FOLIAR DIAGNOSIS, YIELD AND QUALITY OF GINGER (*Zingiber officinale* ROSCOE) IN RELATION TO NITROGEN, PHOSPHORUS AND POTASSIUM

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Foliar diagnosis, yield and quality of ginger in relation to nitrogen, phosphorus and potassium" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
31st August, 1978.

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CERTIFICATE

Certified that this thesis is a record of research work done by Shri Johnson, P.T. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

The ginger of commerce is the underground stem or rhizome of Zingiber officinale Roscoe. (Zingiberaceae), a perennial herbaceous plant cultivated as an annual crop in India, Africa, Jamaica, Indonesia, Australia and Japan. India, the largest producer and exporter of this important spice produces 43500 tonnes of green ginger annually from an extensive area of 26800 hectares.

Though the crop deserves national importance in terms of foreign exchange earnings, research on ginger remains very much limited. Systematic investigation on ginger was first undertaken in the country with the commencement of a ginger research scheme in 1950 at the Horticultural Research Station, Ambalavayal (Kerala). Subsequently, research on ginger was started in other research centres also. However, most of these investigations were confined to the screening of varieties suited for different agro-climatic regions while no attempt has been made to assess the nutritional requirement of the crop in relation to the pattern of uptake and the nutrient level maintained in the plant.

The highly heterogenous nature of the soil and the complexities of transmission of nutrient from soil to the plant necessitate the use of tissue analysis as a better guide rather than soil analysis in predicting the crop performance. Detection of nutrient status of the plant, assessment of the nutrient need of the crop and prediction of crop performance by foliar diagnosis have been successfully followed in many crops while such a study has not been reported in ginger. The present investigation was therefore undertaken with the following objectives in view:

1. To develop a foliar diagnosis technique in ginger in relation to N, P and K;
2. To study the pattern of uptake of N, P and K under the influence of the graded doses of these nutrients added;
3. To study the effect of N, P and K treatments on the yield, quality and morphological characters of ginger; and
4. To examine the influence of increasing period of grwoth on the morphological characters, chemical composition and quality of ginger.

The results of this investigation are presented and described in the following pages.

REVIEW OF LITERATURE

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1. Foliar Diagnosis

The advent of foliar diagnosis heralds a new phase in the realm of crop fertilization. The term 'Diagnostic Foliaire' was first used in France by Lagatu and Maume (1926) and the concept of tissue analysis as a diagnostic technique for mineral deficiencies in plant was given a rational and scientific footing by these scientists. Foliar diagnosis is used as a guide to the nutritional status of the plant. It helps to establish threshold levels for nutrients below which plants show deficiency symptoms, and even more important, to establish nutrient values associated with optimum growth or yield.

Foliar diagnosis continues to be an empirical correlation between the leaf nutrient level at a particular part of the plant at a particular growth period and the final performance of the plant. The nutrient content of a leaf is not static, but subject to changes with various factors both external and internal. For practical convenience, a period when the leaf nutrient content is relatively stable is chosen

for sampling and related to the performance of the plant in quality and quantity. The position of leaf, part of leaf and form of nutrient to be estimated are all standardised. After a good deal of analysis of leaves from plants fed with varying levels of nutrients, the deficient or responsive levels, the critical or optimum levels, and high or luxury levels are identified to give guidance for fertilization.

Wadleigh (1949) remarked 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 deviation from this affects it. This is the strong basis on which plant analysis as a diagnostic tool stands.

Friis-nielsen (1966) reported that the interpretation of chemical plant analysis should be based on the total yield curves as a composite function of the absorbed nutrient and applied growth factor. Results of plant analysis belong to intervals of such yield curves, each interval being characteristic of particular inter-relationship between yield, nutrient absorption and growth factor level.

1.1 Sampling technique

Steenbjerg (1954) stated that care must be taken to choose such organs of the plant that the differences in the analytical results will be as great as possible, and that the sampling should be carried out during that part of the growing season when differences in the analytical results will be greatest.

Thomas (1937) found that the whole plant analysis will not furnish a sensitive index of the differences in nutrition of plant due to 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. Lagatu and Maume (1934) envisaged the leaf as the ideal tissue to sample, since it was considered the chemical laboratory of the plant. Rogers et al. (1955) compared 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.

Time of day for the collection of samples is also important. Ulrich (1952) opined that the best time to take samples was from 8 a.m. to 12 noon.

Velasco et al. (1953) studied nitrogen relations in rice plant by foliar diagnosis. They grew rice plants for 45 days in a nitrogen deficient subsoil or in complete nutrient solution and then treated with ammonium sulphate or transferred into nitrogen deficient media respectively. Analysis after 6 days showed the nitrogen level of the most recently matured leaves to be the best indicator of the nitrogen needs of the plant.

Boldyrev (1959) in his work entitled 'diagnosis of the nitrogen and phosphorus requirement of wheat during flowering by means of the general chemical analysis of the leaves' reported that the grain yield in wheat was correlated with nitrogen and phosphorus content of leaves. In field and pot tests in which nitrogen and phosphorus were applied to chernozomes, the percentage of nitrogen in leaves at flowering was highly and positively correlated with percentage nitrogen in the mature grain. Grain yield was correlated with the nitrogen and phosphorus contents of the leaves. Foliar diagnosis at flowering indicated whether or not the late top dressing with nitrogen and phosphorus was necessary. The Tserling method for the rapid determination of nitrogen requirement of wheat and prediction of grain

yield and quality was described by Opanasenkov et al. (1977). It was based on the determination of plant nitrate-nitrogen contents at different growth stages in relation to the colour intensity of stem sections stained with phenylamine on a scale of 1 to 6. High yields and high grain protein contents could be expected when the value at the earing stage was 5 to 6.

Goodall (1949) reported that response of barley to muriate of potash in terms of grain yield was significantly correlated with the potassium content of the older leaf blades and stems.

Tyner (1947) suggested tentative critical level of nitrogen, phosphorus and potassium in the sixth leaf of corn.

In a study on inorganic nutrition of bhindi, Chhonkar and Singh (1963) showed that increase in the supply of nitrogen, phosphorus and potassium to bhindi increased their contents in the shoot of 96 day old 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 on phosphorus content and vice versa.

In a study on the foliar diagnosis of crop yield and chemical composition of pea seeds, Sherstov and Boldyrev (1967) reported that seed yield and percentage contents of nitrogen, phosphorus and potassium in the seed 20 to 25 days before harvest can be predicted by foliar diagnosis at the flat stage of seed formation.

The application of tissue analysis to green house tomato nutrition was studied by Ward (1963). He collected tissue samples from 9 crops each week, the samples comprised a composite of the fifth leaf from the growing tip from 6 plants. Analytical results were correlated with visual symptoms of healthy or abnormal growth.

Preliminary report on the periods of critical need of potatoes for nitrogen and phosphorus by Emmert (1946) revealed that for higher yields, the petiole should contain 1200 ppm nitrogen in the early stages. Gallo *et al.* (1965) recorded that in pot experiments, determination of nitrate-nitrogen, phosphate-phosphorus, and total potassium in the petiole of the third leaf from the apical bud was a sensitive and simple method for following the mineral nutrition of potatoes.

Vomel and Ulrich (1963) in their work of leaf analysis for determination of manganese deficiency in sugarbeet reported that blades of physiologically mature (middle) leaves reflected the manganese status of sugarbeet better than any other tissue.

In the nutritional studies on cassava (Manihot esculenta Crantz), Pushpadas et al. (1974) has described the sampling technique for foliar diagnosis. They reported that middle one-third of total petioles would serve as the best tissue for nitrogen, phosphorus, potassium and calcium. The percentage of nitrogen, phosphorus and potassium in the petioles from middle one-third of total leaves, collected four and half months after planting, correlated well with the yield, thereby justifying the choice of the tissue for analysis and indicating the possibility of predicting yield by tissue analysis.

The detection of nitrogen, phosphorus and potassium deficiency trends in sugarcane crops by means of foliar diagnosis was undertaken by Halais (1963) in Mauritius. He observed that the requirement of the major nutrients of sugarcane could be ascertained by analysis of the circle, 7 mm in diameter, punched from the third leaf sampled before flowering. Miller (1963)

in his study of foliar diagnosis of nitrogen in sugarcane, sampled the central part without veins, of leaves 3 to 6 from the top of the plant, dried, ground and analysed for nitrogen. The leaf nitrogen percentage 72 days after fertilization gave the closest correlation with sugar production at harvest.

In banana, the concentrations of nitrogen, phosphorus and potassium of tnird, fifth and seventh leaves were determined and recommended to adopt the third leaf as the standard for sampling (Simmonds, 1959).

Lin (1963) in his work entitled 'leaf analysis as a guide to nitrogen fertilization of tea bushes' remarked that the second or third leaf from the apex of the young shoot of tea reflected nitrogen status of the plant most sensitively. Sampling error was reduced if two leaves of average size were selected for each tree. Variability was least when sampling was done from May to mid July and before noon.

Gachon (1952) based on his studies on foliar diagnosis in apple, reported that it is advisable to undertake sampling at the end of the season (September-October) and to use the first two leaves from a twig on the central part of the tree.

In his studies on the sampling methods in citrus, Nadir (1967) remarked that leaves should be sampled from the beginning of September to end of October, when they are five and half to seven months old. An additional sampling of ten month old leaves is essential for potassium. It has been reported that top three leaves of fruit bearing citrus plant (six to seven month old leaves) are found to be the best for leaf analysis.

Relationships between nutrient concentrations and the growth of the fast growing tropical eucalypt (Eucalyptus deglupta) were examined at two sitkes in Papua (New Guinea) by Lamb (1977). At the Gogol valley site, a predominantly linear relationship was found between growth and foliar nitrogen over the range 0.68 to 2.04 per cent nitrogen. At the Kerevat site, the relationship between growth and foliar nutrients was less strongly developed (foliar nitrogen varied from 1.77 to 3.36 per cent).

In the determination of nutrient status of oil palm by leaf sampling, Smilde and Chapas (1963) found that the first, seventeenth, and twentyfifth leaves were best suited for foliar diagnosis.

Chapman and Brown (1950) reported that the status of potassium of orange trees can be deduced from the potassium content of 3 to 7 month old spring cycle leaves.

Although leaf sampling technique for foliar diagnosis has been reported for most of the important agricultural crops, the same as employed in ginger, has not been recorded so far.

1.2 Critical level of nutrients

Critical level is defined as the level of a given element in the leaves above which the use of fertilizers is unprofitable. Generally it is assumed that the yield and foliar level of a given element are continuous functions dependent on the fertilizer doses applied to the soil.

Goodall (1949) reported that responses of barley to muriate of potash in terms of grain yield was significantly correlated with the potassium content of older leaf blades and stems and the following tentative limiting values at the time of ear emergence were suggested, above which no increase in grain yield as a result of potassium manuring was expected. a) 0.92 per cent potassium in older leaf blades b) 1.01 per cent

potassium in stems.

Effects of applied nitrogen, phosphorus and potassium fertilizers on the chemical composition of the earleaf of maize were examined in 28 fertilizer trials carried out in four islands of eastern Caribbean by Forde (1976). The sites were divided into two groups a) dry Leeward islands of Antigua b) wet islands of Dominica. Sufficiency ranges for nitrogen, phosphorus and potassium in the earleaf were 2.1 to 2.96 per cent nitrogen, 0.25 to 0.41 per cent phosphorus and 1.39 to 2.57 per cent potassium. Critical values for nitrogen, phosphorus, and potassium in the Leeward islands were 2.19, 0.25 and 2.17 per cent respectively, while for Dominica, these values were 2.53, 0.18, and 2.32 per cent respectively. Oke (1966) reported that in leaves of maize, the soluble nitrate content ranged from 210 to 320 ppm on nitrogen deficient plots and from 460 to 2820 ppm on plots supplied with different forms of nitrogen fertilizers. Three hundred ppm was taken as the critical nitrate level. Soluble nitrate content was a more effective index than total nitrogen content.

The following set of satisfactory nutrient levels were determined for tomato by Ward (1963) in America; nitrogen - 5.25 per cent, phosphorus - 0.8 per cent, potassium - 4.0 per cent, calcium -

1.5 per cent, magnesium - 0.45 per cent, N/K ratio -1.31.

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 atleast 2 per cent potassium at all stages of growth, produced maximum yield.

Vomel and Ulrich (1963) in their work of leaf analysis for determination of manganese deficiency in sugarbeet reported that the critical concentration of manganese was 10 ppm, and 15 to 25 ppm levels were required for high yield.

The detection of nitrogen, phosphorus and potassium deficiency trends in sugarcane by means of foliar diagnosis was undertaken by Halais (1963) in Mauritius. He recorded that levels of 1.95 per cent N, 0.48 per cent P_2O_5, and 1.5 per cent K_2O, on dry matter basis in the central part of the third leaf omitting the midrib for ratoon crops aged five months were optimum in his study from year to year on a follow up basis.

In banana, 2.6 per cent N, 4.5 per cent P_2O_5, and 3.3 per cent K_2O are recognised as critical concentrations (Simmonds, 1959).

Lin (1963) in his work entitled, 'leaf analysis as a guide to nitrogen fertilization of tea bushes' remarked that the critical nitrogen concentration in third leaf in various varieties was 4.6 to 3.6 per cent. Pritula (1966) reported that the optimum contents in the flesh were 5.0 per cent N, 1.0 per cent P_2O_5, and 1.9 per cent K_2O. Lin (1966) remarked that the critical concentrations of nitrogen, phosphorus and potassium in leaf were approximately 4.0 per cent, 0.26 per cent and 1.5 per cent respectively. Increasing the nitrogen supply usually increased leaf nitrogen and leaf phosphorus, but decreased leaf potassium. Optimum ratios for N/K, N/P and P/K were 3, 14 and 0.2 respectively. Highly significant relationships were found between leaf nitrogen, phosphorus and potassium and annual leaf yields.

Guyon (1947) found that healthy apple leaves contained about 2.3 per cent nitrogen, whereas deficient leaves contained only 1.5 per cent.

A tentative critical foliar nitrogen concentration of 2.1 per cent was proposed by Lamb (1977) in his study of the relationship between nutrient concentration and the growth of the fast growing tropical eucalypt, Eucalyptus deglupta.

Foliar diagnosis as a research tool to evaluate the nutritional status of ginger has not been tried so far and the critical level of nutrients of the crop has not been reported.

2. Yield and quality of ginger in relation to nitrogen, phosphorus and potassium

2.1 Yield and plant characteristics

Experiments conducted in India and abroad showed that the yield of rhizomatous crops like turmeric and ginger could be increased by application of fertilizers. Broyer and Hoagland (1943) reported that the maximum rhizome development took place, when there was intermediate long days, medium light intensity and abundant nitrogen supply, while long days, high temperature and large nitrogen supply resulted in abundant shoot growth and poor rhizome development. Temperature, length of day and nitrogen supply significantly influenced rhizome top ratio. Ashby (1948) reported that increased dose of nitrogen increased the rate of leaf production in all cultivated crops while insufficient nitrogen drastically reduced the yield and also decreased the quality of plant products whereas excess nitrogen delayed flowering.

In rhizomatous and tuberous crops in which the main constituent is carbohydrate, the benefit of

nitrogen manuring is brought about by increased leaf area and consequent shoot growth. Russel (1973) reported that nitrogen was helpful for rhizome development of long duration crops. But in short duration crops the effect of nitrogen was only on the top.

Pillai (1973) found that higher level of nitrogen produced significant effect on the number, length and breadth of leaves, and number of tillers. Dasaradhi *et al.* (1971) stressed the importance of nitrogen at the active growth and tillering stage which was during the period from 120th to 135th day after sowing. At this stage, the nitrogen consumption was so high that the leaves normally contained 3 per cent nitrogen. They further stressed that readily available form of nitrogen should be applied during this stage.

Rajan and Singh (1972) showed that though saw dust alone when used for soil amendment was harmful, the application of urea to soil amended with saw dust significantly increased the yield of ginger. There was also increase in growth characters such as number of tillers, leaves per plant and height of plant.

Nair (1975) in his studies on the effect of foliar application of urea and planofix on the growth,

yield and quality of ginger varieties, observed that the combinations of urea and planofix, especially urea 2.0 per cent + planofix 400 ppm were better than the single application of above chemicals and influenced the yield and height of the plant significantly.

Aiyadurai (1966) in his review of the ginger development scheme, Himachal Pradesh showed that nitrogen fertilization of the crop with 50 to 100 kg nitrogen per hectare had significantly increased the yield by 18 to 32 per cent and improved the dry matter content of rhizome.

In the fertilizer trials conducted under the technical collaboration between Kerala Agricultural Department and Indian Potash Institute during 1957-60, application of 50 kg N, 50 kg of P_2O_5 and 100 kg of K_2O per hectare gave the maximum yield of ginger. The original trials conducted at the Agricultural Research Station, Ambalavayal had shown that the application of nitrogen and phosphorus either alone or in combination had no response. Later series of experiments at Ambalavayal and Thodupuzha showed that the application of complete fertilizers was better than application of nitrogen, phosphorus and potassium separately (Anon. 1954)

Kannan and Nair (1965) reported that ginger required heavy manuring with 25 to 30 tons of cattle manure as basal dose and 450 kg of 8 : 8: 16 fertilizer mixture per hectare for increased production.

The influence of nitrogen was evidenced by the trials conducted by the Jamaican Department of Agriculture (Anon. 1953). They got an increase in yield of 21 per cent by the application of nitrogen but no clear response to phosphorus and potash. Grossmann (1954) recommended a side dressing with 10:8:7 fertilizer mixture at the rate of 550 kg per hectare for higher yield of ginger.

Trials with nitrogen, phosphorus and potassium conducted at the Regional Research Station, Kandaghat for four years, indicated that the combination of 100 kg nitrogen, 50 kg phosphorus and 50 kg potassium per hectare proved best and produced a significant increase in the height of plants, number of tillers and yield of rhizome of ginger over control (Randhawa and Nandpuri, 1965). The application of 100 kg nitrogen in the absence of phosphorus or potash increased the height of plants, number of shoots and rhizome yield as compared to 50 kg nitrogen, while the growth or yield was not much influenced by the application of phosphorus and potash alone or in combination of both.

Muralidharan et al. (1973) reported that application of nitrogen, phosphorus and potash at the rate of 70, 70, 140 kg per hectare respectively increased the height and yield of plants. The number of tillers steadily increased with the increasing rate of nutrients upto the above level, but declined when applied beyond that level. Muralidharan et al. (1974) revealed that 70 kg nitrogen per hectare increased significantly the number of tillers and yield of rhizome, but the application of phosphorus had no effect, while potash (K_2O) at the rate of 140 kg per hectare significantly reduced the yield of rhizome, other plant characters being remained unaffected.

2.2 Quality of ginger

Sankaracharya and Natarajan (1975) assigned the following specifications on the chemical characteristics of good commercial ginger:

	per cent
Maximum moisture	12
Maximum crude fibre	8
Maximum total ash	5
Maximum ash insoluble in hydrochloric acid	1
Minimum volatile oil	2
Minimum ether extract	8
Minimum starch	42

Essential oil content of ginger varied from 1.5 to 3.5 per cent and it was composed of monoterpenes 5.0 per cent, sesquiterpenes 65.0 per cent and oxygenated compounds 30.0 per cent. They also reported that the percentage of oleoresin in ginger was 5 to 7 and the oleoresin contained 25 to 30 per cent gingerol.

Muralidharan (1972) in his work on varietal performance of ginger in Wynad, Kerala reported that the percentage recovery of dry ginger varied from 14.93 in Rio-de-Janeiro to 22.07 in Sierra Leone. Natarajan et al. (1972) in their study on the chemical composition and dehydration of ginger observed that most of the constituents like volatile oil, oleoresin and crude fibre increased during the course of maturity.

Nair (1975) observed that the foliar application of 2 per cent urea + 400 ppm planofix gave the maximum recovery of oleoresin and the minimum value for crude fibre as compared to the other treatments tried.

The effect of nitrogen, phosphorus and potassium on the quality aspects of ginger has not been tried and reported.

MATERIALS AND METHODS

MATERIALS AND METHODS

A field experiment was conducted during the period from May, 1977 to January, 1978 at the Instructional Farm, Vellanikkara, of the College of Horticulture in order to study the effect of different levels of nitrogen, phosphorus and potassium on the yield and quality of ginger and also to develop suitable foliar diagnosis technique in relation to these nutrient elements.

1. Field experiment

1.1 Site, climate and soil

The farm is situated at 32.1° N latitude and 16.76° E longitude, at an altitude of 22.25 m. The area enjoys a typical humid tropical climate.

The details of the meteorological observations for the period under the experiment are presented in Appendix I.

The soil of the experimental area was deep, well drained, moderately acid, medium clay loam soil and the site presented a uniform level topography. The chemical characteristics of the soil are given in Appendix IX.

