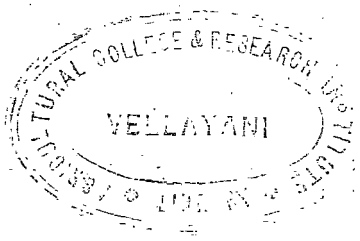
STUDIES ON FOLIAR DIAGNOSIS, YIELD AND QUALITY OF TAPIOCA (*Manihot utilissima* Pohl.) IN RELATION TO NITROGEN AND PHOSPHORUS



By

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL CHEMISTRY) OF THE UNIVERSITY OF KERALA

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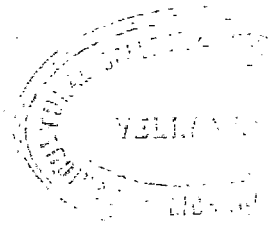

C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bona fide research work carried out by Shri M.N. Vijayan, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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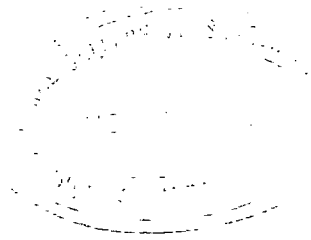
C O N T E N T S

INTRODUCTION



INTRODUCTION

Tapioca (Manihot utilissima Pohl.), also known as cassava, manioc, mandioc or yuca is a subsidiary food crop of vital importance in Kerala State. With about 2.3 lakhs hectares under the crop, Kerala produces tubers worth over Rs.45 crores annually.

As a subsidiary food crop of tremendous calorific value and as a source of starch in textile industries, the crop assumes a unique importance. In the perplexing and acute shortage of food being felt in recent years, no other crop comes to the rescue of the people of Kerala, as tapioca does. Tapioca does not supplant rice as a food crop, but supplements it to a commendable degree.

The manurial trials on tapioca conducted so far in the State have given inconsistent results. Nevertheless, these results prompt the necessity of fertilising the crop to reap rich harvests. Considering this, one is inclined to feel that all the modern tools in agricultural research have not been fully tapped to exploit the immense potentialities of increasing the yield and quality of tapioca.

The study of soil fertility presents a series of dynamic and diverse problems. Hence it is recognised that the conditions for maximum growth of a plant must be sought from its physiology as well.

The complexities of transmission of nutrients from the soil to the plant necessitate tissue analysis as better guides than soil analysis as far as the nutrition of a crop is concerned. To quote Thomas (1937), "Of the numerous methods employed to control the nutrition of plants under the conditions of practical agriculture, only the method of 'foliar diagnosis' has any serious claim to be based on physiological facts established by consistent experimental results obtained over a long period of years".

The advent of foliar diagnosis heralds a new phase in the realm of crop fertilisation. The term 'Diagnostic Foliaire' was first used in France by Lagatu and Maume (1926) in their pioneer work. The technique as a routine control of manurial practices in sugarcane is now being adopted in Mauritius, British Guiana, Jamaica and other places.

Foliar diagnosis as a research tool to evaluate the nutritional status of tapioca has not been tried so far in India. It was therefore thought worthwhile to carry out an investigation in this direction with reference to the nutrients nitrogen, phosphorus, potassium and calcium and with the following objectives.

1. To evolve a sampling technique for the choice of plant part for analysis,

2. To correlate the data on tissue analysis with the yield of tubers,

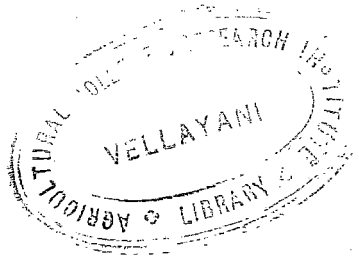
3. To study the interaction of nutrients;

4. To evaluate the quality of tubers in relation to nutrition of the plant; and

5. To delineate varietal differences, if any, on the pattern of uptake of nutrients and yield and quality of tubers.

The work allotted to the author pertains to the nutrients nitrogen and phosphorus. The studies on the nutrients potassium and calcium were undertaken by another post-graduate student of the Division of Agricultural Chemistry, Agricultural College and Research Institute, Vellayani.

REVIEW OF LITERATURE



REVIEW OF LITERATURE

Foliar analysis as a research tool

Goodall and Gregory (1947), in their discussion on chemical composition of plants as an index of their nutritional status expressed the possibility and indicated the methods of diagnosis of fertilizer requirements of plants.

Wadleigh (1949) remarked that one could reasonably postulate that for any given combination of environmental factors, within a plant tissue there is an optimum content of mineral nutrients for maximum plant growth and deviations from this affect it. This is the strong basis on which plant analysis as a diagnostic tool stands.

Lundegardh (1951) of Sweden, considered by some as the father of leaf analysis, established some fundamental concepts regarding the technique of plant analysis in his extensive researches on cereals and pasture grasses.

Ochlrogge (1960) working on the mineral nutrition of soyabean opined that the diagnosis of the mineral nutrition problems of plants would be facilitated by knowing separately the cardinal concentration of each nutrient in the whole plant and plant parts, whereby distinguishing deficiency, adequacy and luxury levels of nutrition.

Raheja (1962) through his studies on plant tissue tests as a means to determine soil deficiency in nitrogen, phosphorus and potassium, found that it was a good index of the nutrient status of plant and soils.

Guyon (1948) in an experimental verification of the nitrogen deficiency in apple tree by foliar analysis found that the healthy leaves contained about 2.3 per cent nitrogen, whereas deficient leaves contained only 1.5 per cent.

Tamm (1954) in a study of forest nutrition by foliar analysis recorded that birch trees suffering from extreme phosphorus deficiency contained less than 0.1 per cent phosphorus in the leaves. With 2.0 per cent nitrogen in the leaves, an extreme nitrogen deficiency was indicated and with 2.2 to 2.4 per cent a moderate deficiency.

Beyers (1955) trying to find out the effect of fertilizer on the leaf composition of grape revealed that ammonium sulphate increased nitrogen, magnesium and manganese in leaves and reduced the uptake of potassium.

Inner (1948) studied plant analysis in relation to the nutrition of sugarcane in Jamaica and found that the relationship between leaf composition and the major soil types was pronounced and advocated leaf analysis as a basis for fertiliser prescription. Relative yield responses of the crop to nitrogen were closely related to the percentage of nitrogen in the leaf dry matter early in the growing season.

Clement (1953), from a study of crop logs in sugarcane over a period of years developed a growth equation representing stages in sugarcane growth. The log was made from laboratory analysis for different constituents of stalks and green tops of the plants taken once in five weeks.

Sen (1954) conducted research on the absorption of nutrients by various parts of sugarcane stool at different stages of growth and found that the nutrient reserves of the mother setts were sufficient for the initial growth of 30 to 40 days.

Evans (1955) studied the mineral status of sugarcane as revealed by foliar analysis in British Guiana. Maximum yields were found to be associated with the following values in the chlorophyllous tissues of 3 to 6 month old dewlap leaves. Nitrogen 2.0 to 2.5 per cent, phosphours 0.2 per cent, potassium 1.2 per cent, calcium 0.17 to 0.18 per cent and magnesium 0.08 to 0.1 per cent.

Studies on the nitrogen and phosphorus nutrition of sugarcane at the Indian Institute of Sugarcane Research, Lucknow, indicated a nitrogen index of 1.75 to 1.8 per cent in the prescribed leaves by applying 60 lb. nitrogen per acre. Increasing the nitrogen content to 1.9 to 2.0 per cent by heavier application of fertilizer did not increase the yield (Anonymous, 1961).

Ulrich (1946) conducted plant nutrient surveys in sugar beets by analysing petioles and reported that addition of nitrogen

to soils, where plants were already high in petiole nitrogen, failed to produce any visible effect on their growth.

Brown (1946) reported that soil tests and petiole tests on sugar beet had shown excellent correlation.

Alexander et al. (1954) found a definite relationship between the sucrose percentage and leaf analysis values and between the yield and leaf analysis values in sugar beet.

Joham (1951) reported that there was highly significant positive correlation between the nutrients in the petioles of cotton or corn and their respective levels in the substrate.

Zuer and Abasheeva (1956) recorded that an application of 70 kg. per hectare of phosphoric acid had markedly increased the utilisation of nitrogen by plants and enhanced the potassium and calcium contents in the lower and upper leaves of cotton.

Tyner (1947) suggested tentative critical levels for nitrogen, phosphorus and potassium in the sixth leaf of corn. The term 'critical level' was interpreted by him as the optimum concentration of a nutrient, above which response to further increments of this nutrient was doubtful.

Dumenil (1961) found in corn that the nitrogen and phosphorus content of leaf at 95 per cent of the total yield varied with the concentration of other nutrients.

Boldyrev (1959) found that the grain yield in wheat was correlated with nitrogen and phosphorus content of leaves.

Chhonkar and Singh (1963) showed that increase in the supply of nitrogen, phosphorus and potassium increased their contents in the shoot of 96 day old bhindi plants grown in sand culture. Increase in phosphorus and potassium did not influence the nitrogen content, while an increase in nitrogen augmented the potassium content. Potassium had no effect in phosphorus content and vice-versa.

Leonard et al. (1949) attempting to establish the relationship between the mineral content of sweet potato leaves and the yield, observed that plants with leaf blades of 4.7 to 5.0 per cent nitrogen in early summer, 3.0 to 3.8 per cent nitrogen at harvest and with at least 2.0 per cent potassium at all stages of growth, produced maximum yields.

Emmert (1946) correlated the amount of nitrogen in the petioles with the yield in potato plants and found that for high yields the petioles should contain 1200 ppm. nitrogen in the early stages, about 500 ppm. in the pre-bloom stage and 2500 ppm. in the post-bloom stage.

Jordan et al. (1952) found that the percentage of phosphorus decreased in the leaves of potato as the growth progressed. He also reported that when nitrogen was deficient, a luxury consumption of phosphorus occured as evidenced by higher percentage of phosphorus in the tubers.

Cours et al. (1961) in their studies on the phellodermic diagnosis of the nutritional status of tapioca, concluded that the potassium content of the phelloderm was correlated with the potassium applied and also with the yield and density of tubers. The correlations were, however found to be non-significant for nitrogen and significantly negative for phosphorus. The study was made in Madagascar on a crop of two year duration.

Sampling technique for foliar analysis:

Thomas (1937) found that the whole-plant analysis will not furnish a sensitive index of the differences in nutrition of plants due to the heterogenous nature of tissues involved. He designated the plant part selected for foliar analysis as the 'reflect', as it reflects the mineral status of the plant as a whole.

Lundegardh (1954) pointed out that analysing the whole plant might be undesirable as minerals in inactive tissues would mask functional differences.

Ulrich (1952) opined that the best time to take samples was from 8 a.m. to 12 noon.

Prevot and Ollagnier (1954) expressed the view that consistency of sampling was of prime importance, both in regard to comparable tissues and time of sampling.

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Emmert (1959) and Steyn (1961) observed that diurnal fluctuations in the mineral content of tissues occured but were not normally very large.

Smith (1962) reported that the samples have to be wiped clean with a damp cloth before drying and analysing. He emphasised the importance of collecting plant samples when the mineral shifts in them would be at a minimum.

Emmert (1932) working with tomato and lettuce indicated that the percentage of a nutrient in the mature conducting tissue of a plant was a good index of its nutritional status.

Arnon and Hoagland (1943) and Ulrich (1946) stressed the importance of selecting 'recently matured' tissues for foliar analysis as they would contribute actively to the growth of the plant.

Lagatu and Maume (1934) envisaged leaf as the ideal tissue to sample since it was considered the chemical laboratory of the plant.

Thomas (1937) pinpointed the fact that the composition of leaves of the same physiological age on different plants would reflect the differences, if any, in their nutrition.

Lundegardh (1947) reported that the nutrient content of the leaves reflected in general the supply of the nutrient from the soil and its effect on the future yield.

Halais (1952) observed that the requirements of the major nutrients of sugarcane could be ascertained by analysis of the circles 7 mm. in diameter punched from the third leaf sampled before flowering.

Hill et al. (1954) recorded a continuous relationship between phosphorus supply and the total phosphorus content of potato leaves and hence recommended leaf analysis as an index of the relationship between yield and phosphorus content.

Rogers et al. (1955) and Ballinger and Mason (1960) compared the different plant parts of strawberry and showed that leaf was as sensitive as or even more sensitive than any other plant part as an index of the nutritional status of the crop.

Smilde and Chapas (1963) found in the case of oil palm (Elaeis guineensis) that the 1st, 17th and 25th leaves were the best suited for foliar diagnosis, when collected between 7 a.m. and 1 p.m.

Delmas et al. (1959) proved that the sap from the veins of potato, oats and maize, when analysed, would reveal the slightest variation in the nutrient uptake.

Ulrich (1942) showed that the petioles of the recently matured, grape vine leaves reflected the potassium status of the vines better than the blades.

Lorenz (1944) selected petioles from definite positions of potato plants for analysing the mineral contents.

Ulrich (1955) advocated petioles for assessing nitrate nitrogen in beet.

Cours et al. (1961) in their investigation to evolve a diagnostic technique for tapioca found the phelloderm of the main stem of the plant to be most suitable for assessing the potassium status of the plants. The phelloderm was removed as a ring of about 1 cm. high and 1 to 2 mm. thick from the base of the main stem of one year old plants.

Nutritional requirements of tapioca with special reference to nitrogen and phosphorus

Cours (1953) reported that a harvest of 50 tons of roots and 25 tons of wood removed from the soil 253 kg. nitrogen, 28 kg. phosphorus, 250 kg. potassium, 42 kg. calcium and 29 kg. magnesium.

Malevolta et al. (1955) reported that nitrogen and phosphorus were the most important nutrients for tapioca, under their experimental conditions for increasing the yield and shoot growth.

Abraham (1956), based on the experiments conducted at the Tapioca Research Station, Trivandrum, reported that the yield of the crop could be considerably raised by balanced NPK fertilization.

Chadha (1958), giving a statistical interpretation of the results of fertilizer experiments on tapioca in Kerala State, showed that there was a significant interaction of nitrogen and potassium

on the yield. The mean response to nitrogen varied from 20 to 50 per cent for 40 lb. nitrogen per acre and from 23 to 79 per cent for 80 lb. nitrogen per acre. The mean response to phosphorus varied from 4 to 12 per cent for 40 lb. and from 3 to 25 per cent for 80 lb. phosphoric acid per acre.

