THE EFFECT OF DIFFERENT LEVELS OF NITROGEN AND POTASH ON THE GROWTH, YIELD AND QUALITY OF TAPIOCA - VARIETY, H-165.

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THESIS
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CERTIFICATE

Certified that this thesis is a record of research work done independently by Shri. M. Natarajan 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

INTRODUCTION

INTRODUCTION

In Kerala where the production of rice is less than 50 per cent of the requirements, the use of tapioca as a subsidiary food has gained vital importance. As a subsidiary food crop of tremendous calorific value and also as a source of starch in textile industry cassava assumes a significant role.

Considering the gravity of the present food situation, it is essential to step up the annual production of tapioca in our State. The idea of extensive cultivation of tapioca is out of question since all the available cultivable lands are already under cultivation. The only alternative at present is to maximise the yield per hectare by adopting improved agronomic practices.

The introduction of high yielding varieties has opened up new horizons in stepping up tapioca production in our country. But the object of getting higher yield cannot be achieved by the introduction of high yielding varieties alone. Development of suitable agronomic practices assumes greater importance in giving full expression of the yield potentialities of these varieties. Therefore, it is of great significance that the response of this crop to different levels of major nutrients may be studied in detail under various agro-climatic conditions to find out the optimum levels of nutrients for each variety to get maximum returns.

The Central Tuber Crop Research Institute, Trivandrum, has evolved three high yielding varieties of tapioca viz., H-97, H-165 and H-226. The variety H-165 was released by the State and the Central Variety Release Committees in the year 1970. It has been tested in all southern stages under the " All India Co-ordinated Research Project on tuber crops". Of these three varieties, H-165 gave the highest yield. It is an early maturing variety, well suited for home consumption if harvested within 8 months and comparatively resistant to pests and diseases.

The manurial trials on tapioca conducted so far in the State have given inconsistent results. From the trials undertaken for five years at the Tapioca Research Stations, Trivandrum, Thiruvalla and Ollukkara it was concluded that an optimum manurial dose for tapioca, will be 112 kg of nitrogen and 135 to 180 kg of potash per hectare over a basaldose of 5 to 8 tonnes of farm yard manure.

The response of tapioca to phosphatic fertilization was found to be erratic and hence it was recommended only for soils poor in available phosphorus.

The effects of nitrogen and potash on growth, yield and quality of the tapioca variety H-165 have not been studied in detail, so far.

The present investigation was therefore undertaken with a view to study the response of the high yielding variety of tapioca H-165 to the graded doses of nitrogen and potash on its growth, yield and quality and also to determine the optimum as well as the economic doses of these nutrients under the agro-climatic conditions of Vellayani.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Tapioca is a tropical crop which thrives under a warm humid climate with a moderate annual rainfall of about 150 cm. The gravelly laterite and red loam soils of Kerala are ideally suited for this crop. These soils are however generally defecient in available nitrogen, available phosphoric acid and potash where as the nutrient requirements of the crop are very high. This demands a systematic study of the effect of various nutrients on the growth and yield of the crop. The present review relates to the effect of different levels of nitrogen and potash on growth, yield and quality of tapioca.

A. Effect of nitrogen on growth and yield

The beneficial effects of nitrogen on plant growth and final yield of tubers have been conclusively proved as a result of manurial-cum-spacing trials conducted for five years consecutively in the different Tapioca Research Stations in our State. Manurial experiments on tapioca conducted at Tapioca Research Stations at Trivandrum, Mavelikara and Ollukara have revealed that the effect of nitrogen on plant growth and yield of tubers was highly significant (Anonymous 1954, 1955 and 1957). Malavolta *et al*. (1955) have shown that the highest tuber yield in tapioca could be obtained by doubling the dose of nitrogen thereby enhancing the shoot and root growth. They also recorded that the weight of roots was increased by higher levels of nitrogen.

In a statistical examination of results of manurial trials on tapioca conducted in Kerala State, Chadha (1958) has reported that the mean response of nitrogen varied from 1.02 to 2.75 tons for 40 lbs of nitrogen per acre (45 kg per hectare) and from 1.17 to 4.0 tons for 80 lbs nitrogen per acre (90 kg per hectare). The economic optimum dose of nitrogen for tapioca recommended by " Potascheme " in 1961 on the basis of manurial trials conducted in Kerala for over a period of five years was 96 lbs per acre (108 kg per hectare). In another experiment it was found that 110 lb of nitrogen per acre (112 kg per hectare) applied in the form of ammonium sulphate was the optimum dose for tapioca (Anonymous 1963).

Kroachmal and Samuels (1967) reported that the production of tops as gram per plant was favoured by higher levels of nitrogen. They have also found that tubers were not formed with high nitrogen and increasing nitrogen levels reduced the tuber development by 70 per cent. Experiments conducted at Vellayani has also shown that the weight of the vegetative parts was significantly influenced by higher doses of nitrogen (Pillay, 1967). Vijayan and Iyer (1968) observed that nitrogen has a significant positive influence on the yield of tubers.

Experiments with two improved varieties of tapioca H-97 and H-165 have revealed that increasing levels of nitrogen have increased the tuber yield upto a level of 80 kg N/ha beyond which the response was not significant. They also observed that the size of tubers was not much affected by levels of nitrogen (Mandal et al. 1971 a). The optimum yield and economic return was obtained with 80 kg N/hectare in the case of H-165 and H-97 and 40 kg N/ha. in the case of M-4 (Anonymous 1971). In a study to find out the varietal response to nitrogen Mandal et al. (1971 b) found that only H-165 was highly responsive to nitrogen upto 150 kg/hectare.

Mandal and Mohankumar (1972 a) found that the number of tubers per plant was increased with the increase in the level of nitrogen in both H-165 and H-97 varieties. They also reported that the average size of tubers increased with the increase in the level of nitrogen though the trend was not uniform in all the varieties. Maximum size of the tuber was observed in H-226 followed by H-165 and the tuber size was found to be small in H-97. The tuber number per plant in H-97 was more but the size of the tuber did not increase accordingly. They have also observed that there was a significant increase in yield with increase in nitrogen levels from 50 to 125 kg per hectare but the yield was low in 150 kg N per hectare. Mandal and Mohankumar (1972 b) observed that the number of tubers per plant in the variety H-165 increased significantly with increase in the level of nitrogen from 40 to 80 kg per hectare beyond which there was not much difference.

B. Effect of potash on growth and yield

The influence of potassium on the starch synthesis has been well recognised (Russel, 1961). It appears that potassium is not directly concerned with carbondioxide assimilation and therefore the synthesis of carbohydrates; but it takes part in certain physio-chemical reaction.

The defeciency of potassium adversely affects the formation of polysaccharides and proteins which are the condensation products of primary sugars (Raheja,1966). A good number of experiments have revealed the influence of potash on the growth, and yield of taopica.

Grossman and de Assis (1951) in Brazil have found significant increase in yield and quality of tapioca due to potash fertilisation. Chadha (1958) reported that the mean response due to potash varies from 19 to 34% for 80 lb K_2O/acre (90 kg per hectare) and from 23 to 75% for 150 lb K_2O/acre (180 kg per hectare). White (1928) had shown the importance of potash in increasing the yield of tapioca in Jawa.

Manurial trials conducted at the Tapioca Research Stations in different regions of Kerala have conclusively proved the beneficial effects of potash in increasing the yield. 120 to 160 lb K_2O/acre (135 to 180 kg per hectare) have been reccommended as the optimum dose (Anonymous, 1963). Silva and Freire (1968) stated that potash markedly increased yields in Manihot esculenta in poor sandy soils. But there are reports that the tuber yield of cassava increased with potash application upto 100 kg per hectare beyond which there was a gradual decline in yield (Anonymous 1968). Magoon et al.(1971) also reported that the tuber yield of cassava increased progressively with the application of potash upto 100 kg per hectare beyond which it decreased and the optimum level was found to be 103 kg per hectare. Mandal and Mohankumar (1972 a) observed that there was not much difference in the number of tubers of variety H-165 with the application of potash from 40 to 80 kg per hectare and 80 to 120 kg per hectare did not show any significant increase in yield. However, higher level of potash (120 kg per hectare) was found to be significantly superior to the low level (40 kg per hectare) in increasing the yield of tuber.

C. Interaction effects

Cours (1953) reported that a harvest of 50 tonnes of roots and 25 tonnes of wood of tapioca, removed from soil 253 kg of nitrogen, 28 kg phosphorus 250 kg potassium, 42 kg calcium and 29 kg magnesium. Acosta and Perez (1954) have reported a close interaction between nitrogen and potassium on the yield of tapioca in Costa Rica. Abraham (1956) based on the experiments conducted at the

Tapioca Research Station, Trivandrum and found that the yield of the crop could be considerably raised by balanced NPK fertilisation. In another experiment Chadha (1958) had reported a highly significant interaction between doses of nitrogen and potassium on the yield of tapioca at a ratio of 1:1.75. Kroachmal and Samuels (1967) have reported the highest yield of tops with high nitrogen and potash and low phosphorus.

In the manurial trials on tapioca conducted at the Central Farm, Coimbatore for over a period of five years using three levels each of different organic manures, nitrogen and potash and 2 levels of phosphorus have shown that the main effects of nitrogen, potash and interaction NPK, and MNPK were significant during the second year of the experiment (Anonymous 1962). Manuring-cum-spacing trials conducted for five years at three different Tapioca Research Stations in Kerala revealed that a steady response to yield was due to nitrogen and potassium (Anonymous, 1963). Experiments conducted at Vellayani revealed that the optimum manurial dose for tapioca was 150 kg nitrogen, 130 kg P_2O_5 and 250 kg K_2O and 1100 kg CaO per hectare (Pillay, 1967). He also observed that higher doses of nitrogen and potash alone influenced the weight of the vegetative parts. Chew (1970) reported that the best fertiliser recommendation for tapioca on peat consisted of a mixture of 180 lb N per acre (202.5 kg per hectare) 50 to 60 lb P_2O_5 per acre (56.25 to 121.25 to 135 kg per hectare).

The combination of 120 kg nitrogen and 120 kg potash recorded the highest yield in cassava. Interaction of nitrogen and potash was significant in increasing the number of tubers per plant with the variety-165 (Anonymous, 1972). Kumar _et al._(1972) reported that there was significant interaction between nitrogen and potash in increasing yield. The yield in treatment N:K 100:100 was significantly superior to that of treatment N:K-100:50.

D. Influence of nitrogen and potash on the quality of tuber.

Dry matter content

Pillay (1967) reported that the nutrients nitrogen phosphorus, potassium and calcium individually and nitrogen and potassium in combination increased the per cent of dry matter content of tapioca tuber. Similar results were obtained by Vijayan and Iyer (1968) who found that the individual effects of nitrogen and phosphorus as well as their combined effect were significant in increasing the per cent of dry matter. He also observed that there was not much difference in the dry matter content with varying levels of nitrogen.

Crude protein content

Mudaliar (1957) and Magoon and Appan (1966) reported that the Crude protein content of tapioca generally ranged from 1.20 to 1.75 per cent though varieties having upto 10 per cent of crude protein had been noticed.

Malavolta et al.(1955) reported that high levels of nitrogen while decreasing the starch content increased the protein percentage. Investigations at the Tapioca Research Station, Trivandrum revealed that the application of nitrogen increased the nitrogen content of tuber while potassium showed a negative influence (Anonymous, 1960). Pillai (1967) observed that crude protein content of tuber was significantly increased with the application of higher doses of nitrogen and phosphorus while the highest dose of potash ie. 200 kg per hectare resulted in significant reduction in crude protein. Vijayan and Iyer (1968) found nitrogen had significant effect in increasing the crude protein percentage of tuber. He also observed that there was not much difference in the protein content of tubers with varying levels of nitrogen.

