NITROGEN NUTRITION IN RAINFED BANANA *cv.* 'PALAYANKODAN'

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THESIS

Submitted in partial fulfilment of the

requirement for the degree of

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Department of

Horticulture (Pomology & Floriculture and Landscaping)

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1980

DECLARATION

I hereby declare that this thesis entitled "Nitrogen nutrition in rainfed banana cv. Palayankodan" is a record of research work done by me during the course of research and 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.

(VALSAMMA MATHEW)

Vellanikkara,

5-8-1980.

CERTIFICATE

Certified that this thesis is a record of research work done independently by Kumari Valsamma Mathew, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CERTIFICATE

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Introduction

INTRODUCTION

India at present occupies the second position in the world for production of banana with its cultivation in more than two lakh hectares (Anon, 1980). Banana in India is now grown under varying soil and seasonal conditions, exploiting the wide variability existing in the crop. The chief banana growing States in the country are Kerala, Tamil Nadu, Maharashtra, Andhra Pradesh, Karnataka, Orissa, Bihar and West Bengal. Of the total area under cultivation, 54 per cent is being shared by Kerala, Tamil Nadu and Maharashtra. Kerala ranks first among these States with an area of 50,100 hectares and a production of 615,227 tonnes (Anon, 1980). As the demand for the fruit in the international trade is growing very fast and as it fetches a higher foreign exchange among the fruits of tropics, any attempt to increase the per hectare yield is most attractive.

India is blessed with enormous number of banana cultivars suited to the different localities. The most popular cultivars are Palayankodan, Dwarf Cavendish, Virupakshi, Rasthali, Nendran, Monthan, Robusta, Ney Poovan and Red Banana. Among these Palayankodan (AAB) syn. Champa (West Bengal), Poovan (Tamil Nadu), Karpurachakkarakeli (Andhra Pradesh) is reported to be tolerant to poor soil and drought conditions(Simmonds, 1959). This group is by far the most important banana in India contributing over 70 per cent of the total crop in the country (Simmonds, 1959). In Kerala, approximately 80 per cent of the banana cultivation is reported to be under rainfed conditions and the most predominant cultivar is 'Palayankodan'.

It is well known that the banana plant requires rich and fertile soils, if a regular harvest is to be obtained. Being a gross feeder, heavy fertilization schedule becomes necessary for obtaining higher yields in banana. Simmonds (1959) reported that even an inherently fertile soil gets depleted of its fertility within a few years of banana cultivation. Hence, a stable cultivation at a satisfactory level of production can only be achieved by adequate fertilization.

Investigations done in the past in India and abroad have shown that banana has a very high requirement of N and K compared to P. Considerable data on the significance of NPK nutrition in banana for various growth and yield attributes are available for different varieties under different climatic conditions. However, these fertilizer recommendations are mainly for irrigated bananas.

So far, no systematic approach seems to have been made to study the response of nutrients in banana under rainfed conditions. The investigations on the different aspects of crop production in rainfed banana therefore assumes greater significance in a State like Kerala where 80 per cent of this crop is under unirrigated conditions. The present study was directed to understand in detail the nitrogen nutrition in Palayankodan cultivar and is the first in the series of the proposed comprehensive investigations on nutritional requirements on rainfed bananas.

The experiment was undertaken with the following objectives:-

i) to study the effect of different levels of nitrogen on growth, yield and quality of fruits

ii) to study the uptake and distribution of nutrients at different phases of growth and development, and

iii) to assess the most economic dosage of nitrogen under rainfed conditions.

Review Of Literature

REVIEW OF LITERATURE

In order to have a proper appraisal of the problems involved and for a critical interpretation of the results obtained, the available literature on the role of different nutrients in banana is briefly reviewed below.

1. NITROGEN IN BANANA NUTRITION

Nitrogen as a plant food affects growth and development of plants to a marked degree and its role in the plant life has been emphasized by various workers in the field of plant nutrition.

Croucher and Mitchell (1940) in their investigations on the nitrogen needs of Gros Michel banana observed that an increase in yield could be secured by the application of nitrogen in soils which were rich in available K_2O and P_2O_5.

Norries and Ayyar (1942) reported that banana plants require large quantities of potassium, moderate quantities of nitrogen and relatively little phosphorus for optimum production. Summerville (1944) observed for the Dwarf Cavendish banana grown on red basaltic soils of Queensland that there was considerably greater response to nitrogen and potassium when applied together than when these were applied separately, while application of phosphorus to these soils had no effect on growth.

Gandhi (1951) reported that in the Poona region nitrogen application was found highly beneficial whereas addition of phosphorus and potassium produced no additional yield. Similar results have been reported by Gopalan Nayar (1962) based on the manurial trial in the Cauvery delta. Gopalan Nayar (1953) studied the effect of nitrogen, phosphorus and potassium in the cultivar 'Poovan' grown on the heavy clay soils of Aduthurai in Thanjavur District and reported a positive response only for the application of nitrogen. Bhan and Majumdar (1956) in West Bengal also observed the same effect of nitrogen when nitrogen, phosphorus and potassium were applied. Phosphorus and potassium either alone or in combination, when applied in conjunction with nitrogen did not prove beneficial.

The studies undertaken by the Banana Board Research Department, Jamaica (Anon, 1960-61) revealed that nitrogen was the first mineral nutrient to which banana responded well and that potassium also was found to induce better yields in many localities. Butler (1960) conducted fertilizer experiments with Gros Michel banana in Jamaica over a period of 13 years and on further studies in Honduras over a three year period reported that economic responses to fertilizing could be effected only from the use of nitrogen. Phosphorus and potassium alone or in combination did not produce statistically increased production as compared to nitrogen used alone.

Wardlaw (1961) reported that bananas responded well to nitrogen even when it was relatively more abundant than potassium and phosphorus in the soil. But beneficial influence of potassium was observed in soils which have been long under cultivation or heavily leached, while phosphorus gave little or no response. Investigations by Bhangoo et al. (1962) in Honduras indicated significant response to the application of phosphorus and potassium in conjunction with nitrogen improving the average bunch weight of Giant Cavendish banana. Little or no response was obtained from the use of nitrogen alone, while phosphorus and potassium without nitrogen had no effect on yield.

2. EFFECT OF NITROGEN ON GROWTH

Tanaka (1937) conducted manurial trials with Hokuehu variety of banana in sand culture and reported nitrogen as the most important nutrient and its omission resulted in poor growth.

In fertilizer experiments conducted in Jamaica with Gros Michel banana, Croucher and Mitchell (1940) found increased plant growth by the application of nitrogen along with P_2O_5 and K_2O. Steinhausen as quoted by Ashokkumar (1977) reported that nitrogen promoted vegetative growth including longitudinal growth of petioles and length of bunch. He also observed a promotive effect on the sprouting of the corm bits as well as on the shooting of the young plants due to the application of nitrogen. In the same trial he observed that excess nitrogen reduced the rigidity of the pseudostem, delayed shooting and resulted in abnormally wide spaced hands in the bunch. Butler (1960) working in Jamaica and Honduras on Gros Michel banana reported that nitrogenous fertilizers increased growth substantially, but the other major and minor elements had comparatively little effect and were economically unimportant or even little feasible.

A positive influence on the periodicity of the plant and induced growth of leaves due to the effect of nitrogen was reported by Katyal and Chadha (1961) in banana. Battikhah and Khalidy (1962) applied 0, 100, 200 and 400 g of ammonium nitrate in three applications at intervals of 45 days with constant level of 400 g super phosphate and 200 g potassium sulphate and noted an increase in the height of the pseudostem, leaf area and leaf production besides an increase in nitrogen content in the leaf with increase in nitrogen application. Jagirdar et al. (1963) reported that higher levels of nitrogen resulted in increased plant growth and vigour in banana.

Venkatesam *et al*. (1965) studied the effect of nitrogen, phosphorus and potassium each at three levels on the growth of Karpurachakkarakeli variety of banana under Andhra Pradesh conditions. They observed that application of nitrogen induced better growth in the plants while phosphorus and potash had little or no influence. The effective leaf area increased with increase in the nutrient levels especially of nitrogen. Arunachalam et al (1976) studied the effect of nitrogen on Dwarf Cavendish, Giant Cavendish, Robusta and Lacatan. Promotive effects were noticed by them in almost all characters viz., pseudostem height, girth, leaf area and number of leaves retained. The sucker production was also enhanced due to nitrogen application in all the varieties. Shanmugam and Velayudham (1972) reported that banana plants which did not receive nitrogen produced only seven leaves whereas plants supplied with adequate nitrogen produced 17 leaves.

3. EFFECT OF NITROGEN ON FLOWERING AND MATURITY

In fertilizer experiments conducted in Jamaica at various locations of sedentary hill side soil with Gros Michel banana, Croucher and Mitchell (1940) found that the time of shooting was hastened upto 20 per cent by the application of nitrogen. In manurial investigations on banana (Martman variety) conducted in West Bengal, Bhan and Majumdar (1956) found that the plants cropped earlier when heavy applications of nitrogen were employed.

Simmonds (1959) stated that the rate of maturity (time to shooting) was nearly always hastened by nitrogen. Jagirdar et al. (1963) reported that higher level of nitrogen, although did not increase yield, improved grade and the period of maturity. Plants given 100 lb nitrogen and irrigated every six days produced mature fruits 83 days earlier than unfertilized plants irrigated at 14 days interval. Venkatesam et al. (1965) observed that the duration from the setting of suckers upto shooting was markedly reduced with an increase in the level of nitrogen. But the maturity period of the bunch was not influenced by different levels of nitrogen. Martin-Prevel (1966) while working with Dwarf Cavendish found an earliness of the crop due to nitrogen application.

4. EFFECT OF NITROGEN ON YIELD AND YIELD ATTRIBUTES

Ballion et al. (1933) obtained increased yield with nitrogen and potash applications in banana. Bowman and Eastwood (1940) and Croucher and Mitchell (1940) found increased yield due to the application of nitrogen in the variety Gros Michel under Jamaican conditions.

Bhan and Majumdar (1956) and Katyal and Chadha (1961) noticed a significant increase on the number of hands and fingers per bunch due to heavy nitrogen application. Simmonds (1959) stated that there was an increase in bunch weight with increase in added doses of nitrogen.

Stenihausen as quoted by Ashokkumar (1977) reported that nitrogen increased the length of bunch and number of hands per bunch. Simmonds (1959), Venkatesam et al.(1965) and Arunachalam et al (1976) reported an increase in all the yield attributing characters and finally the yield owing to the application of nitrogen.

Valmayor et al. (1965) in their trial with various combinations of nitrogen, phosphorus and potassium including double nitrogen dressings and one or more minor elements found no response from phosphorus or potassium or the minor elements. But the single dose of nitrogen (120 g/stool/year) increased banana yield by 75.73 per cent and double dose (240 g/stool/year) by 166.67 per cent. In four years' comparisons of various combinations of nitrogen, phosphorus and potassium applications on non-irrigated Lacatan banana in Jamaica, Osborne and Hewitt (1963) found that best yields and quality fruits were obtained with three applications per annum of ammonium sulphate at 10.6 oz per plant. Superphosphate caused no response; but application of muriate of potash at the rate of 1.5 lb per plant appreciably increased plant growth, finger length, yield and average bunch weight.

Teaotia and Dubey (1971) studied the effect of nitrogen on growth and yield of *Musa cavendishii* (L) variety Harichal. They applied nitrogen from five sources - ammonium sulphate, urea, diammonium phosphate, calcium ammonium nitrate and ½ ammonium sulphate + ½ compost at the rate of 45, 90 and 180 g per plant. They observed that all sources significantly increased the yield but 180 g diammonium phosphate followed by ammonium sulphate gave the highest yield. Veeraraghavan (1972) reported significant increase in number and weight of fruits in Nendran banana in Kerala with 228 g N, 228 g P_2O_5 and 456 g K_2O per plant per year.

Ramaswamy and Muthukrishnan (1973) studied the effect of nitrogen on fruit development in Robusta banana and obtained best results with 170 g N per plant which increased the length and girth of fruit at harvest to 21.26 cm and 11.47 cm respectively compared with 16.31 cm and 8.66 cm where no nitrogen was used. Ramaswamy and Muthukrishnan (1974 a) studied the effect of different levels of nitrogen on Robusta banana and obtained best results with 170 kg N per acre.

Kohli et al. (1976) reported that 180 g N, 155 g P_2O_5 and 186.75 g K_2O per plant/year was the best fertilizer dose for Robusta banana, giving the maximum fruit yield of 420 to 530 q/ha. under Bangalore conditions. Singh et al. (1977) reported that 150 g N, 90 g P_2O_5 and 170 g K_2O supplemented with 20 kg compost per plant can be recommended for Basrai banana of Uttar Pradesh for better yield. Pillai et al. (1977) studied the response of Nendran banana to different levels of nitrogen, phosphorus and potassium at the Banana Research Station, Kannara for five consecutive seasons from 1963-1964. The results revealed that nitrogen and potassium exerted a significant positive influence on fruit number and bunch weight. The optimum dose of N and K_2O corresponding to maximum yield of fruit was worked out as 191 and 301 g per plant respectively.