1.2 Design, layout and treatments

The experiment was laid out in a 3^3 factorial experiment with three levels of nitrogen, phosphorus and potassium in randomised block design confounding the effect of interaction NP^2K^2 totally. The procedure followed for the allocation of various treatments to different plots was in accordance with Yates (1937). The details of the layout (Fig. 1) are as follows:

Total No. of treatments	..	27
No. of replications	..	3
No. of blocks	..	9
Total No. of plots (beds)	..	81
Gross plot size	..	1 m x 4 m
Net plot size	..	0.5m x 3.5m
Total experimental area	..	0.035 ha
Spacing	..	25 cm x 25 cm
No. of plants per plot	..	64

The levels of nitrogen, phosphorus and potassium employed are:

Levels of nitrogen

1	n_0	40 kg	N/ha (4 g/m^2)
2	n_1	80 kg	N/ha (8 g/m^2)
3	n_2	120 kg	N/ha (12g/m^2)

FIG.1 LAYOUT PLAN 3^3 FACTORIAL EXPERIMENT IN RBD CONFOUNDING NP^2K^2 TOTALLY

REP I			REP II			REP III		
$n_0p_0k_2$	$n_2p_1k_0$	$n_2p_0k_1$	$n_2p_0k_0$	$n_2p_2k_1$	$n_0p_0k_1$	$n_2p_2k_1$	$n_0p_0k_1$	$n_0p_2k_2$
$n_2p_2k_2$	$n_0p_1k_1$	$n_0p_2k_0$	$n_0p_2k_2$	$n_0p_1k_0$	$n_2p_1k_2$	$n_1p_2k_0$	$n_1p_1k_1$	$n_1p_0k_2$
$n_1p_0k_0$	$n_1p_2k_1$	$n_1p_1k_2$	$n_1p_1k_1$	$n_1p_2k_0$	$n_1p_0k_2$	$n_0p_1k_0$	$n_2p_0k_0$	$n_2p_1k_2$
$n_0p_2k_2$	$n_1p_1k_1$	$n_1p_0k_2$	$n_2p_1k_0$	$n_2p_2k_2$	$n_2p_0k_1$	$n_1p_1k_0$	$n_2p_2k_1$	$n_0p_0k_0$
$n_0p_2k_2$	$n_1p_1k_1$	$n_1p_0k_2$	$n_2p_1k_0$	$n_2p_2k_2$	$n_2p_0k_1$	$n_1p_1k_0$	$n_0p_2k_1$	$n_0p_0k_0$
$n_0p_1k_0$	$n_2p_2k_1$	$n_0p_0k_1$	$n_0p_0k_2$	$n_1p_0k_0$	$n_1p_1k_2$	$n_1p_0k_1$	$n_0p_1k_2$	$n_2p_1k_1$
$n_1p_0k_1$	$n_0p_2k_1$	$n_1p_1k_0$	$n_0p_0k_0$	$n_1p_0k_1$	$n_0p_1k_2$	$n_1p_2k_1$	$n_2p_0k_1$	$n_1p_1k_2$
$n_2p_2k_0$	$n_0p_1k_2$	$n_0p_0k_0$	$n_2p_2k_0$	$n_1p_1k_0$	$n_0p_2k_1$	$n_0p_0k_2$	$n_2p_1k_0$	$n_1p_0k_0$
$n_2p_1k_1$	$n_2p_0k_2$	$n_1p_2k_2$	$n_1p_2k_2$	$n_2p_0k_2$	$n_2p_1k_1$	$n_0p_2k_0$	$n_0p_1k_1$	$n_2p_2k_2$

Treatments

N	P_2O_5	K_2O
n_0 - 40 kg/ha	p_0 - 30 kg/ha	k_0 - 40 kg/ha
n_1 - 80 kg/ha	p_1 - 60 kg/ha	k_1 - 80 kg/ha
n_2 - 120 kg/ha	p_2 - 90 kg/ha	k_2 - 120 kg/ha

Gross plot size : 4 m x m
Net plot size : 3.5m x 0.5m
Spacing : 25cm x 25cm

Levels of phosphorus

1	P_0	30 kg P_2O_5/ha (3 g/m^2)
2	P_1	60 kg P_2O_5/ha (6 g/m^2)
3	P_2	90 kg P_2O_5/ha (9 g/m^2)

Levels of potassium

1	K_0	40 kg K_2O/ha (4 g/m^2)
2	K_1	80 kg K_2O/ha (8 g/m^2)
3	K_2	120 kg K_2O/ha (12g/m^2)

1.3 Field culture

The land was thoroughly ploughed and beds of size 4 m x 1 m x 0.25 m were formed at a spacing of 40 cm between the beds. Bunds were taken separating blocks and replications, and adequate facilities for drainage were provided. A basel dose of farm yard manure of 0.41 per cent N, 0.23 per cent P_2O_5 and 0.39 per cent K_2O was given at the rate of 30 tonnes per hectare. The bits of seed rhizome weighing 15 to 20 g each and having atleast two viable healthy buds, of the variety Rio-de-Janeiro were planted in small pits taken in the beds at a spacing of 25 cm x 25 cm. Planting was done on 4th May, 1977. All cultural practices followed were in accordance with the Package of Practices of the Kerala Agricultural University, 1977.

Nitrogen, phosphorus and potassium were supplied in the form of urea, superphosphate and muriate of potash respectively. The full dose of phosphorus and half the dose of potassium were given as basal application. The remaining quantity of potassium was applied on 120th day after planting. Nitrogen was given in two equal doses on 60th and 120th day.

The crop was harvested on 13th of January, 1978.

1.4 Observations

The following observations namely, number of tillers per clump, number of leaves per tiller, height of tiller, fresh weight of rhizome, dry weight of rhizome and total dry matter were recorded on 90th, 120th, 150th, 180th, 210th, and 240th day after planting and these days were referred as periods 1, 2, 3, 4, 5 and 6 respectively. Plant samples were also collected at these periods for chemical analysis. One of the replications, was completely used for these periodical removal of samples, while the other two were retained till harvest.

For the standardisation of leaf positions for foliar diagnosis, leaf samples were collected on 180th day ($\frac{4}{5}$th period). The leaves were numbered from top to

bottom of the tiller, the last fully opened leaf being referred as leaf No.1. The leaf numbers 1-4, 5-8, 9-12, 13-16 and, 17 and above were sampled separately and are referred as leaf positional groups 1, 2, 3, 4 and 5 respectively.

2. Analytical methods

2.1 Soil

The mechanical analysis of the soil was carried out by the International Pipette method (Piper, 1942). The pH of the soil was determined in a pH meter using a soil water ratio of 1: 2.5. For the determination of organic carbon, the method of Walkley and Black described by Piper (1942) was followed Total nitrogen was determined by Kjeldahl digestion-distillation method given by Jackson (1958). Available phosphorus was determined in the Bray No.1 extract of soil, by the chlorostannous-reduced molybdo phosphoric blue color method in hydrochloric acid system (Jackson, 1958).The potassium extracted by 1 N neutral ammonium acetate was determined flame photometrically and reported as available potassium.

2.2 Plant material

The total nitrogen content of the plant material was determined by the micro-Kjeldahl method(Jackson,1958).

For the determination of phosphorus and potassium, the plant material was digested with a mixture of perchloric, sulphuric and nitric acids (1:2:9). The phosphorus in the tripple acid extract was determined by the vanadomolybdate yellow colour method. While potassium was determined using a flame photometer (Jackson, 1958).

For the determination of oleoresin, freshly ground dry ginger was extracted with acetone, by the counter-current extraction using a Soxhlet apparatus (A.S.T.A., 1960).

The data relations to each character were analysed by applying the analysis of variance technique as suggested by Panse and Sukhatme (1967) for confounded factorial experiments.

RESULTS

RESULTS

1. Effect of NPK treatments and period of growth on the morphological characters and dry matter yield of ginger

The mean values on the morphological characters and dry matter yield of ginger as influenced by the NPK treatments and the period of growth are given in Table 1. The analysis of variance is given in Appendix II.

1.1 Number of tillers per clump

As evident from the table, the production of tillers was not influenced by the fertilizer treatments. But there was a progressive increase in the number of tillers per clump with increasing period of crop growth. However, the increase in number of tillers per clump after 180th day was not statistically significant. The rate of tiller production was maximum during the 4th month (90-120 days) after planting, and 27.85 per cent of the total tillers formed was produced during this period. The relationship between period of growth and number of tillers per clump is graphically represented in Fig.2.

1.2 Number of leaves per tiller

The data on the number of leaves per tiller

Table 1. Effect of NPK treatments and period of growth on the morphological characters and dry matter yield of ginger:

(Table of means)

Treatment groups	No.of tillers per clump	No.of leaves per tiller	Height of tiller cm	Total dry matter yield kg/m^2	Fresh weight of rhizome kg/m^2	Dry weight of rhizome kg/m^2
n_0	15.9	10.8	37.1	0.786		
n_1	17.2	10.5	42.7	0.946		
n_2	17.6	11.1	39.9	0.858		
p_0	16.0	10.9	40.2	0.826		
p_1	17.1	10.8	38.8	0.901		
p_2	17.6	10.8	40.8	0.863		
k_0	17.0	10.8	40.5	0.872		
k_1	16.5	10.9	38.8	0.821		
k_2	17.1	10.7	40.5	0.897		
Periods:						
1	6.41	7.17	28.80	0.208	1.11	0.072
2	12.76	9.73	38.50	0.428	2.43	0.172
3	16.15	10.90	41.10	0.463	2.64	0.198
4	20.30	12.30	43.70	0.640	3.28	0.272
5	22.80	12.30	43.70	0.789	3.41	0.408
6	22.80	12.30	43.70	0.863	3.62	0.470
C.D.for comparing: Periods	3.65	1.17	4.060	0.440	0.35	0.047
Levels of nitrogen	N.S.	N.S.	2.870	0.103	N.S.	N.S.
Combination of N & P	N.S.	N.S.	4.096	N.S.	N.S.	N.S.

FIG. 2 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND NO. OF TILLERS PER CLUMP

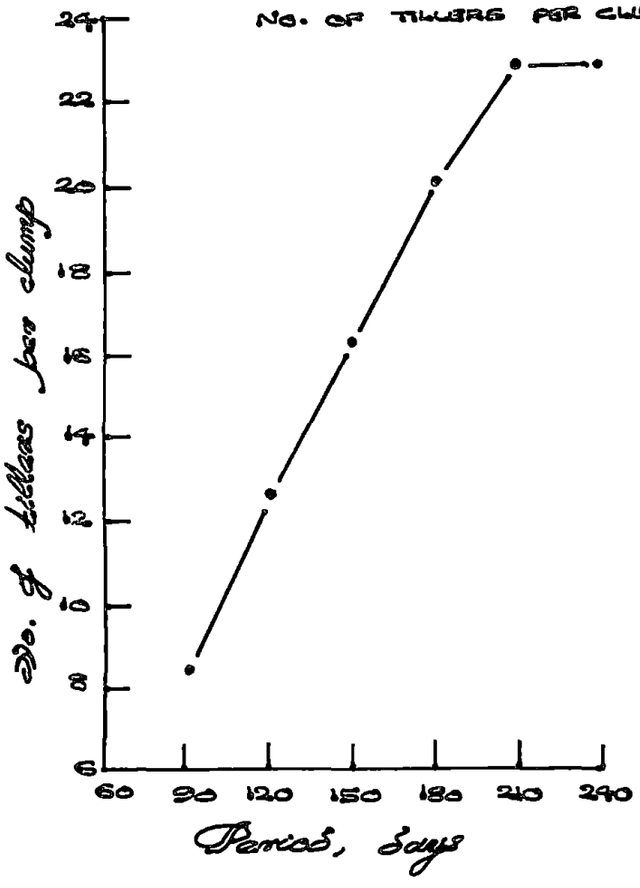


FIG. 3 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND NO. OF LEAVES PER TILLER

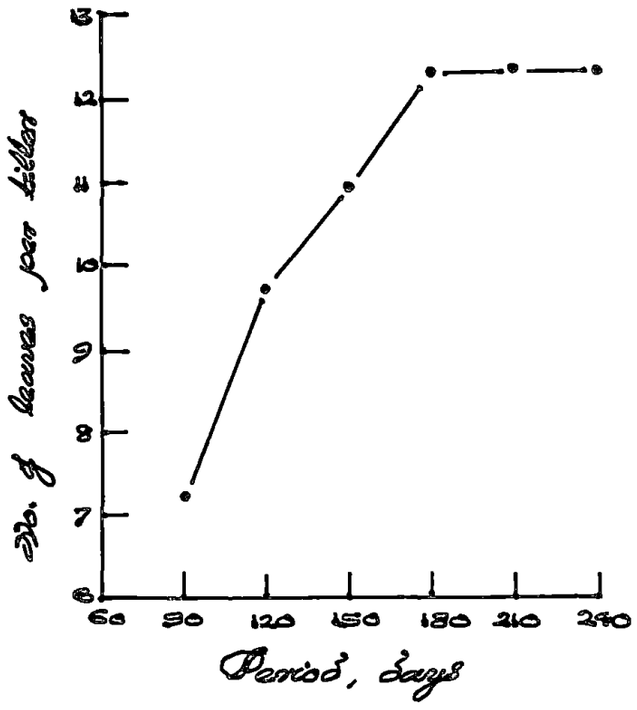


FIG. 4 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND HEIGHT OF TILLERS

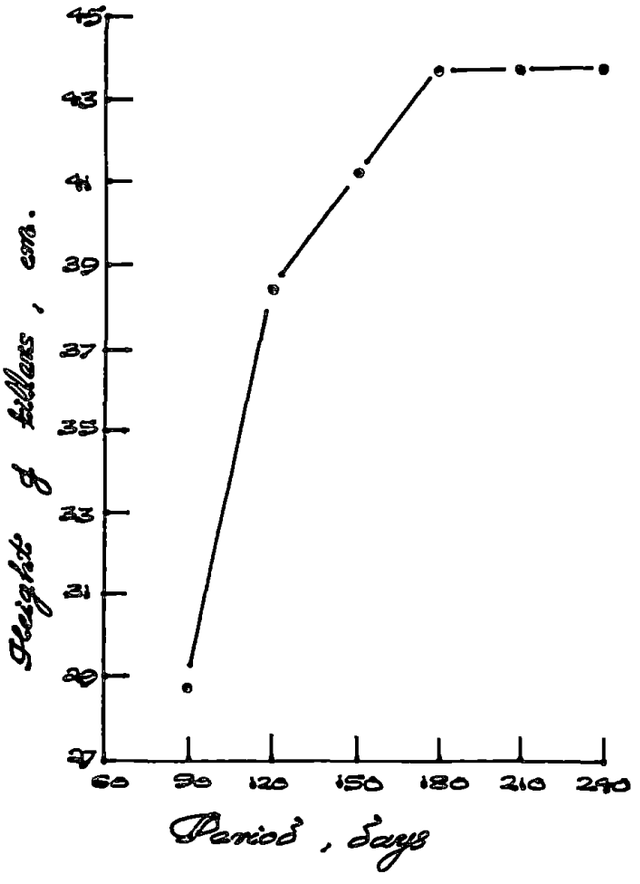
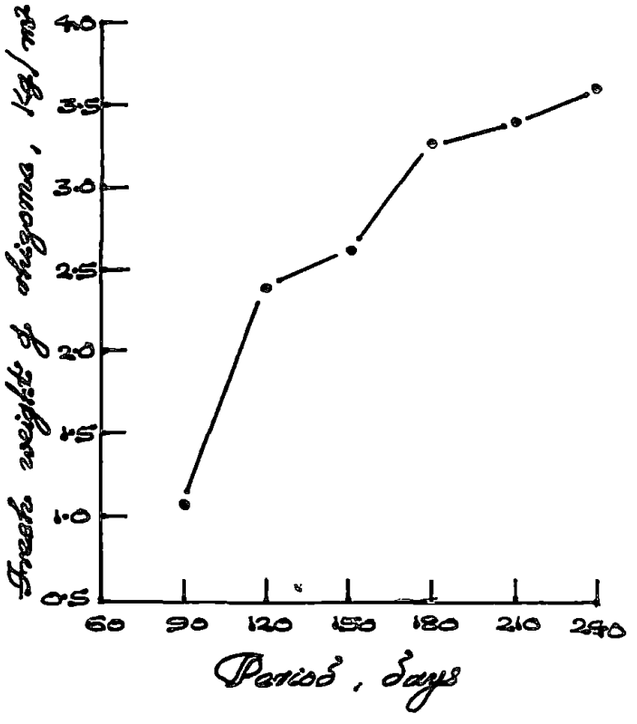


FIG. 5 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND FRESH WEIGHT OF RHIZOME



[illegible] the case of number of tillers, the mean number of leaves per tiller increased with increasing period of crop growth up to 180th day after planting after which it remained constant till harvest. Again, the maximum leaf production was noticed during the 4th month after planting. The relationship between period of growth and number of leaves per tiller is graphically represented in Fig. 3.

1.3 Height of tiller

The observations showed that height of the plant was the only morphological character affected by the fertilizer treatments. Among the various treatments employed, the effect of nitrogen and the NP interaction significantly influenced the height of tillers. Of the nitrogen treatments, the highest value for mean height of tillers was at the n_1 level (80 kg/ha) while difference between n_0 and n_2 was not significant. The height of the plant was found significantly correlated with the yield of rhizome ($r = +0.476$). The n_1 level at which the maximum mean height was observed also registered the maximum yield of ginger. The increase of nitrogen from n_0 to n_1 level enhanced the mean height of plant by

15.1 per cent, but further increase in nitrogen seemed to have a depressive effect on this character.

The influence of the period of growth on the height of tiller followed the same pattern (Fig.4) as in the case of the other two morphological characters already examined. The height increased with the increasing period of growth up to 180th day after planting and remained constant afterwards. The rate of growth in terms of height was maximum during the 4th month (90 to 120 days) accounting for 22.2 per cent of the total height attained by the tillers.

1.4 Fresh weight of rhizome

The influence of fertilizer treatments on the fresh weight of ginger at harvest (yield) has been examined and presented separately.

As regards the effect of increasing period of growth on the fresh weight of rhizome, it was observed that the weight progressively increased till the last period (Fig. 5). The maximum increase in the fresh weight of rhizome took place during the 4th month after planting. The rate of increase during this period was 118.56 per cent of the weight at the previous period and 36.5 per cent of the total fresh weight at harvest.

FIG.6 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND TOTAL DRY MATTER

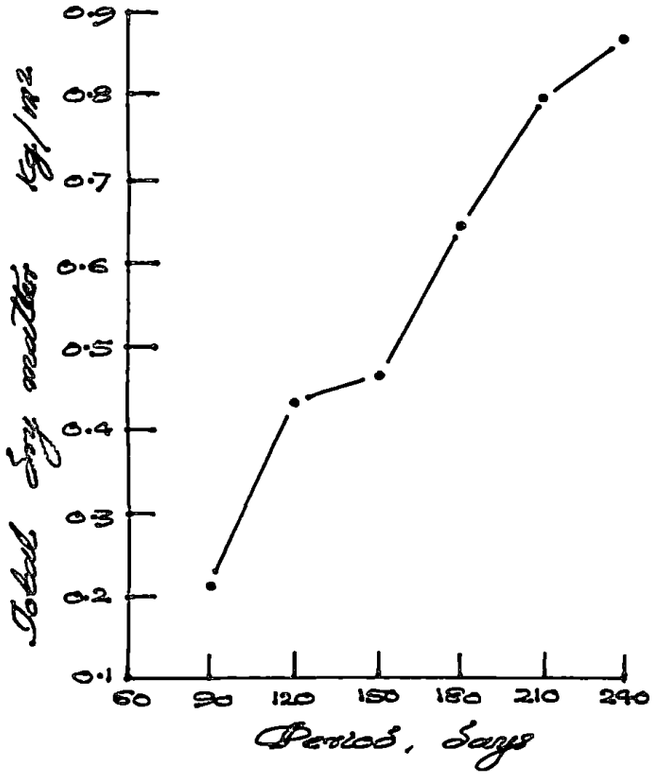


FIG.7 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND NITROGEN PERCENTAGE IN LEAF

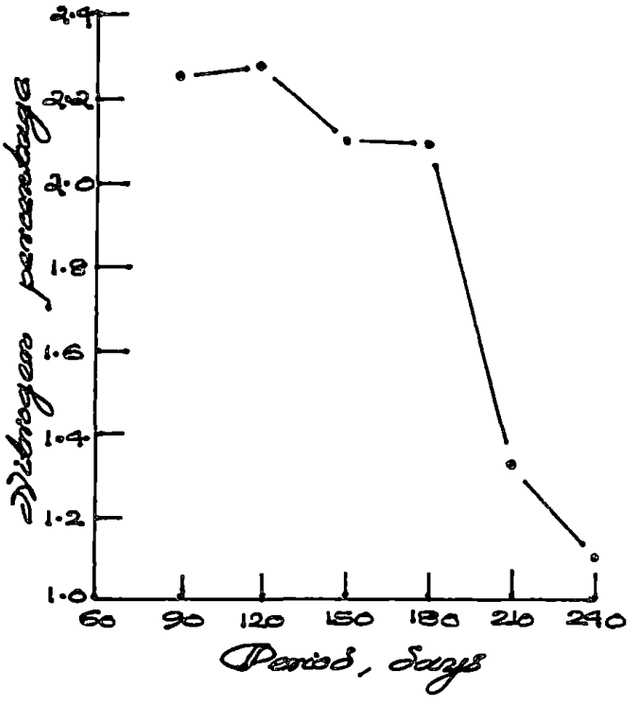


FIG.8 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND PHOSPHORUS PERCENTAGE IN LEAF

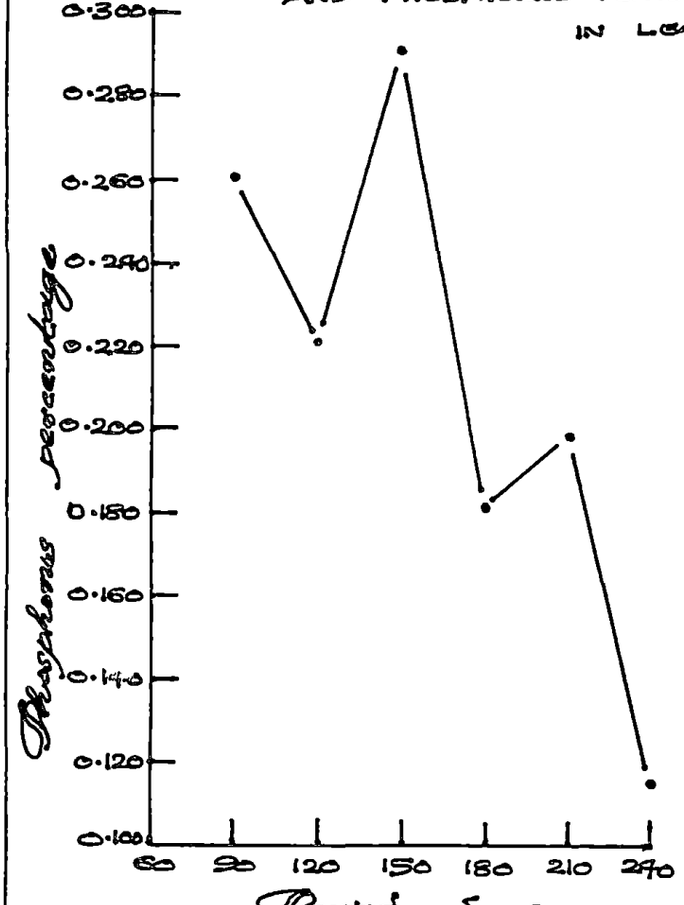
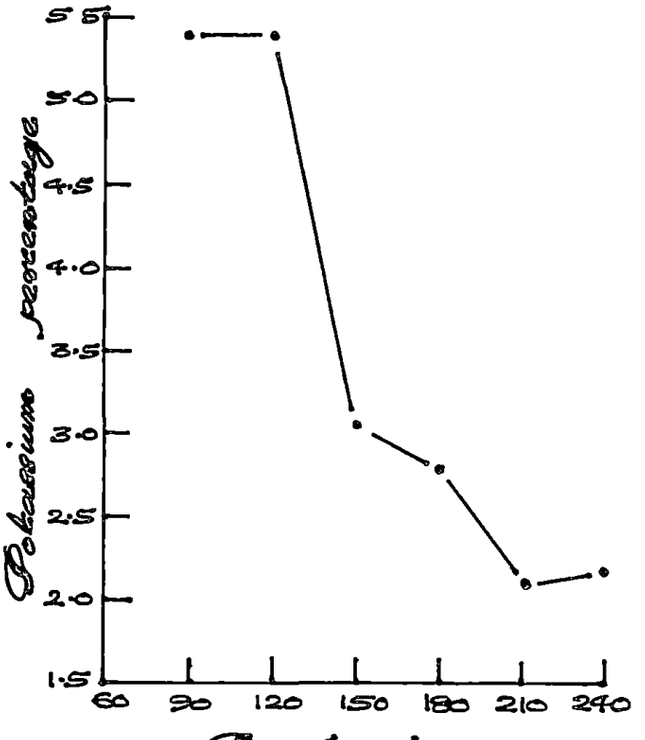


FIG. 9 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND POTASSIUM PERCENTAGE IN LEAF



1.5 Dry weight of rhizome

The data on the dry weight of rhizome as influenced by the period of growth are presented in Table 1. Observations revealed that the dry weight of rhizome increased with the increasing age of the plant till the last period.