Jacob and Uexkull (1960), quoting Nijholt (1935), reported the nutrient removal of tapioca at Buitenzorg as follows:

Nitrogen	124 kg.	per hectare
Phosphoric acid	104	"
Potash	584	"
Lime	217	"
Magnesia	71	"

'Potascheme' in 1961, based on a few experiments conducted in Kerala State, reported that a crop yielding 20,000 lb. of raw tuber per acre removed 54 lb. nitrogen, 45 lb. phosphoric acid and 230 lb. potash per acre.

Manuring-cum-spacing trials conducted for five years at three different Tapioca Research Stations in Kerala revealed a steady response to nitrogen and potassium. The response to phosphorus was, however, erratic (Anonymous, 1963).

Pillai (1967) showed that the response of tapioca (variety M-4) to nitrogen, phosphorus and calcium under the agro-climatic conditions of Vellayani, was highly significant.

The effect of potassium was also significant. However, nitrogen and phosphorus did not influence the leaf number and height of plants.

Influence of nitrogen and phosphorus on the quality of tubers

1. Dry matter content

Investigations at the Tapioca Research Station, Trivandrum, indicated that in varieties with high starch content, the moisture content was comparatively low, ranging from 51.0 to 73.0 per cent (Anonymous, 1955).

Pillai (1967) reported that the nutrients nitrogen, phosphorus, potassium and calcium individually, and nitrogen and potassium in combination, increased the percentage dry matter content of tapioca tubers.

Sheard and Johnson (1958) found that the dry matter content of katahdin potato was sometimes increased by phosphates, consistently decreased by potassium and slightly decreased by nitrogen.

Harrap (1960) observed that high nitrogen rate in combination with normal rates of phosphorus and potassium tended to decrease the dry matter content of potato tubers, as evidenced by a taste panel.

2. Edible portion of tubers

Work conducted at the Tapioca Research Station, Trivandrum, revealed that the percentage of rind varied from 10 to 22 depending

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on the variety, period of growth and the nutrient supply (Anonymous, 1955).

Pillai (1967) found that the percentage edible portion of tubers decreased with increased doses of nitrogen. The individual effect of phosphorus was not significant though it tended to increase the percentage of edible portion.

3. Starch content

Malavolta et al. (1955) through their experiments on tapioca in sand cultures, observed a decrease in starch content of 32 to 25 per cent when phosphorus was not supplied along with nitrogen and potassium.

Research in Kerala showed that the application of nitrogen as ammonium sulphate decreased the starch content of tapioca tubers, while higher doses of potassium produced a significant increase in starch (Anonymous, 1957).

Pillai (1967) observed that nitrogen, phosphorus and potassium had significantly contributed towards an increase in the percentage of starch in the tubers of tapioca.

4. Crude protein content

Subbiah Mudaliar (1951), 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 10.0 per cent had been recorded.

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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 application of nitrogen as ammonium sulphate increased the nitrogen content of tubers with potassium showing a negative influence (Anonymous, 1960).

Pillai (1967) reported that incremental doses of nitrogen and phosphorus significantly increased the percentage of crude protein in tapioca tubers, the effect being more pronounced in the case of nitrogen.

5. Hydrocyanic acid content

Dean (1937) estimated the hydrocyanic acid content of 14 varieties of tapioca in Hawaii and found that it varied from 40 to 65 mg. per kg. of fresh tubers.

Joachim and Panditteseker (1944), in their investigation on the hydrocyanic acid content of cassava, reported that it varied from tuber to tuber in the same clump and within a tuber itself.

Bolhuis (1954), investigating the toxicity of tapioca roots in Netherlands, could not establish any relationship between soil nitrogen and the degree of toxicity.

Pereira et al. (1960), after estimating the hydrocyanic acid in a number of tapioca varieties in Brazil, found that the bitter varieties contained three 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 34 to 490 mg. per kg. of fresh tuber. The hydrocyanic acid content between tubers of the same plant and between different parts of the same tuber was not significant.

Boyd et al. (1938) reported that when the soil phosphorus was too low and the nitrogen adequate, compounds that hydrolysed to form cyanide accumulated in cyanogenetic plants.

Patel and Wright (1958) found in the case of sweet sudan grass that the levels of hydrocyanic acid were positively associated with the levels of nitrogen and negatively associated with the levels of phosphorus.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was undertaken to evolve a suitable diagnostic technique to ascertain the status of nitrogen and phosphorus in two varieties of tapioca - M-4 and H-105 - by foliar analysis. The response of the two varieties to graded doses of nitrogen and phosphorus in relation to yield and quality of tubers was also a part of the study. The experiment was conducted under field conditions using three levels each of nitrogen and phosphorus in factorial combinations, keeping the doses for potassium and calcium at an adequate and constant level based on the previous findings from this Institute (Pillai, 1967).

I. Experimental site

Planting was done in the typical red laterite loam soil of the Central Farm attached to the Agricultural College and Research Institute, Vellayani. The results of the chemical analysis of the soil samples collected from the experimental plot and analysed by the methods given by Jackson (1958), are furnished in Table I.

II. Season

The crop was grown from June 1967 to March 1968. The meteorological data for the period are given in Appendix I.

III. Setts for planting

The two varieties chosen for the investigation were Malayan-4 (M-4) and Hybrid-105 (H-105). M-4 is an exotic variety

TABLE I

Chemical characteristics of the soil

Block No.	pH	T.S.S. (mmhos/cm)	Organic carbon (per cent)	Total nutrients (per cent)						Available nutrients (per cent)	
				N	P_2O_5	K_2O	CaO	MgO	R_2O_3	P_2O_5	K_2O
I	6.60	0.20	0.535	0.038	0.112	0.081	0.115	0.091	7.89	0.0018	0.0026
II	5.80	0.00	0.321	0.045	0.124	0.064	0.113	0.125	10.78	0.0014	0.0016
III	5.90	0.00	0.317	0.054	0.118	0.085	0.114	0.154	10.74	0.0008	0.0030

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introduced from Malaya, and is famous for its palatable tubers. H-105 is a hybrid evolved at the Tapioca Research Station, Trivandrum and is well known for its high yield.

Mature stems, harvested and preserved in shade for about a month and a half, were used as the planting material. Cuttings of length 8 - 9 inches were taken from the middle portion of the stems having more or less uniform girth.

IV. Fertilizers

Nitrogen, phosphorus, potassium and calcium were applied in the form of ammonium sulphate (20.5% N), super phosphate (16.0% P_2O_5), potassium sulphate (50.0% K_2O) and fully burnt lime (54.8% CaO) respectively.

V. Lay-out

Experimental design: Split-plot in R.B.D.

Major treatments: Nine (combinations of nitrogen and phosphorus, each at three levels)

n_0P_0	n_1P_0	n_2P_0
n_0P_1	n_1P_1	n_2P_1
n_0P_2	n_1P_2	n_2P_2

Minor treatments: Two varieties

V_1 - Malayan-4 (M-4)

V_2 - Hybrid-105/44 (H-105)

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Replication:	Three
Gross plot size:	4.5 m. x 4.5 m.
Net plot size:	3.6 m. x 3.6 m.
Spacing:	90 cm. x 90 cm.
Number of plants per subplot:	Twenty five
Total number of subplot:	Fifty four

n_0 = Zero level of N.

n_1 = 75 kg. N per hectare.

n_2 = 150 kg. N per hectare.

p_0 = Zero level of P_2O_5.

p_1 = 50 kg. P_2O_5 per hectare.

p_2 = 100 kg. P_2O_5 per hectare.

The levels of individual nutrients were fixed keeping in view the results of a previous manurial trial conducted in this Institute (Pillai, 1967). The levels of potassium (250 kg. K_2O/ha.) and calcium (1200 kg. CaO/ha.) were kept constant for all treatments.

The two varieties H-4 and H-105 were selected to study the varietal differences in the pattern of nutrient uptake and other related aspects.

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VI. Field culture

1. Preparation of the field

The experimental area was dug thrice and the entire area was divided into three blocks. Plots of size 4.5 m. x 4.5 m. were laid out, separated by bunds of about 20 cm. in height and of about the same width. The plots were once again dug and levelled. Mounds of about 45 cm. in height were taken in lines 90 cm. apart on either way.

2. Fertilizer application

The entire dose of lime was applied uniformly as a basal dose on 22nd June 1967 and was incorporated into the soil by digging.

Superphosphate, as per treatments, was applied broadcast completely as a basal dose on 28th June 1967, just before the formation of mounds.

Ammonium sulphate and potassium sulphate were applied entirely as top dressings in two equal split doses, the first on 22nd September 1967 and the second on 13th November 1967. The fertilizers were applied in shallow channels formed around the base of the plant and covered well with soil.

3. Planting

Planting was done on 28th June 1967. The cuttings were planted vertically on the centre of the mounds at the rate of one cutting for each mound.

4. After cultivation

When the cuttings sprouted, sprouts in excess of two per sett were removed retaining the healthy ones. Two weedings and two earthing ups were done at an interval of about two months since planting.

5. Harvest

Harvest was done on 17th March 1968, when the crop showed signs of maturity such as reduced number and size of leaves and cracking up of mounds around the base of the plants. Necessary observations were recorded and the samples of tubers were collected for chemical analysis.

VII. Observations recorded

Three plants standing diagonally in every net plot formed the samples for the study of biometric characters during the growth phase of the crop. The various observations taken are listed below.

A. Pre-harvest observations

1. Sprouting of the cuttings
2. Number of leaves per plant - recorded at intervals of about two months
3. Height of plants - recorded at intervals of about two months

B. Observations on the plants uprooted for chemical analysis

1. Number of leaves
2. Total length of the stem
3. Fresh weight of aerial part
4. Number and weight of tubers

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C. Post-harvest observations

1. Number of tubers from the observation plants
2. Weight of tubers from the observation plants
3. Weight of the aerial parts of the observation plants
4. Number and weight of tubers from the net plots

VIII. Chemical studies

1. Sampling technique and standardisation of the 'reflect' or 'reference part'

It was necessary at the beginning of this investigation to determine the plant part which would be most suitable for a diagnostic analysis (referred to as 'reflect' or 'reference part') for nitrogen and phosphorus status of the plant. It was also essential to ascertain the best period of sampling the plants for such a diagnostic purpose and to satisfy this, sampling was done at different stages of plant growth.

Thus, one representative plant from the first inner row of each plot was uprooted. This was done thrice, the interval between subsequent samplings being about two months (first sampling on 62nd day, second on 136th day and the third on 203rd day, after planting). Samples on all occasions were collected between 8 a.m. and 12 noon. Immediately after uprooting, the observations already listed, were recorded. The total number of leaves in each branch of a plant was counted separately, leaving the leaves of the developing

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bud and the other incompletely opened leaves. The total leaves on the stem were then divided into three sections, the upper onethird, the middle one third and the lower one third, each section being removed and labelled separately. The leaf laminae were then detached from the petioles of each section and labelled. The laminae and the petioles were wiped with a damp cloth to remove any adhering dust particles. The samples thus obtained, were dried in an air oven at 70°C for about 12 hours. The dried leaf blades were powdered in a waring blender and stored in air-tight bottles for chemical analysis. The dried petioles were stored as such in labelled bottles, after slicing off the bottom and top ends to a length of about a centimeter. Thus a total of six samples were obtained from the three morphological positions of each plant uprooted from every plot.

To standardise the reflect for nitrogen and phosphorus, the petioles and leaf blades collected during the second sampling (i.e. 136th day since planting and application of superphosphate and 40th day, since the application of ammonium sulphate) were used. Further, samples from one replication and from the variety M-4, were alone used to arrive at the reflect (27 samples of leaf blades and 27 samples of petioles). The best reflect was chosen by studying the correlation between the nutrient contents in the different tissues and their respective doses applied to soil. The part thus selected for M-4 was tested for its suitability to H-105 through correlation studies.

By the time the middle petioles had been standardised to be reference part for nitrogen and phosphorus, the choice of the reflect for potassium and calcium coincided with the same part (Pushpadas, 1968). Once the reflect was finalised in this manner, that part alone i.e. petioles from the middle third of each plant was analysed for the determination of nitrogen, phosphorus, potassium, calcium and magnesium in the samples collected during the three occasions (162 samples in total).

2. Mineral analysis of plant samples

The requisite samples were analysed for their nitrogen, phosphorus, potassium, calcium and magnesium contents.

Nitrogen and phosphorus were estimated in a sample of about 0.1 g. of the dry powdered leaf. In the case of petioles 0.1 g. of the sample was constituted by small slices taken from the middle portion of every petiole of a morphological group. The two nutrients were determined by standard colorimetric methods after digestion of the material by a micro-Kjeldahl-Gunning method as adopted by Poidevin and Robinson (1964), for foliar diagnosis of sugarcane.

Potassium, calcium and magnesium were determined in a suitable aliquot of the triple acid extract obtained by following the procedure given by Jackson (1958). Potassium was estimated by the turbidimetric method detailed by Lindner (1944). Calcium and magnesium were determined by the versenate method as described by Kuang Lu Cheng and Bray (1951) and also by Welcher (1958).

3. Dry matter content of tubers

A known weight of the fresh tubers from each treatment, chipped into small pieces, were dried to constant weight in an air-oven at 105°C. The weight of the dry matter obtained was expressed as percentage of the fresh weight.

4. Edible portion of tubers

A random sample of about 1000 g. of fresh tubers was taken and weighed accurately. The tubers were then peeled and the weight of the rind was taken. From this, the edible portion was expressed as percentage of the fresh weight of tubers.

5. Starch content of tubers

Starch content of the oven-dried samples of tubers taken from individual plots, was estimated by the A.O.A.C. (1956) method and expressed as percentage of the dry matter.

6. Crude protein content of tubers

The total nitrogen content of the oven-dried samples from individual plots was estimated by the Kjeldahl method given by Piper (1948). The percentage of nitrogen multiplied by the factor 6.25 was taken as the percentage of crude protein.

7. Hydrocyanic acid content of tubers

The hydrocyanic acid content of the tubers sampled from each plot, was determined by the following method standardised by Sinha and Nair (1968).

25 to 50 g. of fresh tuber was macerated well in a waring blender and accurately weighed into a 500 ml. Erlenmeyer flask containing about 250 ml. of tap water. Carbon dioxide-free air was then bubbled through the flask for 12 hours and the hydrocyanic acid liberated was caught in 150 ml. of 2.5 per cent sodium hydroxide solution.

After 12 hours, about 8 ml. of 5 per cent potassium iodide solution was added to the flask containing the sodium hydroxide. The contents of the flask were titrated against 0.02 N silver nitrate solution from a microburette. The end point was marked by a white turbidity, clear on a black background. The result was expressed as milligram of hydrocyanic acid per kilogram of fresh tuber.

1 ml. of 0.02 N silver nitrate = 1.08 mg. of hydrocyanic acid.

RESULTS

R E S U L T S

The various results obtained in the investigation are presented below.