5. EFFECT OF NITROGEN DEFICIENCY IN BANANA

Murray (1959) studied the deficiency symptoms of major elements in banana and observed that nitrogen deficiency resulted in stunted growth, progressive diminution in leaf size, the development of short, thin compressed petioles and reduction in suckering. Wardlaw (1961) reported that the most characteristic symptoms of nitrogen deficiency are slow growth, development of a yellowish green colour in the lamina and a more or less deep reddish tinge or pigmentation in the petiole. Charpentier and

Martin-Prevel (1965) reported that a total deficiency of nitrogen would seriously impair growth beyond flowering stage. A considerable reduction in yield and quality invariably occurred if differentiation coincided with a period of nitrogen deficiency.

6. EFFECT OF NITROGEN ON FRUIT QUALITY

The pre-harvest conditions including mineral nutrition reflect on the quality of the final products in all crops. Pantastico (1975) reported that variations in fruit qualities existed within the variety due to pre-harvest conditions in which the crop was grown. The pre-harvest conditions affecting fruit quality comprised of temperature, relative humidity, light, soil texture, wind, elevation and rainfall under environmental conditions and mineral nutrition, soil management, pruning, thinning, rootstocks, density of planting, irrigation and drainage under cultural aspects. Of the cultural aspects, nutrition of the plant was by far the most extensively explored field especially in the case of citrus (Pantastico, 1975). He had undoubtedly stated that fertilization with major elements affected the internal quality of fruits.

Reuther and Smith (1952), Smith (1967) and Kefford and Chandler (1970) observed that nitrogen nutrition had a positive effect on soluble solids and titratable acidity and an adverse effect on the weight and solid to acid ratio of pineapple fruits. According to Su (1957) and Tay et al. (1968) nitrogen had no effect on fruit quality. But Tay (1972) stated that Yap and Parbery observed an increase in the fruit acidity by higher levels of nitrogen without altering sugar content in pineapple fruits. But Su (1957) and Py (1958) reported a decrease in acidity with increase in nitrogen application in pineapple.

Nijjar and Chand (1969) found in Anab-e-Shahi grapes that medium dose of nitrogen showed the maximum percentage of total soluble solids along with lower acidity. Desai and Phadnis (1979) reported that in Cheema Sahebi grape, total soluble solids, acidity, sugars and total soluble solids/acid ratio were better in lower levels of nitrogen. Nijjar and Singh (1979) in Thompson Seedless grapes reported a decreased acidity with increased nitrogen levels.

Singh et al. (1974) studied the effect of nitrogen and potassium on the physico-chemical characters of Robusta banana and reported an appreciable improvement in fruit qualities with potassium combinations. But Segotia et al. (1972) failed to get any marked effect on the quality of fruits as affected by different levels of nitrogen, phosphorus and potassium in banana variety Cavendish. Chattopadhyay et al. (1980) in Cavendish banana found that nitrogen application increased the total and reducing sugar contents of the fruits.

Bhattacharya *et al.* (1973) in Kagzi lime found that the quality of juice judged in terms of total soluble solids, vitamin C and acidity significantly decreased by the use of higher rates of nitrogen. Singh and Rajput (1976) reported that nitrogen nutrition had a highly significant effect on total soluble solids, reducing sugars and pectin content of guava fruits.

7. UPTAKE AND DISTRIBUTION OF NUTRIENTS

Norries and Ayyar (1942) studied the mineral requirement of banana. Nitrogen was found to be fairly evenly distributed throughout the plant; its highest portion being found in the suckers, the rhizomes of the suckers and in the leaves. Martin-Prevel and Montagut (1966) studied the variations in the relative and actual proportion of nitrogen and total dry matter in the plant organs. It was established that absorbed nitrogen was quickly used and accumulation of nitrogen reserves was practically impossible.

Jacob and Uexkull (1960) found that the nutrient removal by a 30 tonne crop was 50 to 75 kg, 15 to 20 kg and 175 to 220 kg of N, P_2O_5 and K_2O respectively. Martin-Prevel (1964) estimated the nutrient uptake in Dwarf Cavendish banana as 50 kg N, 12.5 kg P_2O_5 and 150 kg K_2O/ha, for a production of 25 metric tonnes/ha/year.

Turner (1969) reported that the quantities of nutrients taken up by banana plants and incorporated into new growth over a 12 month period indicated high requirements of nitrogen and potassium and a low phosphorus.

Based on the total nutrient uptake studies, Joseph (1971) estimated that a banana crop of 16.25 tonnes of fresh fruit would require 38 kg N, 8 kg P_2O_5 and 285 kg K_2O/acre. Shanmugam and Velayudham (1972) found out the uptake of N, P_2O_5 and K_2O by the banana crop as 300, 80 and 800 kg/ha respectively. Jauhari et al. (1974) studied the nutrient uptake of banana variety Basrai Dwarf and reported that the uptake of nitrogen, phosphorus and potassium was rapid in the first four months from planting. Increasing the nitrogen content led to the accumulation of phosphorus. Potassium content decreased in leaves and roots during growth whereas the content in the rhizomes and pseudostem increased. Highest content of silicon, phosphorus and potassium were found in pseudostem, calcium and nitrogen in the leaves and magnesium in the rhizome.

Veerannah et al. (1976) studied the nutrient uptake in Poovan and Robusta varieties. They reported that Robusta required N, P_2O_5 and K_2O at 325, 75 and 1195 kg/ha respectively, whereas Poovan required 408, 35 and 1285 kg/ha. They further reported that nitrogen and potassium were absorbed more in the pre-flowering stage of Robusta.

There was, however, a continuous and steady uptake of nitrogen and potassium and the quantities were almost equal before and after flowering in Poovan. Leaf was found to be the specific tissue for diagnosing nitrogen and phosphorus at all stages of growth. For potassium, however, sheath was found to be the most suitable tissue.

Twyford and Walmsley (1974 a) studied the mineral composition of Robusta banana. The distribution pattern amongst the different plant parts for nitrogen was as follows. At the sucker stage, shoot was richer in nitrogen than the corm. Throughout the vegetative phase, the unemerged leaves had the highest concentration followed by leaves and meristem. During the fruiting phase nitrogen was recorded maximum in the inflorescence followed by leaves and other fruiting parts.

There was little change in nitrogen concentration with plant age in the unemerged leaf as would be expected in a tissue, whose physiological age remained more or less constant. In most other vegetative organs, concentrations tended to decrease with age upto shooting, after which there was little change. In the corm, however, behaviour varied at different sites; at some sites the level remained constant but at others it decreased. Inflorescence and internal fruit stalk levels tended to fall with age. As the fruits matured, nitrogen levels fell; phosphorus and potassium seemed to be of greater importance in most tissues but not so much of those involved in fruit development.

The distribution pattern amongst the different plant parts for phosphorus was as follows. At sucker stage, the shoot had a higher concentration than the corm. At the small and large stage, unemerged leaf had a very much higher concentration than other parts followed by meristem and then usually leaves. In the fruiting phase the inflorescence had a much higher phosphorus concentration than any other organ, followed by the fruit stalk. At all stages of growth, corm and petiole concentrations were the lowest.

The distribution pattern of potassium amongst the different plant parts was as follows. At sucker stage, shoot was richer in potassium than the corm. In later vegetative stage, unemerged leaf was always highest in potassium, followed by meristem, pseudostem, petioles, leaves and corm. In the fruiting phase, the richest tissues were fruit stalk and the inflorescence.

Twyford and Walmsley (1974 b) conducted studies on uptake and distribution of mineral constituents in Robusta banana. The distribution pattern for total nitrogen amongst the various organs was, as for concentrations, leaves always had the highest content of nitrogen. In the vegetative phase and at shooting, the pseudostem and corm were the next largest repositories. But in the fruiting phase, the fruits contained more nitrogen than either to pseudostem or corm.

8. NUTRIENT LEVELS IN LEAF TISSUE

Leaf analysis has come to be accepted as an important tool in modern soil fertility and plant nutrition investigations. The nutrient status of the banana plant at a particular stage may be indicated by the concentration of nutrient elements in the leaf or any other specific plant part.

The leaf analysis technique for banana to determine the nutrient requirements has gained much importance since Fawcett's work (1921) with Dwarf Cavendish banana. Leaf analysis in the banana plant was first originated by Hewitt (1955) in Lacatan banana who sampled the lamina of the third youngest leaf in the succession of leaves from the top of shot plants, since it had the highest concentration of nutrients. The critical level of nutrients reported by him was 2.6 per cent N, 0.45 per cent P_2O_5 and 3.30 per cent K_2O. Besides, he reported that the application of nitrogen promoted the leaf nitrogen and decreased leaf potassium. However, the leaf phosphorus was not altered by the application of fertilizers containing P_2O_5. He also observed that increased yield could be correlated with increased nitrogen content of the leaf and no increased yield was likely to be obtained by the additional application of P_2O_5 and K_2O over and above the critical level.

Boland (1960) worked on the problems of leaf sampling and reported that the levels of 2.8 to 3 percent N, 0.40 to 0.55 per cent P_2O_5, 3.8 to 4.0 per cent K_2O in the leaf were optimum and also found the middle lamina halves of the second leaf before shooting as the best.

Murray (1960) working in Trinidad with Dwarf Cavendish banana plants in pot cultures confirmed the choice of the third leaf as satisfactory, particularly for nitrogen, phosphorus and potassium determinations. The critical levels reported by him were 2.6, 0.45 and 3.30 per cent N, P_2O_5 and K_2O respectively. Twyford (1967) standardised the fourth youngest leaf to assess the critical level of nutrients in Windward islands. The critical level for N was shown to be 2.9 per cent on most soils and 2.6 per cent on very light soils, for P_2O_5 it was 0.29 to 0.48 per cent and for K_2O it was 3.8. The concentrations for nitrogen and potassium were constant and were recommended for wide adoption.

Working on Cavendish banana plants, Battikhah and Khalidy (1962) observed that leaf nitrogen content increased with nitrogen application. Application of more than 200 g N per plant did not substantially increase plant growth. According to them, the third leaf had the maximum nitrogen content. Hewitt and Osborne (1962) working on Lacatan variety observed that for securing high yields, the leaf tissues should have 2.6, 0.40 and 4.0 per cent N, P_2O_5 and K_2O respectively. They also concluded that varying the time of application of nitrogen had little effect on leaf nitrogen content. They further reported that potash application rapidly increased leaf potassium and heavy application decreased leaf nitrogen.

In Israel, Haign et al. (1964) found no significant correlations between yield responses to various levels of available nutrients in the soil and the nutrient contents in the leaves. They recommended addition of nutrients if the leaf content fell below 3.2 per cent for N, 0.19 per-cent for P_2O_5 and 3.3 per cent for K_2O. Twyford and Coulter (1964) reported that adequacy levels of N, P_2O_5 and K_2O was found to be 2.9, 0.29 to 0.48 and 3.8 per cent respectively. Sundarsingh (1972) reported that leaf nutrient content of 3.13 per cent N, 0.44 per cent P_2O_5 and 3.89 per cent K_2O in the fifth month and 3.37 per cent N, 0.51 per cent P_2O_5 and 4.36 per cent K_2O in the seventh month were the optimum for the variety Robusta.

Randhawa et al. (1973) studied the effect of two planting distances and three graded levels of nitrogen, phosphate and potash on nutrient concentration in leaf tissue and the fruit yield of Robusta banana under field conditions. They reported that with increase in the level of nitrogen application there was increase of quadratic nature in the nitrogen content of leaf tissue. Under the existing price situation the optimum level was found to be 206.1 g N per plant resulting in 3.515 per-cent of nitrogen in dry matter of leaf tissue and 44.43 tonnes/ha of fruit yield. Phosphorus concentration of leaf tissue was significantly affected due to nitrogen levels after second dose of fertilizer application, but at shooting stage this effect was not apparent.

Ramaswamy and Muthukrishnan (1974 a) reported that there were fluctuations in leaf nitrogen with increase of nitrogen application. An adequacy level of nutrients comprising of 3.29 per cent N, 0.44 per cent P_2O_5 and 3.11 per cent K_2O in the leaf tissue was obtained due to soil application of 170 kg N, 85 kg P_2O_5 and 283.5 kg K_2O per acre which could be considered as an optimum dose of fertilizers for Robusta banana for maximising the yield. Ramaswamy and Muthukrishnan (1974 b) reported that nitrogen in certain levels were effective in maximising the production in banana and a critical level of leaf nitrogen 1.4 per cent was proved to be an optimum level. Soil application of 150 g N per plant has been fixed as critical level for maximising the yield and beyond that level, production was decreased. Shawky *et al.* (1974) found that lamina had the highest nitrogen and phosphorus contents but the potassium contents of the midrib and petiole were twice as that of lamina. Vadivel (1976) reported that at shooting, leaf concentrations of major nutrients was assessed as 1.72 to 2.3 per cent N, 0.17 to 0.22 per cent P_2O_5 and 4 to 4.5 per cent K_2O in Robusta. Ashok Kumar (1977) reported that leaf concentration of nutrients at shooting in Robusta ranged from 0.98 to 2.66 per cent N, from 0.11 to 0.37 per cent P_2O_5 and from 3.6 to 5.0 per cent K_2O respectively.

Materials and Methods

MATERIALS AND METHODS

The investigations to assess the effect of different levels of nitrogen on growth, development, dry matter accumulation, yield and fruit qualities of banana cultivar 'Palayankodan' under rainfed conditions were carried out in the Department of Horticulture (Pomology), College of Horticulture, Vellanikkara, Trichur during the year 1979-80.