1.6 Total dry matter

The statistical analysis showed that the total weight of dry matter increased with the increase in nitrogen level from n_0 to n_1 while further increase to n_2 level recorded a decline in total dry matter production. However the value at this level was superior to that at the n_0 level.

The total dry matter continuously increased with increasing period of plant growth, although only the difference between the first and the last periods was statistically significant. The relationship between period of growth and total dry matter is graphically represented in Fig. 6.

2. Rhizome yield of ginger at harvest

The data on the yield of ginger at harvest are presented in Table 2 and the analysis of variance

in Appendix III.

The statistical analysis of the data revealed that the effect of nitrogen levels on the yield of rhizome was significant while that of phosphorus and potassium and the interactions of nitrogen, phosphorus and potassium were not significant. Among the three levels of nitrogen namely, n_0, n_1 and n_2; n_1 level (80 kg N/ha) was significantly superior to other two levels (40 kg/ha and 120 kg/ha). An increase of nitrogen from n_0 to n_1 enhanced the rhizome yield significantly, but a further increase of nitrogen to the highest level had a depressive effect on the yield of ginger. No significant difference was observed between n_0 and n_2 levels of nitrogen. The yield of ginger was found significantly correlated with the height of tillers. It should be pointed out that the height of tillers was maximum at the n_1 level of nitrogen application at which the highest yield was obtained.

3. Effect of NPK treatments and period of growth on nitrogen content of ginger

The content and uptake of nitrogen in leaf, pseudostem and rhizome are given in Tables from 3 to 9 and their mean values summarised in Table 10. The results of statistical analysis are shown in Appendix IV.

Table 2. Rhizome yield of ginger at harvest, fresh weight, kg/m^2

Sl. No.	Treatments	Replication I	Replication II	Mean
1	$n_0p_0k_0$	2.72	2.38	2.55
2	$n_0p_0k_1$	1.78	1.95	1.87
3	$n_0p_0k_2$	3.29	0.80	2.05
4	$n_0p_1k_0$	2.20	2.64	2.42
5	$n_0p_1k_1$	3.58	3.39	3.48
6	$n_0p_1k_2$	3.16	1.86	2.51
7	$n_0p_2k_0$	4.06	3.10	3.58
8	$n_0p_2k_1$	1.59	3.09	2.34
9	$n_0p_2k_2$	2.10	4.84	3.47
10	$n_1p_0k_0$	3.00	3.41	3.21
11	$n_1p_0k_1$	3.90	3.28	3.59
12	$n_1p_0k_2$	3.68	2.35	3.02
13	$n_1p_1k_0$	3.18	3.55	3.37
14	$n_1p_1k_1$	3.33	3.38	3.36
15	$n_1p_1k_2$	4.82	4.45	4.64
16	$n_1p_2k_0$	3.93	2.50	3.22
17	$n_1p_2k_1$	3.13	3.28	3.21
18	$n_1p_2k_2$	2.50	4.94	3.72
19	$n_2p_0k_0$	2.88	4.04	3.46
20	$n_2p_0k_1$	3.10	1.22	2.16
21	$n_2p_0k_2$	2.11	2.69	2.40
22	$n_2p_1k_0$	3.43	3.31	3.37
23	$n_2p_1k_1$	2.36	2.64	2.50
24	$n_2p_1k_2$	3.01	1.14	2.08
25	$n_2p_2k_0$	1.95	3.32	2.64
26	$n_2p_2k_1$	1.86	3.29	2.58
27	$n_2p_2k_2$	2.68	2.71	2.68
	n_0	2.70	p_0 2.70	k_0 3.09
	n_1	3.48	p_1 3.08	k_1 2.79
	n_2	2.65	p_2 3.05	k_2 2.95

C.D. for comparing levels of nitrogen - 0.57

The relationship between period of growth and uptake of nitrogen is graphically represented in Fig. 10.

3.1 Nitrogen content of leaf

The observations revealed that the incremental dose of nitrogen significantly influenced the nitrogen percentage of leaf, while the application of phosphorus and potassium at different levels did not influence this parameter significantly. The treatment of 80 kg N/ha(n_1) recorded the maximum content of nitrogen in leaf which was significantly higher than that at n_0 level. The difference between nitrogen content at n_1 and n_2 levels was not statistically significant. Similarly, the nitrogen percentage of leaf at n_0 and n_2 levels did not differ significantly. Regarding the effect of increasing period of growth on nitrogen percentage of leaf (Fig. 7), it was seen that the nitrogen content decreased with increasing period of growth. However, the differences between the periods 1, 2, 3 and 4 were not statistically significant while nitrogen contents at the 5th and 6th periods were significantly lower than that at the earlier periods. The nitrogen percentage of leaf ranged from 0.45 to 3.11, the average value being 1.86.

3.2 Nitrogen content of pseudostem

The results showed that the effect of nitrogen,

Table 3. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Nitrogen content of leaf, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	1.68	1.90	1.96	1.96	1.12	1.09
2	$n_0p_0k_1$	1.54	2.46	2.02	2.12	1.18	0.95
3	$n_0p_0k_2$	1.82	2.52	2.24	1.18	1.40	0.98
4	$n_0p_1k_0$	2.38	1.88	1.99	2.37	1.20	1.04
5	$n_0p_1k_1$	1.68	1.68	1.96	0.45	1.15	0.98
6	$n_0p_1k_2$	1.54	2.46	1.90	1.99	1.32	1.12
7	$n_0p_2k_0$	2.24	2.55	1.96	2.51	1.26	1.06
8	$n_0p_2k_1$	2.38	1.65	1.76	2.59	1.57	1.09
9	$n_0p_2k_2$	1.68	1.68	1.90	2.17	1.20	1.18
10	$n_1p_0k_0$	2.24	3.11	2.13	2.51	1.40	1.51
11	$n_1p_0k_1$	2.24	2.60	1.96	2.01	1.43	1.09
12	$n_1p_0k_2$	2.52	2.41	2.10	1.56	1.62	1.26
13	$n_1p_1k_0$	2.38	2.77	2.21	1.67	1.32	1.40
14	$n_1p_1k_1$	2.66	3.08	1.59	2.28	1.48	0.92
15	$n_1p_1k_2$	1.96	2.86	2.30	2.65	1.29	1.09
16	$n_1p_2k_0$	2.24	2.74	1.96	2.95	1.34	1.09
17	$n_1p_2k_1$	2.10	2.77	2.24	2.79	1.20	1.06
18	$n_1p_2k_2$	2.66	1.65	2.30	2.62	1.32	1.18
19	$n_2p_0k_0$	3.08	2.04	2.16	2.39	1.43	1.06
20	$n_2p_0k_1$	2.38	2.63	2.08	2.54	1.34	0.90
21	$n_2p_0k_2$	2.66	1.82	1.96	2.37	1.32	1.20
22	$n_2p_1k_0$	2.80	2.10	2.55	1.48	1.29	1.09
23	$n_2p_1k_1$	2.52	2.02	1.90	1.23	1.34	1.09
24	$n_2p_1k_2$	2.24	2.07	3.02	2.06	1.45	1.12
25	$n_2p_2k_0$	2.38	1.68	2.10	2.15	1.37	1.15
26	$n_2p_2k_1$	2.80	2.16	2.52	2.01	1.20	1.06
27	$n_2p_2k_2$	2.10	1.96	2.27	2.12	1.46	1.09

Table 4. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Nitrogen content of pseudostem, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	2.38	1.34	1.68	1.26	1.43	1.09
2	$n_0p_0k_1$	1.54	1.43	1.23	1.90	1.18	1.06
3	$n_0p_0k_2$	1.54	1.65	1.57	1.51	1.09	1.04
4	$n_0p_1k_0$	1.40	1.54	1.37	1.57	1.40	1.04
5	$n_0p_1k_1$	1.68	1.37	1.23	1.04	1.06	1.01
6	$n_0p_1k_2$	1.68	1.34	1.48	0.78	1.15	1.06
7	$n_0p_2k_0$	2.66	1.32	1.40	1.04	1.09	1.12
8	$n_0p_2k_1$	1.68	1.46	1.34	1.32	1.06	1.15
9	$n_0p_2k_2$	1.26	1.40	1.43	1.20	1.01	1.09
10	$n_1p_0k_0$	2.24	1.40	1.60	0.87	1.09	1.34
11	$n_1p_0k_1$	1.54	1.40	1.29	1.12	1.43	1.09
12	$n_1p_0k_2$	2.66	1.85	1.20	1.43	1.12	1.26
13	$n_1p_1k_0$	3.08	1.71	1.93	1.90	1.06	1.17
14	$n_1p_1k_1$	1.54	1.76	1.54	1.65	1.43	1.01
15	$n_1p_1k_2$	1.68	1.46	1.29	2.29	1.46	1.12
16	$n_1p_2k_0$	1.54	1.37	1.68	1.57	1.37	1.09
17	$n_1p_2k_1$	1.82	1.40	1.43	1.82	1.18	1.09
18	$n_1p_2k_2$	1.82	1.40	1.26	1.71	1.40	1.06
19	$n_2p_0k_0$	1.54	1.09	1.43	1.43	1.43	1.12
20	$n_2p_0k_1$	2.10	1.32	1.54	1.26	1.74	1.15
21	$n_2p_0k_2$	1.82	1.62	1.48	1.40	1.26	1.06
22	$n_2p_1k_0$	1.68	1.68	1.32	1.34	1.09	1.09
23	$n_2p_1k_1$	1.54	1.71	1.43	1.20	1.76	1.18
24	$n_2p_1k_2$	1.68	1.46	1.62	1.37	1.06	1.15
25	$n_2p_2k_0$	1.82	1.23	1.40	1.68	1.18	1.12
26	$n_2p_2k_1$	1.54	1.32	1.54	1.40	1.20	1.06
27	$n_2p_2k_2$	1.40	1.37	1.65	1.46	1.37	1.09

Table 5. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Nitrogen content of rhizome, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	1.26	1.09	1.51	1.29	1.09	1.59
2	$n_0p_0k_1$	1.26	1.23	1.18	1.06	1.06	1.48
3	$n_0p_0k_2$	1.68	1.40	1.85	1.12	1.18	1.45
4	$n_0p_1k_0$	1.12	1.85	1.46	1.04	1.15	1.40
5	$n_0p_1k_1$	1.26	1.26	1.76	0.92	1.85	1.54
6	$n_0p_1k_2$	1.12	1.46	1.82	1.09	1.68	1.51
7	$n_0p_2k_0$	1.26	1.37	0.98	0.98	1.09	1.54
8	$n_0p_2k_1$	1.12	1.23	1.34	0.78	1.12	1.51
9	$n_0p_2k_2$	1.26	1.32	1.60	1.34	2.21	1.54
10	$n_1p_0k_0$	1.40	1.51	1.74	0.81	1.96	1.59
11	$n_1p_0k_1$	1.26	1.29	2.07	0.98	1.74	1.57
12	$n_1p_0k_2$	1.54	1.43	1.60	1.26	1.51	1.62
13	$n_1p_1k_0$	1.54	1.29	1.65	1.12	1.09	1.68
14	$n_1p_1k_1$	1.40	1.32	1.68	1.06	1.09	1.74
15	$n_1p_1k_2$	1.26	1.65	1.96	1.09	1.32	1.65
16	$n_1p_2k_0$	1.40	1.54	1.34	0.92	1.46	1.71
17	$n_1p_2k_1$	2.38	1.23	1.85	1.01	1.54	1.62
18	$n_1p_2k_2$	1.12	0.95	1.54	1.04	1.37	1.59
19	$n_2p_0k_0$	1.40	1.48	1.88	0.92	1.34	1.59
20	$n_2p_0k_1$	1.54	1.26	1.46	1.12	1.43	1.59
21	$n_2p_0k_2$	1.40	1.71	1.82	0.98	1.09	1.68
22	$n_2p_1k_0$	2.80	1.37	1.54	0.81	1.06	1.82
23	$n_2p_1k_1$	1.26	0.90	1.34	0.87	1.18	1.96
24	$n_2p_1k_2$	1.26	0.95	1.74	0.78	1.40	1.99
25	$n_2p_2k_0$	1.68	1.32	1.79	0.98	1.26	1.93
26	$n_2p_2k_1$	1.54	1.46	1.57	1.06	1.09	1.40
27	$n_2p_2k_2$	1.40	1.06	1.65	0.76	1.34	1.54

phosphorus and potassium levels and their interactions on the nitrogen content of pseudostem was not significant. The nitrogen content of pseudostem decreased with increasing period of crop growth. The values for nitrogen percentage ranged from 0.78 to 3.08.

3.3 Nitrogen content of rhizome

The data on the nitrogen content of rhizome furnished in Table 5 revealed that the effect of fertilizer treatments was not significant on the percentage of this nutrient element in the rhizome. As against the minimum percentage of nitrogen at the sixth period in leaf and pseudostem, the nitrogen percentage of rhizome was maximum at the sixth period. However, no consistent relationship was noticed between the nitrogen content of rhizome and the increasing period of growth. The values for nitrogen percentage ranged from 0.76 to 2.80.

3.4 Nitrogen uptake in leaf

The nitrogen uptake in leaf as affected by different NPK treatments and period of growth is furnished in Table 6 and the analysis of variance in Appendix IV.

As evident from the Table, the levels of nitrogen significantly influenced the uptake of this

Table 6. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Uptake of nitrogen in leaf, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.97	2.87	3.92	4.12	2.35	2.29
2	$n_0p_0k_1$	0.11	3.36	3.64	4.11	2.28	1.85
3	$n_0p_0k_2$	1.13	4.05	4.46	2.51	2.97	2.08
4	$n_0p_1k_0$	1.38	2.56	3.83	5.30	2.69	2.32
5	$n_0p_1k_1$	1.01	2.82	3.30	0.76	1.97	1.69
6	$n_0p_1k_2$	0.96	3.49	3.74	3.01	2.84	2.42
7	$n_0p_2k_0$	1.08	4.53	3.31	5.37	2.69	2.28
8	$n_0p_2k_1$	1.09	2.42	3.10	6.11	3.70	2.58
9	$n_0p_2k_2$	1.04	2.35	2.88	3.99	2.22	2.16
10	$n_1p_0k_0$	1.52	6.37	4.89	5.82	3.25	3.51
11	$n_1p_0k_1$	1.66	5.16	3.89	4.53	3.23	2.47
12	$n_1p_0k_2$	1.45	3.88	3.64	2.71	2.83	2.19
13	$n_1p_1k_0$	1.05	4.99	4.42	3.54	2.79	2.97
14	$n_1p_1k_1$	1.76	4.49	2.81	4.71	3.06	1.90
15	$n_1p_1k_2$	1.22	5.86	5.04	5.72	2.78	2.36
16	$n_1p_2k_0$	1.61	3.88	3.51	6.85	3.12	2.53
17	$n_1p_2k_1$	1.34	6.08	4.91	6.35	2.75	2.43
18	$n_1p_2k_2$	2.06	2.40	4.27	6.60	3.32	2.96
19	$n_2p_0k_0$	2.32	2.84	4.40	6.13	3.66	2.72
20	$n_2p_0k_1$	1.48	3.66	4.03	5.58	2.96	1.97
21	$n_2p_0k_2$	2.07	3.73	4.35	5.45	3.03	2.77
22	$n_2p_1k_0$	1.62	3.76	5.84	3.04	2.65	2.25
23	$n_2p_1k_1$	2.03	3.01	3.88	2.71	2.96	2.40
24	$n_2p_1k_2$	1.43	3.37	5.97	5.24	3.69	2.85
25	$n_2p_2k_0$	1.89	2.72	5.05	6.44	4.12	3.44
26	$n_2p_2k_1$	1.80	2.67	5.19	4.37	2.63	2.32
27	$n_2p_2k_2$	1.47	2.67	4.36	4.78	3.29	2.47

element in leaf. Maximum uptake was noticed at the n_1 level of applied nitrogen. The difference between n_1 and n_2 levels was not statistically significant. The nitrogen uptake in leaf continuously increased with increasing period of crop growth up to the fourth period (180th day) and then progressively decreased. The nitrogen uptake ranged from 0.77 g/m^2 to 6.85 g/m^2, the average value being 3.24 g/m^2.

3.5 Nitrogen uptake in pseudostem

The data on nitrogen uptake in pseudostem are furnished in Table 7. Results showed that the levels of nitrogen application significantly influenced the uptake of this nutrient element in the pseudostem as in the case of leaf. The n_2 and n_1 levels were superior to n_0, while n_2 and n_1 were on par. The levels of phosphorus and potassium and the interactions of nitrogen, phosphorus and potassium had no influence on the uptake of nitrogen in the pseudostem. It was also seen that the uptake of nitrogen in the pseudostem progressively increased up to the fourth period (180th day) and then declined in subsequent periods.

3.6 Nitrogen uptake in rhizome

The data on the uptake of nitrogen in rhizome as influenced by the different levels of nitrogen,

Table 7. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Uptake of nitrogen in pseudostem, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	1.67	1.34	1.61	1.84	2.11	1.81
2	$n_0p_0k_1$	1.02	1.19	1.21	2.55	1.62	1.49
3	$n_0p_0k_2$	1.14	1.49	1.91	1.87	1.39	1.62
4	$n_0p_1k_0$	0.95	1.14	1.45	2.38	2.18	1.64
5	$n_0p_1k_1$	1.21	1.88	1.23	1.22	1.32	1.33
6	$n_0p_1k_2$	1.21	1.09	1.69	1.54	2.06	1.98
7	$n_0p_2k_0$	1.86	1.15	1.40	1.51	1.68	1.79
8	$n_0p_2k_1$	1.24	1.31	1.34	2.39	1.98	2.14
9	$n_0p_2k_2$	0.98	1.09	1.14	1.47	1.27	1.75
10	$n_1p_2k_2$	1.34	1.86	1.72	1.65	2.07	2.63
11	$n_1p_0k_1$	1.14	1.47	1.59	1.55	1.97	1.64
12	$n_1p_0k_2$	1.86	1.57	1.39	1.71	1.41	2.02
13	$n_1p_1k_0$	1.97	1.63	2.62	2.17	1.28	1.91
14	$n_1p_1k_1$	0.66	1.41	1.51	2.64	2.37	1.75
15	$n_1p_1k_2$	1.37	1.47	1.03	2.76	1.86	1.93
16	$n_1p_2k_0$	1.29	1.11	2.72	2.48	2.25	1.86
17	$n_1p_2k_1$	1.27	1.87	1.79	2.18	1.48	2.07
18	$n_1p_2k_2$	1.38	1.25	1.44	2.56	2.18	1.85
19	$n_2p_0k_0$	1.02	1.09	1.63	2.79	2.83	2.19
20	$n_2p_0k_1$	1.39	1.03	1.54	2.12	2.95	2.07
21	$n_2p_0k_2$	1.13	1.69	1.99	2.58	2.37	1.96
22	$n_2p_1k_0$	1.31	2.04	1.76	1.91	1.79	1.86
23	$n_2p_1k_1$	1.32	1.78	1.43	2.12	3.49	2.30
24	$n_2p_1k_2$	1.70	1.05	1.69	2.22	1.98	2.18
25	$n_2p_2k_0$	1.20	0.996	1.57	3.53	2.42	2.33
26	$n_2p_2k_1$	0.67	1.10	2.00	1.88	2.09	1.89
27	$n_2p_2k_2$	1.06	1.15	1.47	2.99	2.88	2.36

Table 8. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Uptake of nitrogen in rhizome, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.63	1.70	1.66	3.50	3.95	5.31
2	$n_0p_0k_1$	0.83	1.72	1.48	2.09	3.06	1.59
3	$n_0p_0k_2$	0.91	2.24	2.09	3.25	7.24	4.98
4	$n_0p_1k_0$	0.49	1.15	1.75	2.71	3.81	4.83
5	$n_0p_1k_1$	0.96	2.69	2.33	0.76	1.09	4.79
6	$n_0p_1k_2$	0.63	1.31	3.24	2.49	3.66	5.94
7	$n_0p_2k_0$	1.11	4.50	1.37	2.86	3.84	5.58
8	$n_0p_2k_1$	0.74	1.85	1.45	2.60	3.49	4.29
9	$n_0p_2k_2$	0.91	3.11	2.68	1.29	7.29	3.38
10	$n_1p_0k_0$	1.18	4.93	2.74	2.32	8.86	7.63
11	$n_1p_0k_1$	1.18	1.99	4.56	2.82	8.16	4.85
12	$n_1p_0k_2$	1.42	1.14	2.94	3.55	4.75	6.68
13	$n_1p_1k_0$	1.51	2.45	2.61	3.07	6.12	6.07
14	$n_1p_1k_1$	0.84	1.19	2.05	3.89	3.10	5.43
15	$n_1p_1k_2$	1.01	3.60	2.55	2.97	4.47	6.43
16	$n_1p_2k_0$	0.84	1.29	2.98	2.51	7.13	6.05
17	$n_1p_2k_1$	1.91	4.18	3.36	2.74	6.41	6.77
18	$n_1p_2k_2$	0.78	0.85	1.82	4.06	7.29	6.83
19	$n_2p_0k_0$	0.98	2.49	1.50	2.77	4.13	5.13
20	$n_2p_0k_1$	0.92	2.27	1.57	3.40	2.91	3.83
21	$n_2p_0k_2$	1.23	3.59	5.02	2.58	7.36	5.83
22	$n_2p_1k_0$	1.96	2.47	2.77	2.10	4.64	2.77
23	$n_2p_1k_1$	0.86	0.91	1.88	2.67	9.36	7.83
24	$n_2p_1k_2$	1.13	1.63	2.15	2.85	3.42	6.52
25	$n_2p_2k_0$	0.94	2.64	3.08	2.27	5.79	4.39
26	$n_2p_2k_1$	0.83	1.58	2.51	2.66	3.78	3.51
27	$n_2p_2k_2$	1.46	2.33	3.47	1.03	4.11	3.93

phosphorus and potassium and period of growth are given in Table 8 and their mean values in Table 10. Observations indicated that levels of nitrogen, phosphorus and potassium employed and their interactions had no significant effect on the uptake of nitrogen in rhizome. However, the age of plant considerably influenced the uptake of this element in rhizome. The increasing period of growth resulted in the increased uptake of nitrogen in rhizome. The maximum uptake of nitrogen took place during the period from 180th day to 210th day, when nitrogen uptake in rhizome increased by 106.74 per cent, over the previous period. The uptake of nitrogen during this period accounted for 51.63 per cent of the total nitrogen accumulated in rhizome. The increase in nitrogen uptake in rhizome during the period from 90th day to 120th day was also significant. Though the uptake of nitrogen during this period accounted for only 22.64 per cent of the total nitrogen in rhizome, the percentage of increase over the previous period was conspicuous namely, 120.19 per cent.

