani were considerable during the period of 90 to 240 days.

17. The application of 125 kg N and 200 kg $K_2O$/ha resulted in the highest tuber bulking rates. At 200 kg N/ha tuber bulking rate was decreased.

18. The NAR and CGR values were the maximum in 125 kg N/ha and 200 kg $K_2O$/ha, though the differences were not significant.

19. In general, the plant uptake of nitrogen at Vellayani and at Kayamkulam (harvest) was the highest in treatment 200 kg N/ha and 125 kg $K_2O$/ha. Three split applications resulted in higher uptake values than applications in two splits.

20. Uptake of potassium was the highest in treatment 125 kg N/ha and 200 kg $K_2O$/ha at both locations.

21. A progressive increase in the uptake of nutrients (N and K) was noticed upto 240 days at Vellayani.

22. Available nitrogen content of soil was maximum for the application of 200 kg each of N and $K_2O$/ha at Vellayani. But at Kayamkulam it was a maximum for 200 kg N/ha and 50 kg $K_2O$/ha.

23. Available potassium content of soil was not influenced by nitrogen levels in the two locations. The highest available potassium content of soil was observed at 200 kg $K_2O$/ha. Application of nitrogen and potassium at the highest level alone could maintain the initial soil fertility.

24. Correlation studies revealed that tuber number and mean tuber weight were highly correlated with tuber yield at both locations.

25. Similarly tuber yield was highly correlated with the plant uptake of nitrogen and potassium at harvest in the two locations.

26. Path coefficient analysis showed that the mean tuber weight had exerted the maximum direct effect on yield at both locations.

27. Quadratic effect was found significant for nitrogen at both locations. But for potassium the linear effect was significant.

28. The optimum level of nitrogen at Vellayani and Kayamkulam were 130.98 and 131.60 kg/ha respectively and the economic optimum levels were 102.50 and 95.26 kg/ha.

29. The economics worked out showed that cultivation of this variety of tapioca with the application of 125 kg N + 125 kg $K_2O$/ha gave the maximum net profit at Vellayani during this season. But at Kayamkulam the application of 125 kg N + 200 kg $K_2O$/ha resulted in the maximum net profit.

Future line of work

1. Further studies have to be conducted to assess the optimum dose of nitrogen and potassium for this variety in the different important tapioca growing regions of the State.

2. The study revealed that there was a progressive increase in the uptake of potassium by tapioca upto 240 days after planting. Hence it is worthwhile to assess the performance of this crop by the split application of

potassium extended beyond three months

3. Soil fertility monitoring in the presence and absence of organic matter has to be carried out in detail.

4. Detailed studies to find out the peak period of efficient utilisation of nitrogen and potassium have to be undertaken.

5. Comparative performances of the important varieties for starch production and human consumption with respect to nitrogen and potassium nutrition and time of application have to be assessed.