A. Standardisation of the reflect and its periodic analysis for nutrients

Table II gives the correlation between the doses of nitrogen applied in the soil and the percentage of nitrogen in the laminae and petioles collected from different morphological positions of the variety M-4.

The correlation coefficients were negative for all groups of laminae as well as for the lower group of petioles. The upper and the middle group of petioles gave a positive correlation, the latter being highly significant ($r = 0.84$). A similar correlation worked out for the middle group of petioles of the variety H-105 was also positive and highly significant ($r = 0.86$).

Table III presents the correlation between the quantity of phosphoric acid applied to the soil and its percentage in the different morphological groups of laminae and petioles of M-4.

The general trend of correlation obtained was positive except for the upper group of laminae. But the petioles gave high values of correlation, particularly the lower and the middle groups. Between these two, the middle group gave a correlation significant at

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TABLE II

Correlation between nitrogen applied in the soil and that present in the leaf laminae and petioles from different morphological positions for the variety M-4

Major treatment	Percentage of nitrogen (N) on dry matter basis					
	Leaf laminae			Petioles		
	Upper group	Middle group	Lower group	Upper group	Middle group	Lower group
n_0p_0	1.90	1.70	1.42	1.10	0.60	0.60
n_0p_1	1.85	1.90	2.70	0.80	0.60	0.80
n_0p_2	1.85	1.65	1.50	0.95	0.83	0.75
n_1p_0	1.45	1.66	1.65	0.80	0.85	0.90
n_1p_1	2.10	2.00	1.95	1.02	0.93	0.45
n_1p_2	1.70	1.60	1.64	1.27	0.87	0.50
n_2p_0	1.60	1.40	1.35	1.10	1.05	0.45
n_2p_1	1.95	1.85	1.60	1.20	0.85	0.50
n_2p_2	1.60	1.55	1.60	1.00	0.96	0.80
Partial correlation coefficient	- 0.34	- 0.35	- 0.40	0.42	0.84**	-0.02

** Significant at 1 per cent level

TABLE III

Correlation between phosphorus applied in the soil and that present in the leaf laminae and petioles from different morphological positions for the variety M-4

Major treatment	Percentage of phosphoric acid (P_2O_5) on dry matter basis					
	Leaf laminae			Petioles		
	Upper group	Middle group	Lower group	Upper group	Middle group	Lower group
n_0p_0	0.39	0.45	0.40	0.12	0.13	0.17
n_0p_1	0.29	0.77	0.89	0.16	0.16	0.16
n_0p_2	0.27	0.45	0.40	0.16	0.29	0.51
n_1p_0	0.77	0.59	0.43	0.18	0.13	0.17
n_1p_1	0.69	0.45	0.69	0.13	0.25	0.43
n_1p_2	0.53	0.57	0.53	0.28	0.29	0.32
n_2p_0	0.89	0.59	0.57	0.18	0.17	0.25
n_2p_1	0.56	0.39	0.30	0.17	0.17	0.40
n_2p_2	0.72	0.69	0.56	0.29	0.32	0.43
Partial correlation coefficient	- 0.62	0.01	0.06	0.61	0.92**	0.73*

* Significant at 5 per cent level

** Significant at 1 per cent level

1 per cent level (r = 0.92). Following the same procedure, the correlation obtained for the middle group of petioles in H-105 was found to be positive and highly significant (r = 0.82).

Table IV furnishes the mean percentage of nitrogen in the petioles at three different stages of growth. The analyses of variance of the data are given as Appendices II, III and IV.

There was no significant difference in the nitrogen content in petioles of plants under different major treatments at the first stage. Of the two varieties, M-4 contained significantly higher percentage of nitrogen than H-105.

During the second stage, the nitrogen content of the petioles in both the varieties was found to increase significantly in accordance with the increase in the application of nitrogen. For the same level of nitrogen applied to the soil, the reflect showed a higher percentage of the nutrient in the absence of phosphorus application than in its presence. Unlike in the first stage, H-105 was superior to M-4 in its nitrogen content.

At the third stage the results followed the same pattern as in the second sampling, with the difference that the variation in nitrogen content between the varieties was not significant. Further, both the varieties under different treatments had a lower nitrogen in the petioles compared to that in the second stage.

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TABLE IV

Mean nitrogen (N) content in petioles as percentage of dry matter

Major treatment	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	0.973	0.883	0.567	0.617	0.183	0.283
n_0p_1	0.953	0.993	0.617	0.650	0.253	0.213
n_0p_2	0.983	0.967	0.740	0.733	0.337	0.317
n_0	0.967	0.947	0.641	0.666	0.258	0.271
n_1p_0	0.987	0.883	0.867	0.927	0.407	0.423
n_1p_1	1.047	0.977	0.913	0.930	0.363	0.433
n_1p_2	1.023	0.860	0.843	0.893	0.447	0.410
n_1	1.019	0.907	0.874	0.916	0.406	0.422
n_2p_0	0.957	0.880	1.110	1.100	0.917	0.860
n_2p_1	0.977	0.983	1.030	1.010	0.517	0.583
n_2p_2	1.057	0.927	0.993	1.007	0.557	0.503
n_2	0.990	0.930	1.044	1.039	0.663	0.648
Varietal mean	0.993	0.928	0.853	0.874	0.442	0.453
p_0	0.972	0.882	0.848	0.881	0.502	0.522
p_1	0.992	0.964	0.853	0.863	0.378	0.409
p_2	1.014	0.918	0.858	0.877	0.447	0.410

CD (5%) between:			
1. varieties	0.03	0.02	-
2. varieties under same major	-	0.10	0.14
3. varieties under different major	-	0.08	0.11
4. levels of N or P	-	0.02	0.03

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Table V gives the mean percentage of phosphoric acid in the petioles at the three stages of growth. Appendices V, VI and VII give the analyses of variance of the data.

During the first sampling, the petioles showed a significant increase in phosphorus content with the application of incremental doses of the nutrient to the soil. But the difference between the higher levels of phosphorus was not significant in either variety. The varietal difference was not significant.

In the second stage, the three levels of phosphorus differed significantly in increasing the phosphorus content of petioles. As in the first stage, the varieties did not record any significant difference in their phosphorus content. In comparison with the first sampling, the reflect in general recorded a low phosphorus content, roughly having only one third of what it had previously.

The same trend of results as in the second stage was observed in the third stage also. However, at this stage the highest level of nitrogen significantly reduced the phosphorus content of the reflect. A further drop in the percentage of the nutrient from that in the second stage was recorded. Thus the plants showed a steady decrease in phosphorus content in their petioles with advancing age.

Table VI furnishes the mean percentage of potash in the reflect at the three stages of plant growth. The analyses of variance of the data are presented in Appendices VIII, IX and X.

TABLE V

Mean phosphoric acid (P_2O_5) content in petioles as percentage of dry matter

Major treatment	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	0.534	0.778	0.142	0.134	0.050	0.046
n_0p_1	0.877	0.925	0.196	0.288	0.081	0.079
n_0p_2	0.958	1.004	0.318	0.345	0.128	0.119
n_0	0.789	0.902	0.219	0.256	0.086	0.081
n_1p_0	0.486	0.713	0.161	0.166	0.058	0.066
n_1p_1	0.678	0.999	0.261	0.268	0.079	0.104
n_1p_2	0.991	1.179	0.303	0.257	0.121	0.089
n_1	0.718	0.964	0.242	0.230	0.086	0.086
n_2p_0	0.705	0.532	0.166	0.169	0.054	0.050
n_2p_1	0.922	0.683	0.234	0.245	0.062	0.073
n_2p_2	0.971	0.830	0.341	0.318	0.098	0.090
n_2	0.866	0.682	0.247	0.244	0.071	0.071
Varietal mean	0.791	0.849	0.236	0.243	0.081	0.079
p_0	0.575	0.674	0.156	0.156	0.054	0.055
p_1	0.826	0.869	0.230	0.267	0.073	0.086
p_2	0.972	1.005	0.322	0.307	0.116	0.097

CD (5%) between:			
1. varieties under same major	0.54	0.08	0.05
2. varieties under different major	0.49	0.07	0.03
3. levels of N or P	0.17	0.03	0.01

TABLE VI

Mean potash (K_2O) content in petioles as percentage of dry matter

Major treatment	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	1.77	1.20	2.47	3.53	1.72	2.42
n_0p_1	1.63	1.53	1.98	2.33	1.45	1.98
n_0p_2	1.33	1.75	1.48	1.97	0.93	1.43
n_0	1.58	1.49	1.98	2.61	1.37	1.94
n_1p_0	1.90	2.13	2.75	2.17	2.30	2.17
n_1p_1	1.87	1.47	1.77	2.98	1.67	2.65
n_1p_2	2.03	2.50	1.73	2.07	1.45	1.67
n_1	1.93	2.03	2.08	2.41	1.80	2.16
n_2p_0	2.73	2.87	2.62	3.28	1.75	3.11
n_2p_1	1.67	1.87	2.82	3.02	1.75	2.45
n_2p_2	1.72	3.08	2.28	2.95	1.67	2.47
n_2	2.04	2.61	2.57	3.08	1.72	2.68
Varietal mean	1.85	2.04	2.21	2.70	1.63	2.26
p_0	2.14	2.07	2.61	2.99	1.92	2.57
p_1	1.72	1.62	2.19	2.78	1.62	2.36
p_2	1.69	2.44	1.83	2.33	1.35	1.85
CD (5%) between:						
1. varieties	-		0.33		0.29	
2. varieties under same major	-		0.97		0.89	
3. varieties under different major	-		1.75		0.87	
4. levels of N or P	-		0.42		0.34	

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At the first sampling, neither the major treatments nor the varieties showed any significant difference between them with regard to the potassium content of the reflect.

During the second stage, between the zero and the highest levels of nitrogen, there was significant difference in that the latter increased the potassium percentage in the petioles. As to the influence of phosphorus, its increasing levels progressively decreased the potassium content in M-4, though the difference between the higher levels was not significant. In H-105 the above effect of phosphorus was significant only between its higher levels. H-105 was superior to M-4 in potassium content.

At the final stage also nitrogen had a pronounced effect in increasing the potassium content of the petioles. But in M-4, the higher levels of nitrogen and in H-105, the lower levels of nitrogen did not show any significant difference between them. The negative influence of phosphorus on the potassium content of the reflect, as noticed earlier, still persisted. The varietal difference noticed in the second stage was observed in the final stage also.

Table VII presents the mean percentage of lime in the petioles collected at the three stages of growth. Appendices XI, XII and XIII give the analyses of variance.

TABLE VII

Mean lime (CaO) content in petioles as percentage of dry matter

Major treatment	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	2.35	2.12	1.60	1.58	1.77	1.73
n_0p_1	2.43	3.15	1.36	1.60	1.87	2.03
n_0p_2	2.60	2.63	1.46	1.58	1.63	1.83
n_0	2.46	2.63	1.47	1.59	1.76	1.86
n_1p_0	2.39	2.79	1.77	1.62	1.73	1.63
n_1p_1	2.96	2.62	1.99	1.75	1.83	2.10
n_1p_2	3.17	2.85	1.67	1.67	1.73	1.70
n_1	2.84	2.76	1.81	1.68	1.76	1.81
n_2p_0	3.66	3.44	1.78	1.90	1.80	1.70
n_2p_1	2.83	3.01	1.64	1.84	1.63	1.93
n_2p_2	2.81	2.26	1.94	1.80	1.77	1.53
n_2	3.10	2.90	1.79	1.85	1.73	1.72
Varietal mean	2.80	2.76	1.69	1.71	1.75	1.79
p_0	2.80	2.78	1.72	1.70	1.77	1.69
p_1	2.74	2.93	1.66	1.70	1.78	2.01
p_2	2.86	2.58	1.69	1.68	1.72	1.69
CD (5%) between:						
1. varieties under same major	0.75		-		-	
2. varieties under different major	0.79		-		-	

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The different treatments did not show any significant variation between them in their influence on the calcium content of the reflect at any of the growth stages. One general observation was that the plants had the highest calcium in their petioles at the beginning followed by a decrease in the second stage and then an increase in the final stage of growth.

Table VIII summarises the data on the mean percentage of magnesia in the reflect at the three stages of growth. The analyses of variance of the data are given in Appendices XIV, XV and XVI.

The major treatments had no consistent or significant effect on the magnesium content of the petioles at any of the three stages of growth. The varietal difference was significant at the first and second stages of growth, H-105 being superior. Magnesium content in the reflect followed almost the same pattern as calcium at the different stages of growth.

B. Growth indices and yield

The variety H-105 showed earliness in sprouting and larger number of sprouts per sett than H-4. When H-4 had taken 15 days for 100 per cent sprouting, H-105 took only 9 days.

Table IX furnishes the mean number of leaves at the three stages of growth. Appendices XVII, XVIII and XIX give the analyses of variance of the data.

TABLE VIII

Mean magnesia (MgO) content in petioles as percentage of dry matter

Major treatment	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	3.26	3.43	0.71	0.93	0.90	0.91
n_0p_1	3.29	2.93	0.80	0.83	1.03	1.10
n_0p_2	3.18	3.76	0.80	0.88	0.87	1.03
n_0	3.24	3.37	0.77	0.88	0.93	1.01
n_1p_0	2.54	3.81	0.56	0.59	1.03	1.03
n_1p_1	3.11	3.48	0.71	0.70	0.93	0.80
n_1p_2	2.27	2.78	0.63	1.11	0.77	0.83
n_1	2.64	3.36	0.63	0.80	0.91	0.87
n_2p_0	2.22	2.52	0.44	0.55	0.77	1.03
n_2p_1	2.64	2.72	0.76	0.81	1.00	0.90
n_2p_2	2.36	3.43	0.56	0.57	0.93	1.00
n_2	2.41	2.89	0.59	0.64	0.90	0.98
Varietal mean	2.76	3.21	0.66	0.77	0.91	0.95
p_0	2.68	3.26	0.57	0.69	0.90	0.98
p_1	3.01	3.04	0.76	0.78	0.98	0.93
p_2	2.60	3.32	0.66	0.85	0.86	0.95
CD (5%) between varieties	0.27		0.09		-	

TABLE IX

Mean number of leaves per plant at three stages of growth

Major treatment	Age at observation					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	30.3	39.0	48.7	49.7	59.0	47.0
n_0p_1	25.0	44.3	45.3	52.3	57.3	58.0
n_0p_2	28.0	43.3	44.0	60.0	56.0	64.3
n_0	27.7	42.2	46.0	54.0	57.4	56.4
n_1p_0	28.3	53.0	69.7	73.7	76.7	57.3
n_1p_1	26.7	47.3	66.0	67.0	86.7	64.0
n_1p_2	23.3	47.0	45.0	66.0	43.3	69.3
n_1	26.1	49.1	60.2	68.9	68.9	63.5
n_2p_0	27.3	48.7	51.0	70.7	52.7	78.0
n_2p_1	31.7	41.3	72.3	67.7	79.0	66.7
n_2p_2	29.7	47.3	62.0	68.3	73.0	67.0
n_2	29.6	45.8	61.8	68.9	68.2	70.6
Varietal mean	27.8	45.7	56.0	63.9	64.8	63.5
p_0	28.6	46.9	56.5	64.7	62.8	60.8
p_1	27.8	44.3	61.2	62.3	74.3	62.9
p_2	27.0	45.9	50.3	64.8	57.4	66.8
CD (5%) between:						
varieties	4.11		7.41		-	

None of the major treatments was significant in influencing the leaf number of plants. Nevertheless, the results showed a positive trend for incremental doses of nitrogen. H-105 was superior to M-4 at the first two observations.