Starch content

Investigations carried out in Tapioca Research Station at Trivandrum have shown that application of nitrogen decreased the starch content of tubers, while higher doses of potassium produced a significant increase in the percentage of starch (Anonymous, 1957). Pillai (1967) reported that the graded doses of nitrogen, phosphorus and potash progressively increased the starch content to 80.68 (on oven dry basis) was recorded as a result of combined application of 150 kg nitrogen and 200 kg potash per hectare. Kumar et al.(1971) have reported that the maximum starch content of cassava tubers (33.5%) was obtained by the split application of 100 kg K_2O per hectare.

Hydrocyanic acid content

Joachim and Sekhare (1944) in their investigation on hydrocyanic acid content of cassava reported that it varied from tuber to tuber in the same clump and within a tuber itself. Dean (1957) estimated the hydrocyanic acid content of 14 varieties of tapioca in Hawaii and found that it varied from 40 to 65 mg per kilogram of fresh tuber.

Pereira *et al.*(1960) after estimating the hydrocyanic acid content in a number of varieties in Brazil found that the bitter varieties contained 3 times more of the toxic principle than the sweet varieties. Sinha and Nair (1967) from a study of 33 varieties of tapioca concluded that the hydrocyanic acid content varied from 30 to 490 mg per kilogram of fresh tubers. The hydrocyanic acid content between tubers of the same plant and between the different parts of the same tuber was not significant.

Bruijn (1967) reported that the cyanoglycoside content of tubers and leaves increased by the application of nitrogen and decreased by potassium and farm yard manure.
Magoon et al.(1970) reported that the hydrocyanic acid content of tuber at 10th month stage was 44, 22 and 14 mg per kilogram of tuber from soil, split and foliar application of 100 kg nitrogen per hectare respectively. Indira *et al.*(1972) reported that the application of nitrogen and phosphorus alone increased the hydrocyanic acid content of tubers

while potassium alone or in combination with phosphorus and nitrogen reduced the hydrocyanic acid content of tuber. But Bolhuis (1954) investigating the toxicity of tapioca roots in Netherlands could not establish any relationship between soil nitrogen and degree of toxicity. He also reported that the " Linamarin" content was markedly increased by drought and potash defeciency.

MATERIAL AND METHODS

MATERIAL AND METHODS

The present investigation was undertaken to study the effect of nitrogen and potash on growth, yield and quality of tapioca - variety H-165.

I. Experimental site

The investigation was carried out in the farm attached to the College of Agriculture, Vellayani. The soil of the experimental site is red loam. The chemical properties of the soil from the experimental area are given below:-

Total nitrogen	= 0.056%
Total phosphoric acid ..	= 0.032%
Total potash	= 0.0689%
Available phosphoric acid	= 0.00209%
Available potash	= 0.00065%
pH	= 5.1

II. Season

The crop was planted on 6th July, 1974 and harvested on 12th March 1974. The weather data recorded during the above period are furnished in Appendix I.

III. Planting material

The variety H-165, selected for the experiment is derived from a cross between two local varieties viz., 'Chadayamangalam Vella' and 'Kalikalan', evolved at the Central Tuber Crops Research Institute, Trivandrum. This variety is high yielding (35 to 45 metric tonnes per hectare) and early maturing. It is an unbranched or sparsely branched type facilitating more plants per unit area. The tubers are short, compact and well suited for home consumption if harvested within 8 months. The hybrid responds well to fertilization. This variety also shows field resistance to pests and diseases.

IV. Fertilization

Ammonium sulphate, superphosphate and muriate of potash were used as the source of nitrogen, phosphoric acid and potassium respectively. A uniform basal dose of organic manure was given at the rate of 12.5 tonnes per hectare. The nitrogen and potash were applied in three levels each viz., 50 kg, 100 kg and 150 kg per hectare.

Chemical analysis of the fertilizers showed the following composition.

Ammonium sulphate	= 20.1% nitrogen
Superphosphate	= 16% phosphoric acid.
Muriate of potash	= 60% potash.

V. Experimental details

a) Treatments

Factorial combination of three levels of nitrogen and three levels of potash constituted the treatments. The levels of the individual nutrients were fixed based on the results of the previous trials. The fertilizers were applied in two equal split doses first at the time of planting and the second dose 60 days after planting.

The levels of the individual nutrients are as follows:-

Nitrogen - 3 levels

n_1 - 50 kg N/ha

n_2 - 100 kg N/ha

n_3 - 150 kg N/ha

Potash - 3 levels

k_1 - 50 kg K_2O/ha

k_2 -100 kg K_2O/ha

k_3 -150 kg K_2O/ ha.

The treatment combinations are

1.	n_1	k_1	2.	n_1	k_2	3.	n_1	k_3
4.	n_2	k_1	5.	n_2	k_2	6.	n_2	k_3
7.	n_3	k_1	8.	n_3	k_2	9.	n_3	k_3

b) The layout and design

The experiment was laid out in factorial experiment in Randomised Block Design with four replications. The design of the experiment is given in Figure I.

c) Size of the plot

Gross plot size = 4.5 M x 4.5 M

Net plot size = 3.0 M x 3.0 M

d) Spacing adopted

75 cm x 75 cm on either way.

VI. Details of cultivation

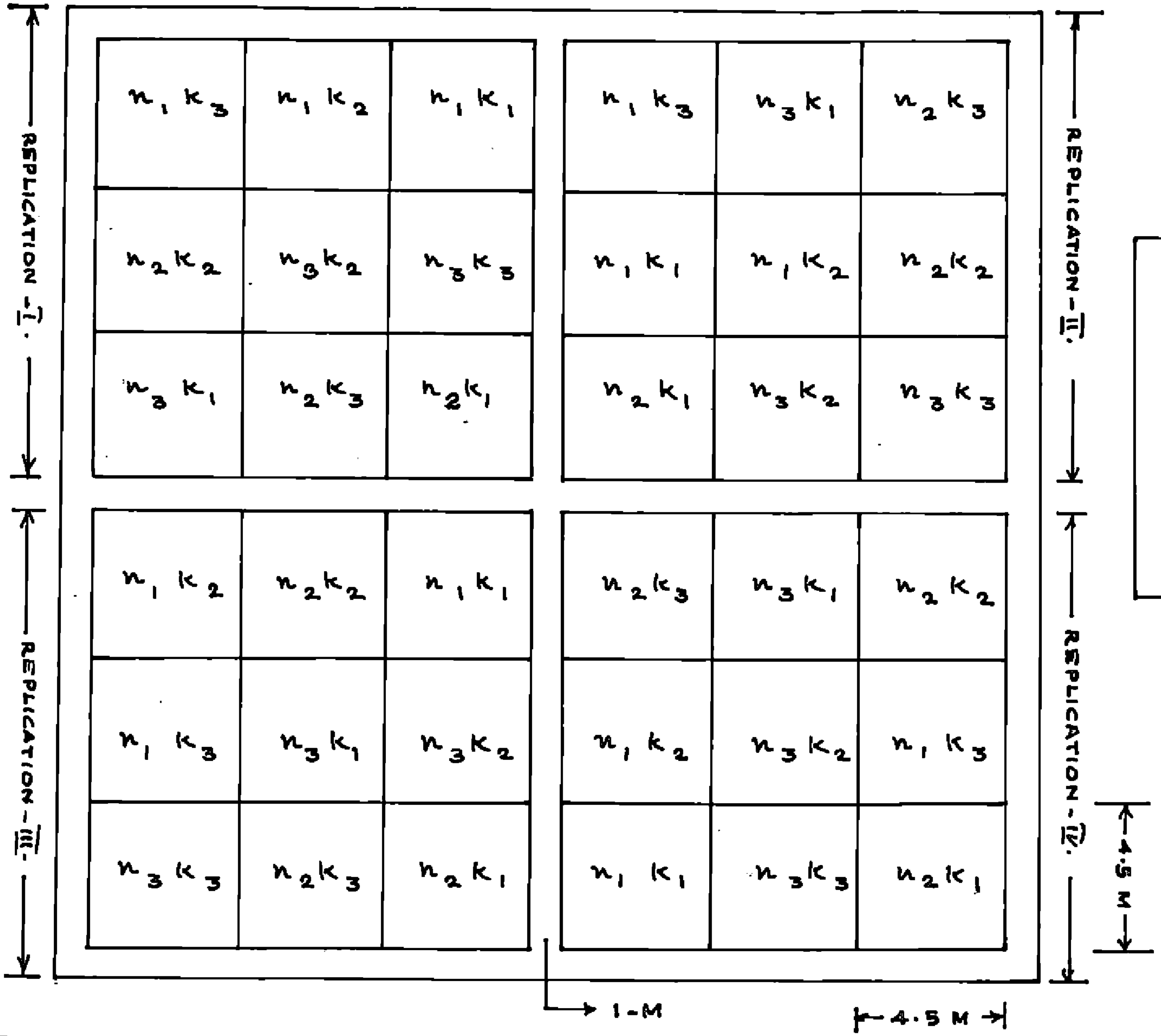
i) Preparatory cultivation

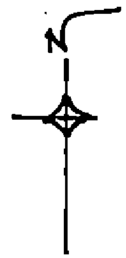
The experimental site was given two deep ploughings with tractor. Plot size of 4.5 M x 4.5 M were laid out in four blocks. The plots were given a thorough digging and then levelled. The cattle manure at the rate of 12.5 tonnes per hectare was uniformly spread in all plots and incorporated into the soil. Mounts were taken in lines 75 cms apart.

ii) Planting

Planting was done on 10-7-1974. Tapioca cuttings were planted vertically at the centre of the mounts at the rate of

LAY OUT PLAN — RANDOMISED BLOCK DESIGN





LEVELS OF NITROGEN

N1 - 50 - Kg. N. / HECTARE
N2 - 100 - Kg. N. / HECTARE
N3 - 150 - Kg. N. / HECTARE

LEVELS OF POTASH

K1 - 50 - Kg. K2O / HECTARE
K2 - 100 - Kg. K2O / HECTARE
K3 - 150 - Kg. K2O / HECTARE

FIG: I.

one sett per mount.

iii) Manuring

Nitrogen, phosphoric acid and potash were applied as ammonium sulphate, superphosphate and muriate of potash in two split doses one dose as the basal on 9-7-1974 and the other at two months after planting on 10-9-1974. The fertilizers were applied in basins formed around each plant and covered properly.

General condition of the crop

Germination of the setts was satisfactory. A few setts found dried up were removed and replanted with fresh cuttings. The sprouts were healthy and vigorous. Sprouts in excess of two per plant were nipped off a week after their emergence. The general stand of the crop was satisfactory throughout the period of growth.

v) Inter-cultivation and weeding

A light raking and weeding was given on 24-4-1974. The first earthing up was given on 11-8-1974. The second earthing and top dressing were done on 10-9-1974. The third earthing up, was given on 9-10-1974.

vi) <u>Plant protection</u>

There was no incidence of any pest or disease.

vii) <u>Harvest</u>

The maturity of the crop was indicated by the falling of leaves, stem colour and also by the cracking of the soil around the base of the plants.

The plants selected for biometric studies were harvested on 11-3-1975 and the necessary observations recorded. The remaining plants were harvested on 12-3-1975 and the yield recorded.

viii) <u>Observations recorded</u>

i) <u>Sampling technique for biometric studies</u>

Four plants from the net plot standing in a diagonal line in the same direction were selected from all the plots for studying the biometrical characters.

ii) <u>Pre-harvest observations</u>

Number of leaves per plant.