Soil

The soil of the experimental area was well drained, acidic and lateritic clay loam. The chemical characteristics of the soil are presented in Table 1.

Weather data

The details of the meteorological observations for the cropping season are given in Appendix I. The daily maximum temperature during the cropping period ranged from 31.1 to 40.1°C, and the minimum from 18.6 to 22.6°C. The range of maximum and minimum relative humidity was from 93 to 98 per cent and 30 to 68 per cent respectively. There were 140 rainy days during the period of 396 days which was the duration of the crop. The total rainfall received during the period was 2795.3 mm. The maximum rainfall was received during the month of July, 1979.

Table 1. Chemical characteristics of the soil

Constituents	Content in the soil, %	Analytical method used
Total nitrogen	0.140	MicroKjeldahl (Jackson, 1958)
Available phosphorus	0.001	In Bray-I extract; chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1958)
Available potassium	0.013	In 1 N neutral ammonium acetate extract; flame photometric (Jackson, 1958)
pH	5.17	1:2.5 soil:water ratio; using a pH meter
E.C. (Specific conductivity)	0.1 millimhos/cm	1:2.5 soil:water ratio; using electrical conductivity bridge

During planting and at harvest, practically there was no rainfall and the temperature was comparatively high. The period of crop establishment (February to May) was also during hot summer, where the average monthly rainfall received was only 56.7 mm. The mean monthly rainfall during shooting and bunch development was high (461.4 mm.). However, the maximum rainfall was received during June to August in the pre-shooting period.

Cultivar

'Palayankodan' a popular cultivar of banana in Kerala, which is mainly grown as a rainfed crop was selected for the study. It comes under the sub group Poovan with AAB genome.

Suckers of uniform size and age (three months old) were selected and the pseudostems were headed back to a height of 60 cm before planting. By taking five random samples, the nutrient contents of corm and pseudostem of the suckers were estimated before planting.

Field preparation

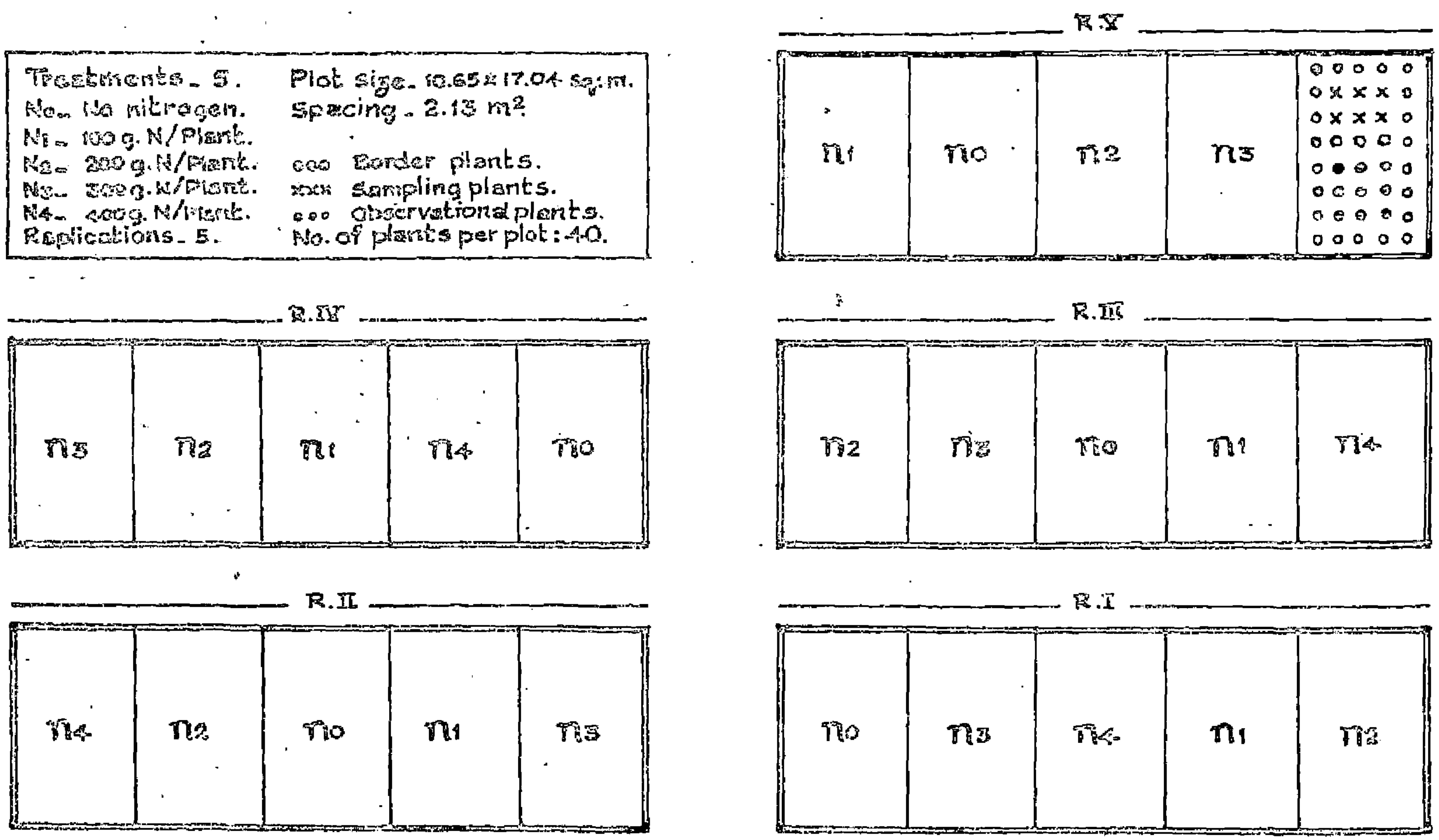
The land was ploughed twice and levelled. Pits of size 50 cm^3 were dug at a spacing of 2.13 m^2. The suckers were planted on 6th January 1979, one week after taking the pits. A basal application of 15 kg farm yard manure (nutrient value: 0.4 per cent nitrogen, 0.3 per cent P_2O_5 and 0.2 per cent K_2O) was given. In addition to this, 2.5 kg of green leaf (nutrient value: 0.98 per cent nitrogen, 0.30 per cent P_2O_5 and 1.96 per cent K_2O) was also incorporated into each pit. Twenty-five g of thimet granule was also applied into the pits before planting.

Pot watering at the rate of nine litres/plant was done at fortnightly intervals from the first week of planting till three months, for the establishment of suckers. Uniform cultural operations and crop management were adopted during the cropping period.

Experimental design and lay out

The experiment was laid out adopting the randomised block design with five treatments and five replications. In each plot there were eight rows spaced at 2.13 m. Five suckers each were planted at 2.13 m in the row. Thus there were fourty plants per plot as shown in Fig.I. For recording morphological characters, nine plants were selected as indicated in the lay out plan. In addition, six plants were kept for nutrient uptake studies. All the plants in the 1st, 5th and 8th rows as well as remaining plants in the 1st and 5th column were kept as border plants.

Fig-1. LAY OUT PLAN



Treatments

n_0 - Control

n_1 - Nitrogen at the rate of 100 g per plant.

n_2 - Nitrogen at the rate of 200 g per plant.

n_3 - Nitrogen at the rate of 300 g per plant.

n_4 - Nitrogen at the rate of 400 g per plant.

Nitrogen was given in the form of ammonium sulphate. Phosphorus and potassium were applied at the rate of 200 g P_2O_5 and 400 g K_2O per plant in the form of superphosphate and muriate of potash, respectively. The recommendations of Kerala Agricultural University for irrigated bananas was taken as a basis for fixing the doses of P_2O_5 and K_2O in the absence of any recommendations for rainfed bananas. All the fertilizers were applied in two equal splits on the 90th and 150th day of planting, taking advantage of summer and pre-monsoon showers.

OBSERVATIONS

1. MORPHOLOGICAL CHARACTERS

Observations on various morphological characters were recorded at monthly intervals from 120th day of planting to shooting adopting the method suggested by Yang and Pao (1962).

1.1. Plant characters

1.1.1. Height

The height of the plant was measured from the base of the pseudostem to the axil of the youngest leaf and recorded in cm.

1.1.2. Girth

Girth of the pseudostem was measured at 20 cm from the ground level.

1.1.3. Number of leaves

Fully opened, functional leaves present at each observation were counted.

1.1.4. Petiole length

Length of the petiole was measured from the pseudostem to the base of the lamina.

1.1.5. Length of lamina

Lamina length was measured from its base to the tip.

1.1.6. Width of lamina

Lamina width was measured at the broadest point in the middle region.

1.1.7. Total leaf area per plant

The leaf area of each functional leaf was calculated by the formula given by Murray (1960) (Leaf area = length x breadth x 0.8).

1.1.8. Duration of the crop

The number of days taken for shooting and from shooting to harvest were recorded. From those, the total number of days from planting to harvest were also computed.

1.1.9. Sucker production

The number of suckers per plant was recorded as and when they were produced. However, the suckers were not allowed until shooting. After the emergence of inflorescence one sucker per plant was retained.

1.2. Growth curves and assessment of relative growth rate of different plant characters

Exponential growth curves of the form $Y = ab^t$, where Y = the observation, a and b are parameters to be estimated and t = time interval, were fitted for the plant characters height, girth, petiole length and total leaf area per plant. The relative growth rates for the different characters were estimated from the fitted curves. A quadratic function of the form of $Y = a + bt + ct^2$ was fitted (a, b and c are the constants of the curves) to describe the changes in the number of leaves during the different periods of growth and development as the growth pattern was found to deviate from the exponential law.

1.3. Bunch characters

The bunches were harvested when they were fully mature as indicated by the disappearance of angles, that is "round full" (Simmonds, 1959). The following observations were made on the bunches.

1.3.1. Weight of the bunch

Weight of the bunch including the peduncle was recorded.

1.3.2. Length of the bunch

Length of the bunch was measured from the point of attachment of the first hand to that of the last hand.

1.3.3. Number of hands and fingers

The number of hands per bunch and the total number of fingers in each bunch were recorded.

1.3.4. Average weight of a hand

Weight of each hand on a bunch was recorded and the mean value calculated.

1.3.5. Average weight of a finger

The middle fruit in the top row of the second hand (from the base of the bunch) was selected as the representative finger (Gottreich *et al.*, 1964) for finding out the average weight, girth and length of the fingers. The weight of this representative finger was recorded as the average weight of a finger.

1.3.6. Girth and length of the finger

Girth of the finger was measured at the mid-portion and the length from the point of attachment to the tip, using a fine thread and a scale.

2. STUDIES ON NUTRIENT UPTAKE AND DRY MATTER PRODUCTION

To assess the nutrient uptake, plant samples were collected at monthly intervals from 5th month of planting to shooting and also at harvest. Sampling was done following the method of Twyford and Walmsley (1973). In each month, one plant was uprooted from each treatment replicationwise and separated into different plant-parts, excluding roots. Sampling of the plant-parts was done as shown in plate I.

The total fresh weight of the different plant-parts was recorded. Samples were weighed fresh and dried in the oven at 70°C until consecutive weights agreed. The per centage of oven dry matter and the total dry weight of the whole part were worked out. After grinding, the samples were analysed separately for N, P and K. Total uptake and distribution of nutrients were computed from the values of concentration of elements and the dry weight of the individual organs sampled.

PLATE 1. SAMPLING TECHNIQUES FOR BANANA

1. Internal leaf
2. Leaf
3. Petiole
4. Pseudostem
5. Meristem
6. Corm
7. Inflorescence
8. Male bud
9. Internal fruit stalk
10. External fruit stalk
11. Fingers