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* originals not seen

# Appendices

## APPENDIX - I

Weather data during the crop periods at the Instructional farm, Vellayani

| Sl. No. | Month | | Maximum tempe- rature (°C) | Minimum tempe- rature (°C) | Relative humidity (%) | Rainfall (m.m) | Number of rainy days |
|---|---|---|---|---|---|---|---|
| 1. | September | 1977 | 30.53 | 23.53 | 83.33 | 101.00 | 7 |
| 2. | October | " | 29.60 | 23.42 | 89.68 | 814.00 | 16 |
| 3. | November | " | 30.60 | 23.23 | 87.13 | 319.00 | 9 |
| 4. | December | " | 31.90 | 22.65 | 76.55 | - | - |
| 5. | January | 1978 | 31.39 | 21.68 | 84.00 | 25.00 | 1 |
| 6. | February | " | 31.10 | 22.20 | 84.00 | 26.00 | 2 |
| 7. | March | " | 32.40 | 23.40 | 85.00 | - | - |
| 8. | April | " | 32.30 | 24.60 | 85.00 | 20.00 | 3 |
| 9. | May | " | 30.80 | 23.90 | 88.00 | 286.00 | 14 |
| 10. | June | " | 31.60 | 23.90 | 79.80 | 138.00 | 8 |
| 11. | July | " | 30.03 | 23.29 | 86.35 | 102.00 | 11 |
| | Total | | | | | 1831.00 | 71 |
| 12. | August | " | 30.39 | 23.74 | 86.00 | 100.00 | 6 |
| 13. | September | " | 30.00 | 23.30 | 92.50 | 96.00 | 6 |
| 14. | October | " | 28.10 | 23.60 | 91.00 | 38.00 | 2 |
| 15. | November | " | 29.90 | 22.20 | 91.00 | 73.00 | 9 |
| 16. | December | " | 31.00 | 22.80 | 91.00 | 119.00 | 17 |
| 17. | January | 1979 | 31.30 | 22.20 | 92.00 | - | - |
| 18. | February | " | 31.50 | 23.00 | 91.00 | 87.00 | 3 |
| 19. | March | " | 31.90 | 23.50 | 90.00 | 52.00 | 3 |
| 20. | April | " | 33.20 | 24.90 | 89.40 | 14.00 | 2 |
| 21. | May | " | 31.90 | 24.30 | 89.00 | 132.00 | 5 |
| 22. | June | | 30.50 | 23.70 | 89.00 | 275.00 | 15 |
| | Total | | | | | 986.00 | 68 |

## APPENDIX - II

Weather data at the Instructional farm, Vellayani (Normal values*)

| Sl. No. | Month | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) | Rainfall (m.m) | Number of rainy days |
|---|---|---|---|---|---|---|
| 1. | January | 30.32 | 23.40 | 79.31 | 64.23 | 3 |
| 2. | February | 30.98 | 23.57 | 81.12 | 36.40 | 2 |
| 3. | March | 31.80 | 24.75 | 79.93 | 40.11 | 2 |
| 4. | April | 31.83 | 25.48 | 81.71 | 113.48 | 6 |
| 5. | May | 31.89 | 25.26 | 83.94 | 231.60 | 11 |
| 6. | June | 30.15 | 24.42 | 84.72 | 363.59 | 14 |
| 7. | July | 29.73 | 24.08 | 85.37 | 285.29 | 14 |
| 8. | August | 29.31 | 23.63 | 83.62 | 137.76 | 10 |
| 9. | September | 29.66 | 23.78 | 83.78 | 197.56 | 9 |
| 10. | October | 29.57 | 24.69 | 85.31 | 306.27 | 10 |
| 11. | November | 29.53 | 24.20 | 84.95 | 187.30 | 10 |
| 12. | December | 30.07 | 24.20 | 84.38 | 89.39 | 5 |
| | Total | | | | 2052.98 | 96 |

*Average values of 21 years (1956 to 1976)

# APPENDIX - III

Weather data during the crop periods at the Rice Research Station, Kayamkulam

| Sl. No. | Months | | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) | Rainfall (m.m) Current values | Rainfall (m.m) Normal values | Number of rainy days Current values | Number of rainy days Normal values |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. | September | 1977 | 31.10 | 24.00 | 92.00 | 125.10 | 253.60 | 9 | 13 |
| 2. | October | " | 30.70 | 24.00 | 95.00 | 508.00 | 336.40 | 20 | 17 |
| 3. | November | " | 31.20 | 23.40 | 95.00 | 292.80 | 119.00 | 11 | 7 |
| 4. | December | " | 32.90 | 21.10 | 90.00 | 16.00 | 61.20 | 1 | 3 |
| 5. | January | 1978 | 33.10 | 20.60 | 89.00 | 6.40 | 12.50 | 1 | 1 |
| 6. | February | " | 34.20 | 22.60 | 89.00 | - | 25.30 | - | 1 |
| 7. | March | " | 33.90 | 24.50 | 93.00 | 47.80 | 29.80 | 4 | 2 |
| 8. | April | " | 34.70 | 25.50 | 92.00 | 67.80 | 177.40 | 6 | 9 |
| 9. | May | " | 31.40 | 24.70 | 94.00 | 638.40 | 290.40 | 18 | 11 |
| 10. | June | " | 29.90 | 23.20 | 94.00 | 356.40 | 413.00 | 18 | 18 |
| 11. | July | " | 29.30 | 23.10 | 93.00 | 411.40 | 448.70 | 21 | 22 |
| | Total | | | | | 2470.10 | 2167.30 | 109 | 104 |