Height of the plants.

iii) <u>Post-harvest observations</u>

Number of tubers per plant.

Number of unproductive roots per plant.

Mean length of tuber.

Mean girth of tuber.

Weight of the aerial parts of plant.

Yield of tuber from the net plot.

Ratio of flesh to rind in tuber.

Starch content of tuber.

Nitrogen and crude protein content of tuber.

Hydrocyanic acid content of tuber.

iv) Techniques adopted forrecording observations

a) Germination

Three observations were taken at an interval of three days viz., on 9th, 12th and 15th day after planting. Gap filling was undertaken on the 9th day of planting. Further observations showed that there was no more drying up of setts.

b) Height of the plants

Height was measured from the base of the sprouts to the tip of the plant in cm at an interval of 30 days upto 210th day after planting. The final height at the time of harvest was also recorded.

c) Number of leaves per plant

The first observation was taken on the 30th day after planting and the subsequent observations were taken at an interval of 30 days upto 210th day. The total number of leaves per plant till the time of harvest was recorded by counting the total number of leaf scars from the base to the tip of the stem, on the previous day of the harvest.

d) Yield of the net plot

The total weight of the tubers of plants in the net plot was recorded in kilogram and the average worked out.

e) Number of tubers per plant

The total number of tubers from each of the four observation plants were counted and the average was recorded as the number of tubers per plant.

f) Number of unproductive roots per plant

The total number of roots which are unproductive from each of the four observation plants was counted and the average recorded.

g) Length of tuber

The length of medium tubers collected from the observation plants was measured in centimetres. The average length was also worked out.

h) <u>Girth of tuber</u>

The measurement of girth of tubers of each four plants in each plot was taken one at the centre and the other at two cms away from the tips of the tuber and the average was recorded in cm as girth of tubers.

i) <u>Weight of the aerial parts of the plant</u>

The total weight of the stem and leaves of the four observation plants at the time of harvest was noted and the average recorded.

j) <u>Ratio of flesh to rind in tuber</u>

A random sample of 1000 gms of tubers was weighed from each plot and the weight of the fleshy edible portion and rind was taken separately after peeling and the percentages were calculated and recorded.

k) <u>Percentage of crude protein content of tuber</u>

The nitrogen content of oven dried samples from individual plots were estimated by the Kjeldahl's method (Piper, 1948). Crude protein content was calculated by multiplying the nitrogen by a constant 6.25 and recorded.

a) Percentage of starch content in tuber

The percentage of starch contained in the oven dried sample from individual plots were estimated by the method as suggested in AOAC (1956).

b) Hydrocyanic acid content

The hydrocyanic acid content of the oven dry sample was estimated by AOAC (1956) method and expressed as mg/kg of dried tuber.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

An investigation was carried out at the College of Agriculture, Vellayani during 1974-1975 to study the effect of nitrogen and potash on the growth, yield and quality of a high yielding variety of tapioca H-165. The effects on the various biometric characters as well as the yield were studied to assess how best each attribute has been influenced by the treatments. The data relating to various observations taken were statistically analysed. The results obtained from the present study are discussed hereunder.

A. Growth characters

1. Number of leaves

The data on the number of leaves per plant at 30, 60, 90, 120, 150, 180, 210 days after planting and the total number of leaves at harvest are presented in Tables 2(a) and (b) and figures II (a) and (b) and their analysis of variance in Appendices from II (a) to II (h).

The results show that in the early stages, ie., at 30 and 60 days after planting, the levels of nitrogen exerted significant influence in increasing the mean number of leaves per plant. Nitrogen being the key element

Table 2 (a)

Effect of different levels of nitrogen on number of leaves per plant

Treatment (Levels of nitrogen)	Days after planting							
	30	60	90	120	150	180	210	At harvest
N_{50}	37.91	48.43	43.86	46.12	26.93	28.03	38.34	209.29
N_{100}	41.28	51.36	43.67	47.61	26.83	28.65	39.44	215.84
N_{150}	42.39	54.13	46.73	48.90	27.35	28.89	29.20	222.89
SEm $\pm$	..	..	1.00	1.41	1.10	1.10	4.75	4.02
C.D.(0.05)	2.07	2.95	..	..	..	..	..	..
'F' test	(Sig)	(Sig)	(NS)	(NS)	(NS)	(NS)	(NS)	(NS)

NS = Not significant

Table 2 (b)

Effect of different levels of potash on number of leaves per plant

Treatments (Levels of potash)	Days after planting							
	30	60	90	120	150	180	210	At harvest
K_{50}	39.99	50.05	42.59	46.03	26.69	27.55	38.18	210.12
K_{100}	40.67	50.82	44.63	46.15	27.03	28.02	38.58	215.43
K_{150}	40.92	53.03	47.05	50.45	27.41	27.97	40.42	221.98
SEM +	0.765	1.00	..	..	1.10	1.10	4.75	4.02
C.D.(0.05)	..	..	2.16	3.71	..	..	..	..
'F' test	(NS)	(NS)	(Sig)	(Sig)	(NS)	(NS)	(NS)	(NS)

NS = Not significant

NUMBER OF LEAVES PER PLANT

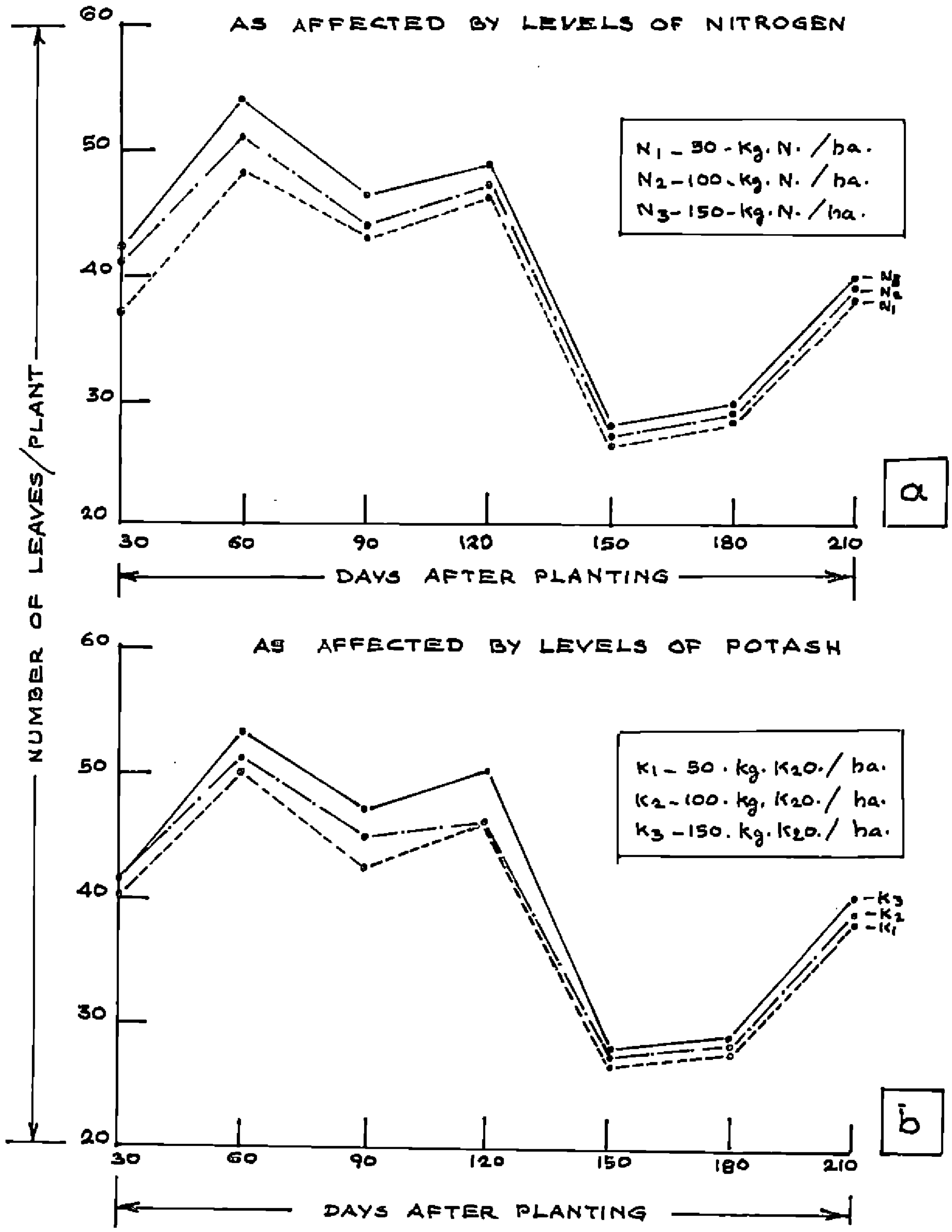


FIG: II

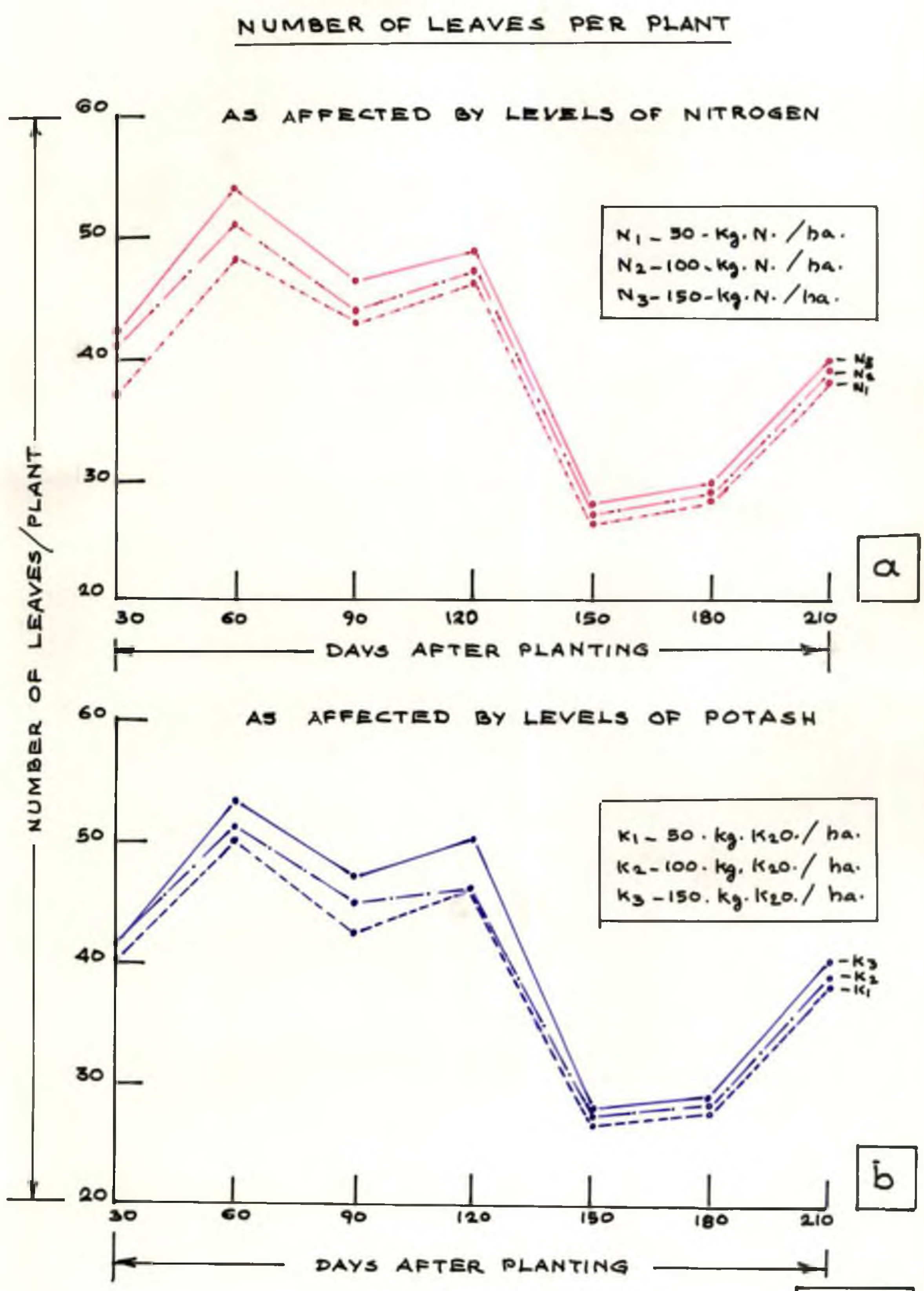

NUMBER OF LEAVES PER PLANT
AS AFFECTED BY LEVELS OF NITROGEN
N1 - 50 - Kg. N. / ha.
N2 - 100 - Kg. N. / ha.
N3 - 150 - Kg. N. / ha.
a
AS AFFECTED BY LEVELS OF POTASH
K1 - 50 . kg. K2O. / ha.
K2 - 100 . kg. K2O. / ha.
K3 - 150 . kg. K2O. / ha.
b
NUMBER OF LEAVES/PLANT
DAYS AFTER PLANTING
30 60 90 120 150 180 210
20 30 40 50 60