3.7 Total uptake of nitrogen

The data furnished in Table 9 revealed that total uptake of nitrogen was influenced by the levels of nitrogen applied. The varying levels of phosphorus

Table 9. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Total uptake of nitrogen, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	3.27	5.91	7.19	9.47	8.42	9.31
2	$n_0p_0k_1$	2.96	6.28	6.33	8.74	6.97	4.93
3	$n_0p_0k_2$	2.05	7.78	8.47	7.63	11.61	8.17
4	$n_0p_1k_0$	2.83	4.85	7.03	10.40	8.69	8.79
5	$n_0p_1k_1$	3.18	7.39	6.86	2.75	4.38	7.81
6	$n_0p_1k_2$	2.79	5.89	8.67	7.04	8.57	10.34
7	$n_0p_2k_0$	4.05	10.17	6.08	9.74	8.22	9.65
8	$n_0p_2k_1$	3.08	5.58	5.89	11.11	9.17	9.01
9	$n_0p_2k_2$	2.93	6.55	6.70	6.76	10.78	7.29
10	$n_1p_0k_0$	4.04	13.17	9.36	9.79	14.18	13.78
11	$n_1p_0k_1$	3.98	8.61	10.05	8.90	13.35	8.95
12	$n_1p_0k_2$	4.73	6.59	7.97	7.98	8.98	10.89
13	$n_1p_1k_0$	4.53	9.07	9.65	8.78	10.18	10.94
14	$n_1p_1k_1$	3.26	7.09	6.37	11.24	8.53	9.08
15	$n_1p_1k_2$	3.61	10.92	8.62	11.44	9.12	10.71
16	$n_1p_2k_0$	3.75	6.29	9.22	11.84	12.50	10.44
17	$n_1p_2k_1$	4.52	12.13	10.07	11.28	10.63	11.27
18	$n_1p_2k_2$	4.23	4.51	7.52	13.22	12.79	11.65
19	$n_2p_0k_0$	4.31	6.42	7.53	11.70	10.61	10.05
20	$n_2p_0k_1$	3.79	6.96	7.14	11.09	8.82	7.87
21	$n_2p_0k_2$	4.44	9.01	11.36	10.61	12.76	10.55
22	$n_2p_1k_0$	4.89	8.27	10.37	7.04	9.08	6.88
23	$n_2p_1k_1$	3.21	5.69	7.19	7.50	15.81	12.54
24	$n_2p_1k_2$	4.26	6.06	9.81	10.31	9.09	11.55
25	$n_2p_2k_0$	4.03	6.36	9.70	12.24	12.33	10.16
26	$n_2p_2k_1$	3.30	5.35	9.70	8.91	8.49	7.72
27	$n_2p_2k_2$	3.99	6.15	9.30	8.81	10.29	8.76

and potassium and the interaction of the three major nutrient elements did not influence the total uptake of nitrogen by the crop. The higher levels of nitrogen application namely n_1 and n_2 resulted in increased uptake of nitrogen. Maximum uptake was noticed at the n_1 level, though the difference between n_1 and n_2 levels was not statistically significant. It should be pointed out that the maximum yield of ginger was also obtained at the n_1 level. The nitrogen uptake progressively increased with the advancing period of crop growth. The maximum uptake of nitrogen was achieved at the fifth period (210th day) after which the uptake values did not increase with the age. There was remarkable intake of nitrogen by the crop during the period from 90th day to 120th day. The nitrogen uptake value of 3.70 g/m^2 recorded at 90th day shot up to 7.37 g/m^2 at 120th day, an increase of 99.18 per cent over the previous period. While considering the quantity of nitrogen taken up by the crop during this period in comparison with total uptake of this element by the crop, again the quantity removed during this period was worth emphasising. The maximum uptake of nitrogen by the crop was 10.16 g/m^2 of which 3.67 g/m^2 was taken up during the period of these 30 days.

Table 10. Effect of NPK treatments and period of growth on nitrogen content of ginger:

Summary

Treatment groups	N % on moisture free basis			Uptake of nitrogen, g/m²			Total
	Leaf	Pseudo-stem	Rhizome	Mean of periods			
				Leaf	Pseudostem	Rhizome	
n_0	1.69	1.35	1.35	2.76	1.55	2.86	8.38
n_1	1.99	1.50	1.45	3.55	1.78	3.68	10.86
n_2	1.89	1.41	1.40	3.40	1.89	3.07	9.56
p_0	1.87	1.43	1.42	3.26	1.74	3.28	9.40
p_1	1.81	1.44	1.41	3.08	1.74	3.18	9.85
p_2	1.89	1.39	1.37	3.36	1.74	3.16	9.55
k_0	1.92	1.46	1.40	3.43	1.82	3.22	10.01
k_1	1.82	1.39	1.37	3.07	1.69	3.08	8.80
k_2	1.84	1.41	1.42	3.20	1.71	3.31	9.99
Periods:							
1	2.26	1.81	1.44	1.46	1.27	1.04	3.70
2	2.27	1.46	1.33	3.70	1.38	2.29	7.37
3	2.11	1.46	1.62	4.17	1.63	2.50	8.30
4	2.08	1.43	1.01	4.66	2.17	2.67	9.49
5	1.33	1.26	1.36	2.96	2.05	5.52	10.16
6	1.11	1.11	1.63	2.45	1.94	5.20	9.60
C.D. for comparing:							
Periods	0.330	0.188	0.175	0.759	1.13	0.283	1.440
Levels of N	0.231	N.S.	N.S.	0.537	0.20	N.S.	1.556

FIG. 10 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND UPTAKE OF NITROGEN

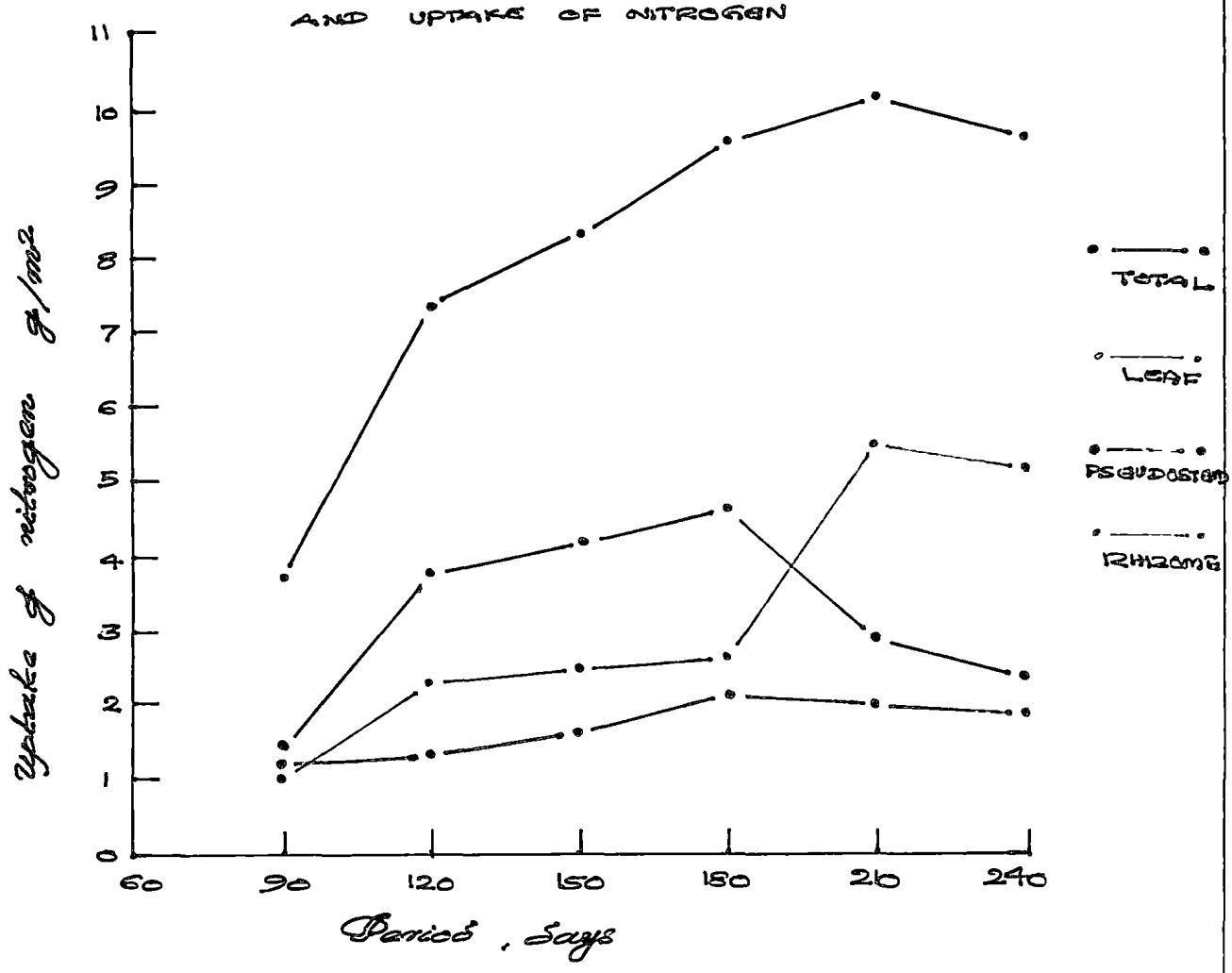
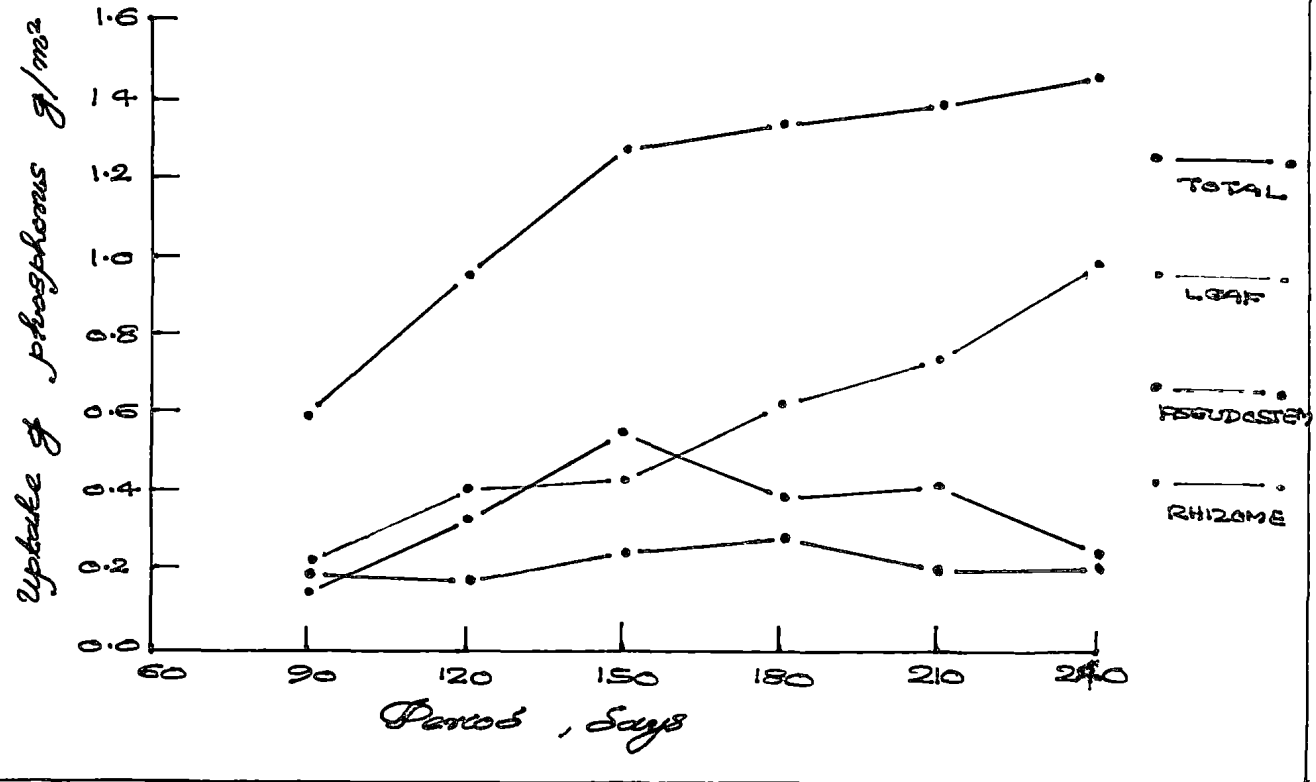


FIG. 11 RELATIONSHIP BETWEEN PERIOD OF GROWTH AND UPTAKE OF PHOSPHORUS



4. Effect of NPK treatments and period of growth on phosphorus content of ginger

The data on the effect of NPK treatments and period of growth on phosphorus content of ginger are tabulated in Tables from 11 to 17 and their summary furnished in Table 18. The results of statistical analysis are given in Appendix V. Fig.11 shows the relationship between period of growth and uptake of phosphorus in different plant parts.

4.1 Phosphorus content of leaf

The results showed that the levels of nitrogen, phosphorus and potassium and their interactions had no marked influence on the percentage of phosphorus in leaf. But the period of growth significantly influenced the level of this nutrient element in leaf. However, the values failed to indicate any definite trend with increasing period of growth. In general, phosphorus percentage of leaf was higher in the early periods. The highest value of 0.285 per cent was recorded at the third period (150th day) and the lowest value of 0.115 per cent at the last period (240th day). The relationship between period of growth and phosphorus percentage in leaf has been shown in Fig. 8.

Table 11. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Phosphorus content of leaf, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.245	0.223	0.312	0.167	0.199	0.111
2	$n_0p_0k_1$	0.253	0.201	0.277	0.167	0.206	0.116
3	$n_0p_0k_2$	0.254	0.214	0.273	0.183	0.210	0.116
4	$n_0p_1k_0$	0.259	0.240	0.296	0.169	0.202	0.098
5	$n_0p_1k_1$	0.270	0.261	0.306	0.173	0.183	0.111
6	$n_0p_1k_2$	0.285	0.207	0.296	0.183	0.185	0.114
7	$n_0p_2k_0$	0.295	0.209	0.306	0.188	0.219	0.106
8	$n_0p_2k_1$	0.249	0.227	0.294	0.175	0.225	0.119
9	$n_0p_2k_2$	0.259	0.253	0.254	0.183	0.199	0.106
10	$n_1p_0k_0$	0.272	0.209	0.256	0.175	0.188	0.114
11	$n_1p_0k_1$	0.273	0.220	0.296	0.183	0.179	0.109
12	$n_1p_0k_2$	0.254	0.238	0.258	0.181	0.175	0.106
13	$n_1p_1k_0$	0.251	0.205	0.252	0.181	0.219	0.119
14	$n_1p_1k_1$	0.242	0.222	0.271	0.135	0.227	0.111
15	$n_1p_1k_2$	0.248	0.197	0.250	0.183	0.225	0.130
16	$n_1p_2k_0$	0.273	0.259	0.288	0.167	0.204	0.109
17	$n_1p_2k_1$	0.264	0.258	0.304	0.171	0.196	0.114
18	$n_1p_2k_2$	0.264	0.182	0.335	0.196	0.167	0.119
19	$n_2p_0k_0$	0.234	0.231	0.244	0.271	0.199	0.119
20	$n_2p_0k_1$	0.258	0.203	0.279	0.192	0.179	0.108
21	$n_2p_0k_2$	0.269	0.213	0.304	0.173	0.177	0.132
22	$n_2p_1k_0$	0.278	0.218	0.254	0.204	0.221	0.124
23	$n_2p_1k_1$	0.262	0.223	0.319	0.179	0.217	0.121
24	$n_2p_1k_2$	0.260	0.214	0.265	0.194	0.215	0.111
25	$n_2p_2k_0$	0.249	0.209	0.342	0.192	0.202	0.119
26	$n_2p_2k_1$	0.275	0.231	0.304	0.181	0.185	0.122
27	$n_2p_2k_2$	0.245	0.222	0.250	0.172	0.192	0.125

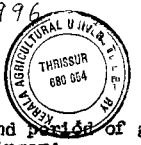


Table 12. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Phosphorus content of pseudostem, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.237	0.238	0.230	0.197	0.149	0.095
2	$n_0p_0k_1$	0.254	0.195	0.217	0.181	0.125	0.087
3	$n_0p_0k_2$	0.273	0.195	0.259	0.10	0.167	0.092
4	$n_0p_1k_0$	0.273	0.219	0.262	0.216	0.122	0.086
5	$n_0p_1k_1$	0.283	0.199	0.243	0.184	0.109	0.106
6	$n_0p_1k_2$	0.218	0.166	0.227	0.171	0.119	0.113
7	$n_0p_2k_0$	0.308	0.174	0.270	0.216	0.144	0.103
8	$n_0p_2k_1$	0.251	0.179	0.243	0.183	0.162	0.106
9	$n_0p_2k_2$	0.305	0.215	0.227	0.165	0.144	0.089
10	$n_1p_0k_0$	0.299	0.190	0.241	0.205	0.127	0.083
11	$n_1p_0k_1$	0.358	0.202	0.206	0.176	0.103	0.098
12	$n_1p_0k_2$	0.330	0.240	0.238	0.167	0.119	0.109
13	$n_1p_1k_0$	0.301	0.195	0.263	0.170	0.135	0.098
14	$n_1p_1k_1$	0.308	0.193	0.243	0.171	0.133	0.110
15	$n_1p_1k_2$	0.256	0.205	0.238	0.200	0.141	0.105
16	$n_1p_2k_0$	0.314	0.223	0.221	0.200	0.132	0.113
17	$n_1p_2k_1$	0.349	0.238	0.281	0.194	0.124	0.122
18	$n_1p_2k_2$	0.307	0.226	0.244	0.198	0.148	0.114
19	$n_2p_0k_0$	0.301	0.203	0.230	0.187	0.151	0.122
20	$n_2p_0k_1$	0.289	0.157	0.227	0.181	0.148	0.121
21	$n_2p_0k_2$	0.295	0.228	0.235	0.202	0.148	0.110
22	$n_2p_1k_0$	0.298	0.189	0.205	0.187	0.122	0.090
23	$n_2p_1k_1$	0.289	0.211	0.263	0.198	0.154	0.087
24	$n_2p_1k_2$	0.264	0.235	0.219	0.190	0.111	0.096
25	$n_2p_2k_0$	0.218	0.236	0.262	0.202	0.162	0.105
26	$n_2p_2k_1$	0.284	0.211	0.241	0.170	0.159	0.114
27	$n_2p_2k_2$	0.327	0.222	0.257	0.199	0.135	0.090

Table 13. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Phosphorus content of rhizome, % on moisture on free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.258	0.272	0.327	0.243	0.178	0.221
2	$n_0p_0k_1$	0.308	0.211	0.257	0.248	0.190	0.224
3	$n_0p_0k_2$	0.256	0.231	0.279	0.198	0.171	0.214
4	$n_0p_1k_0$	0.283	0.363	0.346	0.230	0.257	0.214
5	$n_0p_1k_1$	0.264	0.253	0.268	0.232	0.175	0.209
6	$n_0p_1k_2$	0.298	0.251	0.267	0.227	0.190	0.194
7	$n_0p_2k_0$	0.339	0.248	0.322	0.279	0.164	0.169
8	$n_0p_2k_1$	0.272	0.257	0.323	0.233	0.206	0.273
9	$n_0p_2k_2$	0.329	0.231	0.289	0.237	0.190	0.227
10	$n_1p_0k_0$	0.278	0.260	0.273	0.195	0.179	0.186
11	$n_1p_0k_1$	0.359	0.240	0.260	0.216	0.167	0.186
12	$n_1p_0k_2$	0.317	0.232	0.238	0.233	0.190	0.214
13	$n_1p_1k_0$	0.364	0.275	0.309	0.198	0.162	0.227
14	$n_1p_1k_1$	0.325	0.240	0.302	0.181	0.189	0.211
15	$n_1p_1k_2$	0.366	0.246	0.352	0.252	0.192	0.195
16	$n_1p_2k_0$	0.358	0.269	0.265	0.227	0.198	0.184
17	$n_1p_2k_1$	0.342	0.286	0.314	0.243	0.179	0.227
18	$n_1p_2k_2$	0.345	0.269	0.336	0.228	0.189	0.211
19	$n_2p_0k_0$	0.295	0.231	0.257	0.194	0.189	0.222
20	$n_2p_0k_1$	0.258	0.238	0.263	0.198	0.198	0.200
21	$n_2p_0k_2$	0.339	0.383	0.317	0.211	0.213	0.235
22	$n_2p_1k_0$	0.334	0.257	0.248	0.200	0.156	0.175
23	$n_2p_1k_1$	0.317	0.426	0.276	0.237	0.170	0.214
24	$n_2p_1k_2$	0.323	0.356	0.344	0.197	0.149	0.202
25	$n_2p_2k_0$	0.287	0.227	0.292	0.222	0.179	0.202
26	$n_2p_2k_1$	0.259	0.264	0.278	0.202	0.198	0.200
27	$n_2p_2k_2$	0.339	0.253	0.276	0.232	0.192	0.190

growth are given in Table 14. The uptake of phosphorus in leaf was also not influenced by the various fertilizer treatments. The highest value for uptake of phosphorus in leaf was observed at the third period (150th day) after which the values decreased with increasing age of the crop. The increase in uptake of phosphorus in leaf from 90th day to 120th day and the depression in uptake from 210th day to 240th day, were highly significant.

4.5 Uptake of phosphorus in pseudostem

As evident from the analysis of variance given in Appendix V, the levels of nitrogen employed had a decisive influence on the uptake of phosphorus in pseudostem. The highest level of nitrogen (120 kg/ha) resulted in a significantly increased uptake of phosphorus in pseudostem. The values for uptake of phosphorus in pseudostem at n_0 and n_1 levels were on par, statistically. The variation in uptake of phosphorus in pseudostem in relation to the increasing age of the crop was rather inconsistent. In general, uptake of phosphorus in pseudostem was comparatively high at the third and fourth periods (150th day and 180th day).