APPENDIX - III (Continued)

| Sl. No. | Months | | Maximum temperature (°C) | Minimum temperature (°C) | Relative humidity (%) | Rainfall (m.m) Current values | Rainfall (m.m) Normal values | Number of rainy days Current values | Number of rainy days Normal values |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 12. | August | 1978 | 29.50 | 23.40 | 95.00 | 392.10 | | 22 | |
| 13. | September | " | 30.50 | 23.50 | 94.00 | 116.20 | | 10 | |
| 14. | October | " | 31.70 | 23.90 | 95.00 | 625.80 | | 17 | |
| 15. | November | " | 31.50 | 22.70 | 93.00 | 279.50 | | 7 | |
| 16. | December | " | 32.90 | 22.30 | 92.00 | 93.60 | | 3 | |
| 17. | January | 1979 | 33.70 | 21.20 | 91.00 | - | | - | |
| 18. | February | " | 33.50 | 23.20 | 91.00 | 19.20 | | 2 | |
| 19. | March | " | 34.50 | 24.60 | 92.00 | 9.80 | | 2 | |
| 20. | April | " | 34.50 | 25.00 | 90.00 | - | | - | |
| 21. | May | " | 33.30 | 25.00 | 92.00 | 78.60 | | 8 | |
| 22. | June | " | 31.30 | 24.10 | 93.00 | 551.30 | | 20 | |
| 23. | July | " | 30.20 | 23.90 | 95.00 | 262.60 | | 20 | |
| | Total | | | | | 2428.70 | | 111 | |

# POTASH NUTRITION OF TAPIOCA
## (*Manihot esculenta* Crantz.)

BY

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**ABSTRACT OF A THESIS**
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# ABSTRACT

An investigation was undertaken at the College of Agriculture, Vellayani and Rice Research Station, Kayamkulam for two years during 1977-79 to study the performance of tapioca (Var. Sree Sahya) under two different agroclimatic conditions. The treatments consisted of three levels of nitrogen (50, 125 and 200 kg N/ha) and three levels of potassium (50, 125 and 200 kg $K_2O$/ha) at three times of application. The experiment was laid out in a $3^3$ partially confounded factorial design with two replications.

Application of nitrogen enhanced the growth characters of tapioca such as plant height, number of nodes and number of functional leaves at both locations. Levels of potassium and time of application were not influential in this respect. The highest values of tuber number and mean tuber weight were obtained by the application of 125 kg nitrogen and 200 kg potash/ha. Tuber yield increased only upto 125 kg N/ha at both locations and at 200 kg level it decreased. Application of potassium enhanced the yield upto 200 kg $K_2O$/ha. The NK combinations for maximum yields at Vellayani and Kayamkulam were 125 kg N+125 kg $K_2O$/ha and 125 kg N + 200 kg $K_2O$/ha respectively. Application of nitrogen and potassium in three splits of half the dose as basal, one-fourth at sixty days and one-fourth at ninety days was found

to be the best at Vellayani and Kayamkulam. While nitrogen nutrition increased the protein content of tuber, potassium application enhanced the starch content. Cooking quality of tuber was not affected either by nitrogen or by potassium. The highest root drymatter and tuber bulking rate were observed at 125 kg N and 200 kg $K_2O$/ha. Nutrient levels did not influence the net assimilation rate or the crop growth rate. The plant uptake of nitrogen and potassium progressively increased upto 240 days and declined thereafter. It was also observed that application of nitrogen and potassium at 200 kg/ha each is essential to maintain the initial soil fertility..

The NK combination of 125 kg N and 125 kg $K_2O$ per hectare resulted in the maximum net returns at Vellayani. At Kayamkulam the highest net return was given by the combination of 125 kg N and 200 kg $K_2O$ per hectare.