FIG: II

of plant growth it is quite natural that its effect has been reflected in the vegetative growth in an increased number of leaves. Malavolta *et al.*(1955) and Kroachmal and Samuels (1967) have proved beyond doubut that the higher levels of nitrogen increase the vegetative growth of the plant.

But in the later stages it is seen that the levels of nitrogen did not have any significant influence in increasing the mean number of leaves per plant. This may be due to the fact that a good amount of nitrogen absorbed at the later stages would have been utilised for starch synthesis. Maximum number of leaves was produced at 60th day after planting. The increase in the number of leaves produced at 60th day was found to be more than that noticed at 120th day. This may be due to the fact that the first dose of nitrogen given as basal application would have been more effective for the vegetative development and the later application would have exerted only lesser effect on the vegetative growth.

With regard to potash it is found that the levels of potash had no effect in the early stages in increasing the mean number of leaves per plant. This may be due to low absorption of potash by plants in the early stages. At the Tapioca Research Station, Trivandrum it was observed that the maximum absorption of potash is only at 3 to 4 months after planting (Anonymous, 54, 1962).

It is seen that at 90th and 120th day the levels of potash had a marked influence in increasing the mean number of leaves per plant. In both cases the higher level of potash (150 kg per hectare) was found to be superior to lower levels. Ward (1955) and Thomas (1965) have reported increase in the number of leaves with increasing levels of potash in potato and sweet potato respectively.

Maximum number of leaves was produced at 60th day after planting. As in the case of nitrogen the increase in the number of leaves produced at 60th day after planting was found to be more than the increase noticed at 120th day. Here also the basal application would have exerted greater influence on the vegetative development whereas the top dressing had a lesser effect. In the later stages of growth the effect of potash was not significant in increasing the mean number of leaves per plant. The reduction in the number of leaves after 120th day of planting indicates that the active vegetative phase was being completed and the plants were advancing towards maturity. The food materials produced by photosynthesis which are being utilised by aerial parts of plants in larger amounts till then, get translocated for the development of storage organs namely the tuber.

The interaction between nitrogen and potash remained not significant throughout the growth period.

2. Height of plant

The data relating to height of plants at 30, 60, 90, 120, 150, 180, 210 days after planting and the total height at harvest were statistically analysed and their analysis of variance are presented in Appendices from III (a) to III (h).

The data on mean height of plants are presented in Tables 3 (a) and 3 (b) and figures III (a) and (b).

The data in Table 3 (a) reveal that the levels of nitrogen had a significant effect on the mean height of plants in all successive stages of growth. At 30th, 60th

Table 3 (a)

Effect of different levels of nitrogen on height of plant (in cm)

Treatments (Levels of nitrogen)	Days after planting							
	30	60	90	120	150	180	210	At harvest
N_{50}	39.83	62.62	89.09	102.38	115.44	117.35	137.47	137.63
N_{100}	41.79	67.49	94.52	110.13	120.85	123.22	140.33	141.36
N_{150}	43.63	75.09	104.08	118.79	132.49	129.99	149.83	150.37
'F' test	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)
C.D.(0.05)	2.54	5.12	7.43	7.44	16.77	9.80	9.23	9.23

Table 3 (b)

Effect of different levels of potash on height of plant (in cm)

Treatment (Levels of potash)	Days after planting							
	30	60	90	120	150	180	210	At harvest
K_{50}	40.25	65.35	90.58	104.39	115.03	116.65	135.36	136.27
K_{100}	42.98	68.25	95.86	110.94	120.50	121.79	141.77	141.41
K_{150}	42.92	71.59	101.24	115.96	133.26	132.12	150.51	151.76
SEM ±	0.90	1.74	..	..	..	..	..	..
C.D.(0.05)	..	..	7.43	7.44	16.77	9.80	9.23	9.23
'F' test	(NS)	(NS)	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)	(Sig)

NS = Not significant

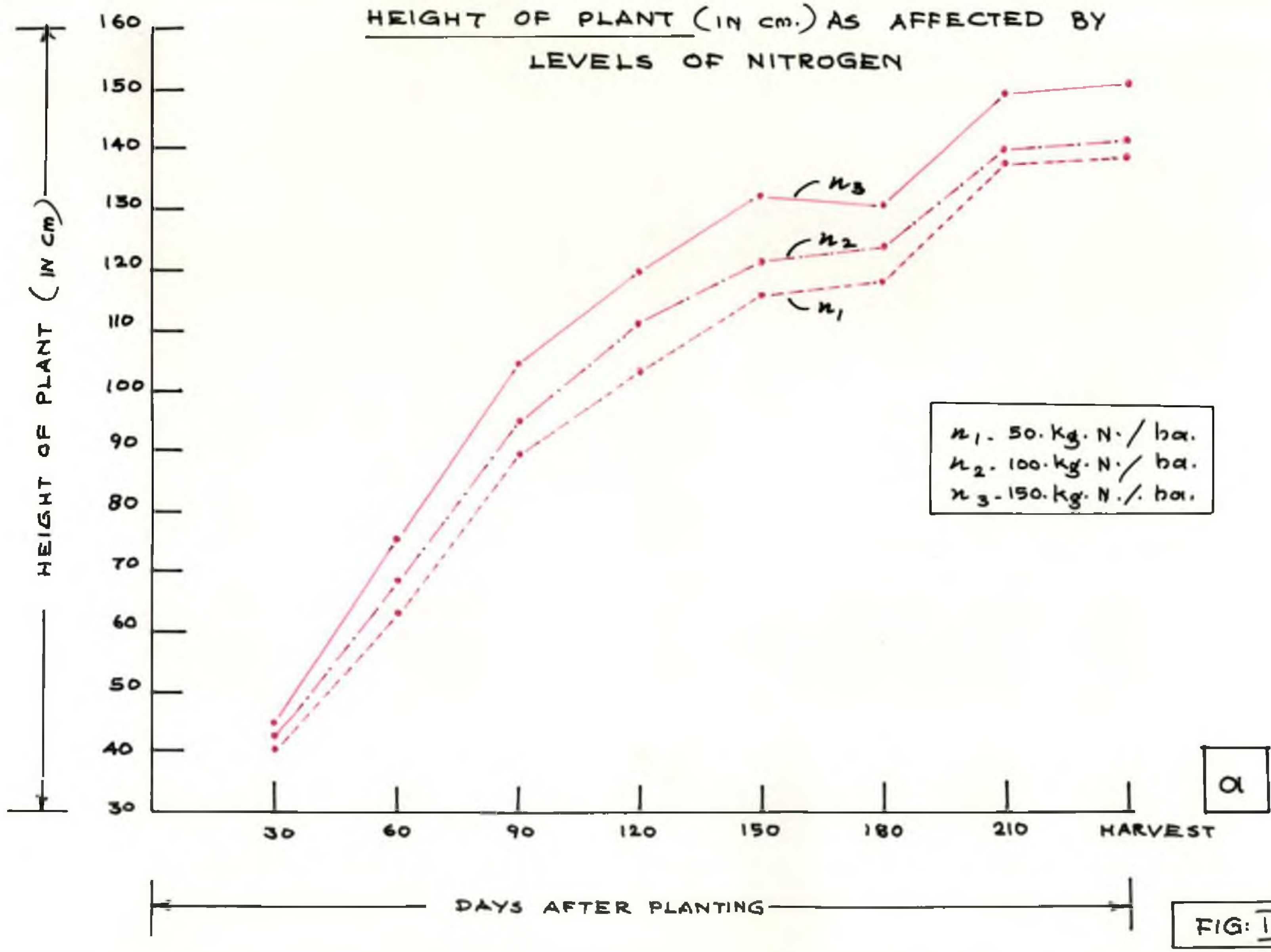
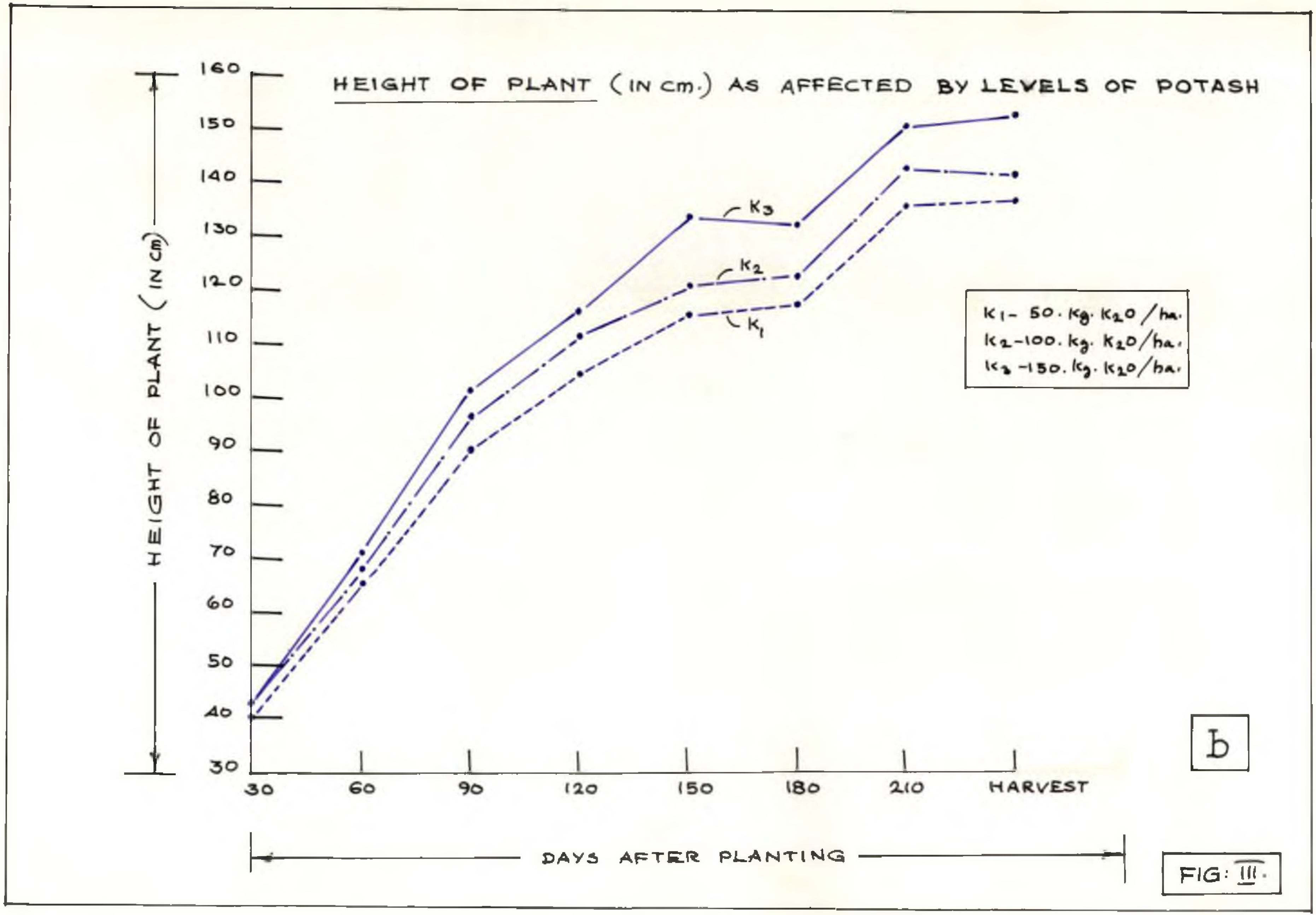