4.6 Uptake of phosphorus in rhizome

Results furnished in Table 16 indicated that the fertilizer treatments tried had no effect on the uptake of

Table 14. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Uptake of phosphorus in leaf, g/m²

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.142	0.337	0.625	0.350	0.420	0.233
2	$n_0p_0k_1$	0.183	0.274	0.501	0.323	0.400	0.225
3	$n_0p_0k_2$	0.158	0.344	0.544	0.389	0.446	0.246
4	$n_0p_1k_0$	0.150	0.327	0.569	0.378	0.453	0.220
5	$n_0p_1k_1$	0.162	0.438	0.516	0.297	0.315	0.191
6	$n_0p_1k_2$	0.177	0.294	0.580	0.396	0.401	0.247
7	$n_0p_2k_0$	0.142	0.371	0.518	0.401	0.468	0.228
8	$n_0p_2k_1$	0.115	0.333	0.516	0.413	0.531	0.281
9	$n_0p_2k_2$	0.161	0.355	0.384	0.337	0.368	0.196
10	$n_1p_0k_0$	0.185	0.430	0.589	0.406	0.435	0.265
11	$n_1p_0k_1$	0.202	0.437	0.588	0.414	0.405	0.247
12	$n_1p_0k_2$	0.146	0.382	0.447	0.315	0.304	0.185
13	$n_1p_1k_0$	0.111	0.369	0.503	0.384	0.464	0.252
14	$n_1p_1k_1$	0.149	0.324	0.477	0.279	0.468	0.229
15	$n_1p_1k_2$	0.155	0.403	0.548	0.396	0.486	0.281
16	$n_1p_2k_0$	0.197	0.366	0.515	0.387	0.474	0.253
17	$n_1p_2k_1$	0.169	0.495	0.666	0.389	0.446	0.261
18	$n_1p_2k_2$	0.204	0.266	0.623	0.443	0.420	0.299
19	$n_2p_0k_0$	0.176	0.322	0.498	0.693	0.512	0.305
20	$n_2p_0k_1$	0.160	0.283	0.542	0.422	0.197	0.237
21	$n_2p_0k_2$	0.209	0.435	0.675	0.398	0.407	0.303
22	$n_2p_1k_0$	0.161	0.390	0.582	0.420	0.455	0.255
23	$n_2p_1k_1$	0.211	0.332	0.649	0.394	0.238	0.265
24	$n_2p_1k_2$	0.167	0.349	0.522	0.492	0.545	0.282
25	$n_2p_2k_0$	0.198	0.338	0.822	0.575	0.606	0.357
26	$n_2p_2k_1$	0.177	0.286	0.626	0.395	0.404	0.266
27	$n_2p_2k_2$	0.171	0.302	0.481	0.389	0.433	0.283

Table 15. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Uptake of phosphorus in pseudostem, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.166	0.237	0.221	0.287	0.221	0.158
2	$n_0p_0k_1$	0.168	0.164	0.213	0.242	0.173	0.172
3	$n_0p_0k_2$	0.202	0.177	0.316	0.236	0.213	0.144
4	$n_0p_1k_0$	0.186	0.163	0.278	0.328	0.191	0.135
5	$n_0p_1k_1$	0.204	0.273	0.243	0.217	0.134	0.140
6	$n_0p_1k_2$	0.157	0.136	0.259	0.336	0.214	0.210
7	$n_0p_2k_0$	0.215	0.151	0.269	0.315	0.222	0.165
8	$n_0p_2k_1$	0.186	0.161	0.243	0.332	0.301	0.198
9	$n_0p_2k_2$	0.238	0.169	0.182	0.201	0.182	0.142
10	$n_1p_0k_0$	0.179	0.253	0.261	0.389	0.241	0.162
11	$n_1p_0k_1$	0.265	0.212	0.256	0.243	0.142	0.148
12	$n_1p_0k_2$	0.231	0.204	0.276	0.199	0.150	0.175
13	$n_1p_1k_0$	0.193	0.186	0.358	0.194	0.162	0.159
14	$n_1p_1k_1$	0.132	0.155	0.238	0.274	0.221	0.191
15	$n_1p_1k_2$	0.209	0.205	0.191	0.240	0.181	0.180
16	$n_1p_2k_0$	0.264	0.181	0.357	0.316	0.216	0.192
17	$n_1p_2k_1$	0.244	0.317	0.354	0.232	0.156	0.232
18	$n_1p_2k_2$	0.234	0.201	0.279	0.298	0.230	0.199
19	$n_2p_0k_0$	0.199	0.203	0.262	0.367	0.299	0.240
20	$n_2p_0k_1$	0.192	0.123	0.227	0.304	0.251	0.217
21	$n_2p_0k_2$	0.183	0.238	0.315	0.371	0.278	0.371
22	$n_2p_1k_0$	0.233	0.230	0.274	0.266	0.200	0.318
23	$n_2p_1k_1$	0.249	0.220	0.263	0.349	0.301	0.389
24	$n_2p_1k_2$	0.266	0.169	0.228	0.308	0.207	0.362
25	$n_2p_2k_0$	0.144	0.191	0.293	0.423	0.334	0.419
26	$n_2p_2k_1$	0.123	0.176	0.314	0.228	0.276	0.302
27	$n_2p_2k_2$	0.248	0.186	0.231	0.412	0.283	0.432

Table 16. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Uptake of phosphorus in rhizome, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.129	0.424	0.360	0.660	0.643	0.070
2	$n_0p_0k_1$	0.203	0.296	0.324	0.485	0.548	0.336
3	$n_0p_0k_2$	0.138	0.370	0.508	0.575	1.060	0.925
4	$n_0p_1k_0$	0.124	0.275	0.415	0.603	0.854	0.972
5	$n_0p_1k_1$	0.700	0.542	0.354	1.900	1.030	1.090
6	$n_0p_1k_2$	0.167	0.226	0.474	0.517	0.415	1.070
7	$n_0p_2k_0$	0.298	0.814	0.451	0.816	0.576	0.846
8	$n_0p_2k_1$	0.179	0.386	0.350	0.775	0.644	1.020
9	$n_0p_2k_2$	0.237	0.545	0.485	0.227	0.389	0.681
10	$n_1p_0k_0$	0.233	0.848	0.431	0.558	0.510	1.060
11	$n_1p_0k_1$	0.338	0.370	0,573	0.622	0.783	0.825
12	$n_1p_0k_2$	0.292	0.186	0.438	0.658	0,598	1.140
13	$n_1p_1k_0$	0.357	0.522	0.489	0.544	0.907	1.170
14	$n_1p_1k_1$	0.195	0.216	0.368	0.662	0.536	1.140
15	$n_1p_1k_2$	0.293	0.535	0.458	0.686	0.653	1.120
16	$n_1p_2k_0$	0.215	0.276	0.588	0.617	0.972	1.000
17	$n_1p_2k_1$	0.274	0.974	0.572	0.660	0.746	1.410
18	$n_1p_2k_2$	0.242	0.242	0.397	0.896	1.020	1.360
19	$n_2p_0k_0$	0.207	0.388	0.206	0.581	0.597	1.020
20	$n_2p_0k_1$	0.155	0.430	0.284	0.603	0.405	0.668
21	$n_2p_0k_2$	0.298	0.804	0.876	0.557	1.430	1.290
22	$n_2p_1k_0$	0.234	0.463	0.446	0.516	0.678	0.443
23	$n_2p_1k_1$	0.216	0.216	0.387	0.728	1.350	1.430
24	$n_2p_1k_2$	0.291	0.291	0.427	0.716	0.360	1.150
25	$n_2p_2k_0$	0.161	0.161	0.502	0.516	0.825	0.789
26	$n_2p_2k_1$	0.140	0.140	0.444	0.501	0.686	0.660
27	$n_2p_2k_2$	0.353	0.353	0.580	0.315	0.588	0.685

phosphorus in rhizome. Significant differences were noticed between the values recorded at varying stages of crop growth. The uptake of phosphorus in rhizome steadily increased with increasing age of the plant, the differences between the values at most of the periods being statistically significant.

4.7 Total uptake of phosphorus

The observations on total uptake of phosphorus are furnished in Table 17. The results showed that only the levels of nitrogen applied influenced total uptake of phosphorus among the various fertilizer treatments employed of the nitrogen levels, n_1 was superior to n_0 while n_1 and n_2 were on par in this respect. Also there was no significant difference between n_0 and n_2. But the age of the plant influenced the uptake of phosphorus significantly. The values progressively increased with increasing period of crop growth. However, differences between the values at the higher periods were not statistically significant.

5. Effect of NPK treatments and period of growth on potassium content of ginger

The data on the percentage and uptake of potassium by ginger as influenced by the fertilizer

Table 17. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Total uptake of phosphorus, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	0.437	0.997	1.210	1.300	1.290	1.880
2	$n_0p_0k_1$	0.553	0.733	1.040	1.050	1.120	0.683
3	$n_0p_0k_2$	0.498	0.890	1.370	1.200	1.720	1.310
4	$n_0p_1k_0$	0.460	0.714	1.260	1.310	1.500	1.330
5	$n_0p_1k_1$	0.566	1.250	1.110	2.410	1.480	1.420
6	$n_0p_1k_2$	0.501	0.656	1.310	1.250	1.030	1.530
7	$n_0p_2k_0$	0.659	1,340	1.240	1.530	1.270	1.070
8	$n_0p_2k_1$	0.480	0.881	1.110	1.520	1.480	1.660
9	$n_0p_2k_2$	0.636	1.070	1.050	0.766	0.939	1.020
10	$n_1p_0k_0$	0.598	1.530	1.280	1.350	1.490	1.480
11	$n_1p_0k_1$	0.805	1.020	1.420	1.280	1.330	1.220
12	$n_1p_0k_2$	0.669	0.772	1.160	1.170	1.050	1.500
13	$n_1p_1k_0$	0.661	1.080	1.350	1.120	1.530	1.600
14	$n_1p_1k_1$	0.477	0.695	1.080	1.220	1.230	1.560
15	$n_1p_1k_2$	0.657	1.140	1.200	1.320	1.320	1.580
16	$n_1p_2k_0$	0.675	0.774	1.460	1.320	1.660	1.450
17	$n_1p_2k_1$	0.687	1.780	1.590	1.280	1.350	1.900
18	$n_1p_2k_2$	0.680	0.709	1.300	1.690	1.670	1.850
19	$n_2p_0k_0$	0.581	0.913	0.966	1.640	1.410	1.560
20	$n_2p_0k_1$	0.506	0.836	1.050	1.330	0.853	1.120
21	$n_2p_0k_2$	0.691	1.480	1.870	1.330	2.120	1.960
22	$n_2p_1k_0$	0.628	1.080	1.300	1.200	1.330	1.020
23	$n_2p_1k_1$	0.675	0.768	1.300	1.47	1.890	2.080
24	$n_2p_1k_2$	0.724	0.809	1.180	1.520	1.120	1.790
25	$n_2p_2k_0$	0.503	0.690	1.620	1.520	1.760	1.560
26	$n_2p_2k_1$	0.440	0.602	1.380	1.130	1.370	1.230
27	$n_2p_2k_2$	0.772	0.841	1.291	1.120	1.30	1.400

Table 18. Effect of NPK treatments and period of growth on phosphorus content of ginger:

Summary

Treatment groups	P % pn moisture free basis			Uptake of phosphorus, g/m²			Total
	Leaf	Pseudo-stem	Rhizome	Mean of periods			
				Leaf	Pseudostem	Rhizome	
n_0	0.212	0.189	0.248	0.340	0.210	0.555	1.322
n_1	0.207	0.198	0.250	0.363	0.225	0.630	1.570
n_2	0.213	0.195	0.247	0.381	0.268	0.547	1.520
p_0	0.207	0.193	0.240	0.357	0.228	0.567	1.410
p_1	0.211	0.189	0.254	0.354	0.228	0.599	1.550
p_2	0.213	0.200	0.251	0.373	0.248	0.565	1.460
k_0	0.213	0.195	0.246	0.381	0.244	0.566	1.440
k_1	0.211	0.193	0.246	0.347	0.227	0.581	1.430
k_2	0.208	0.194	0.253	0.356	0.235	0.585	1.550
Periods:							
1	0.261	0.289	0.315	0.168	0.204	0.229	0.601
2	0.221	0.207	0.269	0.355	0.196	0.415	0.965
3	0.285	0.241	0.289	0.559	0.267	0.451	1.280
4	0.182	0.189	0.222	0.405	0.293	0.648	1.350
5	0.199	0.137	0.186	0.426	0.222	0.745	1.390
6	0.115	0.102	0.208	0.255	0.226	0.976	1.470
C.D.for comparing periods	0.034	0.038	0.03	0.081	0.034	0.175	0.209
C.D.for comparing N levels	N.S.	N.S.	N.S.	N.S.	0.024	N.S.	0.206

treatments and period of growth are furnished in Tables from 19 to 25 and their summary in Table 26. The analysis of variance is given in Appendix VI.

5.1 Potassium content of leaf

The varying levels of the fertilizer nutrients applied could not bring about any significant difference in potassium content of leaf. The age of the plant, considerably influenced the percentage of this element in leaf. There was a steady decrease in the content of potassium with increasing period of crop growth. The potassium content of leaf at the first period (90th day) was as high as 5.36 per cent, which decreased to 2.17 per cent at the last period (Fig 9).

5.2 Potassium content of pseudostem

The results given in Table 20 indicated that the content of potassium in pseudostem also was not determined by the level of nitrogen, phosphorus and potassium applied. But the period of growth influenced the content of this element in pseudostem. However, no regular pattern of variation was observed with increasing age of the crop. The potassium percentage of pseudostem at the first and third period was significantly higher as compared to the values at the other periods.

Table 19. Effect of NPK treatments and period of growth on potassium content of ginger:

Potassium content of leaf, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	4.40	5.70	2.55	2.60	1.90	2.20
2	$n_0p_0k_1$	4.70	5.60	2.75	2.80	3.00	2.20
3	$n_0p_0k_2$	5.70	5.30	3.45	2.60	2.10	2.30
4	$n_0p_1k_0$	4.90	6.20	2.85	2.60	1.90	2.50
5	$n_0p_1k_1$	4.70	6.00	3.85	3.20	2.00	2.00
6	$n_0p_1k_2$	5.90	5.50	3.75	3.20	2.20	2.60
7	$n_0p_2k_0$	4.40	3.90	2.85	2.70	2.25	2.20
8	$n_0p_2k_1$	5.70	5.30	2.75	2.80	2.20	2.25
9	$n_0p_2k_2$	5.80	5.80	3.40	2.30	2.20	2.50
10	$n_1p_0k_0$	6.70	5.40	2.60	2.70	2.25	2.00
11	$n_1p_0k_1$	5.70	5.60	2.60	2.70	2.00	2.40
12	$n_1p_0k_2$	5.50	5.20	3.85	2.70	1.90	2.00
13	$n_1p_1k_0$	6.70	5.40	2.45	2.90	2.45	2.00
14	$n_1p_1k_1$	5.70	5.70	2.85	3.00	2.25	2.00
15	$n_1p_1k_2$	5.50	4.50	3.45	2.60	2.20	1.95
16	$n_1p_2k_0$	4.60	6.35	2.80	2.70	2.25	2.25
17	$n_1p_2k_1$	5.70	4.70	3.60	2.80	1.90	2.00
18	$n_1p_2k_2$	5.90	5.15	2.75	2.90	1.90	2.25
19	$n_2p_0k_0$	4.60	6.00	3.60	3.30	2.20	2.00
20	$n_2p_0k_1$	5.40	4.40	2.55	3.00	2.00	2.00
21	$n_2p_0k_2$	5.80	5.00	3.75	2.80	1.90	2.20
22	$n_2p_1k_0$	4.70	6.00	2.90	3.50	2.55	2.40
23	$n_2p_1k_1$	5.10	6.00	3.05	2.60	2.30	2.30
24	$n_2p_1k_2$	5.50	5.30	2.55	2.60	2.25	2.30
25	$n_2p_2k_0$	4.70	4.20	2.30	2.00	2.20	2.00
26	$n_2p_2k_1$	5.60	5.15	2.55	2.90	1.90	2.00
27	$n_2p_2k_2$	5.20	5.30	3.40	2.40	2.10	1.90

Table 20. Effect of NPK treatments and period of growth on potassium content of ginger:

Potassium content of pseudostem, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	9.40	6.40	9.70	4.70	6.00	5.00
2	$n_0p_0k_1$	9.90	4.50	5.40	7.05	5.90	4.70
3	$n_0p_0k_2$	9.55	6.80	8.20	8.95	6.00	5.45
4	$n_0p_1k_0$	9.30	6.00	8.60	7.50	6.80	4.70
5	$n_0p_1k_1$	9.55	6.50	8.40	6.60	6.00	5.30
6	$n_0p_1k_2$	8.40	5.60	8.95	7.80	7.30	5.80
7	$n_0p_2k_0$	9.60	5.30	7.20	5.60	6.50	5.45
8	$n_0p_2k_1$	9.40	6.20	8.40	7.50	6.80	5.45
9	$n_0p_2k_2$	9.10	6.00	7.10	6.60	6.35	4.70
10	$n_1p_0k_0$	9.10	5.80	8.20	7.30	6.20	5.00
11	$n_1p_0k_1$	9.40	6.20	8.70	6.80	6.20	5.00
12	$n_1p_0k_2$	9.40	7.65	8.60	7.65	6.50	5.40
13	$n_1p_1k_0$	9.55	6.60	8.60	7.10	6.60	5.80
14	$n_1p_1k_1$	9.70	6.20	7.30	6.80	6.35	5.00
15	$n_1p_1k_2$	8.75	6.80	8.40	6.50	6.00	4.70
16	$n_1p_2k_0$	9.10	5.90	9.00	7.30	6.80	4.90
17	$n_1p_2k_1$	9.90	6.50	8.20	5.30	5.65	4.60
18	$n_1p_2k_2$	9.90	6.60	8.95	6.50	6.50	5.75
19	$n_2p_0k_0$	9.90	7.00	8.95	8.95	7.00	5.30
20	$n_2p_0k_1$	9.40	5.30	8.40	6.60	6.00	4.60
21	$n_2p_0k_2$	9.70	7.30	9.55	7.80	6.35	6.20
22	$n_2p_0k_0$	9.90	4.70	9.10	7.80	6.80	5.80
23	$n_2p_1k_1$	9.90	5.40	8.60	7.80	5.85	5.60
24	$n_2p_1k_2$	6.60	6.50	8.20	6.60	6.55	5.15
25	$n_2p_2k_0$	8.95	6.00	7.10	7.30	7.00	5.50
26	$n_2p_2k_1$	7.80	6.00	9.40	7.65	6.35	5.30
27	$n_2p_2k_2$	9.90	6.60	6.35	6.35	5.90	7.50

5.3 Potassium content of rhizome

The observations recorded in Table 21 are indicative that potassium content of rhizome was unaffected by the levels of fertilizer nutrients employed. As in the case of potassium content of leaf and pseudostem, percentage of potassium in rhizome also was influenced by the age of the crop. During the early periods of growth, the rhizome contained higher percentage of potassium which progressively decreased with increasing maturity of the crop.

5.4 Uptake of potassium in leaf

The data on uptake of potassium in leaf are given in Table 22. The results indicated that the levels of nitrogen, phosphorus and potassium introduced could not bring about significant differences in uptake of potassium in leaf. When the influence of period of growth on potassium uptake in leaf was studied, it was found that age of the plant influenced the uptake of this nutrient. In general, potassium uptake decreased with progressing age of the plant. The highest value for potassium uptake in leaf was at the second period (120th day).

5.5 Uptake of potassium in pseudostem

The observations recorded in Table 23 and the

Table 21. Effect of NPK treatments and period of growth on potassium content of ginger:

Potassium content of rhizome, % on moisture free basis

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	7.65	5.00	5.90	3.50	2.25	3.10
2	$n_0p_0k_1$	8.40	6.00	5.15	4.20	2.75	2.90
3	$n_0p_0k_2$	8.95	7.50	4.90	3.90	2.60	2.90
4	$n_0p_1k_0$	7.50	8.00	5.80	3.30	2.50	2.90
5	$n_0p_1k_1$	8.40	7.00	5.15	4.50	2.80	2.70
6	$n_0p_1k_2$	7.65	6.80	5.30	4.60	2.70	3.30
7	$n_0p_2k_0$	8.20	5.00	4.90	3.70	2.30	2.50
8	$n_0p_2k_1$	2.72	4.90	5.50	3.90	2.80	4.10
9	$n_0p_2k_2$	8.70	5.55	4.00	3.40	3.70	2.60
10	$n_1p_0k_0$	7.00	6.20	4.00	3.30	2.30	2.90
11	$n_1p_0k_1$	8.20	7.30	4.85	3.70	2.40	2.50
12	$n_1p_0k_2$	5.30	4.60	4.60	4.15	2.90	3.30
13	$n_1p_1k_0$	8.60	5.40	5.50	3.60	2.50	3.60
14	$n_1p_1k_1$	6.50	8.30	4.65	3.80	2.60	3.40
15	$n_1p_1k_2$	8.60	5.15	5.00	3.10	2.40	2.80
16	$n_1p_2k_0$	9.10	7.60	5.50	3.50	2.60	2.90
17	$n_1p_2k_1$	8.40	5.50	4.75	3.80	2.50	2.60
18	$n_1p_2k_2$	8.40	8.95	6.35	3.80	2.60	2.55
19	$n_2p_0k_0$	6.60	7.10	5.30	4.00	2.75	3.20
20	$n_2p_0k_1$	7.50	5.80	4.60	2.90	2.80	2.50
21	$n_2p_0k_2$	7.80	7.10	4.20	3.90	2.50	3.00
22	$n_2p_1k_0$	7.65	7.30	5.15	4.00	2.70	2.70
23	$n_2p_1k_1$	7.80	8.70	4.60	3.70	2.25	2.90
24	$n_2p_1k_2$	8.00	8.40	5.60	3.60	2.50	2.90
25	$n_2p_2k_0$	7.10	6.35	4.65	2.90	2.50	3.10
26	$n_2p_2k_1$	7.10	7.70	4.80	3.40	2.10	3.30
27	$n_2p_2k_2$	8.95	6.50	4.10	3.60	2.70	3.00

Table 22. Effect of NPK treatments and period of growth on potassium content of ginger:

Uptake of potassium in leaf, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	2.55	8.60	5.10	5.46	3.99	4.62
2	$n_0p_0k_1$	3.39	7.65	4.97	5.63	3.88	4.27
3	$n_0p_0k_2$	3.53	8.52	6.87	5.51	4.45	4.88
4	$n_0p_1k_0$	2.84	8.44	5.49	5.82	4.26	5.60
5	$n_0p_1k_1$	2.82	10.06	6.48	5.50	3.44	3.44
6	$n_0p_1k_2$	3.66	7.81	7.36	6.91	4.75	5.62
7	$n_0p_2k_0$	2.11	6.93	4.82	5.78	4.82	4.71
8	$n_0p_2k_1$	2.62	7.78	4.84	6.61	5.19	5.31
9	$n_0p_2k_2$	3.60	8.12	5.14	4.23	4.05	4.60
10	$n_1p_0k_0$	4.56	11.07	5.98	6.26	5.22	2.32
11	$n_1p_0k_1$	4.22	11.09	5.16	6.10	4.52	5.42
12	$n_1p_0k_2$	3.16	8.28	6.67	4.70	3.31	1.74
13	$n_1p_1k_0$	2.96	9.73	4.89	6.15	5.19	4.24
14	$n_1p_1k_1$	3.76	8.32	5.02	6.18	4.64	4.12
15	$n_1p_1k_2$	3.43	9.23	7.57	5.62	4.75	4.21
16	$n_1p_2k_0$	3.31	8.99	5.02	6.26	5.22	5.22
17	$n_1p_2k_1$	3.65	10.32	7.88	6.38	4.33	4.56
18	$n_1p_2k_2$	4.57	7.50	5.12	7.31	4.79	5.67
19	$n_2p_0k_0$	3.46	8.35	7.35	8.45	5.63	5.12
20	$n_2p_0k_1$	3.35	6.12	4.95	6.60	4.40	4.40
21	$n_2p_0k_2$	4.52	10.24	8.32	6.44	4.37	5.06
22	$n_2p_1k_0$	2.73	10.75	6.64	7.21	5.25	4.94
23	$n_2p_1k_1$	4.10	8.93	6.21	5.32	5.06	5.06
24	$n_2p_1k_2$	3.52	8.64	5.03	6.60	5.72	5.84
25	$n_2p_2k_0$	3.72	6.80	5.53	6.00	6.60	6.00
26	$n_2p_2k_1$	3.61	6.36	5.25	6.32	4.14	4.36
27	$n_2p_2k_2$	3.64	7.21	6.54	5.42	4.75	4.29

analysis of variance given in Appendix VI showed that the fertilizer treatments significantly influenced the uptake of potassium in pseudostem. However, only levels of nitrogen became significant in this respect. There was increased uptake of potassium in the pseudostem at the highest level of nitrogen applied. The values for the uptake of potassium in pseudostem at n_0 and n_1 levels remained on par, statistically. The data on the effect of period of growth on potassium content of pseudostem indicated that age of the plant significantly affected the uptake of this element. However, no regular pattern of variation was observed with increasing age of the crop.