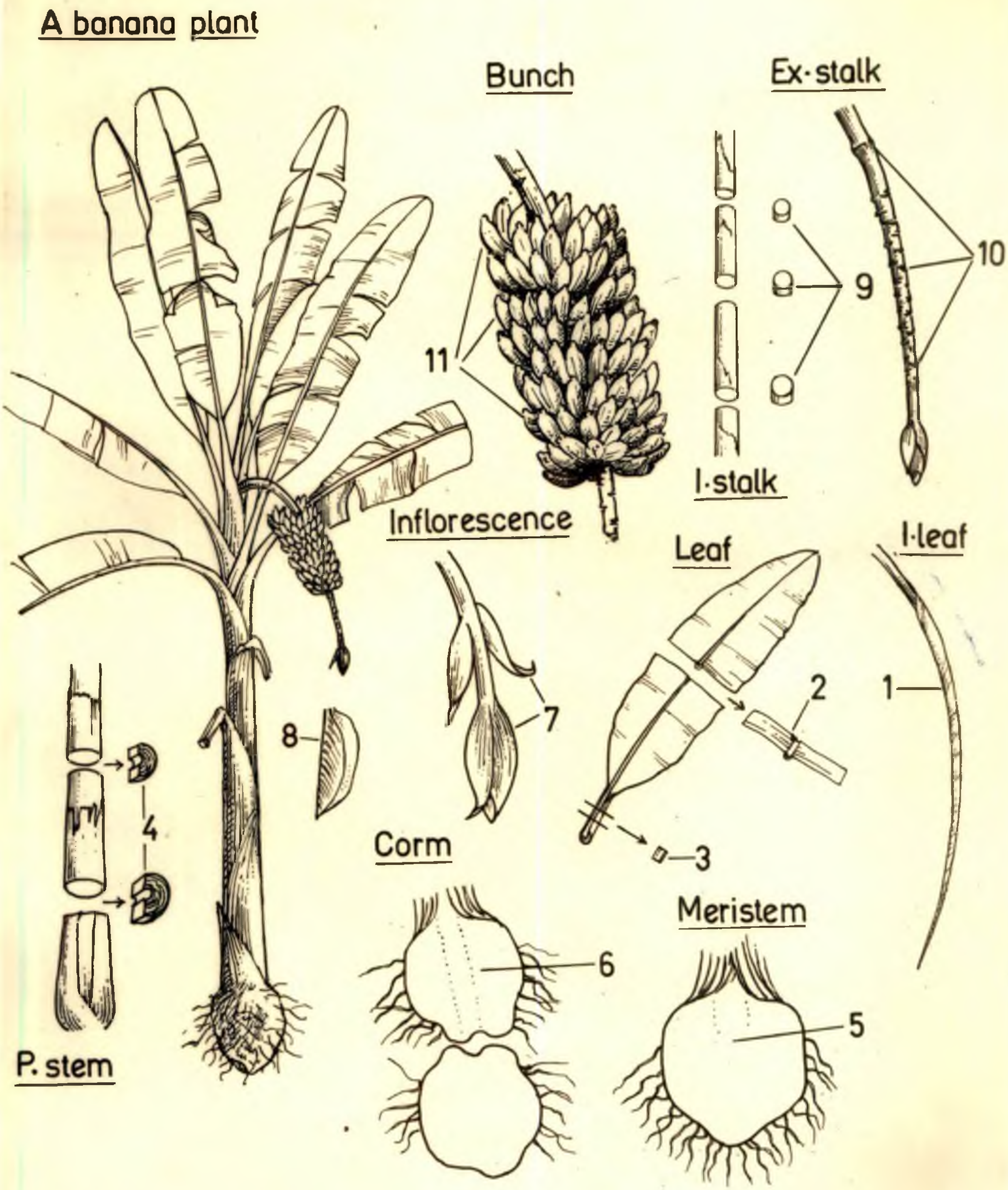


PLATE 1. SAMPLING TECHNIQUES

Sampling of different organs

Phase	Period of sampling	Organs sampled
Vegetative phase	1. 5th month	Corm, meristem, pseudostem, petiole, laminae and internal leaf.
	2. 6th month	Corm, meristem, pseudostem, petiole, laminae and internal leaf.
	3. 7th month	Corm, pseudostem, petiole, laminae and internal leaf.
	4. 8th month	Corm, pseudostem, petiole, laminae, internal leaf and inflorescence.
Shooting phase	5. 9th month (at the first appearance of the flower)	Corm, pseudostem, petiole, laminae, internal leaf and inflorescence.
	6. Harvest	Corm, pseudostem, petiole, laminae, internal stalk, external stalk, fruits and male bud.

Each part was weighed and sampled as given below:-

2.1. Internal leaf

The whole tissue.

2.2. Emerged leaves

Cross sections of 2.5 cm including both laminae and midribs from the middle portion of all leaves were bulked and sampled.

2.3. Petioles

Cross sections of 2.5 cm from the middle portion of all petioles were taken, bulked and sampled.

2.4. Pseudostem

Two cross sections of 2.5 cm from near the top and near the base were taken and split into halves longitudinally. One half from each section was taken, pooled and sampled.

2.5. Meristem

Several thin cross-sections of the meristem (growing point of the corm) were taken and sampled.

2.6. Corm

As for meristem.

2.7. Inflorescence

The inflorescence was cut longitudinally and a minimum of one fourth of it was bulked.

2.8. Male bud

The male buds were pruned soon after the completion of bunch formation, leaving a 15 cm length of barren axis. The male bud at this stage was separated, quartered and samples from the diagonally opposite quarter sectors were pooled.

2.9. Internal fruit stalk

Transeverse sections from the point near the top, middle and near the base were taken and combined.

2.10. External fruit stalk

Three transverse sections were made - one near the point of emergence from the pseudostem, one from near the bunch portion and one from near the male bud. These were bulked and sampled for chemical analysis.

2.11. Fingers

The middle finger from one hand each at the top, middle and bottom of the bunch was bulked.

3. LEAF ANALYSIS

In order to assess the nutrient status of the plants under different treatments at shooting, the leaf analysis technique as adopted by Hewitt (1955) was followed.

The cross sections of 2.5 cm including both lamina and midribs from the middle portion of the third leaf were taken for chemical analysis. The samples were analysed for N, P and K.

4. CHEMICAL ANALYSIS

4.1. Plant parts

4.1.1. Nitrogen

Nitrogen content of the plant sample was estimated by microKjeldahl digestion-distillation method (A.O.A.C., 1960).

4.1.2. Phosphorus

One g of the ground sample was digested in 15 ml of a mixture of concentrated perchloric acid:sulphuric acid: nitric acid in the proportion of 1:2:9 and the volume made upto 100 ml with distilled water and filtered. Phosphorus in an aliquot of this extract was determined colorimetrically using vanadomolybdophosphoric yellow colour method (Jackson, 1958).

4.1.3. Potassium

Potassium in an aliquot of the triple acid extract of the sample was determined using a flame photometer (Jackson, 1958).

4.2. Qualitative analysis of fruits

The fruits collected from well ripe bunches were used for quality analysis. The middle fruit in the top row of the second hand was selected as the representative sample. Samples were taken from each fruit from three portions viz., top, middle and bottom and these samples were then pooled and macerated in a waring blender. Triplicate samples from this were used for analysis of different constituents as detailed below.

4.2.1. Total soluble solids

Total soluble solids were found out by a pocket refractometer and were expressed as percentage.

4.2.2. Ascorbic acid

A known quantity of the pooled sample of the fruit was macerated in a mortar by adding small quantity of two per cent oxalic acid. The solution was made upto a known volume and filtered. An aliquot of the extract was taken to which an equal volume of two per cent oxalic acid was added. The content was titrated against a standard solution of 2,6-dichlorophenol indophenol dye. The ascorbic acid content of the juice was then calculated and expressed as mg/100 g of the pulp (A.O.A.C., 1960).

4.2.3. Acidity

Ten g of the macerated sample was mixed with distilled water and made upto a known volume. An aliquot of the filtered solution was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid (A.O.A.C., 1960).

4.2.4. Reducing sugars

The reducing sugars of the sample were determined as per the method described by A.O.A.C. (1960).

To a known quantity of macerated pulp, a small quantity of distilled water was added. The solution after thorough mixing was clarified with neutral lead acetate and deleaded with sodium oxalate and made upto a known volume. The solution was titrated against a mixture of Fehling's A and B solutions using methylene blue as indicator. The content of reducing sugars was expressed as percentage.

4.2.5. Total sugars

Total sugars were determined as per the method described by A.O.A.C. (1960). Five ml of concentrated hydrochloric acid was added to a known volume of clarified solution and the content was kept overnight. The solution was then neutralised by adding sodium hydroxide and titrated against a mixture of Fehling's A and B solutions.

4.2.6. Non-reducing sugar

This was computed by working out the difference between the total and reducing sugars.

4.2.7. Sugar/acid ratio

This was arrived at by dividing the total sugars with titratable acidity and this was reckoned as a measure of fruit quality.

5. STATISTICAL ANALYSIS

The data collected on different plant characters were analysed by applying the techniques suggested by Snedecor and Cochran (1967). Effect of nitrogen on various plant characters, dry matter accumulation and nutrient uptake was studied by employing the analysis of variance technique. Exponential growth curves were fitted for height, girth, petiole length and leaf area to describe the pattern of growth at different periods of growth and development of the plant. The relative growth rate was estimated from the fitted curves. A quadratic function was fitted to describe the changes in the number of leaves at different intervals of time.

5.1. Response curve and estimation of optimum dose of nitrogen

A response curve of the form $Y = a + bN + cN^2$ (where a, b, c are constant and Y = mean yield/plant, N = dose of nitrogen/plant) was fitted to find out the optimum dose of nitrogen. The optimum dose was calculated from the formula $N_{opt} = \frac{-b}{2c}$. The economic optimum was estimated by using formula $N_{econ} = \frac{q/p-b}{2c}$ where q = price of 1 kg of input and p = price of 1 kg of output. The values of q and p were taken to be 4 rupees and 80 paise respectively.

Results

RESULTS

The results of the different aspects of investigations are presented under the following sections.

1. EFFECT OF NITROGEN ON GROWTH PARAMETERS

1.1. Height of pseudostem

Data on the mean height of plants from 4th to 9th month (shooting) of planting are furnished in Table 2.

It may be seen that in the initial stage of growth i.e., in the 4th month after planting there was no significant difference in the increase in height of the pseudostems of plants under different treatments. From the 5th month onwards, however, there was significant increase in the height of the pseudostem with increasing levels of nitrogen upto shooting (9th month) except in 7th and 8th months. During 7th and 8th months the dose of 300 g N/plant resulted in maximum height.

1.2. Girth of pseudostem

Data presented in Table 3 represent the girth of the pseudostem under different treatments.

The results showed that there was no significant difference between different treatments in the increase in girth of pseudostem during the 4th month. But the effect

Table 2. Effect of nitrogen on plant height at different periods of growth, cm.

Levels of nitrogen, g/plant	Periods, months after planting					
	4th	5th	6th	7th	8th	9th
0	56.91	65.98	96.58	144.30	178.27	188.45
100	54.98	75.11	102.07	161.86	199.56	205.22
200	55.46	86.16	113.64	163.84	198.82	207.67
300	58.06	85.20	112.66	174.48	207.11	208.29
400	57.66	90.13	114.40	167.38	203.45	210.67
C.D (5%)	NS	11.11	11.38	14.19	9.74	10.42
SEm ±	2.02	3.71	3.80	4.73	3.25	3.48

Table 3. Effect of nitrogen on plant girth at different periods of growth, cm

Levels of nitrogen, g/plant	Periods, months after planting					
	4th	5th	6th	7th	8th	9th
0	20.29	24.61	31.45	43.93	50.29	52.29
100	20.20	25.62	32.42	44.74	50.31	53.93
200	20.64	26.70	34.80	44.92	50.93	57.02
300	20.16	27.15	35.22	47.25	51.94	56.64
400	21.36	27.79	35.27	45.37	52.89	56.19
C.D (5%)	NS	2.04	2.97	NS	NS	2.29
SEm ±	0.54	0.68	0.99	0.74	0.81	0.76

of nitrogen was significant during 5th, 6th and 9th months of planting. The highest level of nitrogen recorded the maximum girth during the 5th and 6th month of planting. But at shooting (9th month) the maximum girth was noticed in treatment with nitrogen at 200 g/plant.

1.3. Number of functional leaves

Data on the total number of functional leaves per plant at various stages of growth under the different treatments are presented in Table 4.

The treatments did not show any significant effect on the number of functional leaves except in 5th and 6th months. During the 5th month, n_3 and n_4 showed significantly higher leaf number compared to n_0 (control) and in the 6th month a similar effect was noticed at the higher three levels of nitrogen.

1.4. Length of petiole

The data on petiole length under the different treatments showed that there was no significant effect of the levels of nitrogen on the length of the petiole during the 4th and 7th months of planting (Table 5). In the other months, the highest level of nitrogen recorded the maximum length; and the control the minimum.

Table 4. Effect of nitrogen on number of functional leaves at different periods of growth.

Levels of nitrogen, g/plant	Periods, months after planting					
	4th	5th	6th	7th	8th	9th
0	6.80	8.80	11.71	10.91	9.44	9.67
100	6.69	9.71	12.73	10.99	9.89	9.69
200	6.71	10.13	13.40	11.21	9.82	9.80
300	6.98	10.75	13.75	11.35	10.17	9.36
400	6.84	11.13	14.97	10.89	10.27	10.11
C.D (5%)	NS	1.34	1.43	NS	NS	NS
SEm ±	0.48	0.45	0.48	0.23	0.20	0.23

Table 5. Effect of nitrogen on petiole length at different periods of growth, cm

Levels of nitrogen, g/plant	Periods, months after planting					
	4th	5th	6th	7th	8th	9th
0	16.01	19.76	23.62	30.63	31.65	34.20
100	16.71	20.37	24.58	31.79	33.20	37.29
200	16.60	22.08	26.35	32.70	34.44	37.44
300	16.33	23.01	28.03	33.46	34.60	37.78
400	16.98	23.87	28.80	34.24	34.93	39.00
C.D (5%)	NS	2.42	3.17	NS	1.62	2.65
SEm ±	0.79	0.81	1.06	0.93	0.54	0.88

1.5. Total leaf area

Data on total leaf area from 4th to 9th months of planting are given in Table 6. It is evident that the leaf area was not affected significantly by the different levels of nitrogen except in the 7th month. However, there was significant increase of leaf area at 100 g N/ plant at 7th month.

1.6. Effect of nitrogen on relative growth rate for different morphological characters

Data on the relative growth rate for different morphological characters viz., plant height, girth of pseudostem, petiole length and total leaf area under different levels of nitrogen are presented in Table 7 (Fig. 2).

The results showed that the level of 100 g N/plant (n_1) recorded the maximum relative growth rate for height, petiole length and total leaf area while the highest level registered the minimum growth rate for all the morphological characters referred. In the case of girth of the pseudostem, the relative growth rate was maximum at the level of 300 g N/plant.