HEIGHT OF PLANT (IN cm.) AS AFFECTED BY LEVELS OF NITROGEN
HEIGHT OF PLANT (IN cm)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
30
60
90
120
150
180
210
HARVEST
DAYS AFTER PLANTING
n3
n2
n1
n1 - 50. kg. N. / ha.
n2 - 100. kg. N. / ha.
n3 - 150. kg. N. / ha.
a

FIG: III



HEIGHT OF PLANT (IN cm.) AS AFFECTED BY LEVELS OF POTASH
HEIGHT OF PLANT (IN cm)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
30
60
90
120
150
180
210
HARVEST
DAYS AFTER PLANTING
K3
K2
K1
K1- 50. kg. K2O / ha.
K2-100. kg. K2O / ha.
K3-150. kg. K2O / ha.
b

FIG: III.

and 90th days, the highest level of nitrogen (150 kg per hectare) was found to be superior to lower levels. But the lower levels remained on par. At 120th day there was an increase in the mean height of plant with incremental doses of nitrogen. But in the latter stages the highest level of nitrogen alone was significant in increasing the mean height of plant. As stated earlier nitrogen being a key element of plant growth, its effect on the vegetative growth is reflected on the height of plants.

In the early stages of growth the effect of potash on mean height of plant was not significant (Table 3 (b)). Again, as in the case of number of leaves per plant, the lack of effect of potash on the height of plants may be due to the lesser absorption of potash by plants in the early stages. The limited absorption of potash in the early stages is in agreement with the findings of the Tapoica Research Station where it was found that the maximum absorption of potash is only after 3-4 months of planting (Anonymous, 1954, 1962).

At 90th day the highest level of potash (150 kg per hectare) was found to be significantly superior to the lower levels in increasing the mean height of plants. But the lower levels remained on par. In all the remaining stages the higher levels of potash had a significant effect over lower levels in increasing the mean height of plants. But between lower levels there was no significant difference The effect of potash in increasing the plant height was reported by Pillai (1967) who found that the plant height was significantly increased by the application of higher doses of potash. Purewal and Dargon (1957) have also recorded increase in height of colocasia due to application of nitrogen and potash in Punjab.

The interaction of nitrogen and potash had no effect in the height of plants as in the case of number of leaves per plant.

B. Yield attributes and yield

1. Number of tubers per plant

The data on mean number of tubers per plant are presented in Table 4 and their analysis of variance in Appendix IV.

The results show that neigher the levels of nitrogen and potash nor their combination had any effect in

Table 4

Effect of levels of nitrogen and potash on number of tubers per plant

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	8.43	11.50	10.40	10.11
K_{100}	10.50	10.70	9.28	10.16
K_{150}	10.48	11.40	11.78	11.22
Mean	9.80	11.20	10.49	10.49

SEM $\pm$ = 0.458

increasing the mean number of tubers per plant. Although the levels of potash had no significant effect, there was an increasing trend on the mean number of tubers per plant with higher doses of potash. The above finding is in agreement with that of Mandal and Mohankumar (1972) who found that there was not much difference in the number of tubers per plant by the application of higher levels of potash with the same variety (H-165).

2. Number of unproductive roots

The data on mean number of unproductive roots per plant are presented in Table 5 and their analysis of variance in Appendix V.

The data show that neither the levels of nitrogen and potash nor their interaction had any effect in the mean number of unproductive roots per plant. But a decreasing trend in the number of unproductive roots with the increasing levels of potash was noticed. It is quite natural that when there is an increasing trend in the number of tubers per plant (Table 4) there will be a fall in the number of unproductive roots per plant. This may probably be the reason why the levels of potash could

Table 5

Effect of different levels of nitrogen and potash on number of unproductive roots per plant

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	4.53	5.28	4.28	4.69
K_{100}	4.23	4.60	4.58	4.47
K_{150}	4.78	4.33	3.90	4.33
Mean	4.51	4.73	4.25	4.49

SEM $\pm$ = 0.489

produce a decreasing trend in the mean number of unproductive roots.

3. Length of tuber

The data on mean length of tuber at harvest are presented in Table 6 and their analysis of variance in Appendix VI.

The results show that the levels of nitrogen and potash and their combination had no significant effect in increasing the mean length of tuber. But an increasing trend in the length of tuber with increasing levels of nitrogen was noticed.

Since nitrogen is involved in the vegetative growth, the present observation that nitrogen had no effect in increasing the length of tuber is in agreement with the findings of Alexander (1973) in sweet potato. Pillai (1967) observed that the effect of nitrogen and potash was not significant in increasing the length of tuber in tapioca.

4. Girth of tuber

The Table 7 presents the data on the mean girth of tubers and their analysis of variance is given in Appendix VII.

Table 6

Effect of different levels of nitrogen and potash on length of tuber (in cm)

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	21.55	22.33	21.75	21.87
K_{100}	20.65	22.98	22.60	22.07
K_{150}	22.83	21.65	21.98	22.15
Mean	21.68	22.32	22.11	22.03

SEM $\pm$ = 0.469

Table 7

Effect of different levels of nitrogen and potash on girth of tuber (in cm)

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	14.53	14.78	14.95	14.75
K_{100}	14.85	14.98	14.78	14.87
K_{150}	15.75	15.75	15.30	15.60
Mean	15.04	15.17	15.01	15.07

C.D.(0.05) for the comparison between marginal means = 0.70

The results show that neither the levels of nitrogen nor the treatment combinations had any effect on the mean girth of tuber. But with increasing levels of potash there was an increase in the girth of tuber. The highest level of 150 kg K_2O per hectare was found significantly superior to 50 kg and 100 kg K_2O per hectare. Here again the effect of nitrogen follows the similar pattern as in the case of length of tuber.

In sweet potato it was found that nitrogen had no effect in increasing the girth of tuber (Alexander, 1973). Pillai (1967) observed that the higher levels of potash increased the girth of tuber. Since the potash is involved in the synthesis of starch, the higher levels would have enabled the uptake of more potash which in turn resulted in the increase in the girth of tuber.

5. Weight of the aerial parts of plant

The data on mean weight of aerial parts are presented in Table 8 and their analysis of variance in Appendix VIII.

From the results it is seen that higher levels of nitrogen and potash had significant effect in increasing the weight of the aerial parts of plant. Pillai (1967) observed that the weight of the vegetative parts of the

Table 8

Effect of different levels of nitrogen and potash on weight of the aerial parts of plant (in kg)

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	2.330	3.200	3.700	3.076
K_{100}	3.000	3.800	4.000	3.600
K_{150}	4.100	3.330	3.450	3.626
Mean	3.143	3.443	3.716	3.434

C.D.(0.05) for comparison between marginal means = 0.290
C.D.(0.05) for comparison between combinations = 0.490

plants increased with the application of higher doses of nitrogen and potash. The interaction between nitrogen and potash was also highly significant in increasing the mean weight of the aerial parts of plant. The maximum weight of 4.100 kg was recorded under combinations of 50 kg nitrogen and 150 kg potash per hectare whereas the minimum weight of 2.330 kg was noted at 50 kg nitrogen and 50 kg potash.

6. Ratio of flesh to rind in tuber

The data on the ratio of flesh to rind are furnished in Table 9 and their analysis of variance in Appendix IX.

The results show that only potash had significant effect in increasing the proportion of flesh to rind. The significant difference noted between the highest level at 150 kg K_2O and lowest at 50 kg K_2O per hectare. As stated earlier, since potash is involved in the starch synthesis, higher levels of applied potash would have resulted in greater uptake of potash which in turn increased the relative proportion of flesh to rind in tuber. This may probably be the reason for the higher flesh to rind ratio at the highest level of potash tried as compared to the lower levels.

Table 9

Effect of different levels of nitrogen and potash on ratio of flesh to rind in tuber

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	7.03	7.74	6.95	7.24
K_{100}	6.85	7.44	7.15	7.13
K_{150}	7.75	8.25	8.94	8.13
Mean	7.21	7.81	7.68	7.56

C.D.(0.05) for comparison between marginal means = 1.032

7. <u>Yield of tuber per hectare</u>

The data on the yield of tubers per hectare are presented in Table 10 and their analysis of variance in Appendix XI and in Figure IV (a).

The yield data show that the incremental doses of nitrogen significantly increased the yield of fresh tuber per hectare. With regard to potash the highest level (150 kg K_2O) significantly increased the yield of fresh tuber per hectare as compared to its lower levels. But between lower levels there was no significant difference. Malavolta *et al.*(1955) reported that highest tuber yield in tapioca could be obtained by doubling the dose of nitrogen. Russel (1961) found that the effect of nitrogen on root and tubers will be perceptible only on long duration crops. The pronounced increase in yield noticed in the present study is in agreement with the above findings.

The nitrogen absorbed by plants are converted into amino acids and proteins in the early stages of growth. Thus with increased levels of nitrogen supply, more protein is produced which enables the plant leaves to grow larger and hence a larger surface becomes available for photosynthesis.

Table 10

The effect of different levels of nitrogen and potash on yield of tuber (in tonnes per ha.)

Treatment	N_{50}	N_{100}	N_{150}	Mean
K_{50}	31.220	32.080	39.030	34.110
K_{100}	31.250	35.940	35.780	34.320
K_{150}	38.360	38.360	37.280	38.000
Mean	33.610	35.460	37.360	35.480

C.D.(0.05) for comparison between marginal means = 1.42
C.D.(0.05) for comparison between combinations = 2.44

In many crops the amount of leaf area available for photosynthesis is proportional to the amount of nitrogen supplied (Russel, 1961).

The effect of potash in increasing the yield of tuber crops is well established. Russel (1961) stated that in the early stages of growth, potassium increases the leaf area of the crop thus favouring better photosynthesis. In addition potassium acts as a corrective to harmful effects of nitrogen and is often required for the crops receiving high levels of nitrogenous manures. High correlation between the percentage of potassium and carbohydrate was found to exist in plants. According to Meyer and Anderson (1952) potassium does not enter into organic combination within the plants. They remain in plants as soluble inorganic salts, their fundamental role in plants being undoubtedly regulatory or catalytic. The carbohydrate metabolism is disturbed by inadequate supplies of potassium.