5.6 Uptake of potassium in rhizome

The results revealed that the uptake of potassium in rhizome was not influenced by the levels of the fertilizer elements applied. The period of growth of the crop influenced the uptake of this element in rhizome, decisively. In general, the values increased with increasing age of the plant, the highest value for uptake being obtained at the last period.

5.7 Total uptake of potassium

The data tabulated in Table 25 and the analysis of variance given in Appendix VI clearly showed that the

Table 23. Effect of NPK treatments and period of growth on potassium content of ginger:

Uptake of potassium in pseudostem, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	6.58	6.37	9.31	6.86	8.88	8.30
2	$n_0p_0k_1$	6.53	3.77	5.29	9.45	8.14	6,58
3	$n_0p_0k_2$	7.07	6.15	10.00	11.10	7.78	8.50
4	$n_0p_1k_0$	6.32	4.45	9.12	11.40	10.61	15.86
5	$n_0p_1k_1$	6.88	8.89	8.40	7.79	7.44	6.99
6	$n_0p_1k_2$	6.06	4.57	10.20	15.29	13.14	10.79
7	$n_0p_2k_0$	6.72	4.60	7.20	8.18	10.01	8.72
8	$n_0p_2k_1$	6.96	5.57	8.40	13.65	12.65	10.14
9	$n_0p_2k_2$	7.10	4.69	5.68	8.05	8.00	7.52
10	$n_1p_0k_0$	5.46	7.73	8.86	13.87	11.78	9.80
11	$n_1p_0k_1$	6.96	6.50	10.79	9.38	8.56	7.50
12	$n_1p_0k_2$	6.58	6.49	9.98	9.18	8.19	8.64
13	$n_1p_1k_0$	6.11	6.28	11.70	8.10	7.92	9.40
14	$n_1p_1k_1$	4.17	4.98	7.15	10.88	10.54	8.70
15	$n_1p_1k_2$	7.16	6.83	6.72	7.80	7.68	8.08
16	$n_1p_2k_0$	7.64	4,79	14.58	11.54	11.15	8.33
17	$n_1p_2k_1$	6.93	8.67	10.33	6.36	7.12	8.74
18	$n_1p_2k_2$	7.52	5.87	10.20	9.75	10.14	10.01
19	$n_2p_0k_0$	6.53	7.00	10.20	17.54	13.86	10.39
20	$n_2p_0k_1$	6.24	4.16	8.40	11.09	10.20	8.28
21	$n_2p_0k_2$	6.01	7.62	12.80	14.35	11.94	11.41
22	$n_2p_1k_0$	7.72	5.72	12.19	11.08	11.15	9.86
23	$n_2p_1k_1$	8.31	5.63	8.60	13.73	11.58	10.98
24	$n_2p_1k_2$	6.67	4.68	8.53	10.69	12.18	9.79
25	$n_2p_2k_0$	5.91	4.86	7.95	15.33	14.42	11.44
26	$n_2p_2k_1$	3.37	5.00	12.22	10.25	11.05	9.43
27	$n_2p_2k_2$	7.52	5.54	5.71	13.08	12.39	16.20

Table 24. Effect of NPK treatments and period of growth on potassium content of ginger:

Uptake of potassium in rhizome, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	3.82	7.80	6.49	9.52	15.07	8.15
2	$n_0p_0k_1$	5.54	8.40	6.49	8.23	7.92	4.35
3	$n_0p_0k_2$	4.83	12.00	8.92	11.31	16.02	12.33
4	$n_0p_1k_0$	3.30	4.96	6.96	8.65	8.30	13.17
5	$n_0p_1k_1$	6.38	14.98	6.80	3.69	16.52	13.98
6	$n_0p_1k_2$	4.38	6.12	9.43	10.49	5.89	18.35
7	$n_0p_2k_0$	7.22	16.40	6.86	10.80	8.09	12.45
8	$n_0p_2k_1$	1.79	7.35	5.94	12.95	8.74	15.33
9	$n_0p_2k_2$	6.26	13.10	6.72	3.26	12.21	7.80
10	$n_1p_0k_0$	5.88	20.21	6.32	9.44	10.40	16.47
11	$n_1p_0k_1$	10.06	11.24	10.68	10.66	11.28	11.10
12	$n_1p_0k_2$	6.37	3.68	8.46	11.70	9.11	17.49
13	$n_1p_1k_0$	9.33	10.26	8.69	9.86	14.00	18.58
14	$n_1p_1k_1$	3.90	7.47	4.67	13.91	7.38	18.29
15	$n_1p_1k_2$	6.88	11.23	6.50	8.43	8.16	16.07
16	$n_1p_2k_0$	5.46	6.38	12.21	9.52	12.74	16.07
17	$n_1p_2k_1$	6.72	18.70	8.65	10.34	10.40	16.12
18	$n_1p_2k_2$	5.88	8.06	7.49	14.89	13.83	16.37
19	$n_2p_0k_0$	4.62	11.93	4.24	12.00	7.11	14.66
20	$n_2p_0k_1$	4.50	10.44	4.97	8.82	5.71	8.35
21	$n_2p_0k_2$	6.86	14.91	11.59	10.29	16.85	16.44
22	$n_2p_1k_0$	5.36	13.14	9.27	10.32	11.77	6.86
23	$n_2p_1k_1$	5.30	8.87	6.44	11.39	17.91	19.31
24	$n_2p_1k_2$	7.20	14.45	6.94	13.10	6.10	16.47
25	$n_2p_2k_0$	3.98	12.70	7.99	6.73	12.50	12.15
26	$n_2p_2k_1$	3.83	8.32	7.68	8.50	7.27	10.89
27	$n_2p_2k_2$	9.31	14.30	8.61	4.90	10.80	8.26

Table 25. Effect of NPK treatments and period of growth on potassium content of ginger:

Total uptake of potassium, g/m^2

Sl. No.	Treatment	Period					
		1	2	3	4	5	6
1	$n_0p_0k_0$	12.96	22.77	20.90	21.84	21.02	27.98
2	$n_0p_0k_1$	15.47	19.82	16.75	23.31	19.94	15.19
3	$n_0p_0k_2$	15.44	26.67	25.79	27.92	28.15	25.71
4	$n_0p_1k_0$	12.47	17.84	21.57	25.87	23.16	34.63
5	$n_0p_1k_1$	16.08	33.92	21.68	16.98	27.40	24.42
6	$n_0p_1k_2$	14.10	13.50	26.99	32.69	23.78	34.75
7	$n_0p_2k_0$	16.05	27.93	18.88	24.75	22.92	25.88
8	$n_0p_2k_1$	11.37	20.69	19.17	33.21	26.58	30.78
9	$n_0p_2k_2$	16.94	25.92	17.54	15.55	24.26	19.92
10	$n_1p_0k_0$	15.89	29.05	21.16	29.57	27.40	28.59
11	$n_1p_0k_1$	21.23	28.83	26.63	26.15	24.36	24.02
12	$n_1p_0k_2$	16.11	18.45	25.11	25.58	20.60	27.87
13	$n_1p_1k_0$	18.40	26.28	25.28	24.11	30.11	32.21
14	$n_1p_1k_1$	11.83	20.77	16.85	30.97	22.56	31.11
15	$n_1p_1k_2$	17.47	27.28	20.79	21.85	20.59	28.37
16	$n_1p_2k_0$	16.42	20.17	31.81	27.32	29.11	29.62
17	$n_1p_2k_1$	17.29	37.69	26.86	23.08	21.85	29.42
18	$n_1p_2k_2$	17.97	21.43	22.81	31.95	28.76	32.05
19	$n_2p_0k_0$	14.61	16.55	21.79	37.99	26.60	30.22
20	$n_2p_0k_1$	14.09	11.32	18.32	26.50	20.31	21.03
21	$n_2p_0k_2$	17.40	32.77	32.71	31.09	33.16	32.91
22	$n_2p_1k_0$	15.80	29.64	28.11	28.61	28.18	21.66
23	$n_2p_1k_1$	17.92	23.43	21.25	30.84	34.55	35.35
24	$n_2p_1k_2$	17.39	27.77	20.51	30.39	23.99	32.07
25	$n_2p_2k_0$	13.61	24.36	21.48	28.06	32,52	29.59
26	$n_2p_2k_1$	10.81	16.68	25.15	25.07	22.46	24.68
27	$n_2p_2k_2$	20.47	27.05	17.86	26.40	25.39	31.29

Table 26. Effect of NPK treatments and period of growth on potassium content of ginger:

Summary

Treatment groups	K % on moisture free basis			Uptake of potassium, g/m²			
				Mean of period			
	Leaf	Pseudo-stem	Rhizome	Leaf	Pseudostem	Rhizome	Total
n_0	3.48	6.92	4.76	5.12	8.23	8.94	26.58
n_1	3.52	7.10	4.76	5.14	8.27	10.63	29.25
n_2	3.41	7.19	4.74	5.42	9.61	9.67	28.76
p_0	3.46	7.12	4.64	5.03	8.72	9.67	25.95
p_1	3.58	7.09	4.91	5.36	8.59	9.93	30.50
p_2	3.36	7.00	4.71	5.29	8.80	9.64	28.14
k_0	3.41	7.15	4.68	5.39	9.22	9.74	25.95
k_1	3.46	6.92	4.71	4.93	8.08	9.36	30.51
k_2	3.54	7.15	4.86	5.45	8.81	10.14	28.14
Periods							
1	5.36	9.30	7.66	3.46	6.56	5.74	15.76
2	5.36	6.16	6.66	6.47	5.83	11.01	24.02
3	3.03	8.29	5.06	5.97	9.28	7.63	22.73
4	2.77	7.06	3.70	6.12	10.59	9.77	26.95
5	2.12	6.39	2.58	4.69	10.31	10.43	25.55
6	2.17	5.33	2.96	4.65	9.64	13.90	28.19
C.D. for comparing periods	0.837	2.19	1.20	1.53	1.56	2.15	3.15
C.D. for comparing N levels	N.S.	N.S.	N.S.	N.S.	1.11	N.S.	N.S.

fertilizer treatments employed failed to influence the total uptake of potassium by the crop significantly. The period of crop growth had a definite role in the uptake of this nutrient. In general potassium uptake was enhanced with advancing period of growth.

6. Effect of NPK treatments on the nutrient content of leaf in relation to leaf positions

6.1 Nitrogen content of leaf in relation to leaf positions

The data on the nitrogen percentage of leaf in relation to leaf positions are furnished in Table 27, and graphically represented in Fig. 12. The results of statistical analysis are given in Appendix VII. The results revealed that the leaf positions differed significantly in respect of the content of nitrogen in leaf. The highest percentage of this nutrient was observed in the first group of leaves (1st to 4th leaf), which continuously decreased with increasing number of the leaf positions. The differences between the position groups 2nd and 3rd and between 3rd and 4th were not statistically significant. The levels of nitrogen application significantly influenced the nitrogen percentage of leaves in different positional groups. When the coefficients of correlation between the nitrogen percentage in leaf of positional groups and the total

Table 27. Effect of NPK treatments on nitrogen content of leaf in relation to leaf positions, % on moisture free basis

Treatments	Leaf positions			
	1-4	5-8	9-12	13-16
$n_0p_0k_0$	2.28	1.96	1.73	1.34
$n_0p_0k_1$	2.37	2.12	1.73	1.34
$n_0p_0k_2$	2.26	1.18	1.09	1.11
$n_0p_1k_0$	3.29	2.37	2.62	2.59
$n_0p_1k_1$	2.23	0.45	0.72	0.96
$n_0p_1k_2$	2.37	1.39	1.37	0.70
$n_0p_2k_0$	3.34	2.51	2.37	2.23
$n_0p_2k_1$	3.26	2.59	2.56	2.23
$n_0p_2k_2$	2.34	2.17	2.06	2.06
$n_1p_0k_0$	2.62	2.51	2.51	2.05
$n_1p_0k_1$	2.34	2.01	1.92	2.03
$n_1p_0k_2$	1.87	1.56	1.92	2.03
$n_1p_1k_0$	2.26	1.67	1.62	1.14
$n_1p_1k_1$	3.40	2.28	2.28	1.31
$n_1p_1k_2$	2.62	2.65	2.34	2.51
$n_1p_2k_0$	2.87	2.95	2.62	2.76
$n_1p_2k_1$	3.18	2.79	2.79	2.03
$n_1p_2k_2$	3.12	2.62	2.20	2.23
$n_2p_0k_0$	3.12	2.40	2.37	1.70
$n_2p_0k_1$	2.62	2.54	2.42	1.87
$n_2p_0k_2$	2.95	2.37	2.48	1.87
$n_2p_1k_0$	1.76	1.48	1.64	1.14
$n_2p_1k_1$	1.17	1.23	0.39	1.08
$n_2p_1k_2$	2.73	2.06	1.89	1.37
$n_2p_2k_0$	3.34	2.15	1.89	1.87
$n_2p_2k_1$	2.56	2.01	2.03	1.89
$n_2p_2k_2$	2.42	2.12	1.98	2.79
n_0	2.64	1.86	1.81	1.62
n_1	2.70	2.34	2.24	2.01
n_2	2.52	2.04	1.90	1.73
Mean	2.62	2.08	1.98	1.79

C.D. for comparing positions 0.24
C.D. for comparing levels of N & levels of P 0.168

nitrogen uptake were examined, it was seen that the highest correlation ($r = +0.859^{**}$) was obtained for the positional group 2 (Fig. 15). The percentage nitrogen in leaf of the other positional groups was also positively correlated with the total nitrogen uptake, the values for coefficient of correlation being 0.741^{**}, 0.692^{**} and 0.326^{**} for the positional groups 3, 1 and 4 respectively. The relationship between leaf nitrogen percentage (positional group 3) and total nitrogen uptake is given in Fig. 16.

6.2 Phosphorus content of leaf in relation to leaf positions

The data on the phosphorus content of leaf in relation to leaf positions are furnished in Table 28 and graphically represented in Fig. 13. The results of statistical analysis are shown in Appendix VII. The observations indicated that the leaf positions differed significantly in respect of the content of phosphorus in leaf. The highest percentage of phosphorus was noticed in the first group of leaves (1st to 4th leaf) which progressively decreased with increasing number of the leaf positions thus showing that the pattern of variation in the phosphorus content of leaf in relation to leaf position closely resembled with that of nitrogen.

Table 28. Effect of NPK treatments on phosphorus content on leaf in relation to leaf positions, % on moisture free basis

Sl. No.	Treatments	Leaf positions			
		1-4	5-8	9-12	13-16
1	$n_0p_0k_0$	0.206	0.167	0.171	0.146
2	$n_0p_0k_1$	0.185	0.167	0.175	0.146
3	$n_0p_0k_2$	0.219	0.183	0.167	0.148
4	$n_0p_1k_0$	0.188	0.169	0.171	0.165
5	$n_0p_1k_1$	0.181	0.173	0.171	0.146
6	$n_0p_1k_2$	0.198	0.183	0.181	0.156
7	$n_0p_2k_0$	0.208	0.188	0.183	0.175
8	$n_0p_2k_1$	0.188	0.175	0.177	0.173
9	$n_0p_2k_2$	0.213	0.183	0.177	0.167
10	$n_1p_0k_0$	0.183	0.175	0.171	0.169
11	$n_1p_0k_1$	0.192	0.183	0.171	0.171
12	$n_1p_0k_2$	0.219	0.181	0.189	0.165
13	$n_1p_1k_0$	0.192	0.181	0.179	0.173
14	$n_1p_1k_1$	0.240	0.135	0.135	0.154
15	$n_1p_1k_2$	0.208	0.183	0.150	0.146
16	$n_1p_2k_0$	0.252	0.167	0.196	0.185
17	$n_1p_2k_1$	0.208	0.171	0.179	0.169
18	$n_1p_2k_2$	0.246	0.196	0.188	0.167
19	$n_2p_0k_0$	0.260	0.271	0.258	0.150
20	$n_2p_0k_1$	0.256	0.192	0.185	0.175
21	$n_2p_0k_2$	0.229	0.173	0.183	0.177
22	$n_2p_1k_0$	0.194	0.204	0.770	0.138
23	$n_2p_1k_1$	0.234	0.179	0.167	0.163
24	$n_2p_1k_2$	0.204	0.194	0.202	0.165
25	$n_2p_2k_0$	0.235	0.192	0.163	0.165
26	$n_2p_2k_1$	0.188	0.181	0.179	0.163
27	$n_2p_2k_2$	0.177	0.179	0.152	0.167
	p_0	0.217	0.188	0.184	0.161
	p_1	0.205	0.178	0.170	0.156
	p_2	0.191	0.181	0.177	0.170
	Mean	0.211	0.182	0.177	0.162

C.D. for comparing positions 0.008
C.D. for comparing levels of Nitrogen, phosphorus and potassium 0.006

FIG 12. RELATIONSHIP BETWEEN LEAF POSITIONS AND % OF N IN LEAF

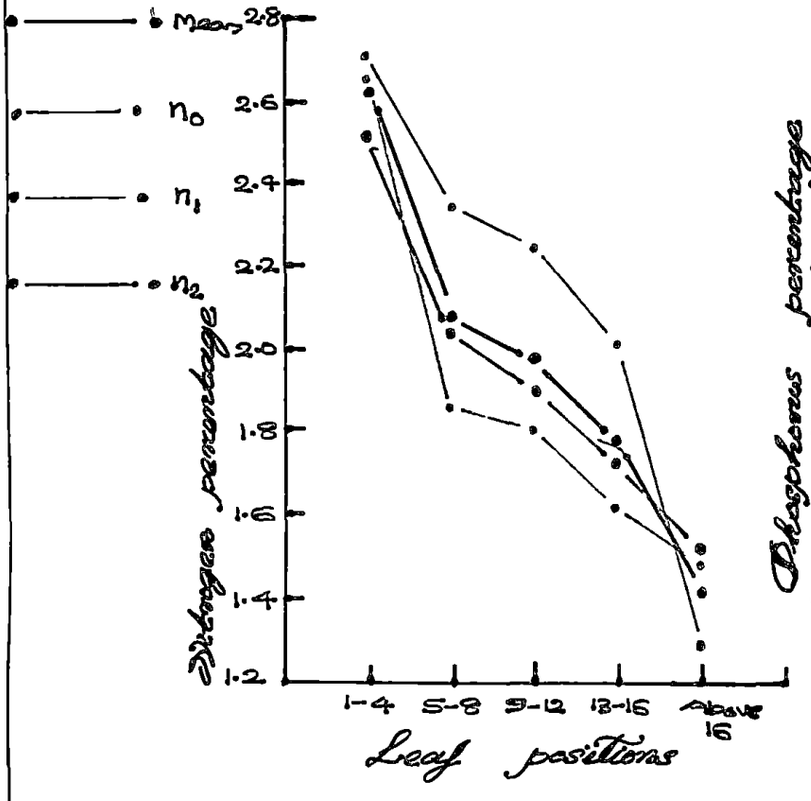


FIG. 13 RELATIONSHIP BETWEEN LEAF POSITIONS AND % OF P IN LEAF

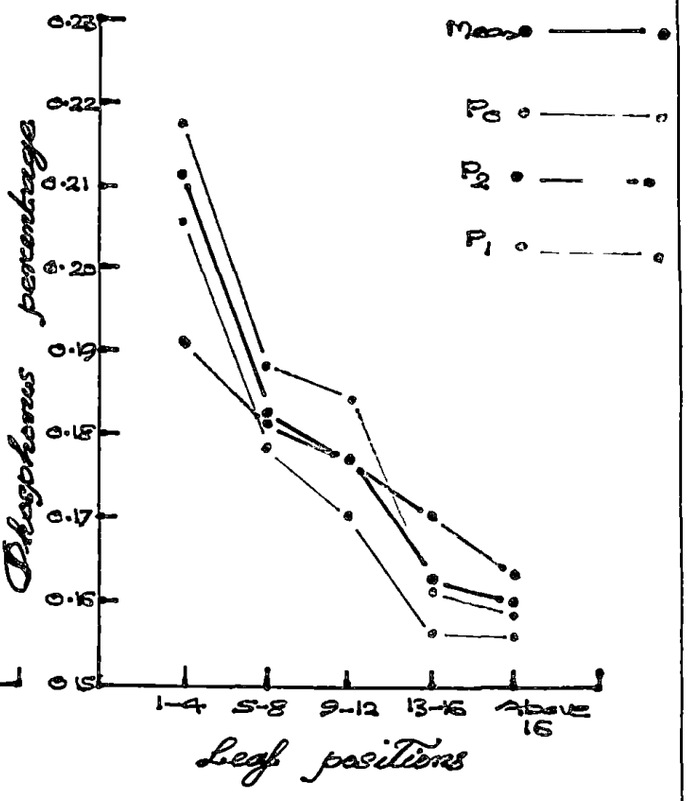
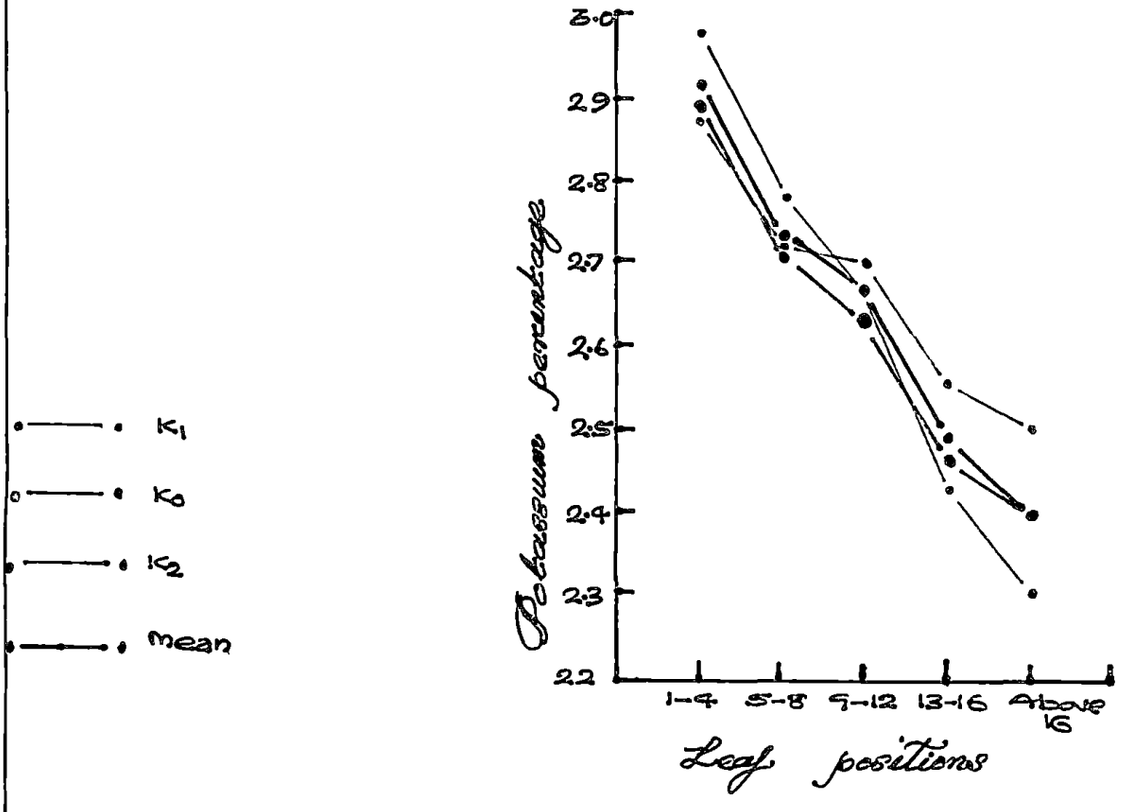