1.7. Growth curves of different plant characters

The growth curves fitted for different plant characters under varying levels of nitrogen are presented in Table 8 (Figs. 3 to 7).

Fig-2. RELATIVE GROWTH RATE.

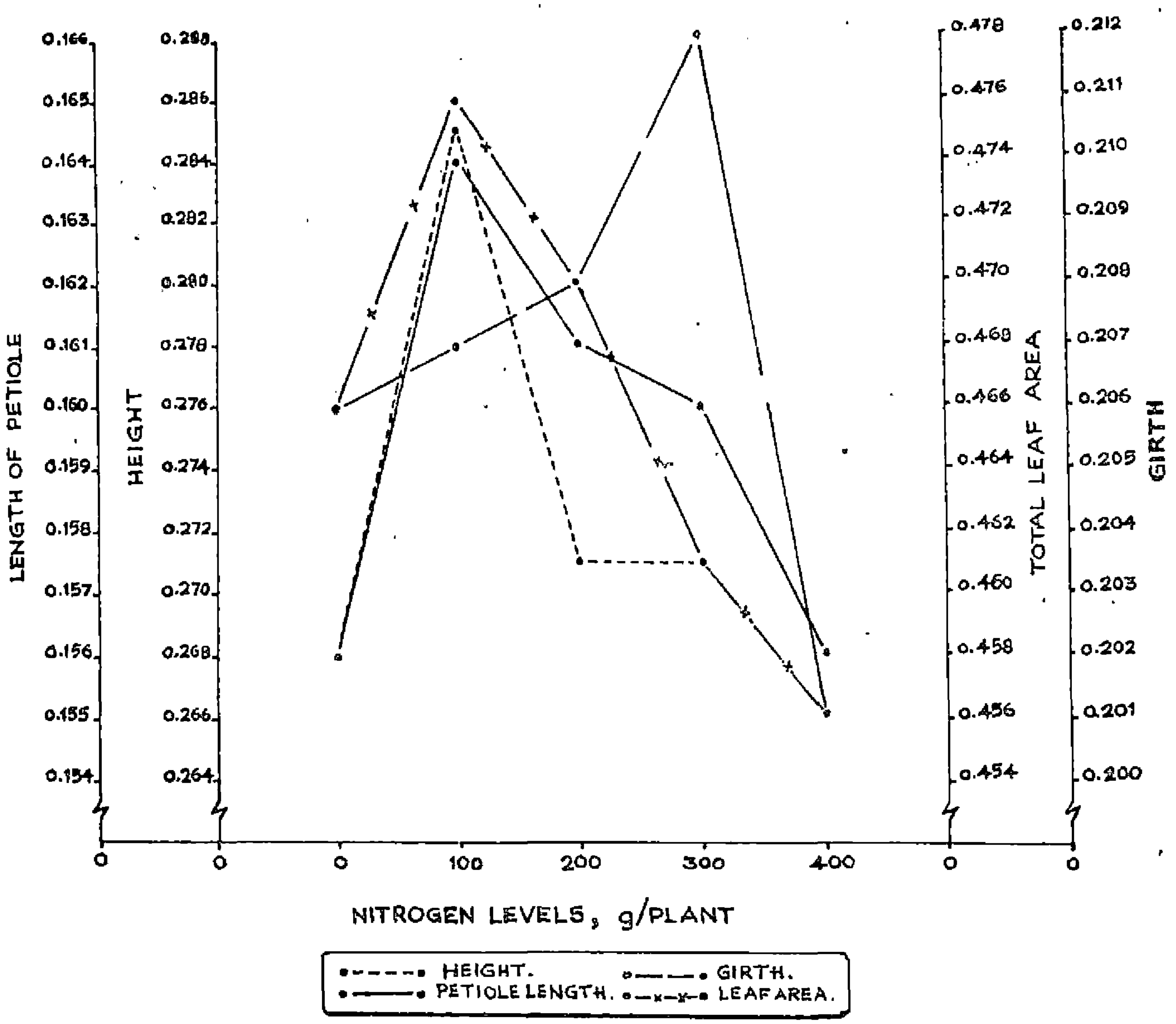


Table 6. Effect of nitrogen on total leaf area at different periods of growth, m^2

Levels of nitrogen, g/plant	Periods, months after planting					
	4th	5th	6th	7th	8th	9th
0	1.12	2.22	5.49	7.83	9.0	11.70
100	1.20	2.86	6.70	10.23	10.74	13.94
200	1.12	2.69	6.47	8.81	10.05	12.85
300	1.17	2.80	6.48	8.41	10.07	12.97
400	1.16	2.65	6.31	8.19	9.37	12.53
C.D (5%)	NS	NS	NS	1.21	NS	NS
SEm ±	0.09	0.20	0.59	0.40	0.41	1.0

Fig-2. RELATIVE GROWTH RATE.

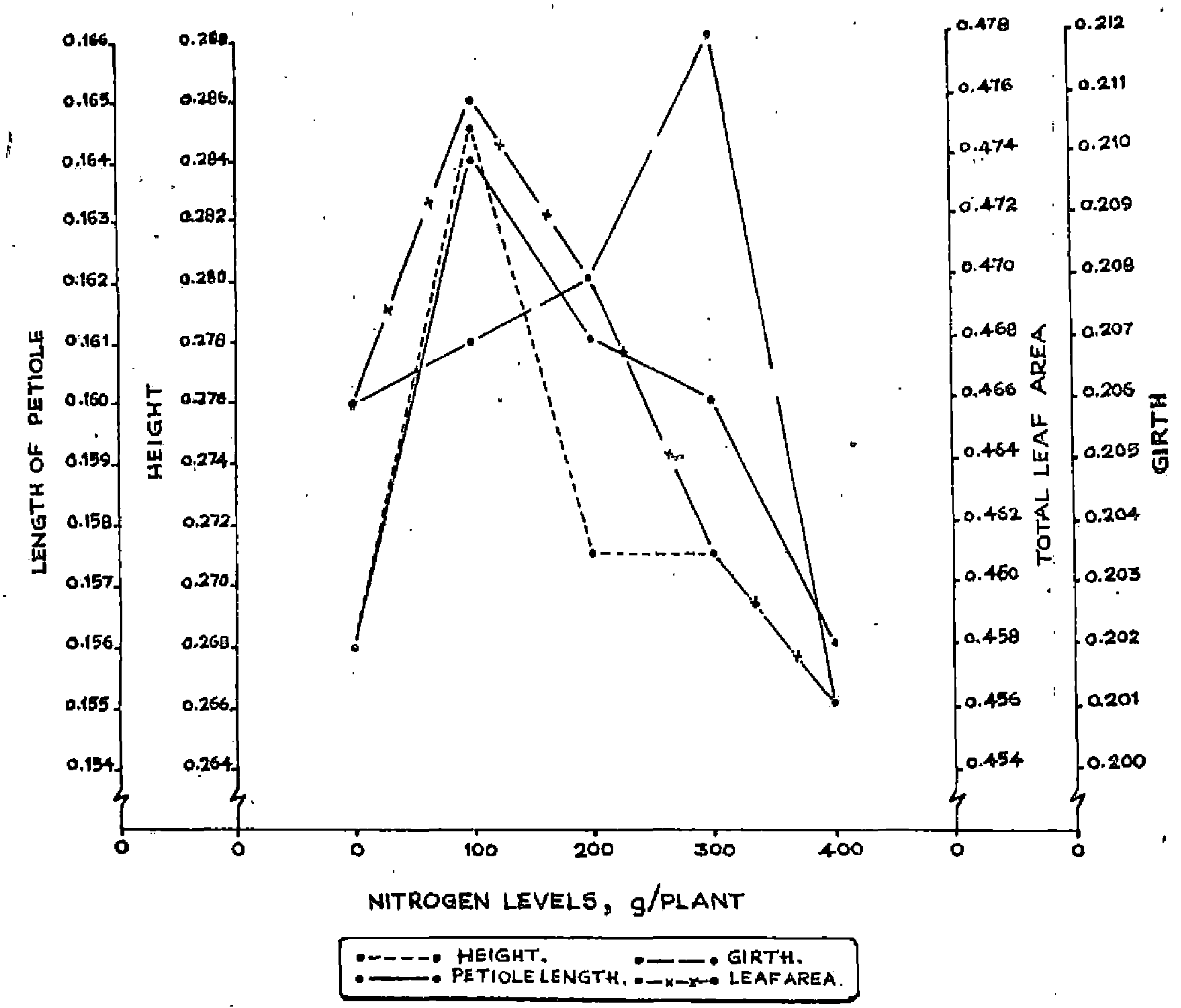


Table 7. Effect of nitrogen on relative growth rate

Levels of nitrogen, g/plant	Relative growth rate			
	Height	Girth	Petiole length	Total leaf area
0	0.268	0.206	0.156	0.466
100	0.285	0.207	0.164	0.476
200	0.271	0.208	0.161	0.470
300	0.271	0.212	0.160	0.461
400	0.266	0.201	0.156	0.456

Table 8. Growth curves of different plant characters

Character	Levels of nitrogen, g/plant	Equation	Coefficient of determination (R^2), %
Height	0	$Y = 19.28\ e^{0.268\ x}$	83
	100	$Y = 18.60\ e^{0.285\ x}$	89
	200	$Y = 21.37\ e^{0.271\ x}$	89
	300	$Y = 21.80\ e^{0.271\ x}$	86
	400	$Y = 22.63\ e^{0.266\ x}$	89
Girth	0	$Y = 9.15\ e^{0.206\ x}$	92
	100	$Y = 9.26\ e^{0.207\ x}$	93
	200	$Y = 9.55\ e^{0.208\ x}$	96
	300	$Y = 9.42\ e^{0.212\ x}$	92
	400	$Y = 10.21\ e^{0.201\ x}$	94
Length of petiole	0	$Y = 9.08\ e^{0.156\ x}$	92
	100	$Y = 9.06\ e^{0.164\ x}$	95
	200	$Y = 9.59\ e^{0.161\ x}$	92
	300	$Y = 9.84\ e^{0.160\ x}$	88
	400	$Y = 10.34\ e^{0.156\ x}$	97
Total leaf area	0	$Y = 2293.4\ e^{0.466\ x}$	77
	100	$Y = 2661.1\ e^{0.456\ x}$	68
	200	$Y = 2501.1\ e^{0.470\ x}$	80
	300	$Y = 2662.1\ e^{0.461\ x}$	76
	400	$Y = 2602.8\ e^{0.476\ x}$	76
Number of leaves	0	$Y = -12.19 + 6.68\ x - 0.48\ x^2$	80
	100	$Y = -16.25 + 8.26\ x - 0.60\ x^2$	79
	200	$Y = -17.33 + 8.68\ x - 0.64\ x^2$	68
	300	$Y = -19.36 + 9.58\ x - 0.72\ x^2$	78
	400	$Y = -19.44 + 9.64\ x - 0.72\ x^2$	61