Table X shows the mean height of plants at the three stages of growth. The analyses of variance are given as Appendices XX, XXI and XXII.

The effect of the various major treatment combinations on plant height was not significant. But the general trend showed an increase in height of plants with higher levels of nitrogen and phosphorus. During the first and the last observations, H-105 showed superiority over M-4.

Table XI gives the data on mean yield, number of tubers and fresh weight of shoot of the two varieties. The respective analyses of variance are given as Appendices XXIII, XXIV and XXV.

As is evident from the table, the effect of different levels of nitrogen and phosphorus was highly significant and positive in relation to the yield of tubers. The combined effect of nitrogen and phosphorus was also found to be significant. Of the different treatment combinations n_2p_2 recorded the maximum yield, followed by n_1p_1 in both the varieties. The highest level of nitrogen with zero level of phosphorus (n_2p_0) and the highest level of phosphorus with zero level of nitrogen (n_0p_2) showed no significant difference between them in either variety.

TABLE X

Mean height of plants in cm. at three stages of growth

Major treatment	Age at observation					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	28.0	31.3	77.7	89.0	120.7	113.0
n_0p_1	32.7	33.0	85.3	94.3	137.7	138.7
n_0p_2	33.7	33.7	95.7	113.0	142.3	183.0
n_0	31.5	32.7	86.2	98.8	133.6	144.9
n_1p_0	33.7	41.7	128.7	133.3	177.0	196.0
n_1p_1	32.0	40.3	121.7	128.0	175.7	193.7
n_1p_2	24.3	34.7	111.3	120.3	166.3	180.7
n_1	30.0	38.9	120.6	127.2	173.0	190.1
n_2p_0	29.7	34.7	118.0	115.7	182.7	191.3
n_2p_1	29.7	31.0	114.0	115.0	172.7	195.3
n_2p_2	31.0	38.0	129.3	130.0	204.7	215.3
n_2	30.1	34.6	120.4	120.2	186.7	200.6
Varietal mean	30.5	35.4	109.1	115.4	164.4	178.5
p_0	30.5	35.9	108.1	112.7	160.2	166.7
p_1	31.4	34.8	107.0	112.4	162.0	175.9
p_2	29.7	35.5	112.1	121.1	171.1	193.0
CD (5%) between:						
varieties	2.28		-		7.62	

TABLE XI

Mean values for yield and number of tubers and fresh weight of shoot

	Yield in tonnes per hectare		No. of tubers per plant		Shoot in tonnes per hectare	
	M-4	H-105	M-4	H-105	M-4	H-105
n_0p_0	7.8	8.7	3.70	6.30	6.5	7.2
n_0p_1	10.0	9.5	4.70	6.40	6.5	10.4
n_0p_2	16.9	17.8	6.10	6.70	11.7	18.9
n_0	11.6	12.0	4.83	6.47	8.2	12.2
n_1p_0	10.8	11.1	6.80	8.40	10.4	14.3
n_1p_1	24.0	26.0	6.70	8.90	24.7	33.8
n_1p_2	20.5	22.1	5.60	8.20	18.9	23.4
n_1	18.4	19.7	6.37	8.50	18.0	23.8
n_2p_0	17.3	19.5	6.00	6.30	13.0	26.0
n_2p_1	21.5	21.7	6.30	9.20	18.9	25.4
n_2p_2	28.6	30.9	5.90	9.80	26.7	37.7
n_2	22.5	24.1	6.07	8.43	19.5	29.7
Varietal mean	17.5	18.6	5.75	7.80	15.2	21.9
p_0	12.0	13.1	5.50	7.00	9.9	15.8
p_1	18.5	19.1	5.90	8.17	16.7	23.2
p_2	22.0	23.6	5.87	8.23	19.1	26.7

CD (5%) between:			
1. varieties	0.65	0.44	2.51
2. varieties under same major	1.96	1.34	7.53
3. varieties under different major	5.74	1.93	8.48
4. levels of N or P	3.19	0.97	3.77

H-105 showed definite superiority in yield over M-4.

As far as the number of tubers is concerned, only the effect of nitrogen was significant. An increase of nitrogen from n_0 to n_1 enhanced the number of tubers significantly. But a further increase of nitrogen to the highest level had a slight depressing effect on the number of tubers per plant. Yet the highest level of nitrogen was superior to the zero level. The varietal difference was significant and H-105 was superior to M-4.

The results for the mean weight of shoot, in general, followed the same trend as that for the yield of tubers, except that the higher levels of nitrogen showed no significant difference in M-4. Among the treatment combinations, n_2p_2 recorded the maximum shoot weight followed by n_1p_1. H-105 was superior to M-4 in this character.

C. Quality of tubers in relation to the application of nutrients

Table XII presents the mean percentage dry matter and edible portion of tubers. Appendices XXVI and XXVII give the analyses of variance.

An enhanced nitrogen dose increased the dry matter in tubers, though this effect was not significant in M-4 between the higher levels. Phosphorus exerted a significant positive influence on the dry matter content of tubers. The interaction between nitrogen and phosphorus was also significant. This showed that the effect of nitrogen was dominant only in the presence of phosphorus and vice-versa. M-4 contained a significantly higher percentage of dry matter than H-105.

TABLE XII

Mean percentage of dry matter and edible portion of tubers

Major treatment	Dry matter as percentage of fresh weight		Edible portion as percentage of fresh weight	
	M-4	H-105	M-4	H-105
n_0P_0	36.2	35.2	85.5	84.4
n_0P_1	36.9	36.0	84.4	83.8
n_0P_2	37.1	36.8	84.9	83.7
n_0	36.7	36.0	84.9	83.9
n_1P_0	36.7	35.8	82.0	82.3
n_1P_1	39.1	37.3	83.3	83.0
n_1P_2	39.3	37.5	83.1	83.3
n_1	38.4	36.8	82.8	82.8
n_2P_0	37.3	36.6	81.8	80.7
n_2P_1	38.3	37.1	83.9	81.2
n_2P_2	39.9	37.9	83.0	81.1
n_2	38.5	37.2	82.9	81.0
Varietal mean	37.9	36.7	83.5	82.6
P_0	36.7	35.8	83.1	82.4
P_1	38.1	36.8	83.8	82.6
P_2	38.8	37.4	83.7	82.7

CD (5%) between:		
1. varieties	0.16	0.66
2. varieties under same major	0.49	1.99
3. varieties under different major	0.65	0.29
4. levels of N or P	0.33	0.79

Increase of nitrogen from zero to the n_1 level had a significant depressive effect on the percentage edible portion of tubers. A further increase of nitrogen to the highest level had no effect on M-4, but had decreased the edible portion in H-105. Phosphorus individually did not show any definite influence, though in combination with nitrogen tended to increase the edible portion. M-4 was found to be superior to H-105 in this character.

Table XIII gives the mean values for starch, crude protein and hydrocyanic acid content of tubers. Appendices XXVIII, XXIX and XXX give the respective analyses of variance.

The starch content showed a significant increase with an increase of nitrogen from the n_0 to the n_1 levels. The highest dose of nitrogen significantly decreased the starch content in both varieties. However, the highest level was better than the zero level. The influence of phosphorus was considerably higher than that of nitrogen in increasing the percentage of starch in tubers. The treatment n_1p_2 recorded the maximum starch percentage. H-105 was superior to M-4 in this quality.

The effect of nitrogen, phosphorus and their interaction was found significant in augmenting the percentage crude protein in tubers. Phosphorus too had the same effect on M-4, but in H-105 the increase of crude protein between the higher levels of phosphorus was not significant. The varieties did not show any significant difference between them in this character.

TABLE XIII

Mean values for starch, crude protein and hydrocyanic acid content of tubers

Major treatment	Percentage on dry matter basis				Hydrocyanic acid in mg. per kg. of fresh weight	
	Starch		Crude protein			
	M-4	H-105	M-4	H-105	M-4	H-105
n_0P_0	69.4	71.7	1.49	1.46	41.7	38.2
n_0P_1	72.6	72.6	1.48	1.49	39.6	38.2
n_0P_2	76.7	77.5	1.69	1.70	37.4	38.2
n_0	72.9	73.9	1.55	1.55	39.6	38.2
n_1P_0	74.9	76.7	1.95	1.98	48.2	47.5
n_1P_1	81.4	81.4	1.74	1.94	38.9	40.3
n_1P_2	82.5	82.8	1.91	1.76	39.6	41.0
n_1	79.6	80.3	1.87	1.89	42.2	42.9
n_2P_0	73.3	72.4	1.89	1.89	48.9	54.0
n_2P_1	79.3	79.1	2.35	2.15	47.5	48.9
n_2P_2	80.0	82.3	2.19	2.18	40.3	41.8
n_2	77.5	77.9	2.14	2.07	45.6	48.2
Varietal mean	76.7	77.4	1.85	1.84	42.4	43.1
P_0	72.5	73.6	1.77	1.77	46.3	46.5
P_1	77.7	77.7	1.86	1.86	42.0	42.5
P_2	79.8	80.8	1.93	1.88	39.1	40.3
CD (5%) between:						
1. varieties	0.68		-		-	
2. varieties under same major	2.01		0.22		5.30	
3. varieties under different major	3.07		0.19		5.15	
4. levels of N or P	1.56		0.06		2.02	

Regarding the hydrocyanic acid content of tubers, the influence of nitrogen and phosphorus was significant, the former positively and the latter negatively. The higher levels of nitrogen increased the hydrocyanic acid content, where as the higher levels of phosphorus decreased it significantly. Thus the interaction between nitrogen and phosphorus was highly significant. The maximum hydrocyanic acid content was recorded in the treatment n_2p_0 in both the varieties. The varieties did not differ significantly in this quality.

DISCUSSION

DISCUSSION

The present investigation elucidates the possibility of using the middle group of petioles in tapioca (Var. M-4 and M-105) as a suitable reflect for a diagnostic analysis for nitrogen and phosphorus. The study also brings out the influence of graded doses of nitrogen and phosphorus and their interaction on the pattern of uptake of nutrients, yield components, yield and quality of tubers.

A. The reflect and its nutrient content at different stages of growth

It can be seen from the results (Tables II and III) that the laminae show either a negative or a low positive correlation between their percentage content of nitrogen and phosphorus and the levels of these nutrients added to the soil. The reason for this inverse or poor correlation appears to be due to the effect of nitrogen in causing a rapid elaboration of leaf blades and a resultant dilution of nutrients in them. Similar results were obtained by Prevot and Ollagnier (1954) in peanut.

A positive correlation is obtained between the percentage of nitrogen and phosphorus in the petioles and the doses of these nutrients applied to the soil. The dilution effect manifested in the leaf blades is not evident in the petioles, probably being conducting tissues. The higher levels of nutrients in the substrate leading to the observed higher concentration in the petiole corroborates the

results obtained by Emmert (1932) in tomato and lettuce, Ulrich (1942) in grapes, Brown (1946) in sugar beet and Joham (1951) in cotton.

Nevertheless, a highly significant and positive correlation is obtained only between the nitrogen and phosphorus of the middle group of petioles and the doses of the respective nutrients added to the soil. The nutrient content in the upper and lower group of petiole give only a poor correlation. The greater translocation of nutrients from the lower leaves approaching senescence as well as a greater appropriation of nutrients by the actively growing upper part of the plant may probably account for the observed inconsistent relationship between the nutrient doses and their percentage in the petioles of these two regions.

Cours et al. (1961) used the phelloderm for a similar diagnostic technique for potassium in tapioca. No attempt has been made in this investigation to verify the suitability of the phelloderm as a reflect for nitrogen and phosphorus. Their main objection to choose leaf as a reflect is that the plants under the climatic conditions in Madagascar shed most of the leaves in winter which is the best time for collection of samples. Moreover, the variety with which they worked was one with a duration of 24 months which is uncommon in this region. Besides this, the correlations obtained by them between nitrogen and phosphorus in the phelloderm on one hand and the nutrients in the soil on the other were

respectively non-significant and negatively significant.

The main attributes of the reflect chosen in this study are:

1. ease of handling and sampling,
2. homogenity of the material that minimises errors in sampling,
3. relationship of the concentration of the nutrients in the petioles to the variations of these nutrients in the soil; and
4. suitability to assess potassium and calcium status of the plants (Pushpadas, 1968).

The correlation between the percentages of the nutrients, nitrogen and phosphorus in the reflect at different stages of growth with the final yield are shown in Table XIV.

TABLE XIV

Correlation between the percentage of nutrients in the reflect and the final yield at different stages of growth

Nutrient	Correlation coefficients					
	Age at sampling					
	62 days		136 days		203 days	
	M-4	H-105	M-4	H-105	M-4	H-105
Nitrogen	-	-	0.62	0.54	0.65	0.38
Phosphorus	0.21	0.12	0.64	0.39	0.19	0.28

Values of r, for significance { 0.48 at 1 per cent level; 0.38 at 5 per cent level

It is evident from the Table that the nutrients in the reflect at the second sampling, i.e. 136 days after planting, are better correlated with yield than that at other samplings. Thus for the diagnosis of the nutrient status of the plants with respect to nitrogen and phosphorus and for predicting the yield, the second sampling done on the 136th day is found to be the most suitable. Since nitrogen was top dressed only after the first sampling, correlation coefficients have not been worked out for nitrogen at this stage. Similar procedures to determine the stage of sampling was adopted by Leonard et al. (1949) in sweet potato, Evans (1955) in sugarcane and many other workers on different crops.