FIG. 14 RELATIONSHIP BETWEEN LEAF POSITIONS AND %ogK IN LEAF



The difference between the phosphorus content of the positional groups second and third was not statistically significant. The levels of phosphorus application significantly influenced the phosphorus percentage of leaves from different positional groups. However, the percentage of all the positional groups failed to correlate significantly with the total phosphorus uptake of the plants. The values for the coefficient of correlation for the positional groups 2, 3, 1 and 4 were + 0.191, + 0.186, + 0.057 and -0.156 respectively, which were not significant even at the 5 per cent level.

6.3 Potassium content of leaf in relation to leaf positions

The data on the potassium percentage of leaf in relation to leaf positions are furnished in Table 29 and graphically represented in Fig.14. The analysis of variance table is given in Appendix VII. The results of statistical analysis showed that the leaf positions differed significantly in respect of the content of potassium in leaf. The highest percentage of this nutrient was observed in the first group of leaf. (1st to 4th leaves) which continuously and significantly decreased with increasing number of the leaf groups. The levels of potassium application did not influence

Table 29. Effect of NPK treatments on potassium content of leaf in relation to leaf positions, % on moisture free basis

Sl. No.	Treatments	Leaf positions			
		1-4	5-9	9-12	13-16
1	$n_0p_0k_0$	2.60	2.60	2.60	2.40
2	$n_0p_0k_1$	3.00	2.80	2.60	2.60
3	$n_0p_0k_2$	3.00	2.80	2.60	2.20
4	$n_0p_1k_0$	3.00	2.70	2.50	2.10
5	$n_0p_1k_1$	2.90	2.70	2.60	2.40
6	$n_0p_1k_2$	2.70	2.50	2.50	2.50
7	$n_0p_2k_0$	3.30	3.00	3.00	3.00
8	$n_0p_2k_1$	3.10	3.00	2.70	2.50
9	$n_0p_2k_2$	3.20	3.00	2.80	2.50
10	$n_1p_0k_0$	2.70	2.60	2.50	2.40
11	$n_1p_0k_1$	3.50	3.20	3.00	3.00
12	$n_1p_0k_2$	2.90	2.80	2.70	2.50
13	$n_1p_1k_0$	3.10	2.90	2.90	2.80
14	$n_1p_1k_1$	3.00	3.00	3.00	2.80
15	$n_1p_1k_2$	3.10	2.70	2.60	2.60
16	$n_1p_2k_0$	3.00	2.80	2.80	2.60
17	$n_1p_2k_1$	3.00	2.40	2.00	2.00
18	$n_1p_2k_2$	2.90	2.90	2.80	2.80
19	$n_2p_0k_0$	2.70	2.70	2.70	2.40
20	$n_2p_0k_1$	2.90	2.80	2.80	2.30
21	$n_2p_0k_2$	2.60	2.30	2.00	2.00
22	$n_2p_1k_0$	2.70	2.70	2.50	2.50
23	$n_2p_1k_2$	2.80	2.60	2.60	2.30
24	$n_2p_1k_2$	2.90	2.80	2.80	2.70
25	$n_2p_2k_0$	2.70	2.60	2.50	2.80
26	$n_2p_2k_1$	2.60	2.50	2.40	2.00
27	$n_2p_2k_2$	2.70	2.60	2.60	2.40
	k_0	2.87	2.73	2.67	2.56
	k_1	2.98	2.78	2.63	2.43
	k_2	2.89	2.71	2.60	2.47
	Mean	2.91	2.74	2.63	2.49

C.D. for comparing positions 0.088
C.D. for comparing levels of nitrogen, phosphorus and potassium 0.078

FIG 15. RELATIONSHIP BETWEEN LEAF N % (5th & 8th leaves) AND TOTAL UPTAKE AT 4th PERIOD

$r = +0.889^{**}$

$y = 3.38x + 2.46$

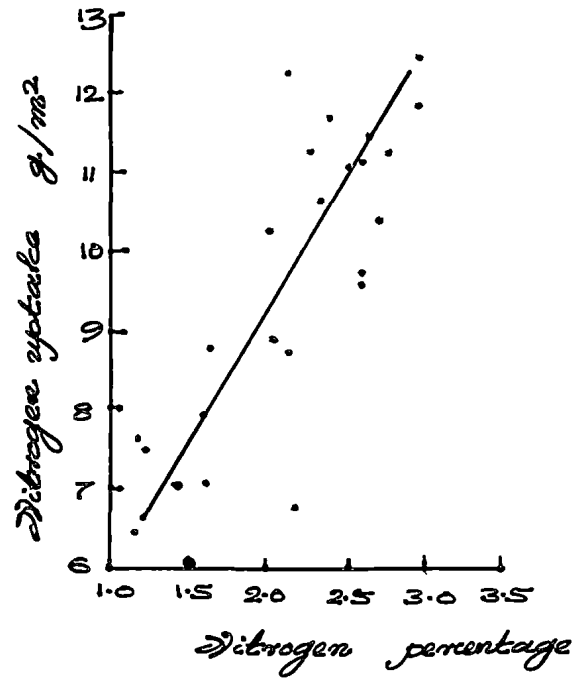
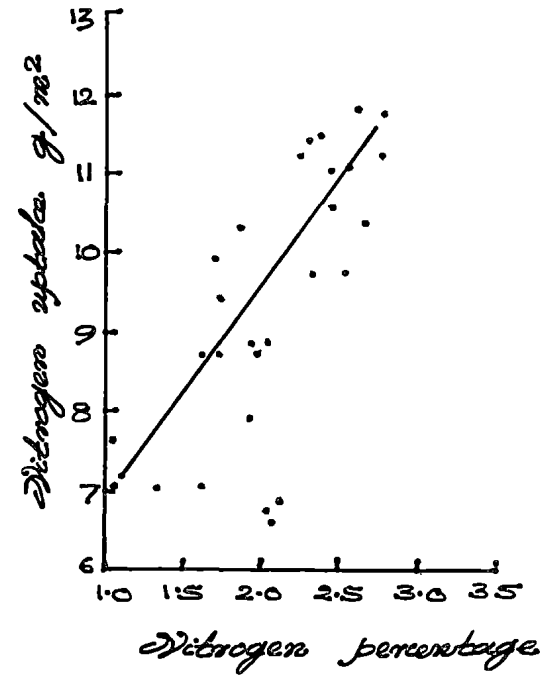


FIG. 16 RELATIONSHIP BETWEEN LEAF NITROGEN % (5th, 12th leaves) AND TOTAL UPTAKE AT 4th PERIOD

$r = +0.741^{**}$

$y = 2.78x + 3.99$



the potassium content of the leaf groups significantly. Also correlations between potassium content of leaf and total potassium uptake were not significant for any of the positional groups examined.

7. Effect of NPK treatments on oleoresin content of ginger

The oleoresin content of ginger as influenced by the fertilizer treatments are given in Table 30. The results of statistical analysis are furnished in Appendix VIII. The results showed that the levels of nitrogen, phosphorus and potassium and their interactions employed in the study could not influence the oleoresin content of ginger significantly.

Table 30. Effect of NPK treatments on oleoresin content of ginger

Sl.No.	Treatments	Oleoresin %
1	$n_0p_0k_0$	11.6
2	$n_0p_0k_1$	10.2
3	$n_0p_0k_2$	12.6
4	$n_0p_1k_0$	10.3
5	$n_0p_1k_1$	8.1
6	$n_0p_1k_2$	11.7
7	$n_0p_2k_0$	8.0
8	$n_0p_2k_1$	21.3
9	$n_0p_2k_2$	7.1
10	$n_1p_0k_0$	8.7
11	$n_1p_0k_1$	8.8
12	$n_1p_0k_2$	11.8
13	$n_1p_1k_0$	8.3
14	$n_1p_1k_1$	13.1
15	$n_1p_1k_2$	7.6
16	$n_1p_2k_0$	11.0
17	$n_1p_2k_1$	10.1
18	$n_1p_2k_2$	14.5
19	$n_2p_0k_0$	9.7
20	$n_2p_0k_1$	7.8
21	$n_2p_0k_2$	10.5
22	$n_2p_1k_0$	10.6
23	$n_2p_1k_1$	9.8
24	$n_2p_1k_2$	8.6
25	$n_2p_2k_0$	9.8
26	$n_2p_2k_1$	10.1
27	$n_2p_2k_2$	12.7

n_0	11.20	p_0	10.19	k_0	9.78
n_1	10.43	p_1	9.79	k_1	11.03
n_2	9.95	p_2	11.62	k_2	10.79

C.D. for comparing levels of N, P and K -- N.S.

DISCUSSION

1. Effect of NPK treatments and period of growth on morphological characters and dry matter yield of ginger

1.1 Effect of NPK treatments

Results presented in Table 1 and analysis of variance in Appendix II elucidate that among the morphological characters examined, the height of tiller and total dry matter yield of the plant are markedly influenced by the varying doses of nitrogen, while the application of phosphorus and potassium could not affect these characters. It is interesting to note that no fertilizer treatment could bring about significant changes on the morphological characters like number of tillers per clump and number of leaves per tiller.

As regards the influence of nitrogen levels on the height of tillers, it is seen that the maximum height is attained at the n_1 level which is superior to that of the n_0 level. The maximum dry matter production is also noticed at the n_1 level. In addition, the superiority of the n_1 level is reflected in the rhizome yield since the yield at this level is the

maximum and is significantly higher as compared to that at the n_0 level. It should be pointed out that the increase of applied nitrogen from n_1 to n_2 level caused a decline in the total dry matter and rhizome yield of ginger.

These observations tend to explain that the requirement of nitrogen for the maximum production of dry matter is met at the n_1 level of nitrogen application namely 80 kg/ha beyond which the plant could not respond. It is assumed that the number of tillers per clump and number of leaves per tiller are not indicative of the total dry matter production of the plant, while the height of the plant registers a significant positive correlation with the rhizome yield. Field observations manifest that heavy yielding plants often put forth tillers with longer internodes which contribute a greater value for the height of the tiller while low yielding plants usually possess tillers with shorter internodes. This observation corroborates the results reported by Nair (1964), who observed that the height of the plant responded to the application of fertilizers and correlated with the yield whereas characters like number of tillers per clump and number of leaves per tiller were not influenced.

1.2 Effect of period of growth

It is apparent from the observations recorded on the morphological features of the plant in relation to increasing period of growth that the total period of growth put under observation (90th to 240th day) can be divided into three phases with respect to the development of aerial plant tissues. They are:(1) a phase of active vegetative growth, which occurs from the 90th day to 120th day during which 25.5 per cent of the total dry matter of the plant is put forth. This period of 30 days accounts for 27.8 per cent of the total number of tillers produced and 22.2 per cent of the total height of the tillers; (2) a phase of slow vegetative growth which occurs during the period from 120th day to 180th day; (3) a phase approaching senescence commencing from 180th day and extending up to harvest, during which the elaboration of aerial plant parts is practically insignificant. The pattern of rhizome enlargement follows almost the same trend as that of the aerial parts in relation to the increasing age of the crop. But, instead of a final phase of senescence of insignificant growth in the case of aerial tissue, the development of the rhizome continues till harvest. It should be pointed out that

during the phase of active growth (90th to 120th day) 36.5 per cent of the total fresh weight of rhizome has been formed, which emphasises the importance of early attention to the crop in the manuring schedule as well as cultural practices. These observations lend support to the results obtained by Nair (1964) who observed similar vegetative phases of different growth rate in the case of turmeric.

2. Rhizome yield of ginger at harvest

Observations recorded in this study indicate that the levels of nitrogen employed influence the yield of rhizome significantly while the effect of phosphorus and potassium and the interactions of nitrogen, phosphorus and potassium are not significant. The yield obtained at the n_1 level (80 kg N/ha) is significantly superior to that at the other two levels (40 kg/ha and 120 kg/ha), the n_0 and n_2 levels being on par, statistically. The increase in applied nitrogen from n_0 to n_1 enhances the rhizome yield significantly while a further increase to the highest level decreases the yield. It should be mentioned that the height of tiller, and total dry matter yield

are significantly influenced at the n_1 level of nitrogen application. The total nitrogen uptake is also found influenced by the levels of nitrogen tried. The uptake at the n_1 level is the maximum and superior to the other levels employed. These observations tend to remark that the maximum requirement of the crop for giving the highest yield is already met at the n_1 level of nitrogen application, since further increase in the quantity of applied nitrogen depresses the yield as well as its uptake. The greater intake and appropriation of this nutrient by the crop at the n_1 level is also reflected in the comparatively low content of total nitrogen in the soil examined after the crop growth. It is interesting to observe that the lowest levels of phosphorus and potassium added are sufficient to give the maximum yield obtained at the n_1 level of nitrogen application. In fact, it is not possible now to presume whether even the lowest levels of phosphorus and potassium applied are required for the maximum yield recorded in the experiment. These observations deserve serious considerations since the present levels of phosphorus and potassium recommended for the crop are 50 kg P_2O_5 and 50 kg K_2O per hectare respectively which is at

variance with the results of this investigation.

The optimum quantity of nitrogen required for the crop worked out from this experiment, is 80.62 kg/ha. Optimum levels of phosphorus and potassium cannot be estimated, since their levels tried have no significant response in terms of yield.

The decisive influence of nitrogen and relatively low effects of phosphorus and potassium on the yield of ginger have been reported by different workers. The Jamaican Department of Agriculture (Anonymous, 1953) reported a yield increase of 21 per cent by the application of nitrogen and no response to application of phosphorus and potassium. Muralidharan *et al.* (1974) observed that 70 kg N/ha increased the yield of ginger significantly while application of phosphorus and potassium had no effect.

3. Uptake of nitrogen

3.1 Effect of fertilizer treatments

The results of the study indicate that the levels of nitrogen tried significantly influence the uptake of nitrogen by the plant. Levels of phosphorus and potassium and interaction of nitrogen, phosphorus and potassium have no significant effect on the uptake

of this nutrient. The nitrogen uptake increases when the level of nitrogen application increases from 40 kg/ha to 80 kg/ha. But a further increase to 120 kg/ha fails to register a significantly higher uptake as compared to that at the 80 kg level. This elucidates that the optimum requirement of nitrogen has been satisfied by its uptake when added at the rate of 80 kg/ha. This increased uptake of nitrogen at the n_1 level is due to the increased production of dry matter as well as the higher percentage of nitrogen present in the plant irrespective of the type of the plant part namely leaf, pseudostem and rhizome. The uptake of nitrogen is well reflected in the yield of rhizome since the maximum uptake synchronizes with the maximum yield.

3.2 Effect of growth

The nitrogen uptake progressively increases with advancing period of crop growth and the maximum uptake is achieved at the 5th period (210 day) after which uptake values do not increase with the age. There is marked intake of nitrogen by the crop during the 30 days from 90th day to 120th day after planting. This spurt in nitrogen intake accounts to 3.67g N/m^2 while the total amount of nitrogen removed over the

entire period of growth is only 10.16 g/m^2. This envisages the need of supplying the crop with nitrogen during this critical period of active growth. In the present experiment, half the quantity of nitrogen was added on 60th day and the remaining on 120th day. In fact, the quantity of nitrogen removed by the crop till 120th day which is 7.37 g/m^2 exceeds the quantity of inorganic nitrogen added to the soil which is only 4 g/m^2 (40 kg/ha). This shows that considerable amount of nitrogen released by the mineralisation of organic manures or that is originally present in the soil has been drawn by the crop to meet this requirement. But, the effective utilisation of the second dose of nitrogen added on 120th day appears to be comparatively poor since the nitrogen uptake during the subsequent periods are not conspicuous. It should be remembered at this point that the vegetative growth and the production of total dry matter are also at the highest rate during 90th day to 120th day as compared to the later periods, which clearly explains the need of enhanced uptake and appropriation of this nutrient by the crop during this period. In the light of these observations the probability of increasing the efficiency of nitrogen utilisation by advancing the second application of

nitrogen to 90th day or 100th day cannot be ruled out.

When the uptake of nitrogen in leaf, pseudostem and rhizome is separately examined in relation to the effect of increasing period of growth, it is observed that the nitrogen uptake in leaf and pseudostem increases up to the 180th day and then decreases while the uptake in rhizome continuously increases till harvest, the increase being more marked from 180th day. This suggests the translocation of this element from the leaf and its subsequent accumulation in rhizome to cope up with the increasing weight of rhizome during the later stages of crop growth.

4. Uptake of phosphorus

4.1 Effect of fertilizer treatments

Results of the studies on uptake of phosphorus shows that only the levels of nitrogen applied influenced the total uptake of phosphorus among the various fertilizer treatments employed. Among the nitrogen levels, n_1 is superior to the other levels. It needs emphasis that the levels of phosphorus employed could not bring about any significant increase

in the uptake of this element by the plant while the levels of nitrogen significantly influenced it. Obviously, this is because that the quantity of phosphorus required by the crop has been obtained even at the p_0 level making the higher levels tried ineffective. Since nitrogen markedly influences the rate of growth and the tissue elaboration of the plant, it can be presumed that higher quantity of phosphorus has to be taken up by the plant to maintain a constant level of phosphorus in the total dry matter produced. As compared to the nitrogen uptake of the crop (10.16 g/m^2) the uptake of phosphorus is comparatively low (1.47 g/m^2) indicating that the total requirement of this element in the plant is only 14.47 per cent of that of nitrogen.

4.2 Effect of period of growth

The uptake of phosphorus steadily increases with the increasing age of the plant. As in the case of nitrogen, the uptake of phosphorus also is at a comparatively enhanced rate during the period of active plant growth (90th to 120th day). This is evidently due to the higher rate of dry matter production during this period as compared to later stages of growth. As

the full dose of phosphorus has been given as a basal dressing, the availability of this nutrient to the crop would have been more in the early period of growth.

Observations on the uptake of phosphorus in leaf, pseudostem and rhizome in relation to the increasing age of the plant reveal that the phosphorus uptake in leaf and pseudostem progressively increases up to the 180th day and then declines while the uptake of this nutrient element in rhizome steadily increses till harvest. This indicates the greater accumulation and appropriation of phosphorus in rhizome necessitiated consequent to the enlargement of the underground stem with advancing period of maturity.

5. Uptake of potassium

5.1 Effect of fertilizer treatments

Results reveal that the fertilizer treatments introduced failed to influence the total uptake of potassium by the crop significantly. When the effect of treatments on the uptake of potassium in different plant parts are examined, it is seen that the levels of nitrogen significantly influence the uptake of potassium in pseudostem, the n_1 level being superior

to other levels in this respect. The failure of introduced potassium levels to generate a higher uptake of potassium by the crop is evidently due to the availability of this nutrient at the required quantity even at the K_0 level. The effect of n_1 level of nitrogen in increasing the uptake of this element in the pseudostem can only be due to the increased production of dry matter under the influence of nitrogen at this particular level.

5.2 Effect of period of growth

The uptake of potassium progressively increases with advancing age of the crop. As in the case of the other two nutrients discussed, the uptake of potassium also is at a remarkably high rate during the period of 90th to 120th day accounting for 29.3 per cent of the total uptake of this nutrient. In the present study, half the dose of potassium is given as basal dose and the remaining on 120th day, while the results show that the active period of uptake is between 90th day to 120th day. However, in this trial, the time of application of potassium would not have been decisive since the levels employed have no significant effect on the uptake.

The pattern of uptake of potassium in leaf, pseudostem and rhizome in relation to increasing period of growth is similar to those for nitrogen and phosphorus. The uptake in leaf and pseudostem progresses till 180th day and then gradually declines while the uptake in rhizome steadily progresses till harvest.

6. Standardisation of leaf positions for foliar diagnosis

One of the objectives of the present investigation is to select an index leaf or reflect for foliar diagnosis in relation to nitrogen, phosphorus and potassium. Leaf samples collected from different positional groups are examined for this purpose. For the selection of the index leaf, the following attributes of a reflect is kept in mind.