Fig-3. EXPONENTIAL GROWTH CURVE FOR HEIGHT

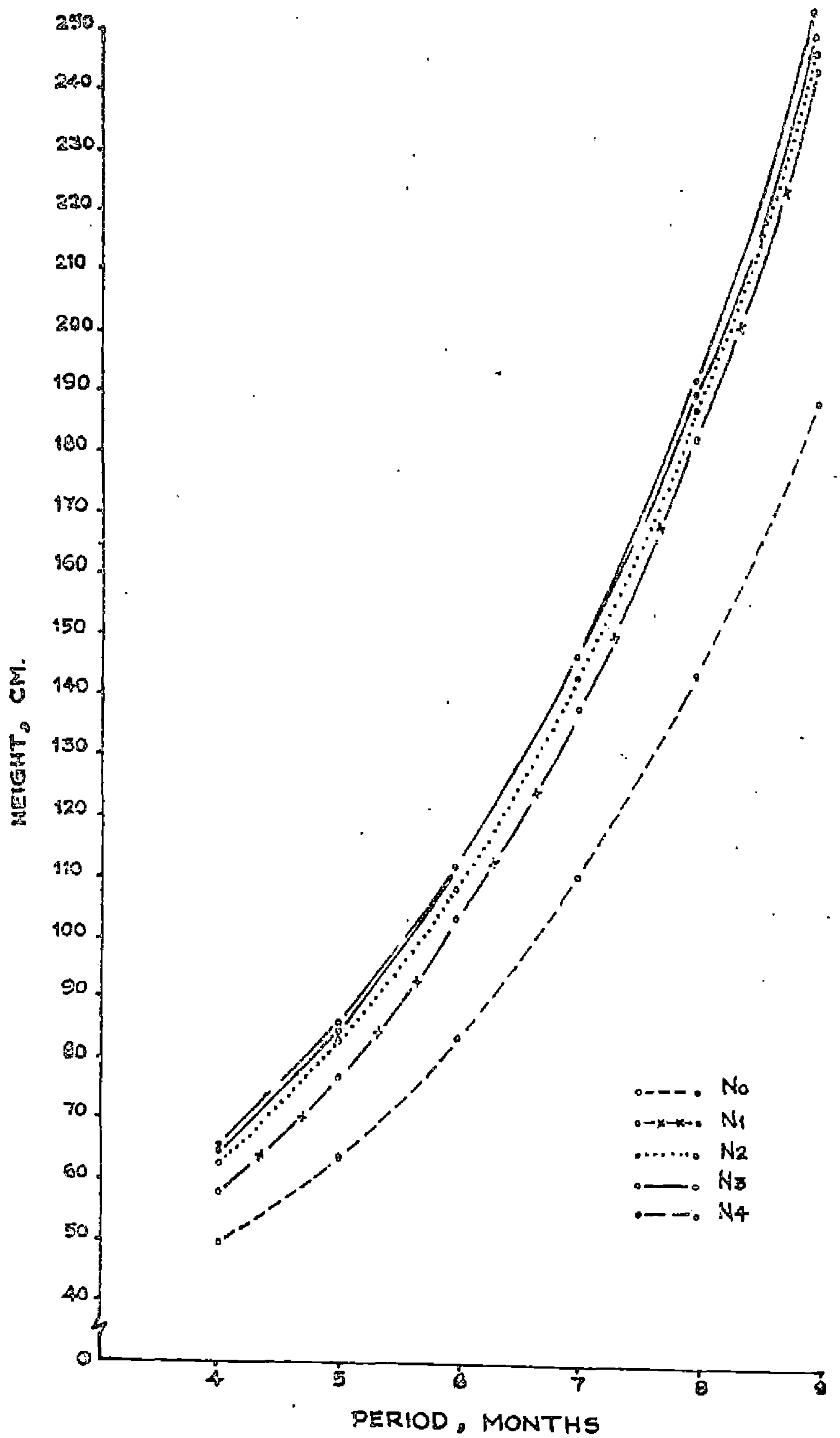


Fig. 4. EXPONENTIAL GROWTH CURVE FOR GIRTH

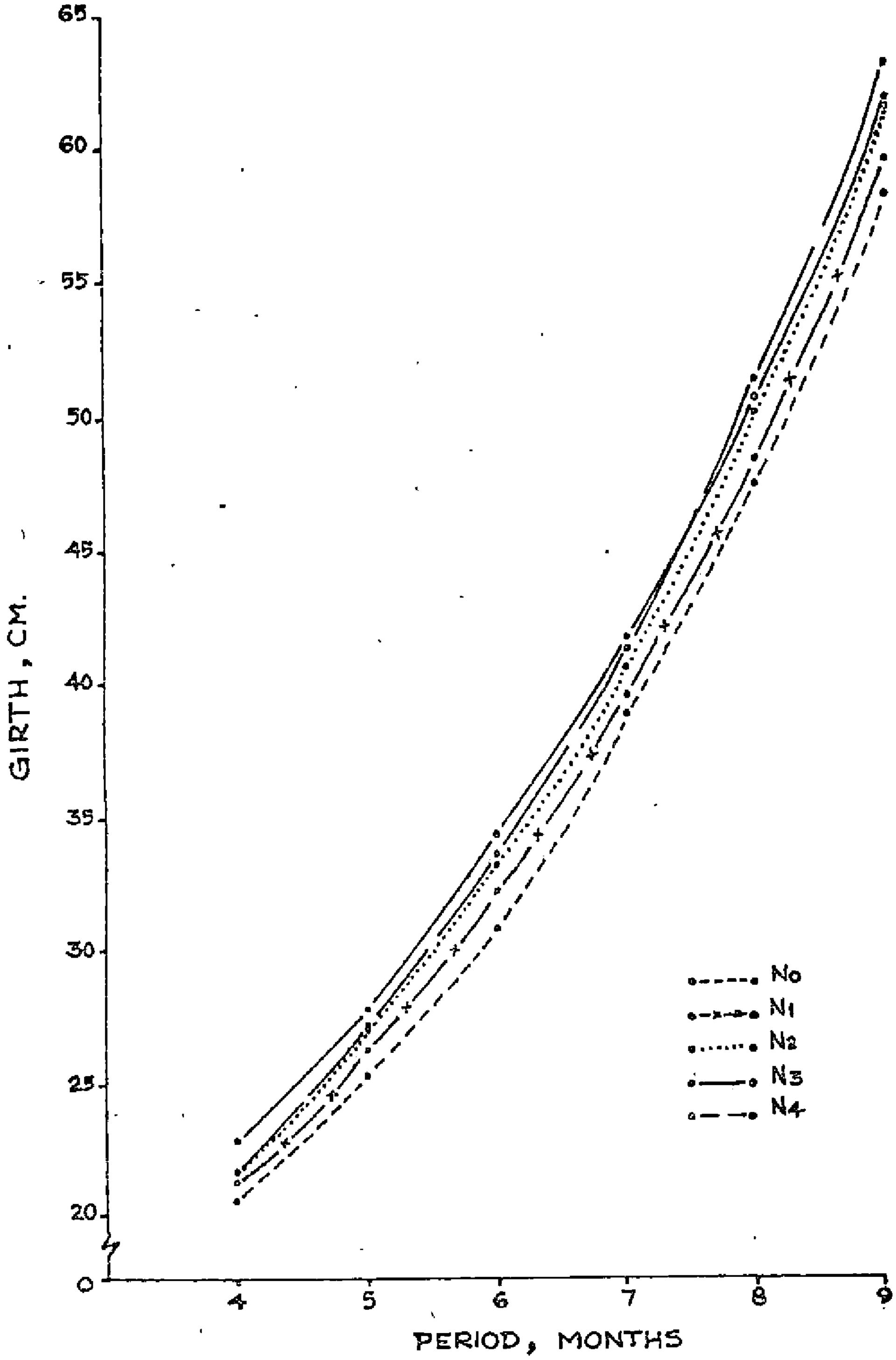
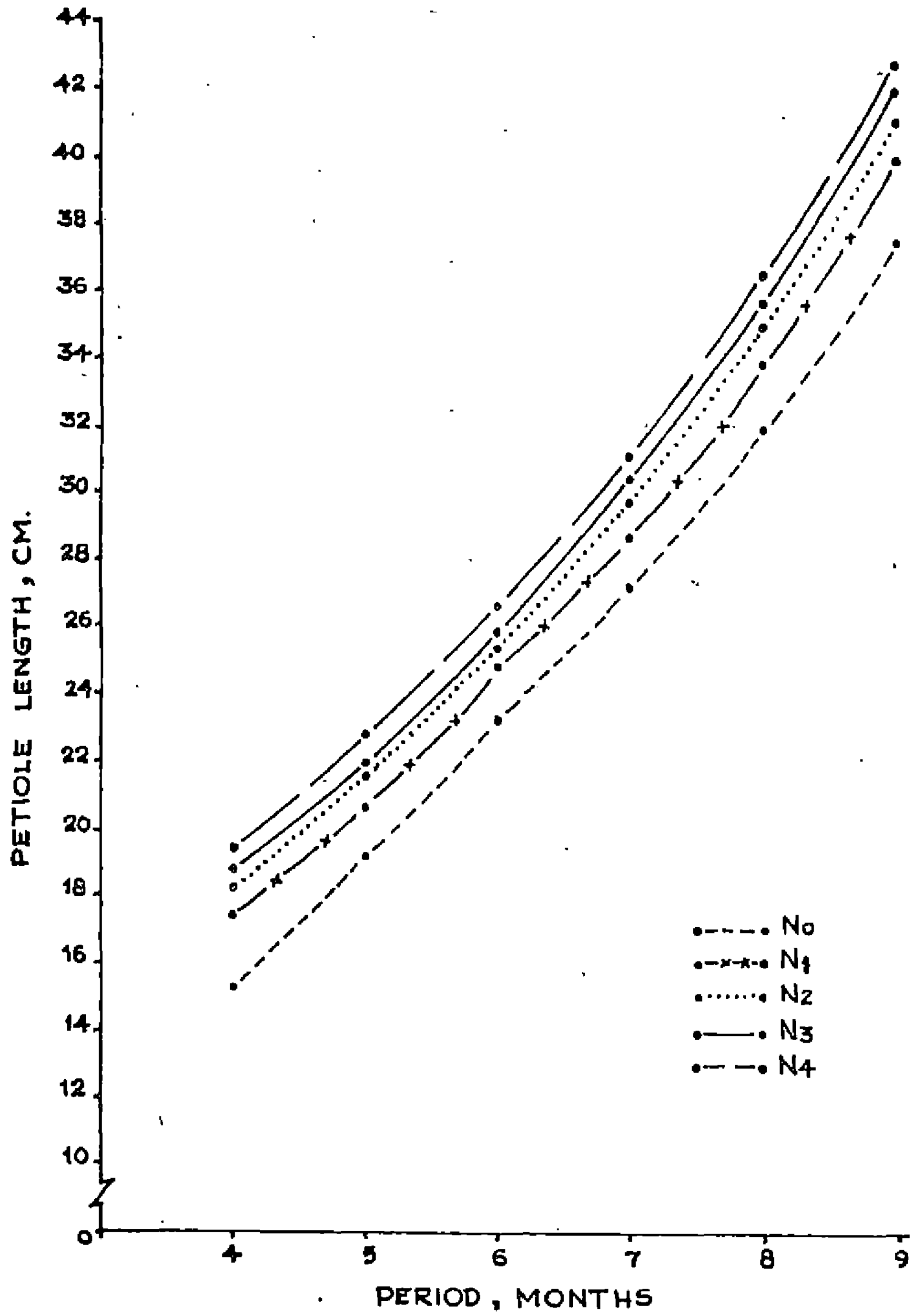


Fig-5. EXPONENTIAL GROWTH CURVE FOR PETIOLE LENGTH



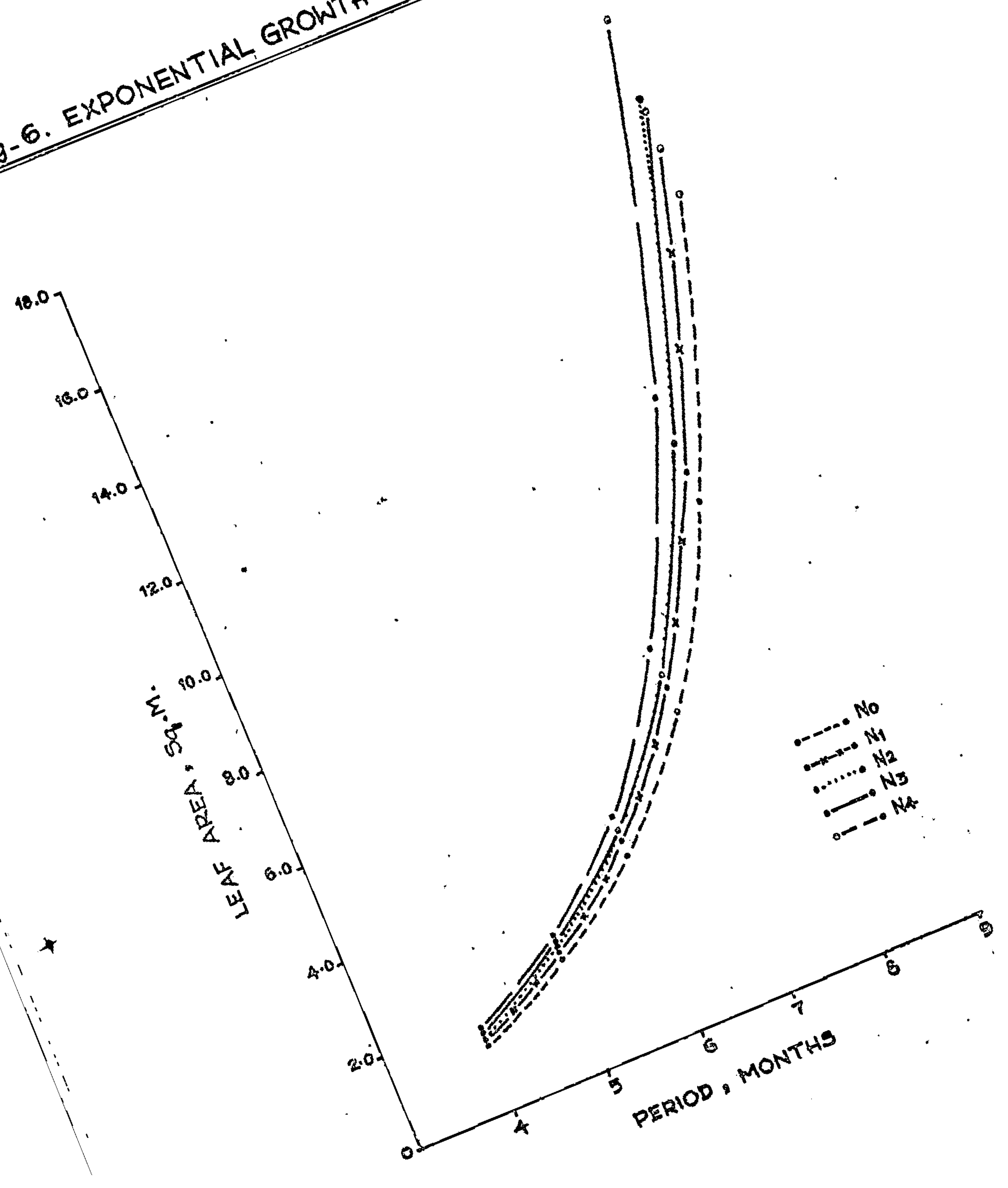
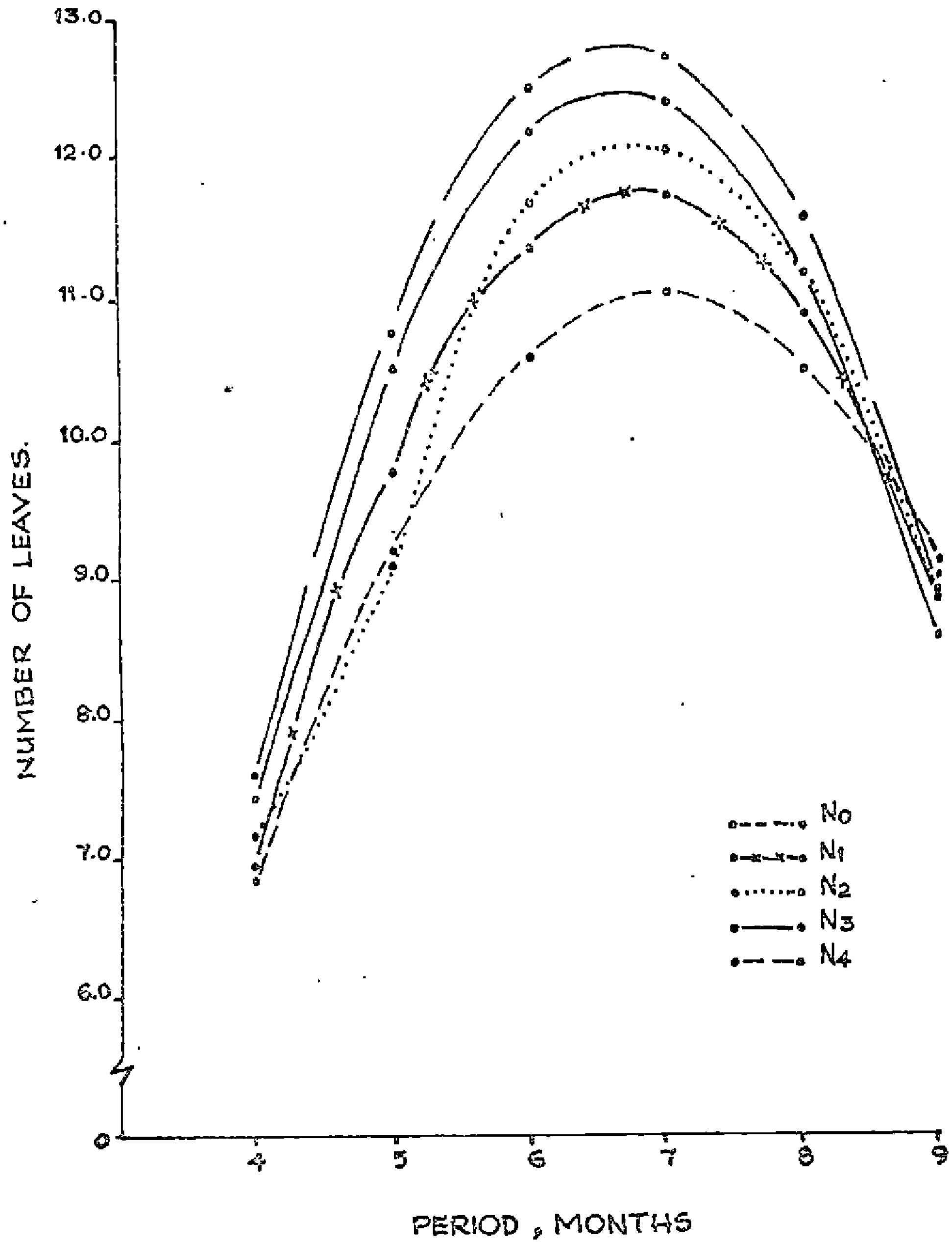