The critical levels of nutrients on a variety of crops by foliar analysis have been established by different workers (Tyner, 1947; Ulrich, 1952 and Prevot and Ollagnier, 1954). It is seen from such studies that the critical levels for a nutrient has to be established for each crop and very often for each variety of a crop. The establishment of critical concentration of nutrients necessitates the analysis of a very large number of tissue samples collected from each variety of the crop under widely varying soil and climatic conditions. Obviously therefore, establishment of critical levels cannot be attempted from the results of the present study. Moreover, no specific deficiency symptoms were exhibited by the plants to facilitate a visual diagnosis. However, it is possible to suggest the percentage of the nutrient in the reflect, below which

a deficiency may exist when sampled from a four and a half month old plant(Table XV).

TABLE XV

Approximate deficiency levels of nitrogen and phosphorus in the reflect

Variety	Percentage of the nutrient in the reflect on dry matter basis	
	Nitrogen (N)	Phosphoric acid (P_2O_5)
M-4	0.70	0.15
H-105	0.70	0.15

The chemical analyses of the reflect for the different nutrients show that their percentage in the reflect is governed by complex interrelationships among the nutrients. The combined application of nitrogen and phosphorus influences the percentage of these nutrients in the reflect, though the interaction is significant only at the final sampling (Tables IV and V). In the final stage, a higher concentration of one nutrient in the reflect is seen to be associated with an inadequate addition of the other nutrient to the soil. An abundant supply of nitrogen as compared to phosphorus might have enhanced the utilisation of phosphorus, decreasing its concentration in the petiole. If nitrogen is deficient, phosphorus accumulates due to decreased utilisation of the same in the synthesis and translocation of organic compounds. Similar observations have been reported by Miller (1938), Meyer and Anderson (1958), De and Singh (1959) and Smith (1962) on other crops.

The rationale for the accumulation of one nutrient in the absence of the other finds manifestation when the relationship between the nutrient content in the reflect and the yield of plants is considered. From Fig. 1, it can be seen that though the maximum percentage of nitrogen is shown by the treatment n_2p_0 (150 kg.N/ha. with no phosphorus), the maximum yield is given by the treatment n_2p_2 (150 kg. N and 100 kg. P_2O_5/ha.). The accumulation of the nutrient indicates a decreased synthesis of starch resulting in a decreased yield. When nitrogen and phosphorus are present in an optimum ratio, synthetic reactions may be sufficiently fast to prevent accumulation of either nitrogen or phosphorus.

Though a uniform dose of 250 kg. potash per hectare has been applied in all the plots, the reflect shows significant differences in the percentage of potassium, based on the different doses of nitrogen and phosphorus. As is seen from Table VI, nitrogen increases the potassium percentage in plants, whereas phosphorus is seen to have a depressing effect. Nitrogen, by its capacity to increase root growth, can be expected to increase the ability of the plants to absorb potassium. The synergetic effect of nitrogen on potassium uptake observed in the present study finds support in similar works reported by De and Singh (1959) in potato and Chhonkar and Singh (1963) in bhindi. Further, the significant interaction between nitrogen and potassium in increasing the yield of tapioca has also been reported by Pillai (1967).

FIGURE 1 Graph showing the relation between yield and percentage of nitrogen (N) in the reflect collected from 136 day old tapioca plants (Var. M-4 and H-105) under the various treatments.

FIGURE 2 Graph showing the relation between yield and percentage of phosphoric acid (P_2O_5) in the reflect collected from 136 day old tapioca plants (Var. M-4 and H-105) under the various treatments.

RELATION BETWEEN YIELD AND N CONTENT IN PETIOLES

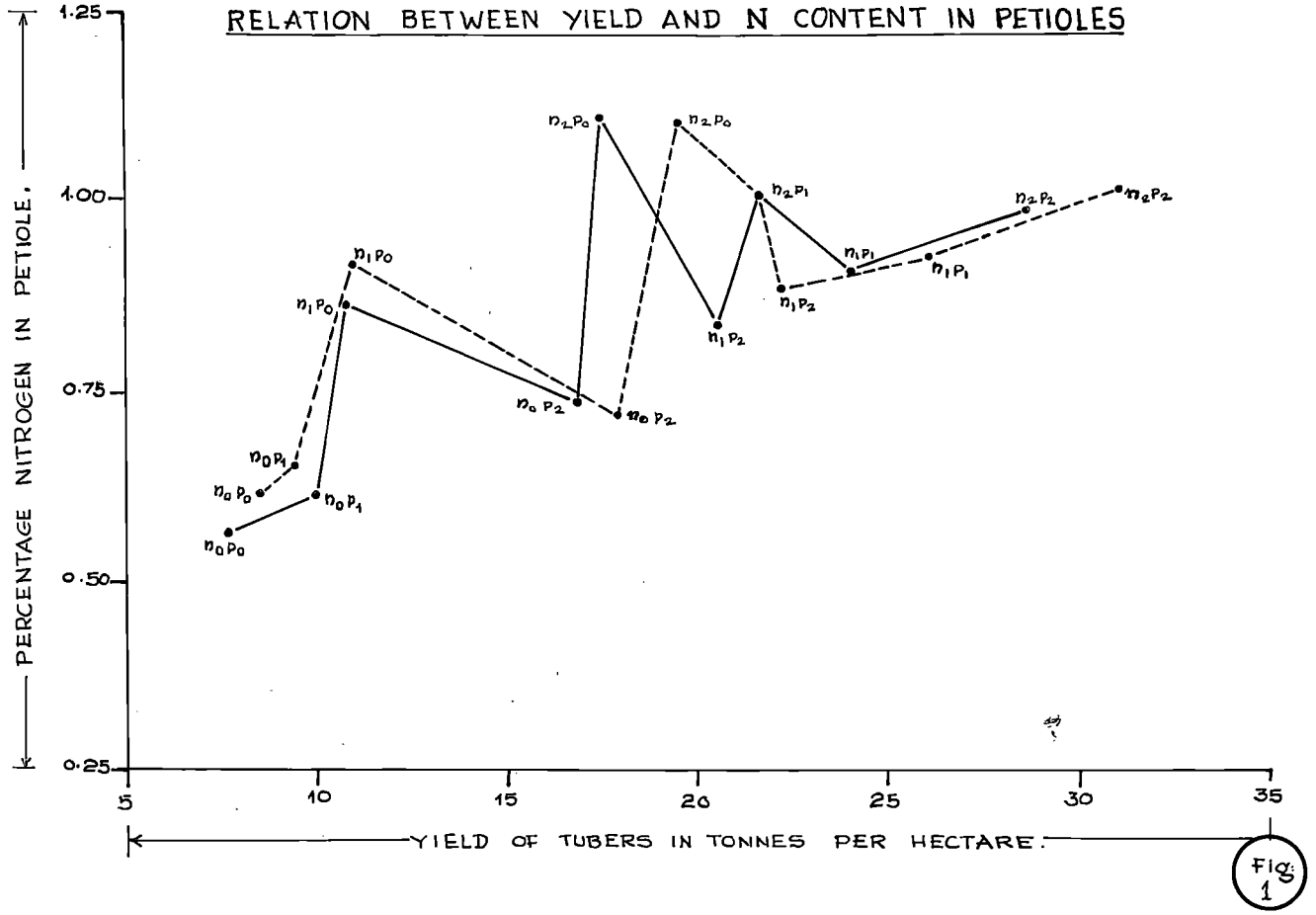

Fig. 1

RELATION BETWEEN YIELD AND P_2O_5 CONTENT IN PETIOLES

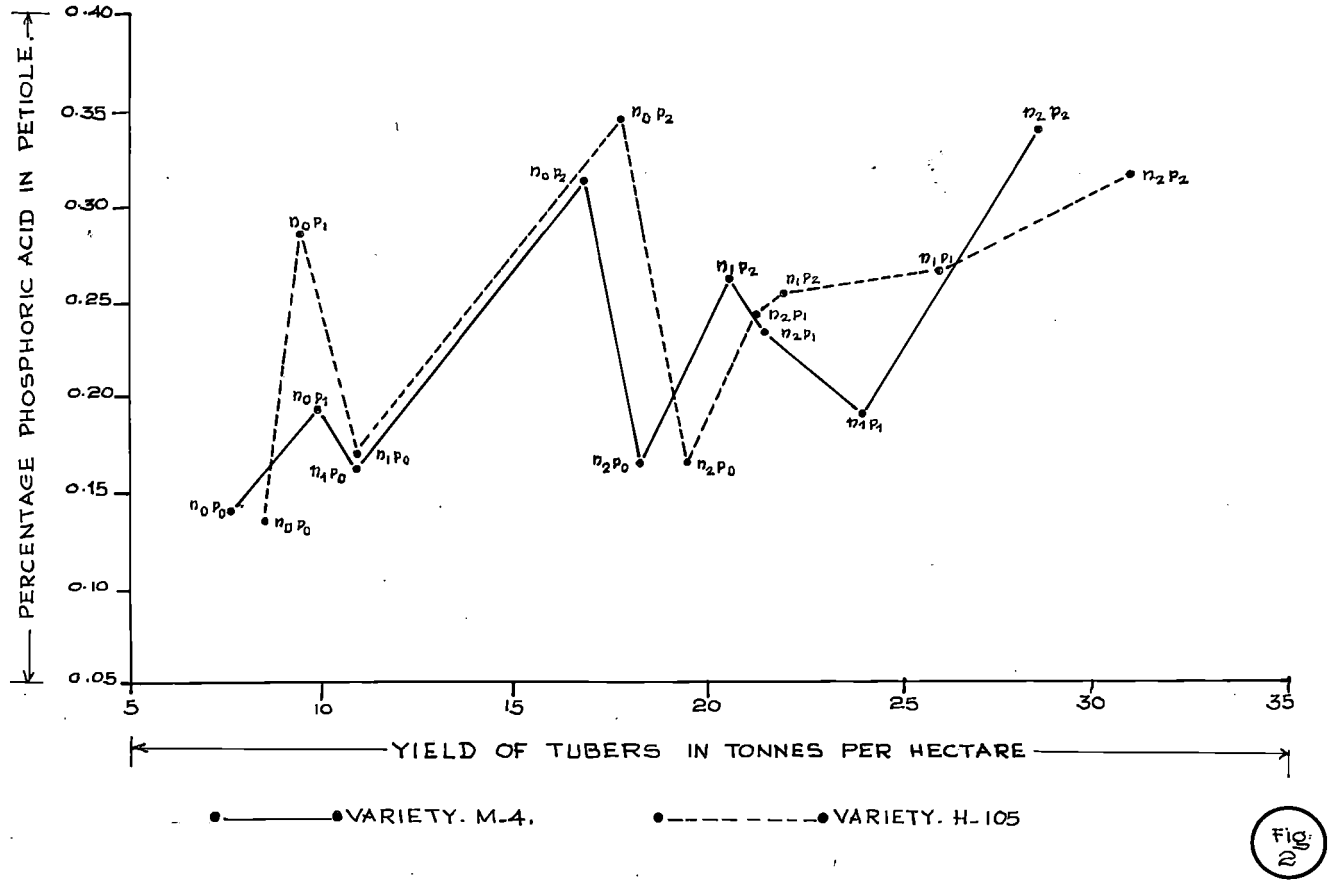

Fig. 2

A progressive decrease in the percentage of nitrogen is observed in successive samples though all the nitrogen has been added between the first and second samplings (Table IV). A similar decreasing trend is noticed in the case of phosphorus, while the entire dose of phosphorus has been applied as a basal dressing. It may be recalled that the second samples were taken 40 days after the application of ammonium sulphate. The spurt of growth in plants that ensued the top dressing with nitrogen might have led to a dilution of the nutrients in plants, though the total uptake of nitrogen would have been more in the second stage. This partially explains the lower percentage of nitrogen and phosphorus in the second stage. Similar dilution effects were reported to occur in many plants (Smith, 1962). However, a similar dilution effect, is not operative on the percentage of potassium. The uniformly high dose of potassium applied and the role of nitrogen in increasing potassium uptake in general, appear to be the probable reasons for the observed result.

The samples collected at the third stage register a further decrease in the percentage of nitrogen and phosphorus (Tables IV and V). This decrease, observed with age, can partly be attributed to the greater increase of structural material as compared to protoplasm (Ulrich, 1952) and partly to the vigorous nutrient absorption over dry matter production in the earlier stages of growth (Remy, 1938). Goodall and Gregory (1947) and Jordan et al. (1952) reported similar findings in the case of phosphorus on certain other crops.

A similar trend in the percentage of calcium and magnesium in the reflect at different periods of growth has been observed. Both show a decrease in the second stage and then an increase in the final stage (Tables VII and VIII). The increase in the percentage of calcium at the final stage may probably be due to the increase in the structural material when the plants grow older, as mentioned earlier. According to Russell (1961), calcium being a structural component of the cell wall gets deposited as calcium pectate, thereby increasing the percentage of calcium in dry matter. The behaviour of magnesium, however, cannot be discussed with the results obtained since magnesium was neither a treatment nor the suitability of the reflect to assess the magnesium status of plants worked out in the present study.

B. Yield and yield components

The maximum yield of tubers, viz. 28.6 tonnes per hectare in M-4 and 30.9 tonnes per hectare in H-105, is given by the treatment combination consisting of 150 kg. per hectare of nitrogen and 100 kg. per hectare of phosphoric acid (n_2p_2). This is nearly three times superior to the yield of the control (Table XI and Plate III). The treatment that has given the next highest yield is the one that includes 75 kg. of nitrogen and 50 kg. of phosphoric acid per hectare (n_1p_1), though n_2p_1 and n_1p_2 are also treatments in the experiment. This leads to the inference that the crop prefers a certain ratio between nitrogen and phosphorus for manifesting its maximum yield

potential. It can also be inferred that increase or decrease in the quantity of any one nutrient to upset the ratio appreciably, may lead to a reduction in yield. From Fig. 1 and 2, it might also be seen that the addition of nitrogen either depresses or increases the yield depending upon the level of phosphorus in the plant. Wittwer et al. (1947) recorded a similar observation in potato. Nitrogen and phosphoric acid in the ratio of 3:2 have recorded the maximum yield.

The importance of application of nitrogen and phosphorus in conjunction with each other is also brought out by Table XIII, which summarises the percentage starch of tubers. Treatments having either nitrogen or phosphorus alone yielded less starch in comparison with n_2p_2 and n_1p_1. The role of nitrogen and phosphorus in metabolic activities of plants is a well recognised fact. Nitrogen, through its effect on vegetative growth of plants especially by increasing the number and size of leaf, increases the total photosynthetic area. Phosphorus on the other hand controls many enzymatic reactions in plant metabolism and takes part in phosphorylation indispensible for the synthesis of starch and other organic compounds. The increases in the percentage of starch brought about by the combined action of nitrogen and phosphorus has reflected in the higher yields obtained. Thus the two nutrients can function in many interrelated ways in plants, as reported by Meyer and Anderson (1958) and Russell (1961).