1. The reflect should contain sufficient amount of the nutrient element in question for its easy estimation.
2. The reflect should respond to varying levels of the nutrient element supplied or its uptake by the plant.
3. The sampling errors should be minimum i.e. the idex leaf should belong to the plateau of the curve when the nutrient percentage of the leaf is plotted against the leaf positions.

4. As far as possible, the nutrient percentage of the leaf should correlate with the yield of the crop.

The results on the nitrogen content of leaf in relation to leaf positions show that the highest percentage of this nutrient is in the first group of leaves (1st to 4th) which continuously decreases with increasing number of the leaf positions. Differences between the positional groups 2nd and 3rd and between 3rd and 4th are not statistically significant suggesting that the values are almost stabilised during this range of leaf positions. The levels of nitrogen application significantly influence the nitrogen percentage of leaf from the different positional groups. The coefficient of correlation between nitrogen percentage in leaf of positional groups and total nitrogen uptake is highest for the positional group 2. Other positional groups are also positively correlated. The above observations suggest that any positional group in the range of group 2 to 4 will serve as a satisfactory reflect for estimating the nitrogen status of the plant.

A higher content of phosphorus is noticed in the first group of leaves which progressively decreases

with the increasing number of leaf positions indicating that the pattern of variation in phosphorus percentage in relation to leaf position closely resembles with that of nitrogen. The difference between the phosphorus content of the positional groups 2 and 3 is not significant thereby indicating an area of stabilised level of this nutrient at this range. However, the content of phosphorus of all the positional groups fail to correlate significantly with the uptake of this nutrient by the crop. Thus, among the positional groups tried, the second and third groups are superior to the other positional groups in satisfying atleast some of the requirements of an ideal reflect.

As in the case of nitrogen and phosphorus, the highest percentage of potassium is observed in the first group of leaves which continuously and significantly decreases with the increasing number of leaf positions. Comparatively, the difference between the second and third groups is smaller than the differences between the other adjacent groups. Correlations between potassium content of leaf and total uptake of potassium are not significant for any of the positional groups examined.

The foregoing observations are supporting for the selection of the second and third positional groups (5th to 12th leaves) as the index leaves for foliar diagnosis in ginger in relation to nitrogen, phosphorus and potassium status of the plant.

Regarding the optimum period of sampling for foliar diagnosis, it appears that the period between 90th day to 120th day after planting will be the ideal range on the following grounds:

(i) This period represents the phase of active vegetative growth both for aerial and underground tissue.

(ii) This period accounts for the major portion of the nutrients removed by the crop.

(iii) Application of fertilizers for adjusting the nutrient status of the fertilizer elements will be effective only if they are applied in the phase of active growth and uptake.

7. Effect of NPK treatments on the oleoresin content of ginger

The results given in Table 30 reveal that the levels of nitrogen, phosphorus and potassium and their interactions have no significant influence on

the oleoresin content of ginger. This suggests that the percentage oleoresin content of ginger is independent of the total nitrogen uptake of the plants, since the increased uptake of nitrogen at the n_1 level could not contribute towards an added content of oleoresin per unit weight of dry ginger. It is also likely that the increased uptake of nitrogen is sufficient only to meet the requirement consequent to increased production of rhizome rather than to raise the content of oleoresin per unit weight of rhizome. The levels of phosphorus and potassium perhaps, cannot be expected to influence the oleoresin content of ginger in the present investigation, since they could not effect an increased uptake of these nutrients. Also, it is equally probable that the synthesis of the components of oleoresin are not significantly governed by the level of these nutrients available in plant tissue.

SUMMARY

SUMMARY

A field experiment was conducted at the Instructional Farm, attached to the College of Horticulture, Vellanikkara during the period from May 1977, to January 1978 to study the effect of graded doses of nitrogen, phosphorus and potassium on the growth, yield and quality of ginger and also to develop suitable foliar diagnosis techniques in relation to these nutrient elements. The treatments comprised of three levels each of nitrogen (40, 80 and 120 kg N/ha), phosphorus (30, 60 and 90 kg P_2O_5/ha) and potassium (40, 80 and 120 kg K_2O/ha). The experiment was laid out in a 3^3 factorial experiment in randamised block design confounding the effect of interaction NP^2K^2 totally. The important findings were summarised below.

1. Among the morphological characters put under observation, only the height of tiller and the total dry matter yield were found influenced by the fertilizer treatments, while other characters like number of tillers and number of leaves per tiller remained unaffected. Of the fertilizer treatments,

nitrogen at 80 kg/ha was superior to the other levels. The effects of varying levels of phosphorus and potassium were not significant.

2. Application of nitrogen influenced the yield of rhizome significantly, while the effect of phosphorus and potassium and the interactions of nitrogen, phosphorus and potassium were not significant. The increase in nitrogen from 40 kg to 80 kg/ha enhanced the rhizome yields significantly, while a further increase to the highest level of 120 kg/ha decreased the yield. Based on the study the optimum level of nitrogen application was worked out to 80.62 kg/ha.

3. Nitrogen uptake by the plant was significantly influenced by the application of nitrogen. Nitrogen uptake was the highest at the n_1 level of 80 kg N/ha.

4. Phosphorus uptake by the plant was significantly influenced by the application of nitrogen. Among the nitrogen levels, 80 kg N/ha was superior to other levels of application.

5. Fertilizer treatments failed to influence the total uptake of potassium by the crop.

6. The total period of growth put under observation (90th to 240th day) was seen belonged to three phases in respect of the development of aerial tissues. They are: a phase of active vegetative growth (90th to 120th day); a phase of slow vegetative growth (120th to 180th day) and a phase approaching senescence (180th day to harvest). The pattern of rhizome development followed the same trend as that of aerial tissue but instead of a final phase of insignificant growth, the development of rhizome continued till harvest.

7. The uptake of nitrogen, phosphorus and potassium progressively increased with advancing period of crop growth. The rate of uptake of these nutrient was remarkably high during the period of active plant growth (90th to 120th day).

8. The pattern of uptake of nitrogen, phosphorus and potassium in relation to increasing age of the plant revealed that the uptake of this nutrient in leaf and pseudostem progressively increased upto 180th day and then declined while their uptake in rhizome steadily increased till harvest.

9. The content of nitrogen, phosphorus and potassium was the highest in the top most leaves and continuously decreased with increasing number of the leaf positions. Differences between positional groups 2nd and 3rd and between 3rd and 4th, when the leaves are numbered from top to bottom of the tiller, were not significant, suggesting that the level of the nutrient elements are almost stablished in this range of leaf positions. The coefficients of correlation between nitrogen perceentage in the leaf and total nitrogen uptake were higher for groups 2 and 3, suggesting the suitability of the leaves of these groups (5th to 12th leaves) as the reflect for foliar diagnosis in ginger. Regarding the optimum age of the plant for sampling, it appeared that the period between 90th to 120th day after planging will be the best.

10. The incremental doses of nitrogen, phosphorus and potassium and their interactions could not influence the percentage oleoresin content of ginger significantly.

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* Originals not seen

APPENDIX I

Weather data (May 1977 to January 1978)

Month	Rainfall, mm	Temperature, °C		Humidity, %	
		Max.	Min.	Morning	Evening
May	294.6	36.3	21.6	95	55
June	586.2	31.3	21.3	98	66
July	721.1	31.0	21.7	98	66
August	194.2	30.9	22.0	98	64
September	162.6	32.5	22.6	98	61
October	389.9	33.0	22.0	97	55
November	440.8	32.8	21.1	97	58
December	--	32.4	17.6	89	40
January	--	34.3	15.3	93	18

APPENDIX II

Effect of NPK treatments and period of growth on the morphological characters and dry matter yield of ginger:

Analysis of variance

Source	df	Mean squares			
		No.of tillers per clump	No.of leaves per tiller	Height of tiller	Total dry matter
Block	2	4.04	8.36	111.33	0.030
Period	5	1133.89**	114.26**	918.19**	
N	2	39.89	3.97	424.75**	0.058*
P	2	34.07	0.17	55.32	0.013
NP	4	39.97	13.74	621.06**	0.015
K	2	6.00	0.89	49.43	0.014
NK	4	10.00	2.36	77.32	0.009
PK	4	20.00	3.15	34.28	0.036
Error	136	46.11	4.76	38.92	0.008 (df - 6)

** Significant at 1% level
* Significant at 5% level

(Contd..)

A. Comparison of periods (Mean values furnished in Table 1)

Conclusion

No.of tillers per clump	$\overline{6\ 5}\ \overline{4}\ 3\ 2\ 1$
No. of leaves per tiller	$\overline{6\ 5\ 4}\ 3\ 2\ 1$
Height of tiller	$\overline{6\ 5\ 4\ 3}\ \overline{2\ 1}$

B. Comparision of nitrogen levels (Mean values furnished in Table 1)

Conclusion

Effect of nitrogen on height of tiller	$\overline{n_1\ n_2}\ \overline{n_0}$
Effect of nitrogen on total dry matter	$n_1\ \overline{n_2\ n_0}$

C.Comparision of NP interaction (Effect of height of tiller)

	n_0	n_1	n_2	Mean
p_0	36.67	42.93	40.86	40.15
p_1	35.44	42.20	38.76	38.80
p_2	39.18	43.02	40.24	40.82
Mean	37.09	42.72	39.95	

APPENDIX III

Rhizome yield of ginger at harvest:

Analysis of variance

Source	df	Mean square
Block	5	0.79
N	2	3.91**
P	2	0.82
NP	4	0.56
K	2	0.42
NK	4	0.65
PK	4	0.39
NPK	2	0.41
NP^2K	2	0.05
NPK^2	2	1.61
Error	24	0.68

**Significant at 1% level.

Comparison of levels of nitrogen

Treatments	Yield
n_0	2.70
n_1	3.48
n_2	2.65
C.D.	0.57

Conclusion n_1 $\overline{n_0 \quad n_2}$

APPENDIX IV

Effect of NPK treatments and period of growth on nitrogen content of ginger: Analysis of variance

Source	df	Mean squares						
		N content of leaf	N content of pseudostem	N content of rhizome	Uptake of N in leaf	Uptake of N in pseudostem	Uptake of N in rhizome	Total uptake N
Block	2	0.13	0.034	0.008	0.37	0.28	6.44	4.75
Period	5	6.91**	1.680**	1.33**	37.57**	3.67**	84.97**	
N	2	1.37*	0.315	0.14	9.39*	1.56**	9.84	13.84**
P	2	0.117	0.047	0.03	1.12	0.0005	0.22	0.47
NP	4	0.086	0.117	0.03	0.13	0.065	1.83	1.88
K	2	0.151	0.058	0.05	1.80	0.227	0.74	4.34
NK	4	0.020	0.096	0.19	0.347	0.073	0.91	1.56
PK	4	0.141	0.034	0.016	1.81	0.034	2.53	5.40
Error	136	0.370	0.124	0.106	2.00	0.284	4.38	1.82 (df - 6)

** Significant at 1 % level
* Significant at 5 % level

(Contd ...)

A. Comparison of periods
(Mean values furnished in Table 10)

Conclusion	
N content of leaf	2 1 3 4 5 6
N content of pseudostem	1 2 3 4 5 6
N content of rhizome	6 3 1 5 2 4
N uptake leaf	4 3 2 5 6 1
N uptake pseudostem	4 5 6 3 2 1
N uptake rhizome	5 6 4 3 2 1
N uptake total	5 6 4 3 2 1

B. Comparison of levels of nitrogen
(Mean values furnished in Table 10)

Conclusion	
N content of leaf	n_1 n_2 n_0
N uptake leaf	n_1 n_2 n_0
N uptake pseudostem	n_2 n_1 n_0
N uptake total	n_1 n_2 n_0

APPENDIX V

Effect of NPK treatments and period of growth on phosphorus content of ginger: Analysis of variance

Source	df	Mean squares						
		P content of leaf	P content of pseudostem	P content of rhizome	Uptake of P in leaf	Uptake of P in pseudostem	Uptake of P in rhizome	Total uptake P
Block	2	0.0002	0.0013	0.0025	0.0149	0.0082	0.2670	0.383**
Period	5	0.0979**	0.1260**	0.0718**	0.5074**	0.0385**	1.9200**	
N	2	0.0005	0.0023	0.0002	0.0230	0.0495**	0.1130	0.157*
P	2	0.0006	0.0029	0.0029	0.0058	0.0070	0.0200	0.041
NP	4	0.0002	0.0029	0.0014	0.0018	0.0014	0.0910	0.055
K	2	0.0004	0.0011	0.0009	0.0170	0.0033	0.0050	0.040
NK	4	0.0001	0.00004	0.0037	0.0104	0.0022	0.0700	0.045
PK	4	0.0002	0.0003	0.0004	0.0092	0.0030	0.1740	0.046
Error	136	0.0039	0.0049	0.0034	0.0218	0.0041	0.1050	0.033 (df - 6)

** Significant at 1 % level
* Significant at 5 % level

A. Comparison of periods
(Mean values furnished in Table 18)

Conclusion

P content of leaf	$\overline{3\ 1}\ \ \overline{2\ 5}\ \ \overline{4\ 6}$
P content of pseudostem	$1\ \overline{3\ 2}\ \ \overline{4\ 5}\ \ \overline{6}$
P content of rhizome	$\overline{1\ 3}\ \ \overline{2\ 4}\ \ \overline{6\ 5}$
P uptake leaf	$3\ \overline{5\ 4}\ \ 2\ 6\ 1$
P uptake pseudostem	$\overline{4\ 3}\ \ \overline{6\ 5}\ \ \overline{1\ 2}$
P uptake rhizome	$6\ \overline{5\ 4}\ \ \overline{3\ 2}\ \ 1$
P uptake total	$\overline{6\ 5\ 4}\ \ 3\ 2\ 1$

B. Comparison of levels of nitrogen
(Mean values furnished in Table 18)

Conclusion

P uptake pseudostem	$n_2 \quad \overline{n_1 \quad n_0}$
P uptake total	$\overline{n_1 \quad n_2 \quad n_0}$

APPENDIX VI

Effect of NPK treatments and period of growth on potassium content of ginger: Analysis of variance

Source	df	Mean squares						
		K content of leaf	K content of pseudostem	K content of rhizome	Uptake of K in leaf	Uptake of K in pseudostem	Uptake of K in rhizome	Total uptake K
Block	2	0.045	1.490	0.473	5.048	12.31	37.21	57.98
Period	5	61.116**	65.250**	118.000**	35.790**	109.07**	215.25**	
N	2	0.154	1.120	0.009	1.540	33.40*	38.72	18.11
P	2	0.640	0.213	1.100	1.640	0.60	1.35	46.83
NP	4	0.189	0.954	1.880	2.650	13.06	8.79	11.42
K	2	0.210	0.935	0.490	3.860	17.68	8.16	26.90
NK	4	0.390	0.275	0.249	0.700	2.73	12.34	14.23
PK	4	0.300	1.360	0.573	1.148	3.29	15.88	27.35
Error	136	2.420	16.560	4.992	8.126	8.50	16.08	19.003 (df - 6)

** Significant at 1 % level
* Significant at 5% level

(Contd...)

A. Comparision of periods
(Mean values furnished in Table 26)

Conclusion	
K content of leaf	1 2 3 4 6 5
K content of pseudostem	1 3 4 5 2 6
K content of rhizome	1 2 3 4 6 5
K uptake leaf	2 4 3 5 6 1
K uptake pseudostem	4 5 6 3 1 2
K uptake rhizome	6 2 5 4 3 1
K uptake total	6 4 5 2 3 1

B. Comparison of levels of nitrogen
(Mean values furnished in Table 26)

Conclusion	
K uptake pseudostem	n_2 n_1 n_0

APPENDIX VII

Effect of NPK treatments on NPK content of leaf in relation to leaf positions

Analysis of variance

Source	df	Mean squares		
		N content of leaf positions	P content of leaf positions	K content of leaf positions
Block	2	0.61*	0.0008	0.0395
Position	3	3.42**	0.0117**	0.8690**
N	2	1.18**	0.0021**	0.4460**
P	2	4.01**	0.0013**	0.0260
NP	4	1.09**	0.0018**	0.2820**
K	2	0.52	0.0012*	0.0180
NK	4	0.83*	0.0003	0.0170
PK	4	0.53	0.00001	0.3740**
Error	84	0.19	0.00029	0.0271

** Significant at 1 % level
* Significant at 5 % level

(Contd...)

A. Comparison of positions

(Mean values furnished in Table 27, 28 and 29)

Conclusion

N content of leaf positions	1 - 4	5 - 8	9 - 12	13 - 16
P content of leaf positions	1 - 4	5 - 8	9 - 12	13 - 16
K content of leaf positions	1 - 4	5 - 8	9 - 12	13 - 16

B. Comparison of nitrogen levels

(Mean values furnished in Table 27, 28 and 29)

Conclusion

N content of leaf positions	n_1	n_2	n_0
P content of leaf positions	n_2	n_1	n_0
K content of leaf positions	n_1	n_0	n_2

C. Comparison of phosphorus levels

P levels	N content	P content
P_0	2.07	0.187
P_1	1.81	0.177
P_2	2.47	0.185
C.D.	0.168	0.006

Conclusion

N content of leaf positions	P_2	P_0	P_1
P content of leaf positions	P_0	P_2	P_1

(Contd...)

D. Comparison of NP interaction

a) N content of leaf positions

	n_0	n_1	n_2	Mean
P_0	1.71	2.11	2.39	2.07
p_1	1.75	2.17	1.49	1.81
p_2	2.48	2.68	2.25	2.47
Mean	1.98	2.32	2.05	2.12

b) P content of leaf positions

	n_0	n_1	n_2	Mean
p_0	0.173	0.18	0.21	0.19
p_1	0.173	0.17	0.19	0.18
p_2	0.184	0.19	0.18	0.19
Mean	0.177	0.18	0.19	0.18

c) K content of leaf positions

	n_0	n_1	n_2	Mean
p_0	2.65	2.82	2.52	2.66
p_1	2.59	2.88	2.66	2.71
p_2	2.93	2.67	2.53	2.71
Mean	2.72	2.79	2.57	2.69

E. Comparison of levels of K

K levels	P content of leaf positions
k_0	0.188
k_1	0.179
k_2	0.183
C.D.	0.0061

Conclusion k_0 k_2 k_1

F. Comparison of NK interaction

N content of leaf positions

	n_0	n_1	n_2	Mean
k	2.39	2.30	2.07	2.25
k	1.88	2.36	1.82	2.02
k	1.68	2.31	2.25	2.08
Mean	1.98	2.32	2.05	2.12

G. Comparison of PK interaction

K content of leaf positions

	p_0	p_1	p_2	Mean
k_0	2.58	2.70	2.84	2.71
k_1	2.88	2.73	2.52	2.71
k_2	2.53	2.70	2.77	2.67
Mean	2.66	2.71	2.71	2.70

APPENDIX VIII

Effect of NPK treatments on oleoresin content of ginger: Analysis of variance

Source	df	Mean square
Block	2	11.925
N	2	3.615
P	2	8.365
NP	4	0.835
K	2	3.990
NK	4	4.768
PK	4	7.943
Error	6	16.520

APPENDIX IX

Effect of NPK treatments and crop growth on NPK content of soil

	Organic carbon	Total nitrogen	Available phosphorus	Available potassium	pH
Pretreatment soil	1.544	0.198	0.0025	0.0325	5
Post harvest soil					
n_0	1.589	0.224	0.0049	0.0300	
n_1	1.579	0.218	0.0043	0.0296	
n_2	1.583	0.236	0.0041	0.0262	
p_0	1.583	0.224	0.0049	0.0296	
p_1	1.587	0.205	0.0039	0.0289	
p_2	1.581	0.249	0.0044	0.0274	
k_0	1.579	0.222	0.0041	0.0255	
k_1	1.589	0.226	0.0043	0.0329	
k_2	1.583	0.230	0.0044	0.0275	

Results of mechanical analysis of pretreatment soil

Coarse sand	- 24%	Silt	- 22.65%
Fine sand	- 21.2%	Clay	- 30.15%

FOLIAR DIAGNOSIS, YIELD AND QUALITY OF GINGER (*Zingiber officinale* ROSCOE) IN RELATION TO NITROGEN, PHOSPHORUS AND POTASSIUM

By

JOHNSON, P. T.

ABSTRACT OF A THESIS

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ABSTRACT

A field experiment was carried out at the Instructional Farm, attached to the College of Horticulture, Vellanikkara during 1977-78 to study the effect of graded doses of nitrogen, phosphorus and potassium on the growth, yield and quality of ginger and also to develop suitable foliar diagnosis techniques in relation to these nutrient elements. The treatments comprised of three levels each of nitrogen (40, 80 and 120 kg N/ha), Phosphorus (30, 60 and 90 kg P_2O_5/ha) and potassium (40, 80 and 120 kg K_2O/ha). The experiment was laid out in a 3^3 factorial experiment in randomised block design confounding the effect of interaction NP^2K^2 totally.

The results revealed that among the morphological characters studied, only the height of tiller and total dry matter of the plant were markedly influenced, while other characters like number of tillers and number of leaves per tiller were not effected. Of the fertilizer treatments, nitrogen at 80 kg/ha significantly effected these two characters, while the effect of phosphorus and potassium were not significant.

Application of nitrogen at 80 kg/ha significantly increased the rhizome yield of the crop, while the levels of phosphorus and potassium employed failed to influence the yield.

Uptake of nitrogen and phosphorus by the plant was significantly influenced by the application of nitrogen at the rate of 80 kg/ha, whereas the graded doses of phosphorus and potassium had no significant influence in this respect. The uptake of potassium on the other hand was not influenced by any of the fertilizer treatment introduced.

The total period of growth put under observation appeared divisible into three phases with respect to the development of aerial tissues namely, a phase of active vegetative growth (90th to 120th day after planting); a phase of slow vegetative growth (120th to 180th day) and a phase approaching senescence (180th day to harvest). The pattern of the rhizome development followed the same trend as that of the aerial tissue, but instead of a final phase of insignificant growth, the development of rhizome continued till harvest.

The uptake of nitrogen, phosphorus and potassium progressively increased with advancing period of crop growth. There was marked uptake of these nutrients by the plant during the period of active plant growth (90th to 120th day after planting). The uptake of nitrogen, phosphorus and potassium in leaf and pseudostem progressively increased upto 180th day and then decreased while their uptake in rhizome steadily increased till harvest.

The content of nitrogen phosphorus and potassium was highest in the top most leaves and continuously decreased with increasing number of the leaf position, when the leaves are numbered from top to bottom of the tiller. In consideration of the stability of nutrient level with leaf positions and sensitivity or correlation with varying doses and uptake, the group of 5th to 12th leaves appeared to be the best suited for foliar diagnosis of N, P and K status of the crop. The period between 90th to 120th day after planting was recommended as the optimum period for the detection and amendment of the nutrient status of the crop.

The graded doses of nitrogen, phosphorus and potassium and their interaction failed to influence the percentage oleoresin content of ginger.