Fig-6. EXPONENTIAL GROWTH CURVE FOR LEAF AREA

Fig. 7. EXPONENTIAL GROWTH CURVE FOR NUMBER OF LEAVES



Exponential growth curves were fitted for describing the variations in plant height, girth, petiole length and total leaf area. Quadratic curves were fitted for assessing the variations in the number of leaves. All the curves were found to fit the data satisfactorily. As regards to plant height, the co-efficient of determination ranged from 83 to 89 but for girth it ranged from 92 to 96. In the case of petiole length and total leaf area, the co-efficient of determination ranged from 88 to 97 and 68 to 80 respectively. As regards to the number of leaves, the co-efficient of determination ranged from 61 to 80. Thus the maximum values were noted in the case of plant girth and petiole length.

1.8. Flowering duration and fruit maturity

Data pertaining to the number of days from planting to shooting, from shooting to harvest and from planting to harvest of the crop are given in Table 9.

The data do not reveal any significant differences among the treatments with regard to the duration from planting to shooting. However, the earliest shooting (260.2 days) was noticed in the treatment receiving nitrogen at 300 g/plant as against 271.7 days in the case of 400 g N/plant.

Table 9. Effect of nitrogen on the duration of the crop

Levels of nitrogen, g/plant	Duration, days		
	Planting to shooting	Shooting to harvest	Planting to harvest
0	268.4	95.2	363.6
100	265.3	90.1	355.4
200	266.9	103.6	370.5
300	260.2	102.4	362.6
400	271.7	113.7	385.4
C.D (5%)	NS	12.01	18.99
SEm ±	4.11	4.04	6.34

Table 10. Effect of nitrogen on production of suckers at shooting

Levels of nitrogen, g/plant	Suckers at shooting
0	1.47
100	1.53
200	1.75
300	1.56
400	1.47
C.D (5%)	NS
SEm ±	0.25

In respect of the duration from shooting to harvest there was significant difference among the treatments. It was least in n_1 (100 g N/plant) and maximum at the highest level of nitrogen (400 g N/plant).

The duration from planting to harvest was significantly influenced by the various treatments. The treatment n_4 showed significantly longer duration than n_0, n_1 and n_3 which were on par with n_2. There was no significant difference between n_2 and n_4.

1.9. Sucker production

Data on the effect of different levels of nitrogen on sucker production are furnished in Table 10. The data showed that there was no significant difference in the number of suckers produced at shooting due to different levels of nitrogen, although apparently the maximum number of suckers per plant was observed in the treatment n_2, which received 200 g N/plant.

2. BUNCH CHARACTERS

The data relating to the various bunch characters as influenced by different levels of nitrogen are presented in Table 11.

Table 11. Effect of nitrogen on bunch characters

Levels of nitrogen, g/plant	Weight of bunch, kg	Length of bunch, cm	Number of hands/bunch	Weight of hand, g	Number of fingers	Length of finger, cm	Girth of finger, cm	Weight of finger, g
0	9.71	45.40	11.27	692.20	174.76	13.17	8.90	57.89
100	10.66	46.37	11.77	716.80	175.20	13.29	10.23	65.56
200	11.09	47.17	11.23	731.40	187.32	13.42	10.56	69.12
300	11.03	48.26	11.21	744.80	178.38	13.81	10.28	68.87
400	10.60	48.59	11.81	695.40	184.63	13.65	10.35	65.93
C.D (5%)	0.92	NS	NS	NS	NS	NS	0.83	6.20
SEm ±	0.31	1.16	0.23	31.74	5.48	0.39	0.28	2.07

2.1. Weight of bunch

Significant difference was observed between the treatments with respect to bunch weight (Table 11, Fig. 8). The yield per plant obtained in the treatments n_3, n_2 and n_1 was on par. These three levels were significantly superior to control. No significant difference was noticed between n_4 and control.

2.2. Length of bunch

Eventhough a linear increase in mean length of bunches was noticed with increased levels of nitrogen application, the differences were not statistically significant.

2.3. Number of hands per bunch

Data on mean number of hands per bunch showed that the effects due to nitrogen application was not significant. However, the maximum number of hands was noted in the highest level of nitrogen application (400 g N/plant).

2.4. Weight of hand

The maximum weight of hand was recorded in the treatment n_3, followed by n_2 and the minimum in the control. However, the differences among the treatments were not significant.

Fig-8. EFFECT OF LEVELS OF NITROGEN ON YIELD OF BANANA

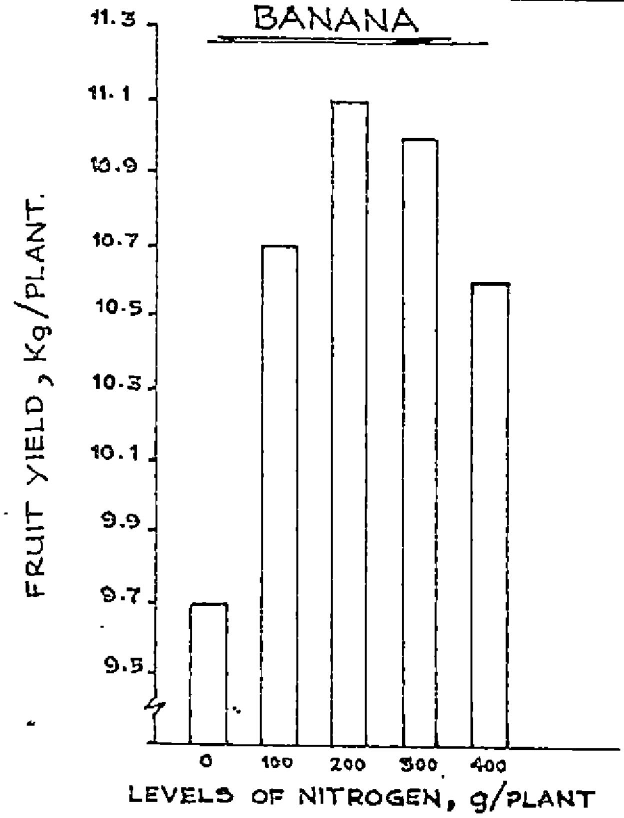
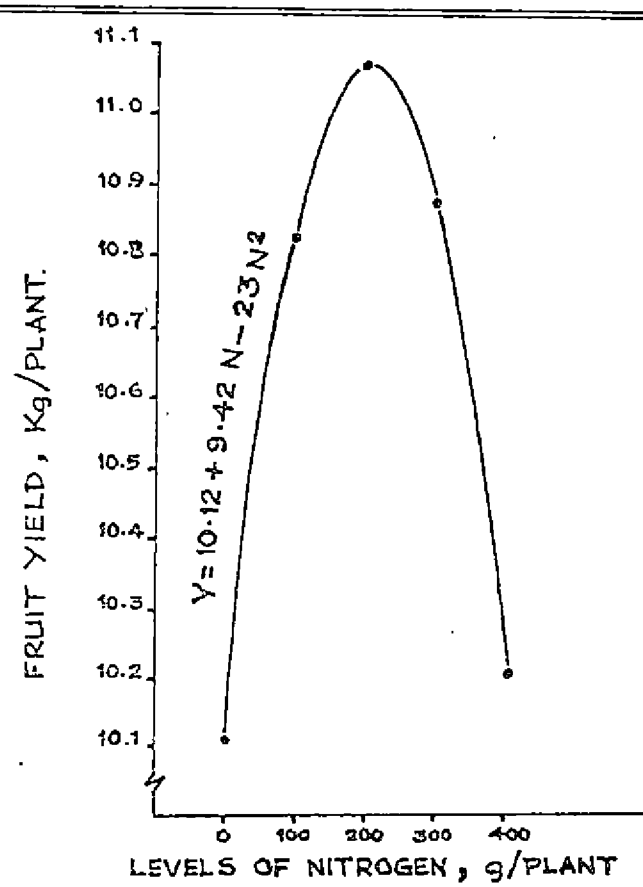


Fig-9. RESPONSE CURVE FOR NITROGEN



2.5. Number of fingers

The number of fingers per bunch showed no significant variation due to the different levels of nitrogen. The maximum number of fingers was noted in the treatment n_2 followed by n_4 and the lowest number was recorded in the control.

2.6. Length of finger

The length of the finger was also not influenced by different levels of nitrogen. The mean values ranged from 13.17 cm (n_0) to 13.81 (n_3).

2.7. Girth of finger

Data on the mean girth of finger showed that the effects due to nitrogen application were significant. Highest girth of the finger was recorded in the treatment n_2 followed by n_4 and the minimum in the control. This represented an increase of 18.7 per cent in n_2 and 16.3 per cent in n_4 respectively as compared to the control.

2.8. Weight of finger

In respect of weight of finger also there was significant increase among the various treatments. All the levels of nitrogen were significantly superior to control. The maximum finger weight was obtained in treatment n_2 (69.12 g) followed by n_3 (68.87 g) which were 19.4 and 19 per cent higher than control, respectively.

3. FRUIT CHARACTERS

Data relating to the physical characters of the fruit are furnished in Table 12.

3.1. Weight of fruit

The different levels of nitrogen showed significant differences with regard to weight of fruit. All the treatments except n_4 showed significant increase over the control. There was no significant differences among the other levels of nitrogen. The highest fruit weight was recorded in n_1 (61.14 g) followed by n_2 (61.07 g) whereas the minimum value was registered in control (50.57 g).

3.2. Weight of pulp

While the weight of the pulp in the various treatments was significantly superior to the control, the various levels of nitrogen did not produce significant difference between themselves. The weight of pulp ranged from 35.63 g in n_0 to 44.84 g in n_2.

3.3. Weight of peel

The data presented in Table 12 showed that the weight of peel was not affected by the treatments although maximum value was noted in n_1 followed by n_2 and the least in n_4.