The increase in the yield of tuber due to application of potash in the present investigation is in agreement with the findings of White (1928), Grossman and de Assis (1951) Silva and Freire (1968), Magoon et al.(1971) and Mandal and Mohankumar (1972 a).

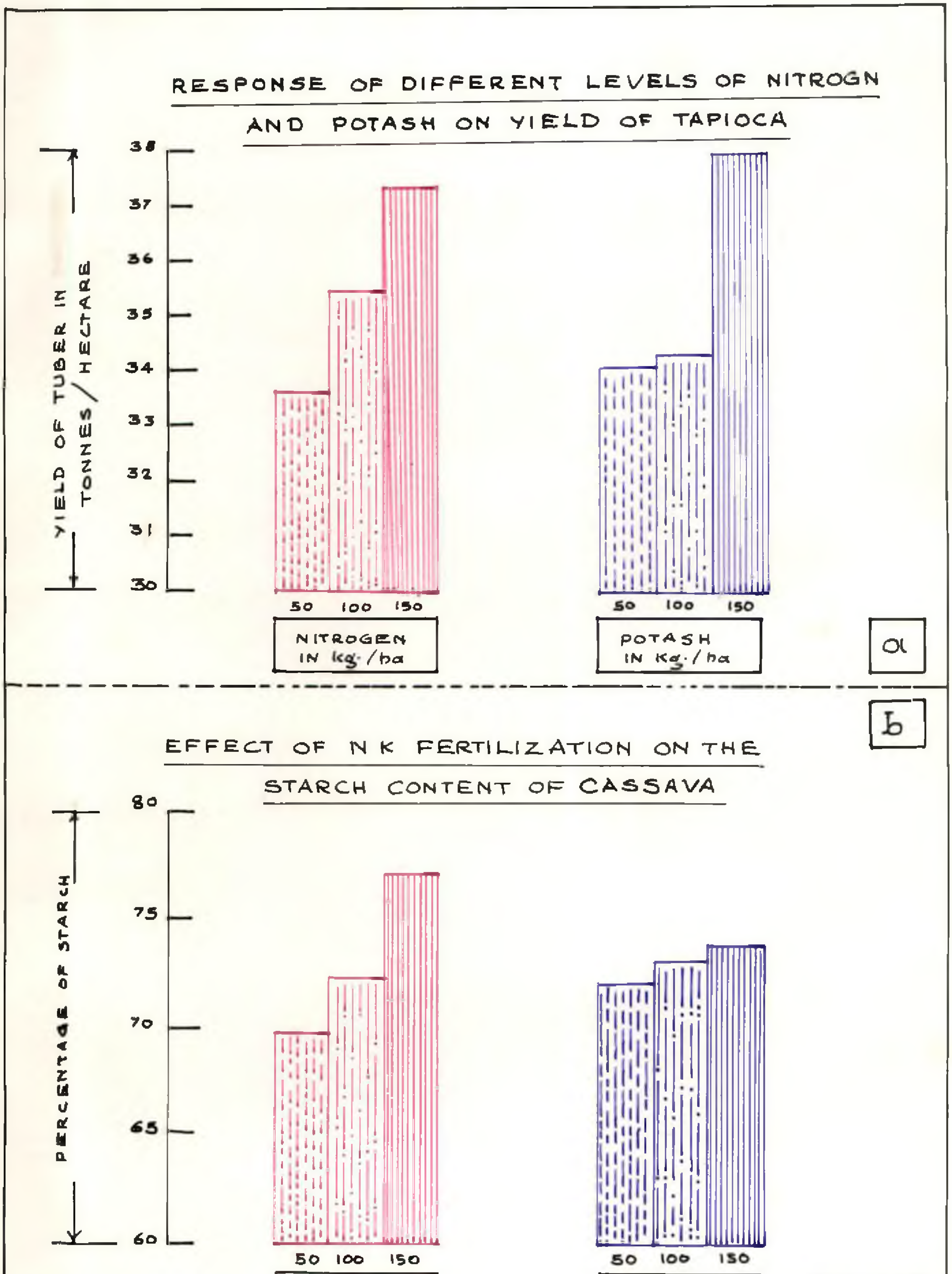

RESPONSE OF DIFFERENT LEVELS OF NITROGN
AND POTASH ON YIELD OF TAPIOCA
YIELD OF TUBER IN TONNES / HECTARE
38
37
36
35
34
33
32
31
30
50 100 150
NITROGEN IN kg./ha
50 100 150
POTASH IN Kg./ha
a
b
EFFECT OF N K FERTILIZATION ON THE
STARCH CONTENT OF CASSAVA
PERCENTAGE OF STARCH
80
75
70
65
60
50 100 150
NITROGEN IN kg./ha
50 100 150
POTASH IN Kg./ha

FIG. IV.

The combination of nitrogen and potash also had similar effect in increasing the yield of tuber per hectare. The highest yield of 39.03 tonnes of tuber per hectare was recorded with 150 kg nitrogen and 50 kg potash per hectare. The lowest yield of 31.22 tons per hectare was noted at 50 kg nitrogen and 50 kg potash per hectare. The increase in yield of tuber in tapioca due to the combined application of nitrogen and potash has been reported by Abraham (1956) and Pillai (1967).

The beneficial effects of nitrogen on length and that of potash on girth as well as their beneficial effects on the primary functions of plant growth would have contributed to the increased yield of tubers.

Quality characters

1. Percentage of starch

The data on the starch percentage of tuber are given in Table 11 and in Figure IV (b) and their analysis of variance in Appendix XII.

From the data it is found that the starch content of tuber increased with increasing levels of nitrogen. Russel (1956) has pointed out that the crops grown for their

Table 11

The effect of different levels of nitrogen and potash on starch content (%) of tuber (on oven dry basis)

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	68.80	71.73	76.65	72.39
K_{100}	69.23	72.65	77.12	73.00
K_{150}	69.73	73.03	77.70	73.48
Mean	69.25	72.47	77.15	72.96

C.D.(0.05) for comparison between marginal means = 0.60

carbohydrates such as root crops benefit from nitrogen manuring through increased leaf area brought about by nitrogen which enables higher rate of photosynthesis. The increased starch percentage due to the application of higher doses of nitrogen is in agreement with the findings of Pillai (1967) and Chidanantha Pillai (1967) in tapioca and colocasia respectively. They observed that the higher levels of nitrogen increased the percentage of starch in tuber and corm respectively.

With regard to potash the highest level of 150 kg per hectare was significantly superior to the lower level (50 kg K_2O per hectare). The lower levels also differed significantly in increasing the percentage of starch. But there was no significant difference between 100 kg K_2O and 150 kg K_2O per hectare.

The translocation of the starch formed in the leaf to the storage tuber is influenced by the action of potash. Tsuno and Fugisi (1965) have shown that potash participates in the protein metabolism or in the hydration of tuber tissues or both processes. It is therefore possible that potash may be associated with the photosynthetic activity through participation in protein metabolism and accelerated translocation of photosynthates from leaves to tubers. Therefore the results obtained in the present investigation are in agreement with the findings of Pillai (1969) and Kumar et al.(1971). The results reported by the Tapioca Research Station, Trivandrum also fully support the above observation (Anon, 1957). Similar results have been observed by Chidananda Pillai (1967) in colocasia. The interaction of nitrogen and potash was not significant in increasing the percentage of starch.

2. Nitrogen and crude protein contents of tuber

The data on the nitrogen and crude protein contents of tuber are furnished in Tables 12 and 13 and their analysis of variance in Appendices XIII and XIV respectively. The protein content of tuber is illustrated in Figure V (a).

The results show that nitrogen increased the nitrogen and crude protein content of tuber progressively. But contrary to the above a gradual reduction in the nitrogen and crude protein contents of tuber was noticed with increasing levels of potash. Malavolta et al.(1955)

Table 12

Effect of different levels of nitrogen and potash on nitrogen % in tuber (on oven dry basis)

Treatment	N_{50}	N_{100}	N_{150}	Mean
K_{50}	0.3575	0.4362	0.4505	0.4137
K_{100}	0.3146	0.4147	0.4290	0.3861
K_{150}	0.2717	0.3933	0.4147	0.3599
Mean	0.3146	0.4137	0.4314	0.3866

C.D.(0.05) for comparison between marginal means =0.0054

and
potash on crude protein content (%) of tubers
(on oven dry basis)

Treatments	N_{50}	N_{100}	N_{150}	Mean
K_{50}	2.210	2.728	2.823	2.587
K_{100}	1.930	2.585	2.680	2.398
K_{150}	1.680	2.443	2.585	2.236
Mean	1.940	2.585	2.696	2.407

C.D.(0.05) for comparison between marginal means =0.036

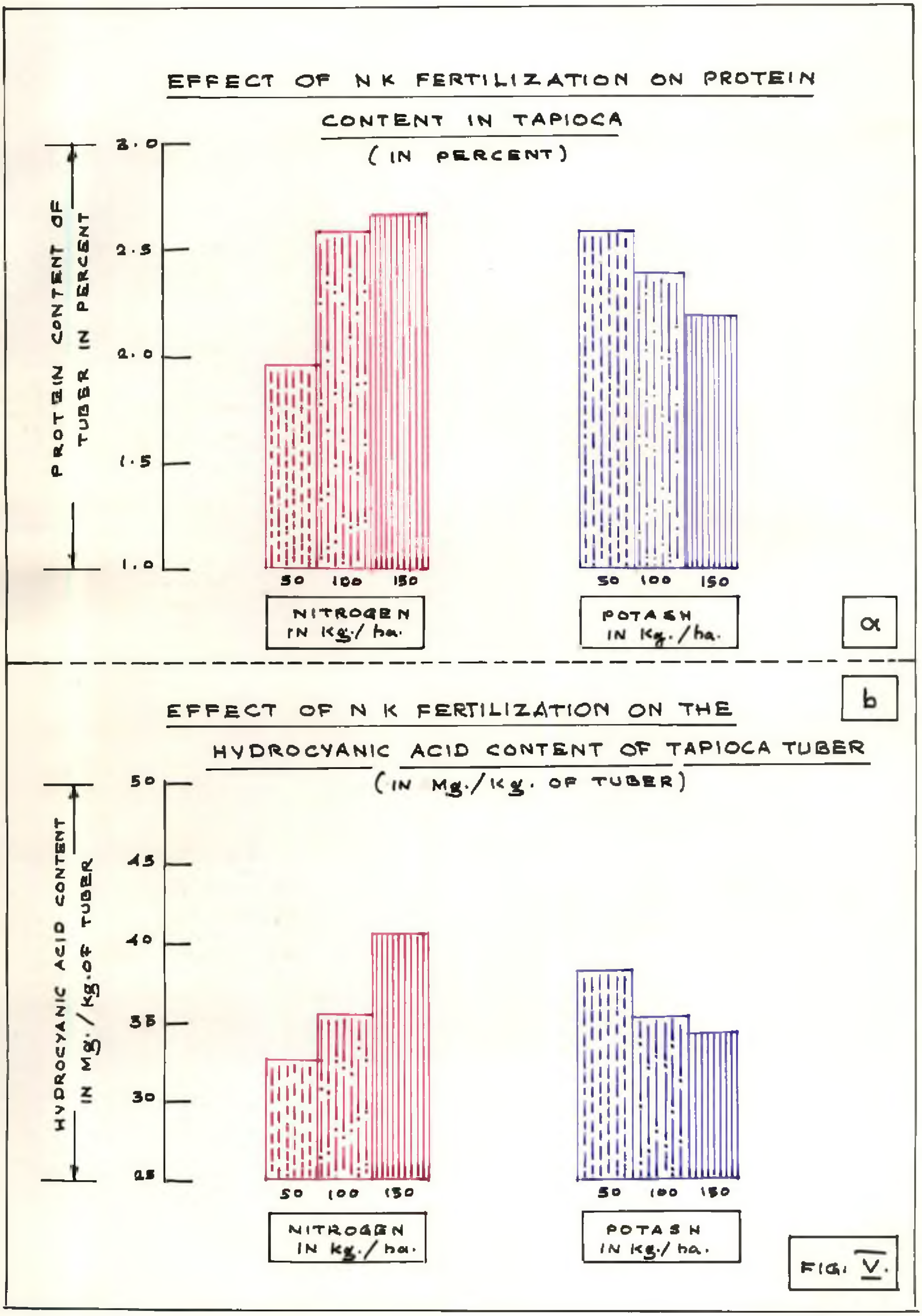

EFFECT OF N K FERTILIZATION ON PROTEIN CONTENT IN TAPIOCA
(IN PERCENT)
PROTEIN CONTENT OF TUBER IN PERCENT
3.0
2.5
2.0
1.5
1.0
50
100
150
NITROGEN IN Kg./ha.
50
100
150
POTASH IN Kg./ha.
a
b
EFFECT OF N K FERTILIZATION ON THE HYDROCYANIC ACID CONTENT OF TAPIOCA TUBER
(IN Mg./Kg. OF TUBER)
HYDROCYANIC ACID CONTENT IN Mg./Kg. OF TUBER
50
45
40
35
30
25
50
100
150
NITROGEN IN Kg./ha.
50
100
150
POTASH IN Kg./ha.