The results obtained at the Tapioca Research Stations in Kerala (Anonymous, 1963) showed that the response of the crop to

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phosphorus was erratic. The high response of the crop to phosphorus and a significant effect of the interaction between nitrogen and phosphorus observed in the present study may probably be due to a greater availability of phosphorus that might have resulted from liming. Truog (1948) reported that liming could increase the availability of phosphorus. The role of nitrogen in increasing the capacity of plants, in general, to absorb phosphorus by enhanced root growth and thereby the foraging capacity for phosphorus was reported by Grunes (1959). The present finding is in conformity with the observation that nitrogen and phosphorus are important in deciding the yield of tapioca (Malavolta et al. 1955 and Pillai, 1967).

The effect of nitrogen and phosphorus and their interaction on increasing the weight of shoot is similar to the observations made on the yield of tubers(Table XI). The highly significant and positive correlation between the weight of shoots and the weight of tubers for the combined data from both varieties ($r = 0.93$) shows that similar factors are operative in increasing vegetative growth. The spectacular role of nitrogen and phosphorus in enhancing vegetative growth and dry matter production in plants, in general, was reported by many workers like Black (1957) and Russell (1961). The present finding agrees with the observations of Malavolta et al. (1955) on tapioca.

C. Quality of tubers

The possibility of regulating the quality of tubers by resorting to a manuring schedule consisting of a judicious combination

of nitrogen and phosphorus is one of the significant conclusions arising from the present study.

The combination of the highest levels of nitrogen and phosphorus (n_2p_2) has recorded a significantly higher starch percentage compared to the treatments n_2p_0 or n_0p_2. It is understandable in the light of the physiological roles of nitrogen and phosphorus in carbohydrate synthesis that a crop like tapioca, rich in starch, might warrant a high absorption of these nutrients. However, the mean for the highest level of nitrogen shows a significant drop in starch percentage in comparison with the next lower level (Table XIII and Fig. 3). To explain this, the possibility of enhanced conversion of carbohydrates into proteins in the presence of adequate nitrogen, as suggested by Russell (1961), cannot be ruled out. This assumption finds support from the data in the same Table and from Fig. 4, which show the maximum percentage of crude protein for the highest level of nitrogen. The result obtained is supported by the findings of Malavolta et al. (1955) and by the report of the TapiocaResearch Station, Trivandrum (Anonymous, 1957). However, the work of Pillai (1967), which recorded a linear relationship between the percentage of starch and the incremental doses of nitrogen upto 150 kg. per hectare is at variance with the results of the present study.

Regarding crude protein, it may be pointed out that the highest level of nitrogen alone has not yielded the maximum

STARCH CONTENT OF TUBERS

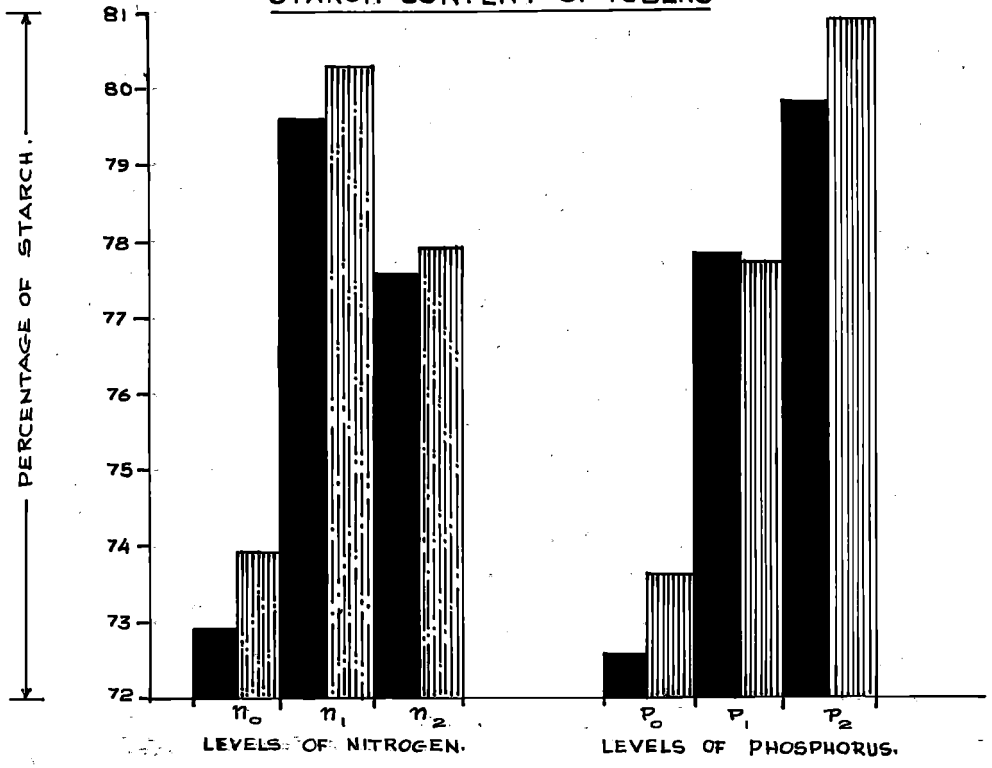

Fig 3

CRUDE PROTEIN CONTENT OF TUBERS

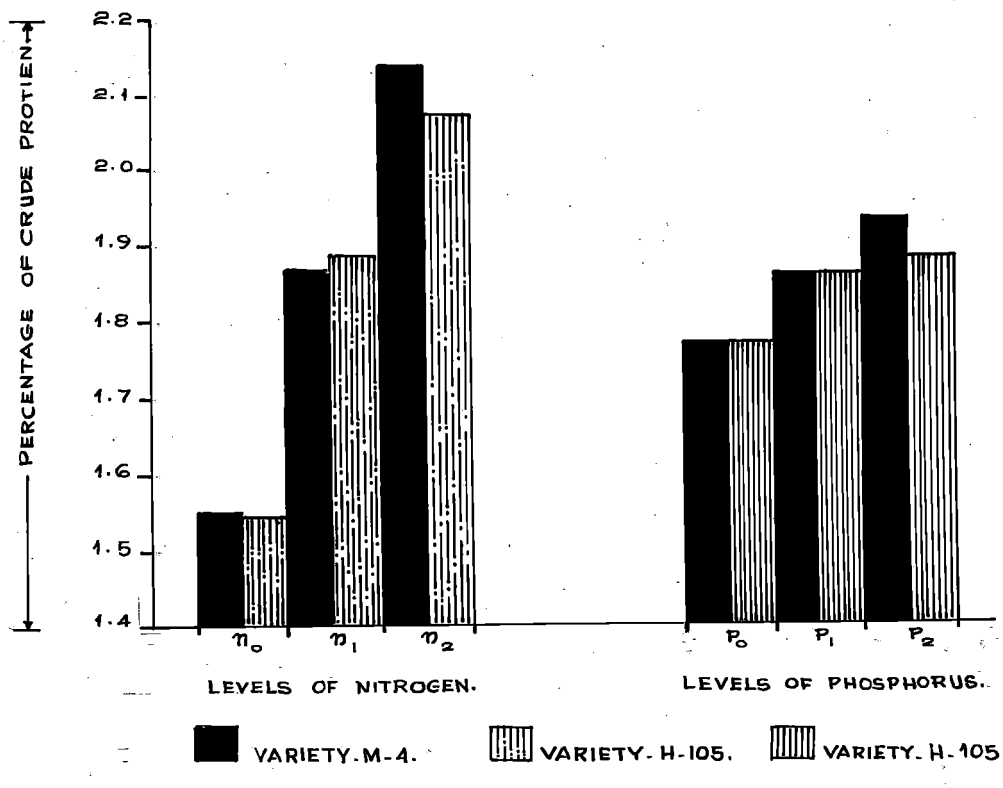

Fig 4

percentage (Table XIII). The plants that received nitrogen alone have recorded a lower percentage of crude protein in their tubers compared to those that received phosphorus along with nitrogen. Similar results were reported from the Tapioca Research Station, Trivandrum (Anonymous, 1960) and also by Pillai (1967). The synthesis of protein would not take place at rapid rates in plants deficient in phosphorus (Meyer and Anderson, 1958).

Phosphorus is seen to influence the dry matter content of tubers, while the effect of nitrogen is significant only upto the middle level, i.e. 75 kg. nitrogen per hectare (Table XII). The result is in partial agreement with the findings of Malavolta et al. (1955), Coura et al. (1961) and Pillai (1967). The treatment n_2p_2 recorded the maximum percentage of dry matter in both the varieties (39.9% in M-4 and 37.9% in M-105). But the highest level of nitrogen in the absence of phosphorus has given a significantly low percentage of dry matter and starch. This indicates a relation between starch and dry matter in tubers, a result that lends support to the report of the Tapioca Research Station, Trivandrum (Anonymous, 1955).

Nitrogen is found to reduce the percentage of edible portion especially in the absence of phosphorus. The minimum values of 81.8 per cent in M-4 and 80.7 per cent in M-105, are recorded by the treatment n_2p_0 (Table XII). A comparable result was recorded by Pillai (1967).

The study on the hydrocyanic acid content of tubers emphasises the special significance of balanced application of nitrogen and phosphorus. When the incremental doses of nitrogen have significantly increased the hydrocyanic acid content in tubers, phosphorus has shown just the reverse effect to a significant magnitude. Thus phosphorus is seen to alleviate the effect of nitrogen in this regard (Table XIII).

It was reported by Meyer and Anderson (1958) that inorganic nitrogen compounds would accumulate in plants in the absence of available phosphates. Boyd et al. (1930) reported that cyanide was formed due to a peculiar type of protein synthesis by which the nitrate nitrogen in the plant tissue would be transformed into hydrocyanic acid in cyanophoric plants, as an intermediate stage between nitrate and amino acid in the formation of protein. In the light of the literature cited, it appears that the low phosphorus supply might have inhibited protein synthesis in the phosphorus deficient plants, resulting in an accumulation of hydrocyanic acid. This view gets strengthened when the crude protein content of the treatments n_2p_0 or n_1p_0 is examined (Table XIII). They record a significantly low crude protein compared to the treatments n_2p_2 and n_2p_1. As nitrogen is an essential constituent of hydrocyanic acid, probably higher quantities of this element might not have accumulated in nitrogen deficient plants to increase the hydrocyanic acid in their tubers. The influence of nitrogen in increasing the hydrocyanic acid content and the role of

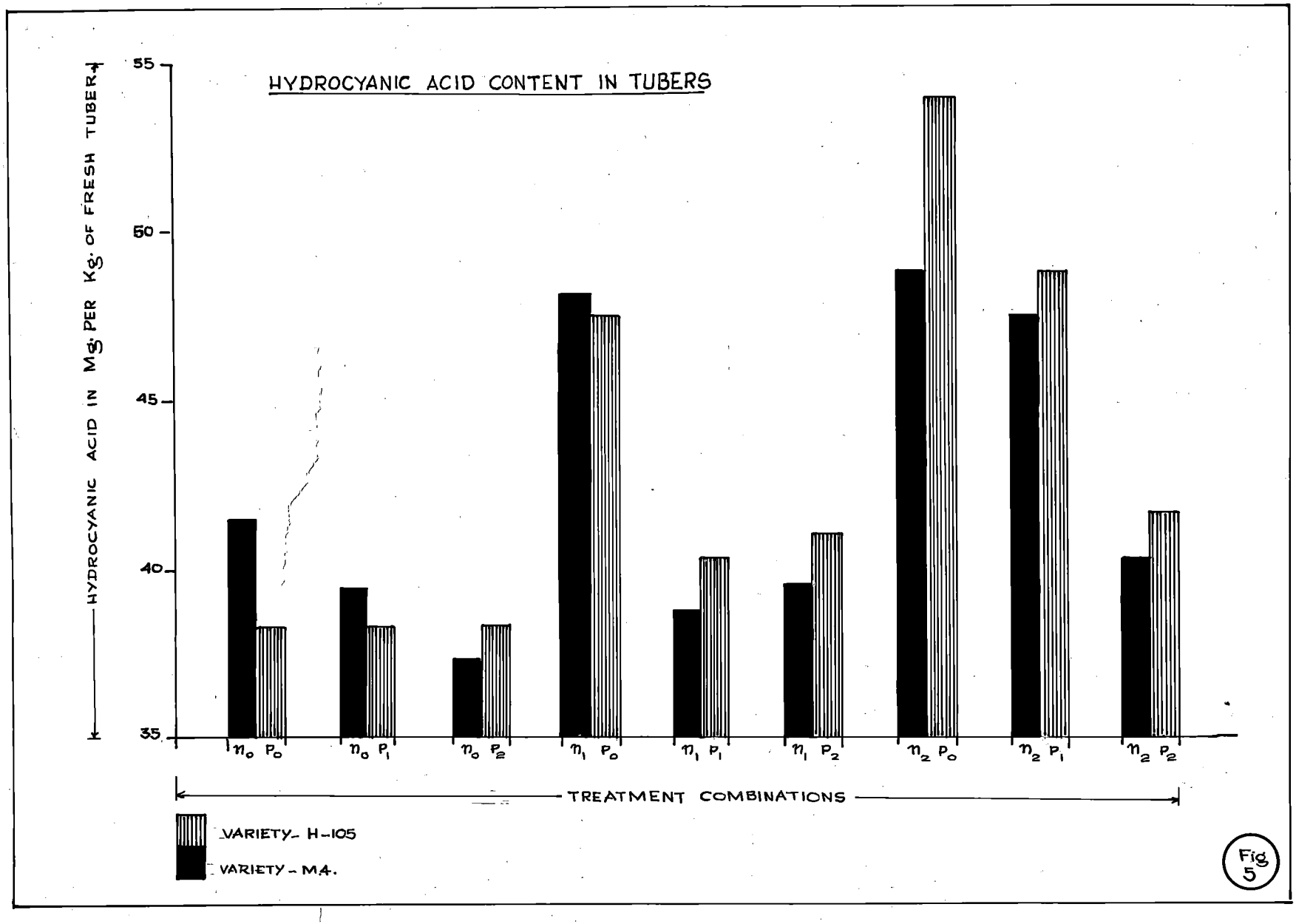
HYDROCYANIC ACID CONTENT IN TUBERS
HYDROCYANIC ACID IN MGS. PER KG. OF FRESH TUBER
55
50
45
40
35
n_0 P_0
n_0 P_1
n_0 P_2
n_1 P_0
n_1 P_1
n_1 P_2
n_2 P_0
n_2 P_1
n_2 P_2
TREATMENT COMBINATIONS
VARIETY- H-105
VARIETY - M4.