FIG. V.

have found that the higher levels of nitrogen increased the protein percentage of crops. Investigation conducted at the Tapioca Research Station, Trivandrum revealed that the application of nitrogen as ammonium sulphate increased the nitrogen content of tubers while potassium showed a negative influence (Anon, 1960). Similar results have been obtained by Pillai (1967) who observed that crude protein content of tubers was significantly increased by higher doses of nitrogen and phosphorus while potash at 200 kg per hectare resulted in significant reduction in the crude protein content of tuber. Pushpadas (1968) also found that there was a reduction in the crude protein content of tuber with the application of potash. The combined effect of nitrogen and potash did not show any significant effect on the nitrogen and the crude protein contents of tuber.

3. Hydrocyanic acid content of tuber

Table 14 and Fig. V(b) present the data on the hydrocyanic acid content of tuber. Their analysis of variance is given in Appendix XV.

The results show that the hydrocyanic acid content of tuber increased with increasing levels of nitrogen. There was a reduction in the hydrocyanic acid content

Table 14

Effect of different levels of nitrogen and potash on Hydrocyanic acid content of tuber (in mg/kg of tuber)

Treatment	N_{50}	N_{100}	N_{150}	Mean
K_{50}	36.18	38.61	43.74	39.51
K_{100}	33.48	37.26	41.58	37.44
K_{150}	32.94	36.18	39.96	36.36
Mean	34.20	37.35	41.76	34.43

C.D.(0.05) for comparison between marginal means = 2.72

with the higher dose of potash ie., 150 kg per hectare. The above results are in agreement with the findings of Bruijn (1967) and Indira et al.(1972) who reported that the cyanoglucoside content of tubers was increased by the application of nitrogen and decreased by potash. Pushpadas (1968) also reported that there was a reduction in the "Linamarin" content of tuber with the application of potash.

Economics of manuring

It is evident from the Table 16 that among the nutrients tried the highest level of potash ie., 150 kg K_2O per hectare gave the maximum profit of Rs.887.00 over its lowest level ie., 50 kg potash per hectare. But there was no corresponding increase in the yield with the 100 kg K_2O per hectare. It resulted in a loss of Rs.77.00 with regard to nitrogen the highest level (150 kg N/ha.) gave the maximum profit of Rs.625.00.

Among the two nutrients tried potash gave the maximum profit followed by nitrogen.

Table 16

Economics of application of different levels of nitrogen and potash to tapioca

Levels of nutrients in kg/ha.	Yield of tubers in tonnes per hectare	Value of produce Rs.	Increase or decrease over the lowest level Rs.	Cost of fertilizers Rs.	Extra cost of fertilizers over that of the lowest Rs.	Profit due to the fertilizer application over the lowest level Rs.
Nitrogen						
50 kg N/ha.	33.610	10083.00	..	250.00	..	..
100 kg N/ha.	35.460	10638.00	555.00	500.00	250.00	305.00
150 kg N/ha.	37.360	11208.00	1125.00	750.00	500.00	625.00
Potash						
50 kg K_2O/ha.	34.110	10233.00	..	140.00	..	..
100 kg K_2O/ha.	34.320	10296.00	63.00	280.00	140.00	-77.00 (loss)
150 kg K_2O/ha.	38.000	11400.00	1167.00	420.00	280.00	887.00

Cost of 1 kg of nitrogen .. .. = Rs.5.00
Cost of 1 kg potash .. .. = Rs.2.80
Price of a tonne of fresh tapioca tuber = Rs.300.00

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

An experiment was conducted at the College of Agriculture, Vellayani, with the object of studying the effect of different levels of nitrogen (50, 100 and 150 kg N per hectare) and potash (50, 100 and 150 kg K_2O per hectare) on the growth yield and quality of a high yielding variety of tapioca, H-165. The experiment was carried out in a 3^2 factorial Randomised Block Design with four replications. Nitrogen and potash were supplied in the form of ammonium sulphate and muriate of potash respectively.

The results of the experiment are summarised hereunder:-

1. Basal dressing of nitrogen and potash increased the number of leaves and plant height.

2. Different levels of nitrogen significantly increased the number of leaves in the early stages of growth. The maximum number of leaves was recorded at 120th day after planting at 150 kg N/hectare.

3. Nitrogen significantly increased the plant height at all stages of growth. The maximum height was recorded at harvest with 150 kg N/hectare.

4. There was increase in the number of leaves on 90th and 120th day after planting due to potash application. Maximum number of leaves was produced on 120th day after planting by 150 kg K_2O per hectare.

5. The different levels of potash increased the plant height at all stages of growth except at 30th day after planting. The maximum height was recorded at harvest with 150 kg per hectare.

6. Levels of nitrogen and potash had no effect on the number and length of tuber.

7. Different levels of nitrogen and potash or their combinations also had no effect on the reduction of unproductive roots.

8. The application of potash significantly increased the girth of tuber. The maximum girth of 15.75 cm was recorded at 150 kg K_2O per hectare.

9. Nitrogen and potash individually and in combination increased the weight of aerial parts of plant.

10. The nitrogen and potash individually and in combination significantly increased the yield of tubers. The maximum yield of 39.03 tonnes of tuber per hectare was recorded by the application of 150 kg nitrogen and 50 kg potash per hectare.

11. There was an increase in the starch content of tuber with increasing levels of both nutrients tried. The maximum per cent of (80.68%) starch was obtained with 150 kg each of nitrogen and potash per hectare.

12. There was an increase in the nitrogen and crude protein content of tuber with different levels of nitrogen and potash. The maximum of 2.587% crude protein was recorded at 150 kg nitrogen and 50 kg potash per hectare.

13. Significant reduction inthe hydrocyanic acid content of tuber was recorded with the increasing levels of potash. On the other hand there was an increase in the hydrocyanic acid content with increasing levels of nitrogen. The maximum hydrocyanic acid content of 39.96 mg per kg was recorded at 150 kg N per hectare and the minimum of 32.94 mg/kg was noted at 150 kg K_2O /hectare.

14. The highest ratio of flesh to rind was obtained for an application of K_2O at 150 kg per hectare. The different levels of nitrogen had no effect in increasing the relative proportion of flesh to rind in tuber.

15. Maximum profit of Rs.887.00 was obtained with the application of 150 kg K_2O per hectare and Rs.625.00 was obtained for the application of 150 kg nitrogen per hectare.

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APPENDICES

Appendix I

Meteorological data recorded at Vellayani during the crop season.

Crop season period (1974 and 1975)	Total Rainfall	No. of rainy days	Weekly average temperature in degree centigrade.		Weekly average humidity %
			Max.	Min.	
(1)	(2)	(3)	(4)	(5)	(6)
July 2 - July 8	58.6	2	28.2	22.3	90
July 9 - July 15	87.9	6	29.2	22.6	87
July 16 - July 22	66.5	5	27.6	22.0	93
July 23 - July 29	189.9	7	28.0	23.0	89
July 30 - Aug. 5	76.6	4	29.1	23.4	90
Aug.6 - Aug. 12	37.4	4	29.1	23.2	92
Aug.13 - Aug. 19	217.2	6	29.2	23.4	92
Aug.20 - Aug. 26	28.0	2	29.3	23.1	88
Aug.27 - Sept.2	..	.	29.6	23.2	84
Sept.3 - Sept.9	22.0	1	29.7	23.2	88
Sept.10 - Sept.16	39.0	3	28.5	23.1	89
Sept.17 - Sept.23	143.0	5	29.1	23.7	89
Sept.24 - Sept.30	70.0	6	29.0	23.7	92
Oct.1 - Oct. 7	9.0	3	29.1	23.6	89
Oct.8 - Oct.14	103.0	2	30.1	23.2	87
Oct.15 - Oct.21	..	.	30.3	23.7	91
Oct.22 - Oct.28	..	.	30.7	24.1	86
Oct.29 - Nov.4	..	.	30.7	23.1	87
Nov.5 - Nov.11	22.4	1	29.3	22.8	90
Nov.12 - Nov.18	8.6	1	30.5	22.3	88

Appendix I (Contd.)

(1)	(2)	(3)	(4)	(5)	(6)
Nov.19 - Nov.25	33.5	1	30.7	23.0	89
Nov.26 - Dec. 2	..	..	31.2	23.9	86
Dec. 3 - Dec. 9	..	..	30.9	23.3	87
Dec.10 - Dec.16	..	..	31.2	22.8	89
Dec.17 - Dec.23	..	..	31.3	23.2	89
Dec.24 - Dec.30	..	..	31.4	23.4	86
Dec.31 - Jan.6 - '75	..	..	31.5	21.6	86
Jan. 7 - Jan.13	..	..	31.2	22.3	87
Jan.14 - Jan.20	40.0	2	30.9	22.4	89
Jan.21 - Jan.27	..	..	31.0	23.2	89
Jan.28 - Feb. 3	..	..	31.2	23.4	87
Feb. 4 - Feb. 10	..	..	31.1	23.2	88
Feb.11 - Feb. 17	..	..	31.3	23.2	88
Feb.18 - Feb. 24	..	..	32.2	24.4	89
Feb.25 - March.3	63.0	1	32.1	23.7	89
March.4 - March.10	..	..	31.1	23.4	86
March.11- March 19	..	..	31.2	23.9	88

Appendix II (a)

Analysis of variance table for number of leaves per plant at 30th day after planting.

Source	SS	df	Variance	F
Total	369.07	35	..	..
Block	22.79	3	7.59	1.15
Treatment	188.43	8	23.55	3.58**
N	130.72	2	65.36	9.94**
K	5.49	2	2.74	<1
N x K	52.22	4	13.05	1.98
Error	157.85	24	6.57	..

** Significant at 1 per cent level.

Appendix II (b)

Analysis of variance table for number of leaves per plant at 60th day after planting

Source	SS	df	Variance	F
Total	737.28	35	..	..
Block	96.50	3	32.16	2.56
Treatment	340.14	8	42.51	3.39**
N	192.74	2	96.37	7.69**
K	57.60	2	28.80	2.30
N x K	89.80	4	22.45	1.79
Error	300.64	24	12.52	..