Fig 5

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phosphorus to mitigate this effect, as noticed in the present study, lends support to similar observations made by Patel and Wright (1958) in sudan grass.

One of the objectives of the present investigation is to delineate the varietal differences with regard to the pattern of uptake of the nutrients and to the yield and quality of tubers.

In a broad sense, the pattern of uptake of the two nutrients under study as judged by their percentage in the reflect, can be considered to be similar (Fig. 1 and 2). The variety H-105 may be considered more efficient in utilising the nutrients as it has registered a higher percentage of nitrogen and potassium at the last two stages of growth studied. The higher capacity of H-105 for nutrient absorption might have naturally led to the larger number of leaves, greater height, more number of tubers, greater shoot weight etc. ultimately leading to a higher yield than M-4.

As to the quality of tubers, M-4 is seen to be superior to H-105 in dry matter and percentage of edible portion. In the percentage of starch content of tubers, H-105 is found to be superior to M-4. Under conditions of varying doses of potassium and calcium it has been found that H-105 is superior to M-4 in percentage starch content, though when the yield potentialities of the two varieties are considered in terms of kilogram starch per hectare, M-4 becomes superior (Pushpadas, 1968). This is due to M-4 being superior to H-105 in respect of percentage of edible portion and dry matter of tubers. But, in the present study such a reversal of superiority has not been observed because of the greater

differences in yield between the two varieties overriding and masking other influencing qualities of M-4.

The findings, in general, point out the importance and need of a balanced application of nitrogen and phosphorus to both the varieties inorder to realise a high yield per unit area and also to produce quality tubers.

TABLE XVI

Relation between the application of nutrients and the yield and quality of tubers

Treatment	Yield in tonnes/ha.		Percentage starch		Percentage dry matter		Hydrocyanic acid in mg. per kg. of fresh tuber	
	M-4	H-105	M-4	H-105	M-4	H-105	M-4	H-105
n_0P_2	16.9	17.8	76.7	77.5	37.1	36.8	37.4	38.2
n_2P_0	17.3	19.5	73.3	72.4	37.3	36.6	48.9	54.0
n_1P_1	24.0	26.0	81.4	81.4	39.1	37.3	38.9	40.3
n_2P_2	28.6	30.9	80.0	82.3	39.9	37.9	40.3	41.8

An examination of the above table reveals that an inbalance of the two nutrients, nitrogen and phosphorus, will be more detrimental than even a lower, yet balanced application of them.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

An investigation was carried out at the Agricultural College and Research Institute, Vellayani during the year 1966-'68 to evolve a suitable diagnostic technique for the nutritional status of nitrogen and phosphorus in two varieties of tapioca (M-4 and H-105) by foliar analysis. The response of the two varieties to graded doses of nitrogen (0, 75 and 150 kg. N/ha.) and phosphorus (0, 50 and 100 kg. P_2O_5/ha.) and their interaction in relation to the pattern of uptake, yield and quality of tubers was also investigated. Potassium and calcium were kept constant at 250 kg. and 1200 kg. per hectare respectively. A Split-plot experiment in R.B.D., with three levels each of nitrogen and phosphorus in factorial combinations as major treatments and with the two varieties as minor treatments, was laid out.

Leaf laminae and petioles each grouped into three morphological categories, were used for testing the suitability for the diagnostic analysis. The plant part thus standardised (reflect) was analysed at three stages of growth for nutrient content. Biometric observations were recorded at three stages of growth. Yield components and quality factors of tuber were assessed in relation to nutrition of the plants. The results obtained and the conclusions drawn are summarised below.

1. Studies on correlation between the percentage of nitrogen and phosphorus in the tissue and the quantity of these nutrients added to the soil revealed that the middle one third of the total petioles would be the best reflect for nitrogen and phosphorus.

2. The percentage of the nutrients in the reflect collected in the second stage, i.e. four and a half months after planting, correlated well with the yield of tubers, justifying the choice of the reflect and indicating the possibility of predicting yield by tissue analysis.

3. 0.70 per cent nitrogen (N) and 0.15 per cent phosphoric acid (P_2O_5) in the reflect of a four and a half month old plant were found to be the approximate concentrations, below which a deficiency of these nutrients would exist in both varieties.

4. Application of nitrogen resulted in a significant increase in its percentage in the reflect, whereas phosphorus decreased the nitrogen percentage.

5. Application of phosphorus significantly increased its percentage in the reflect, while nitrogen showed a depressing effect on phosphorus content.

6. Nitrogen significantly increased the percentage of potassium in the reflect, while phosphorus showed the reverse effect.

7. Neither nitrogen nor phosphorus had any significant influence on the number of leaves or height of plants.

8. Nitrogen and phosphorus, individually and in combination, exerted a significant positive influence on the yield of tubers.

9. The individual effects of nitrogen and phosphorus as well as their combined effect were found to be significant in increasing the percentage of dry matter and crude protein in tubers.

10. Nitrogen significantly decreased the percentage of edible portion of tubers, while phosphorus had no influence on the same.

11. Nitrogen at 75 kg. per hectare significantly increased the percentage of starch in tubers. At 150 kg. per hectare, a significant decrease in starch percentage over that at 75 kg. per hectare was noticed. Phosphorus showed a significant positive influence on the percentage of starch.

12. The effect of nitrogen and phosphorus, the former positively and the latter negatively, was highly significant in influencing the hydrocyanic acid content of tubers. Phosphorus in combination with nitrogen was found to mitigate the influence of nitrogen.

13. As judged by the percentage of the nutrients in the reflect, H-105 was found to be more efficient than M-4 in the uptake of nutrients.

14. H-105 registered superiority over M-4 in number of leaves, height, weight of shoot, number of tubers, yield and starch content of tubers.

15. M-4 recorded superiority over H-105 in percentage of dry matter and edible portion of tubers.

16. No varietal difference was observed in the percentage of crude protein or hydrocyanic acid content of tubers.

17. Considering the yield and the various factors contributing to the quality of tubers, the treatment embracing 150 kg. nitrogen (N) and 100 kg. phosphoric acid (P_2O_5) per hectare could be taken as the best, for both the varieties. The treatment corresponding to 75 kg.

nitrogen and 50 kg. phosphoric acid per hectare ranked second in yield. This showed the importance of a 3:2 ratio between nitrogen and phosphoric acid in the fertilization programme of the crop.

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

(a) improvement of the evolved diagnostic technique by including more frequent samplings at the early stages of growth and by restricting the number of petioles sampled,

(b) establishment of critical levels for nitrogen and phosphorus by carrying out a large number of experiments in different agroclimatic regions of the State,

(c) the study of interrelationship between calcium, magnesium and phosphorus in the plant; and

(d) the possibility of finding out the most suitable doses of the various nutrients, which would give the highest percentage of starch and the lowest hydrocyanic acid content in tubers.

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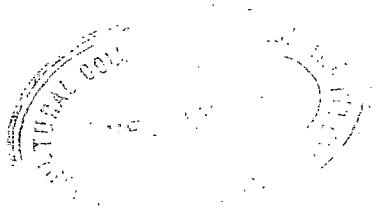
APPENDICES



APPENDIX I

Meteorological data recorded at the Agricultural College Farm during the crop period

Month	Rainfall in mm.	Temperature °F		Relative humidity (per cent)
		Maximum	Minimum	
June 1967 (29th & 30th)	39.0	84.0	80.0	89.0
July	137.8	87.6	77.8	89.9
August	52.0	87.2	77.5	89.8
September	50.0	86.9	77.6	88.6
October	280.0	85.1	79.0	89.3
November	46.0	86.5	77.8	88.3
December	Nil	86.6	79.9	88.2
January 1968	33.9	91.4	68.5	87.3
February	Nil	91.4	68.9	89.3
March (till 16th)	31.3	91.8	68.9	86.5

APPENDIX II

Nitrogen content in petioles - I sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.004	2	0.002	1
Major treatment	0.046	8	0.006	1
Error (1)	0.121	16	0.008	
Minor treatment	0.059	1	0.058	19.33**
Interaction	0.090	8	0.011	3.66*
Error (2)	0.046	18	0.003	
Total	0.365	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX III

Nitrogen content in petioles - II sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.020	2	0.0100	7.7**
Major treatment:				
N	1.381	2	0.6905	552.3**
P	0.001	2	0.0005	1
N x P	0.012	4	0.0030	2.3
Error (1)	0.020	16	0.0013	
Minor treatment	0.039	1	0.0390	11.2**
Interaction	0.077	8	0.0096	2.7*
Error (2)	0.063	18	0.0035	
Total	1.613	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX IV

Nitrogen content in petioles - III sampling

(Anelysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.0313	2	0.0157	10.4**
Major treatment:				
N	1.4064	2	0.7032	46.8**
P	0.1333	2	0.0666	4.4*
N x P	0.3908	4	0.0977	6.5**
Error (1)	0.0240	16	0.0015	
Minor treatment	0.0003	1	0.0003	1
Interaction	0.0432	8	0.0054	1
Error (2)	0.1244	18	0.0069	
Total	2.1537	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX V

Phosphorus content in petioles - I sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.0381	2	0.0190	1
Major treatment:				
N	0.0585	2	0.0292	1
P	1.2132	2	0.6066	9.4**
N x P	0.0837	4	0.0209	1
Error (1)	1.0271	16	0.0642	
Minor treatment	0.0454	1	0.0454	1
Interaction	0.4958	8	0.0619	1
Error (2)	1.8477	18	0.1026	
Total	4.8095	53		

** Significant at 1 per cent level

APPENDIX VI

Phosphorus content in petioles - II sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.0129	2	0.0065	3.61
Major treatment:				
N	0.0012	2	0.0006	1
P	0.2252	2	0.1126	62.55**
N x P	0.0144	4	0.0036	2.00
Error (1)	0.0289	16	0.0018	
Minor treatment	0.0003	1	0.0003	1
Interaction	0.0177	8	0.0022	1
Error (2)	0.0437	18	0.0024	
Total	0.3443	53		

** Significant at 1 per cent level

APPENDIX VII

Phosphorus content in petioles - III sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.0008	2	0.00040	1.28
Major treatment:				
N	0.0023	2	0.00115	3.71*
P	0.0258	2	0.01290	41.59**
N x P	0.0027	4	0.00066	2.12
Error (1)	0.0049	16	0.00031	
Minor treatment	0.00003	1	0.00003	1
Interaction	0.0030	8	0.00037	1.05
Error (2)	0.0064	18	0.00035	
Total	0.04593	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX VIII

Potassium content in petioles - I sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	6.470	2	3.280	3.71*
Major treatment	9.980	8	1.245	1.40
Error (1)	14.160	16	0.885	
Minor treatment	0.510	1	0.510	1.54
Interaction	3.780	8	0.472	1.42
Error (2)	6.050	18	0.336	
Total	40.950	53		

* Significant at 5 per cent level

APPENDIX IX

Potassium content in petioles - II sampling (Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.44	2	0.220	1
Major treatment:				
N	3.76	2	1.880	5.15*
P	4.71	2	2.355	6.45**
N x P	1.83	4	0.457	1.25
Error (1)	5.84	16	0.365	
Minor treatment	3.22	1	3.220	9.75**
Interaction	3.31	8	0.413	1.24
Error (2)	5.94	18	0.330	
Total	29.05	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX X

Potassium content in petioles - III sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	3.455	2	1.728	7.38**
Major treatments:				
N	2.706	2	1.353	5.78*
P	3.762	2	1.881	8.03**
N x P	0.748	4	0.187	1
Error (1)	3.746	16	0.234	
Minor treatment	5.352	1	5.352	19.31**
Interaction	2.248	8	0.281	1.03
Error (2)	4.903	18	0.272	
Total	26.920	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XI

Calcium content in petioles - I sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.8724	2	0.4362	1.8
Major treatment:				
N	1.4242	2	0.7121	3.1
P	0.2671	2	0.1335	1
N x P	4.9651	4	1.2412	5.4**
Error (1)	3.6651	16	0.2291	
Minor treatment	0.0704	1	0.0704	1
Interaction	1.4047	8	0.1756	1
Error (2)	3.4682	18	0.1934	
Total	16.1372	53		

** Significant at 1 per cent level

APPENDIX XII

Calcium content in petioles - II sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.3648	2	0.1824	1.73
Major treatment	1.0473	8	0.1309	1.23
Error (1)	1.6909	16	0.1056	
Minor treatment	0.0028	1	0.0028	1
Interaction	0.3471	8	0.0434	2.16
Error (2)	0.3616	18	0.0201	
Total	3.8145	53		

APPENDIX XIII

Calcium content in petioles - III sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.0110	2	0.0055	1
Major treatment	0.5870	8	0.0734	1
Error (1)	3.2457	16	0.2028	
Minor treatment	0.0313	1	0.0313	1
Interaction	0.4270	8	0.0534	1
Error (2)	2.7967	18	0.1553	
Total	7.0987	53		

APPENDIX XIV

Magnesium content in petioles - I sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.6194	2	0.3097	1
Major treatment	5.8795	8	0.7350	2.23
Error (1)	5.2619	16	0.3290	
Minor treatment	2.2042	1	2.2042	11.08**
Interaction	2.4871	8	0.3109	1.56
Error (2)	3.5980	18	0.1988	
Total	20.0501	53		

** Significant at 1 per cent level

APPENDIX XV

Magnesium content in petioles - II sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.07	2	0.035	1
Major treatment	0.88	8	0.110	2.04
Error (1)	0.87	16	0.054	
Minor treatment	0.16	1	0.160	6.16*
Interaction	0.29	8	0.036	1.38
Error (2)	0.47	18	0.026	
Total	2.74	53		

* Significant at 5 per cent level

APPENDIX XVI

Magnesium content in petioles - III sampling

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.384	2	0.192	6.35**
Major treatment	0.314	8	0.039	1.29
Error (1)	0.483	16	0.030	
Minor treatment	0.036	1	0.036	1.14
Interaction	0.180	8	0.022	1
Error (2)	0.573	18	0.032	
Total	1.970	53		

** Significant at 1 per cent level

APPENDIX XVII

Number of leaves per plant - I observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	237.48	2	118.74	3.06
Major treatment	194.70	8	24.34	1
Error (1)	623.19	16	38.95	
Minor treatment	4283.13	1	4283.13	120.81**
Interaction	427.37	8	53.55	1.51
Error (2)	638.00	18	35.44	
Total	6403.87	53		

** Significant at 1 per cent level

APPENDIX XVIII

Number of leaves per plant - II observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	1843.60	2	921.80	2.42
Major treatment	3792.23	8	486.53	1.60
Error (1)	6097.07	16	381.06	
Minor treatment	848.05	1	848.05	5.40*
Interaction	970.95	8	121.37	1
Error (2)	3026.00	18	168.10	
Total	16577.90	53		