** Significant at 1 per cent level

Appendix II (c)

Analysis of variance table for number of leaves per plant at 90th day after planting

Source	SS	df	Variance	F
Total	1277.09	35	..	..
Block	665.37	3	221.79	18.16
Treatment	318.28	8	38.78	3.17*
N	70.21	2	35.10	2.87
K	119.79	2	59.89	4.90*
N x K	128.28	4	32.07	2.63
Error	293.44	24	12.21	..

* Significant at 5 per cent level

Appendix II (d)

Analysis of variance table for number of leaves per plant at 120th day after planting

Source	SS	df	Variance	F
Total	866.83	35	..	..
Block	72.69	3	24.23	1.14
Treatment	286.08	8	35.76	1.68
N	46.56	2	23.28	1.10
K	152.34	2	76.17	3.59*
N x K	87.18	4	21.79	1.02
Error	508.06	24	21.16	..

* Significant at 5 per cent level

Appendix II (e)

Analysis of variance table for number of leaves per plant at 150th day after planting

Source	SS	df	Variance	F
Total	782.66	35	..	..
Block	366.00	3	122.0000	8.22**
Treatment	60.60	8	7.5700	<1
N	2.20	2	1.1000	<1
K	4.00	2	2.0000	<1
N x K	54.40	4	13.6000	<1
Error	356.06	24	14.8300	..

** Significant at 1 per cent level

Appendix II (f)

Analysis of variance table for number of leaves per plant at 180th day after planting

Source	SS	df	Variance	F
Total	714.15	35	..	..
Block	199.23	3	66.41	3.97*
Treatment	113.90	8	14.23	<1
N	18.44	2	9.22	<1
K	1.58	2	0.79	<1
N x K	93.88	4	23.47	1.41
Error	401.02	24	16.70	..

* Significant at 5 per cent level

Appendix II (g)

Analysis of variance table for number of leaves per plant at 210th day after planting.

Source	SS	df	Variance	F
Total	626.3	35	..	..
Block	35.3	3	11.7	1.09
Treatment	333.6	8	41.7	3.89^{**}
N	10.1	2	5.05	<1
K	39.8	2	19.90	1.85
N x K	283.7	4	70.90	6.62^{**}
Error	257.4	24	10.70	..

** Significant at 1 per cent level

Appendix II (h)

Analysis of variance table for total number of leaves per plant at the time of harvest.

Source	SS	df	Variance	F
Total	6882.22	35	..	..
Block	275.30	3	91.76	<1
Treatment	2031.57	8	253.94	1.290
N	1044.20	2	522.10	2.650
K	833.20	2	416.60	2.110
N x K	154.17	4	38.54	0.196
Error	4775.35	24	196.63	..

Appendix III (a)

Analysis of variance table for height of plant 30th day after planting

Source	SS	df	Variance	F
Total	638.17	35	..	..
Block	253.09	3	84.36	8.60**
Treatment	149.78	8	18.72	1.91
N	86.66	2	43.33	4.42*
K	45.80	2	22.90	2.34
N x K	17.32	4	4.33	<1
Error	235.30	24	9.80	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (b)

Analysis of variance table for height of the plant in cm at 60th day after planting

Source	SS	df	Variance	F
Total	2393.79	35	..	..
Block	186.20	3	62.10	1.67
Treatment	1317.58	8	164.69	4.44**
N	948.86	2	474.43	12.79**
K	234.22	2	117.11	3.15
N x K	134.50	4	33.62	$\angle 1$
Error	890.01	24	37.08	..

** Significant at 1 per cent level

Appendix III (c)

Analysis of variance table for height of the plant in cm 90 days after planting

Source	SS	df	Variance	F
Total	4337.47	35	..	..
Block	109.69	3	36.56	<1
Treatment	2344.30	8	293.03	3.73**
N	1382.50	2	691.25	8.80**
K	682.70	2	341.35	4.30*
N x K	279.05	4	69.76	<1
Error	1883.48	24	78.47	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (h)

Analysis of variance table for total height of the plant in cm at the time of harvest

Source	SS	df	Variance	F
Total	6087.50	35	..	..
Block	65.70	3	21.90	<1
Treatment	3193.60	8	339.20	3.38^{**}
N	1029.40	2	514.70	4.36^{*}
K	1497.37	2	748.68	6.35^{**}
N x K	666.83	4	166.70	1.41
Error	2828.20	24	117.80	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (h)

Analysis of variance table for total height of the plant in cm at the time of harvest

Source	SS	df	Variance	F
Total	6087.50	35	..	..
Block	65.70	3	21.90	<1
Treatment	3193.60	8	339.20	3.38**
N	1029.40	2	514.70	4.36*
K	1497.37	2	748.68	6.35**
N x K	666.83	4	166.70	1.41
Error	2828.20	24	117.80	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (d)

Analysis of variance table for height of the plant in cm at 120th day after planting

Source	SS	df	Variance	F
Total	5223.98	35	..	..
Block	113.25	3	37.75	<1
Treatment	2758.54	8	344.81	3.51**
N	1108.04	2	554.02	5.64**
K	1277.43	2	638.71	6.51**
N x K	373.07	4	93.26	<1
Error	2352.19	24	98.00	..

** Significant at 1 per cent level

Appendix III (e)

Analysis of variance table for height of the plant in cm at 150th day after planting

Source	SS	df	Variance	F
Total	13350.80	35	..	..
Block	3809.30	3	1269.70	6.40**
Treatment	4788.40	8	588.50	3.02*
N	1822.01	2	911.00	4.60*
K	2100.90	2	1050.45	5.30**
N x K	865.49	4	216.37	1.09
Error	4753.10	24	198.04	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix III (f)

Analysis of variance table for height of the plant in cm at 180th day after planting

Source	SS	df	Variance	F
Total	6542.60	35	..	..
Block	78.00	3	26.00	<1
Treatment	2970.70	8	371.30	2.70*
N	960.52	2	480.26	3.50
K	1489.05	2	744.53	5.43*
N x K	521.13	4	130.28	<1
Error	3293.90	24	137.20	..

* Significant at 5 per cent level

Appendix III (g)

Analysis of variance table for height of the plants in cm at 210th day after planting

Source	SS	df	Variance	F
Total	5870.99	35	..	..
Block	87.63	3	29.21	<1
Treatment	2970.33	8	371.29	3.17*
N	1005.61	2	502.80	4.29*
K	1388.02	2	694.01	5.92**
N x K	576.70	4	144.17	1.23
Error	2813.03	24	117.20	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix IV

Analysis of variance table for number of tubers per plant

Source	SS	df	Variance	F
Total	112.60	35	..	..
Block	12.33	3	4.11	1.58
Treatment	37.88	8	4.73	1.83
N	14.45	2	7.23	2.79
K	10.80	2	5.40	2.08
N x K	12.63	4	3.16	1.22
Error	62.39	24	2.59	..

Appendix V

Analysis of variance table for number of unproductive roots per plant

Sourse	SS	df	Variance	F
Total	71.47	35	..	..
Block	2.40	3	0.80	<1
Treatment	4.80	8	0.60	<1
N	1.40	2	0.70	<1
K	0.78	2	0.39	<1
N x K	2.62	4	0.65	<1
Error	70.75	24	2.90	..

Appendix VI

Analysis of variance table for mean length of tuber in cm

Source	SS	df	Variance	F
Total	91.58	35	..	..
Block	10.22	3	3.40	1.270
Treatment	17.19	8	2.14	<1
N	2.57	2	1.28	<1
K	0.48	2	0.24	<1
N x K	14.14	4	3.53	1.320
Error	64.17	24	2.67	..

Appendix VII

Analysis of variance table for mean girth of tuber in cm

Source	SS	df	Variance	F
Total	22.50	35	..	..
Block	0.28	3	0.08	<1
Treatment	6.09	8	0.761	1.11
N	0.18	2	0.090	<1
K	5.10	2	2.550	3.740*
N x K	0.81	4	0.220	<1
Error	16.41	24	0.683	..

* Significant at 5 per cent level

Appendix VIII

Analysis of variance table for weight of the aerial parts of the plant

Source	SS	df	Variance	F
Total	13.48	35	..	..
Block	0.72	3	0.24	2.00
Treatment	9.81	8	1.22	10.16**
N	1.98	2	0.99	8.20**
K	2.31	2	1.55	9.58**
N x K	5.52	4	1.38	11.50**
Error	2.95	24	0.12	..

** Significant at 1 per cent level

Appendix IX

Analysis of variance table for the ratio of flesh to rind

Source	SS	df	Variance	F
Total	59.30	35	..	..
Block	3.64	3	1.21	0.724
Treatment	15.48	8	1.94	1.16
N	2.36	2	2.18	1.30
K	10.31	2	5.15	3.08*
N x K	2.81	4	0.72	<1
Error	40.18	24	1.67	..

* Significant at 5 per cent level

Appendix X

Analysis of variance table for yield of tuber per plant

Source	SS	df	Variance	F
Total	50.73	35	..	..
Block	1.86	3	0.62	1.08
Treatment	35.08	8	4.38	7.68**
N	7.28	2	3.64	6.38**
K	10.72	2	5.36	9.40**
N x K	17.08	4	4.27	7.49**
Error	13.79	24	0.57	..

** Significant at 1 per cent level

Appendix XI

Analysis of variance table for mean yield of tuber

Source	SS	df	Variance	F
Total	315.85	35	..	..
Block	1.14	3	00.38	<1
Treatment	260.11	8	32.51	14.32
N	68.34	2	34.17	15.06**
K	92.92	2	46.46	20.46**
N x K	98.85	4	24.71	10.88**
Error	54.60	24	2.27	..

** Significant at 1 per cent level

Appendix XII

Analysis of variance table for percentage of starch in tuber

Source	SS	df	Variance	F
Total	405.41	35	..	..
Block	5.41	3	1.80	3.30*
Treatment	387.11	8	48.38	79.96**
N	379.60	2	189.80	38.81**
X	7.18	2	3.59	6.70**
N x K	0.35	4	0.08	<1
Error	12.89	24	0.53	..

* Significant at 5 per cent level
** Significant at 1 per cent level

Appendix XIII

Analysis of variance table for percentage of nitrogen in tuber

Source	SS	df	Variance	F
Total	0.123890	35	..	..
Block	0.001340	3	0.000440	1.47
Treatment	0.116741	8	0.014520	33.80**
N	0.095746	2	0.047873	113.00**
K	0.018040	2	0.009020	20.90**
N x K	0.002955	4	0.000738	∠1
Error	0.010316	24	0.0004208	..

** Significant at 1 per cent level

Appendix XIV

Analysis of variance table for percentage of crude protein in tuber

Source	SS	df	Variance	F
Total	5.33	35	..	..
Block	0.05	3	0.016	<1
Treatment	4.83	8	0.603	32.20**
N	4.00	2	2.000	101.95**
K	0.74	2	0.370	19.07**
N x K	0.09	4	0.022	1.10
Error	0.45	24	0.0187	..

** Significant at 1 per cent level

Appendix XV

Analysis of variance table for Hydrocyanic acid in mg/kg of tuber

Source	SS	df	Variance	F
Total	441.35	35	..	..
Block	8.22	3	2.74	2.58
Treatment	407.81	8	50.97	48.08**
N	343.08	2	171.54	161.83**
K	58.47	2	29.23	27.57**
N x K	6.26	4	1.56	1.47
Error	25.32	24	1.06	..

** Significant at 1 per cent level