* Significant at 5 per cent level

APPENDIX XIX

Number of leaves per plant - III observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	2520.3	2	1260.1	1.5
Major treatment	2918.0	8	364.7	1
Error (1)	13141.0	16	821.3	
Minor treatment	22.0	1	22.0	1
Interaction	4267.0	8	533.4	1
Error (2)	10931.0	18	607.3	
Total	33799.3	53		

APPENDIX XX

Height of plants - I observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	363.10	2	181.5	2.77
Major treatment	390.67	8	48.9	1
Error (1)	1047.23	16	65.4	
Minor treatment	332.51	1	332.51	20.80**
Interaction	174.82	8	21.8	1.36
Error (2)	287.67	18	15.9	
Total	2596.00	53		

** Significant at 1 per cent level

APPENDIX XXI

Height of plants - II observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	3967.2	2	1983.6	2.39
Major treatment	13521.0	8	1690.1	2.04
Error (1)	13259.2	16	828.7	
Minor treatment	541.5	1	541.5	4.39
Interaction	448.0	8	56.0	1
Error (2)	2217.0	18	123.1	
Total	33953.9	53		

APPENDIX XXII

Height of plants - III observation

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	14540.6	2	7270.3	3.51
Major treatment	32727.7	8	4090.9	1.97
Error (1)	33099.8	16	2068.7	
Minor treatment	3617.9	1	3617.9	20.33**
Interaction	1482.1	8	185.3	1.04
Error (2)	3203.0	18	177.9	
Total	88671.1	53		

** Significant at 1 per cent level

APPENDIX XXIII

Weight of tubers - yield
(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	169.18	2	84.59	6.97**
Major treatment:				
N	720.18	2	360.09	29.34**
P	572.68	2	286.34	23.33**
N x P	219.90	4	54.98	4.48*
Error (1)	196.40	16	12.27	
Minor treatment	9.38	1	9.38	12.13**
Interaction	6.83	8	0.85	1.10
Error (2)	13.92	18	0.77	
Total	1908.47	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XXIV

Number of tubers

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	603.8	2	301.9	1.97
Major treatment:				
N	2691.9	2	1345.9	8.78**
P	593.0	2	296.5	1.93
N x P	1071.8	4	267.7	1.75
Error (1)	2451.6	16	153.2	
Minor treatment	4574.3	1	4574.3	91.67**
Interaction	1286.3	8	160.8	3.22*
Error (2)	899.9	18	49.9	
Total	14172.6	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XXV

Weight of shoot at harvest

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	245.6	2	122.7	6.91**
Major treatment:				
N	1193.6	2	596.8	34.76**
P	559.1	2	279.5	16.12**
N x P	409.2	4	102.3	5.68**
Error (1)	272.9	16	17.7	
Minor treatment	352.6	1	352.6	30.81**
Interaction	107.8	8	13.5	1.17
Error (2)	206.0	18	11.4	
Total	3346.8	53		

** Significant at 1 per cent level

APPENDIX XXVI

Dry matter of tubers

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	1.45	2	0.725	3.34
Major treatment:				
N	23.48	2	11.740	54.10**
P	29.39	2	14.695	67.72**
N x P	3.89	4	0.972	4.48*
Error (1)	3.48	16	0.217	
Minor treatment	17.91	1	17.910	215.78**
Interaction	4.79	8	0.598	7.20**
Error (2)	1.57	18	0.083	
Total	85.96	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XXVII

Edible portion of tubers

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	0.44	2	0.22	1
Major treatment:				
N	59.85	2	29.92	23.19**
P	2.16	2	1.08	1
N x P	9.09	4	2.27	1.76
Error (1)	20.63	16	1.29	
Minor treatment	11.00	1	11.00	8.14*
Interaction	9.83	8	1.23	1
Error (2)	24.26	18	1.35	
Total	137.26	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XXVIII

Starch content of tubers

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	66.44	2	33.22	6.75**
Major treatment:				
N	484.54	2	242.27	49.24**
P	395.22	2	197.61	40.16**
N x P	35.68	4	8.92	1.81
Error (1)	78.71	16	4.92	
Minor treatment	6.96	1	6.96	4.93*
Interaction	7.84	8	0.98	1
Error (2)	25.43	18	1.41	
Total	1100.82	53		

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX XXIX

Crude protein content of tubers

(Analysis of variance)

Source	Sum of squares	d.f.	Variance	F-ratio
Block	0.136	2	0.068	8.39**
Major treatment:				
N	2.811	2	1.405	173.52**
P	0.152	2	0.076	9.39**
N x P	0.524	4	0.131	16.17**
Error (1)	0.130	16	0.008	
Minor treatment	0.004	1	0.004	1
Interaction	0.154	8	0.019	1.19
Error (2)	0.292	18	0.016	
Total	4.203	53		

** Significant at 1 per cent level

APPENDIX XXX

Hydrocyanic acid content of tubers

(Analysis of variance)

Source	Sum of squares	d.f	Variance	F-ratio
Block	8.29	2	4.14	1
Major treatment:				
N	581.85	2	290.92	35.64**
P	413.57	2	206.78	25.34**
N x P	193.70	4	48.42	5.93**
Error (1)	130.59	16	8.16	
Minor treatment	5.73	1	5.73	1
Interaction	69.17	8	8.64	1
Error (2)	172.31	18	9.57	
Total	1575.21	53		

** Significant at 1 per cent level

PLATE I

A general view of the crop after seven months

PLATE II

M-4; zero level of N and P (n_0p_0)

Vs.

150 kg. N/ha. with zero P (n_2p_0)


STUDIES ON THE UPTAKE OF
SILP BY TWO VARIETIES OF
PAPAYA AT DIFFERENT STAGES
OF GROWTH

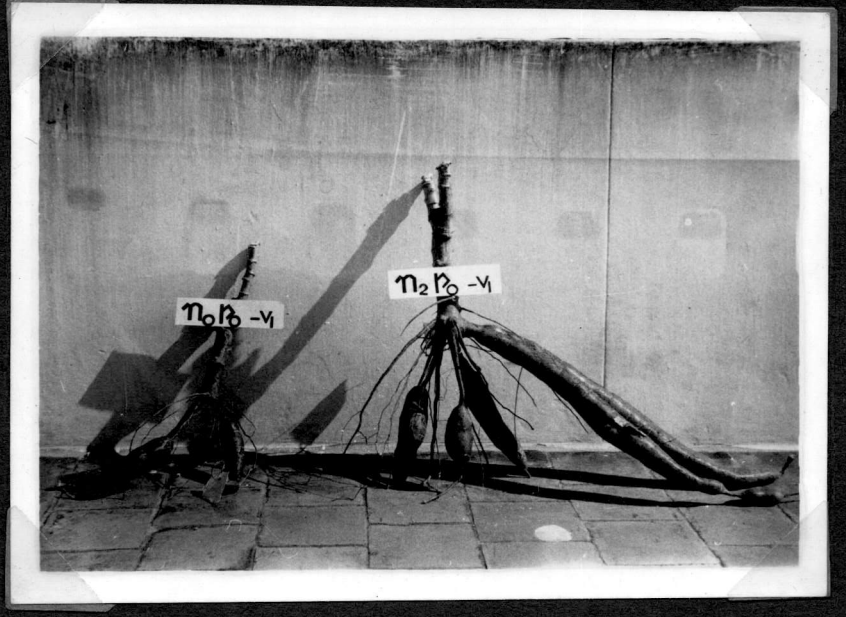

$n_0 P_0 - V_1$
$n_2 P_0 - V_1$

PLATE III

M-4; zero level of N and P (n_0p_0)

Vs.

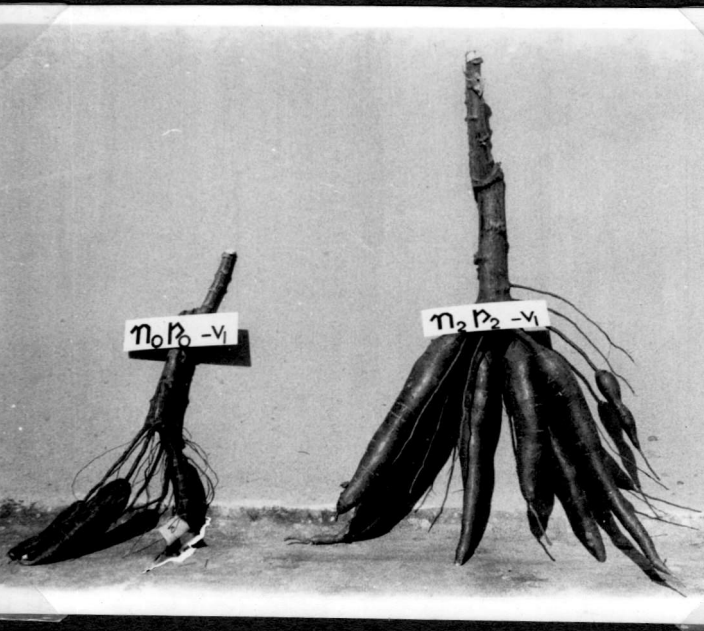
150 kg. N and 100 kg. P_2O_5/ha. (n_2p_2)

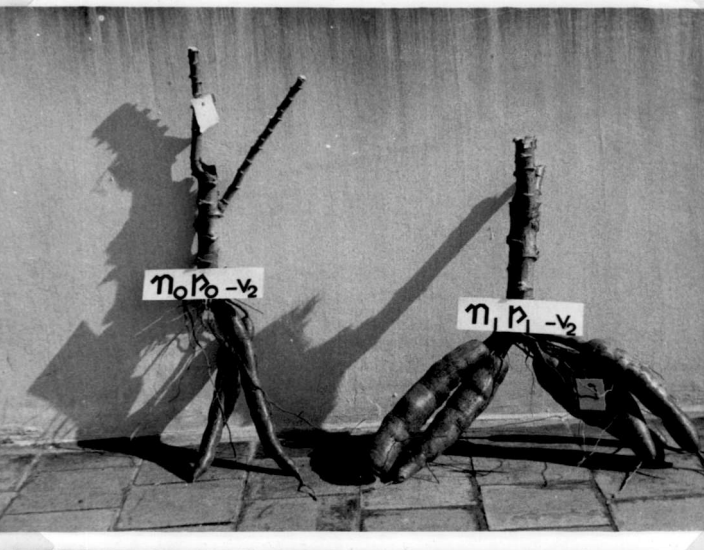
PLATE IV

M-105; zero level of N and P (n_0p_0)

Vs.

75 kg. N and 50 kg. P_2O_5/ha. (n_1p_1)


$n_0 r_0 - v_1$
$n_2 r_2 - v_1$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$n_1 r_1 - v_2$

PLATE V

H-4: 75 kg. N and 50 kg. P_2O_5/ha. (n_1p_1)

Vs.

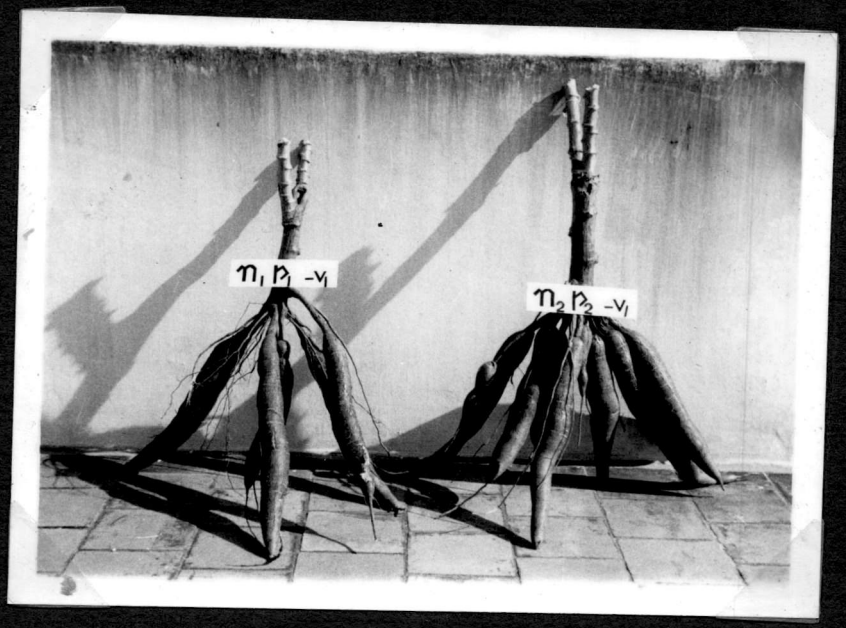
150 kg. N and 100 kg. P_2O_5/ha. (n_2p_2)

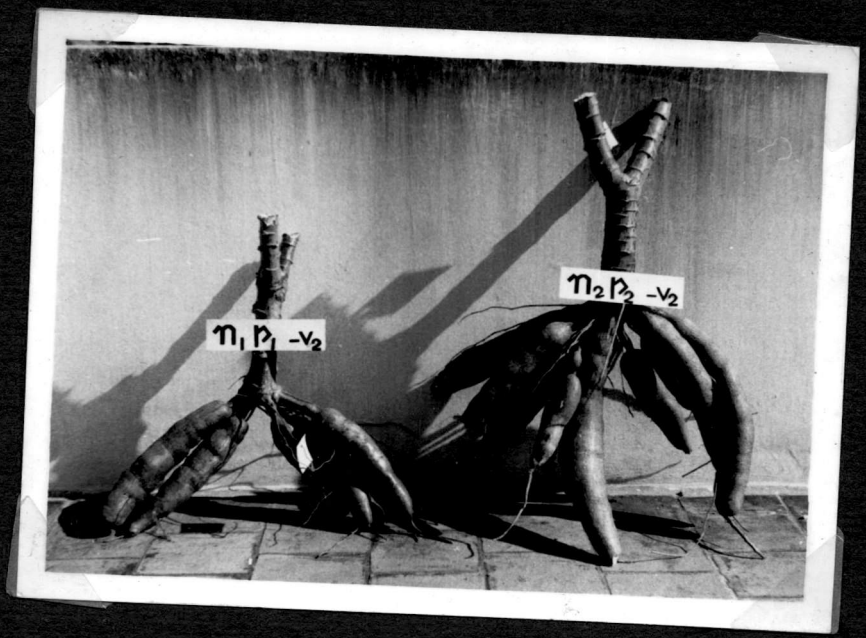
PLATE VI

H-105: 75 kg. N and 50 kg. P_2O_5/ha (n_1p_1)

Vs.

150 kg. N and 100 kg. P_2O_5/ha. (n_2p_2)


$n_1 p_1 - v_1$
$n_2 p_2 - v_1$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$n_1 p_1 - v_2$