Table 12. Effect of nitrogen on fruit characters

Levels of nitrogen, g/plant	Weight of fruit, g	Weight of pulp, g	Weight of peel, g	pulp/peel ratio
0	50.57	35.63	15.36	2.58
100	61.14	44.47	16.76	2.75
200	61.07	44.84	15.77	2.94
300	60.11	43.02	15.38	2.95
400	55.94	41.73	15.10	2.77
C.D (5%)	7.79	5.75	NS	NS
SEm ±	2.60	1.92	0.89	0.13

3.4. Pulp/peel ratio

The pulp/peel ratio did not vary significantly due to the different levels of nitrogen. The maximum value was noted in n_3 (2.95) followed by n_2 (2.94) and the least in control (2.58).

4. EFFECT OF NITROGEN ON FRUIT QUALITY

Data on the various qualitative characters of the fruits as affected by different treatments are presented in Table 13.

4.1. Total soluble solids

Eventhough there was an increase in T.S.S. content as the nitrogen level increased upto 200 g/plant (n_2) there was a decrease with further increases in the level of applied nitrogen. The treatment n_2 recorded the highest T.S.S. of 26.63 per cent, which was 5.2 per cent higher than control.

4.2. Reducing sugars

Data on the reducing sugar content of the fruits showed that the effects due to different levels of nitrogen were significant. The treatment n_2 registered the highest percentage of reducing sugars (17.03 per cent) followed by n_3 (16.94 per cent).

Table 13. Effect of nitrogen on fruit quality

Levels of nitrogen, g/plant	Total soluble solids, %	Reducing sugars, %	Non-reducing sugar, %	Total sugars, %	Sugar/acid ratio	Acidity, %	Ascorbic acid, mg/100 g
0	25.31	14.87	0.94	15.81	30.01	0.53	7.41
100	26.08	15.35	0.50	15.85	31.55	0.50	7.79
200	26.63	17.03	0.14	17.17	37.51	0.46	7.81
300	26.42	16.94	0.29	17.23	34.77	0.49	9.27
400	26.01	16.72	0.32	17.04	33.56	0.51	8.04
C.D (5%)	0.66	1.07	0.36	0.94	3.91	NS	NS
SEm ±	0.22	0.36	0.12	0.32	1.30	0.02	0.48

4.3. Non-reducing sugar

The treatments receiving different levels of nitrogen differed significantly in respect of non-reducing sugar. The treatment n_0 recorded the highest content of non-reducing sugar which was significantly superior to all other treatments. The minimum non-reducing sugar content was observed in n_2 (0.14 per cent).

4.4. Total sugars

Increased levels of nitrogen application increased the content of total sugars upto 300 g N as evident from the data. The highest sugar content was observed in treatment n_3 (17.23 per cent) followed by n_2 (17.17 per cent) and the lowest in control (15.81 per cent). The treatments n_2, n_3 and n_4 were significantly superior to n_0 and n_1 which were on par.

4.5. Sugar/acid ratio

Highly significant differences were observed in sugar/acid ratio due to treatments. The highest value of sugar/acid ratio was recorded in n_2 (37.51) followed by n_3 (30.01). There was no significant differences among n_0, n_1 and n_4.

4.6. Acidity

The lowest acidity was noted in n_2 (0.46 per cent) and the highest in control (0.53 per cent). However, the differences between treatments were not statistically significant.

4.7. Ascorbic acid

Ascorbic acid content of the fruits did not show significant variation due to treatments which ranged from 9.27 mg/100 g (n_3) to 7.41 mg/100 g (n_0).

5. NUTRIENT STATUS AND DRY MATTER CONTENT OF PLANTING MATERIALS (SUCKERS)

The dry matter and NPK content of the corm and pseudostem of suckers before planting were analysed and the data are furnished in Appendix XI.

While pseudostem contained high amounts of nutrients the total dry matter accumulation was comparatively maximum in the corm.

6. DRY MATTER PRODUCTION

6.1. Effect of nitrogen on total dry matter production

The data on the total dry matter production at different stages of growth and at different levels of nitrogen are presented in Table 14 (Fig. 10).

It will be seen from the table that in general the total dry matter content increased with increasing nitrogen levels, in all stages of growth, the highest level of nitrogen recording maximum total dry matter production. The effect of levels of nitrogen on the total dry matter production is thus evident. During the early vegetative phase i.e., between

Table 14. Effect of nitrogen on total dry matter production, g/plant

Levels of nitrogen, g/plant	Period, month of sampling					
	5th	6th	7th	8th	9th	Harvest
0	435.4	722.0 (65.84)	1505.7 (108.53)	2860.2 (89.96)	4227.1 (47.78)	4589.5 (8.57)
100	471.1	817.9 (73.61)	1652.5 (102.04)	3044.9 (84.26)	4582.3 (50.49)	5017.9 (9.51)
200	466.2	970.3 (103.08)	2014.8 (107.64)	3371.3 (67.33)	4947.8 (46.76)	5190.2 (4.90)
300	553.1	1108.2 (100.36)	2064.2 (86.27)	3495.5 (69.34)	5325.3 (52.34)	5577.9 (4.74)
400	603.2	1195.1 (98.13)	2429.2 (103.26)	3981.1 (38.98)	5703.9 (43.27)	5878.8 (3.06)
C.D (5%)	72.6	160.9	206.4	347.4	628.3	413.7
SEm ±	24.2	53.6	68.8	115.9	209.5	137.9

Note: The figures in parenthesis indicate the rate of increase in dry matter production at each time interval,%

Fig-10. EFFECT OF NITROGEN ON TOTAL DRY MATTER.

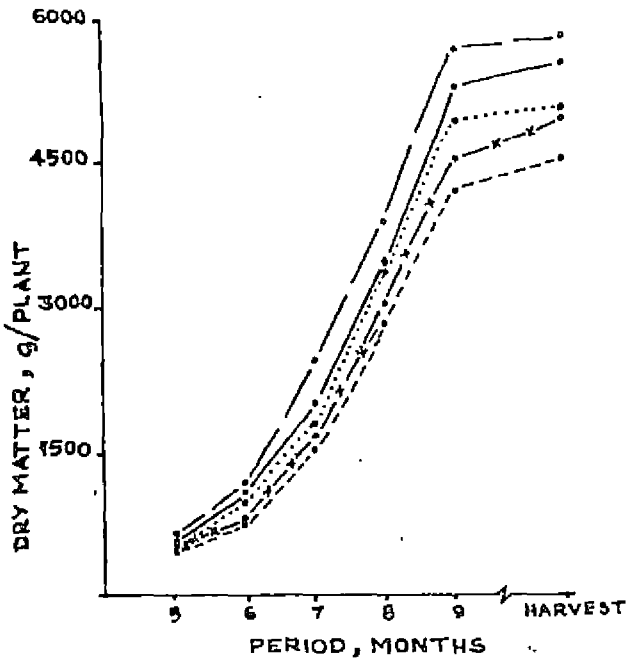


Fig-11. EFFECT OF NITROGEN ON TOTAL UPTAKE OF NITROGEN.

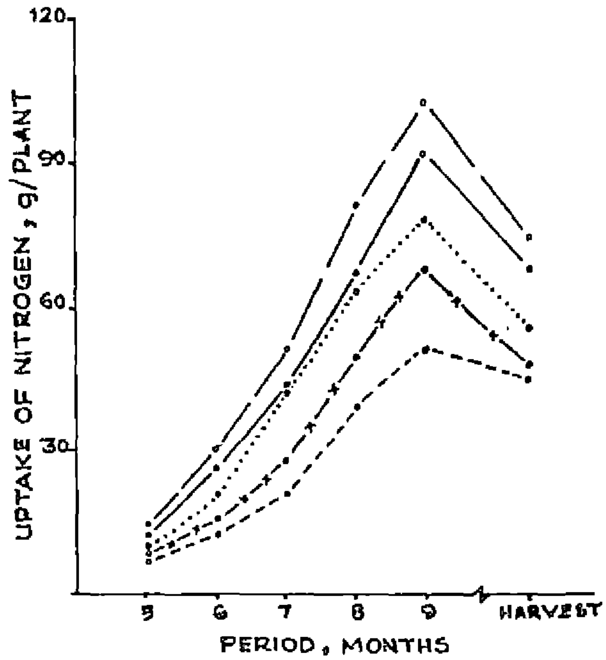


Fig-13. EFFECT OF NITROGEN ON TOTAL UPTAKE OF POTASSIUM.

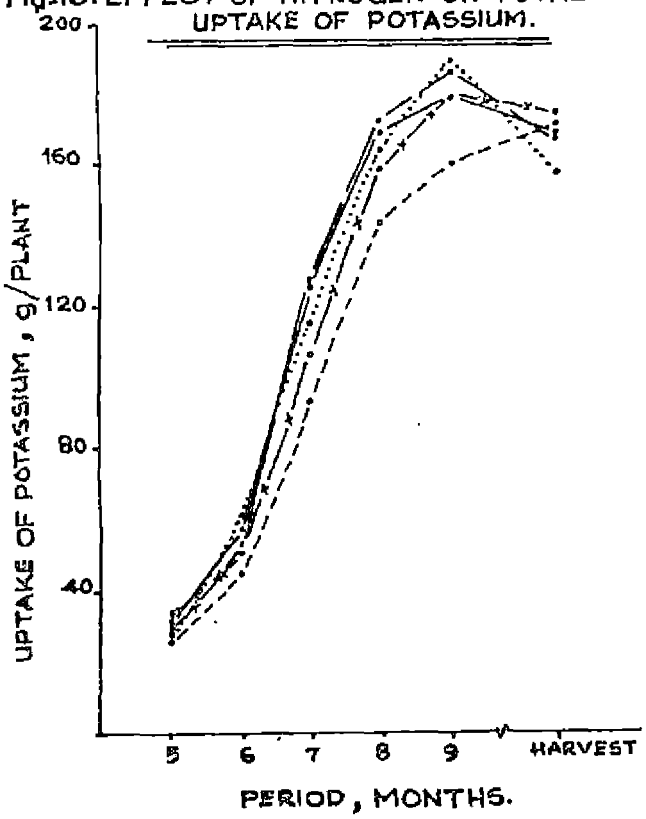
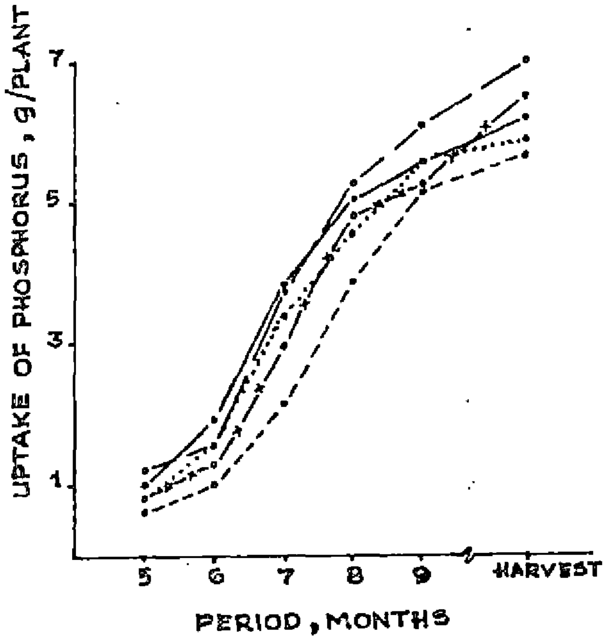


Fig-12. EFFECT OF NITROGEN ON TOTAL UPTAKE OF PHOSPHORUS.



N_0	N_1	N_2	N_3	N_4

5th and 6th month the rate of increase in dry matter was however, highest with 200 g N/plant.

As the plants advanced in age the total dry matter progressively increased, irrespective of the treatments. The rate of increase varied with the stage of plant growth and with the levels of nitrogen. Maximum rate of dry matter production was seen during the 7th month (a mean increase of 101.55 per cent over the previous period), after which the rate gradually declined reaching the minimum (6.16 per cent towards harvest). It was interesting to note that in the control and in the lower level of nitrogen (n_1) the rate of increase in dry matter between shooting and harvest was higher than the other levels.

6.2. Distribution of dry matter within the plant at different periods of growth

The dry weight of various organs at different periods of growth as influenced by various levels of nitrogen are given in Tables 15a and b and their mean values summarised in Table 15c. The data revealed that the levels of nitrogen and the stages of plant growth influenced the dry matter accumulation in various plant parts. In the vegetative phase (5th, 6th, 7th and 8th months) maximum dry matter accumulation was noticed in laminae followed by pseudostem, corm, petiole, internal leaf and meristem. During shooting also

Table 15a. Effect of nitrogen on dry matter content of different organs at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampl-ing	Organs					
		Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Inter-nal leaf
0	5th	130.8	1.80	102.3	19.1	175.1	6.26
	6th	175.8	1.06	200.2	40.7	300.5	3.82
	7th	336.4	-	455.0	101.6	610.1	2.57
	8th	519.3	-	837.9	138.9	1168.7	2.30
	9th	742.6	-	1220.9	176.2	1527.3	-
	Harvest	231.5	-	812.7	103.6	1015.7	-
100	5th	135.3	2.47	103.2	19.7	203.4	7.09
	6th	223.6	1.33	229.2	43.8	316.2	3.84
	7th	320.2	-	500.0	105.2	723.8	3.16
	8th	523.1	-	870.3	153.7	1284.6	2.73
	9th	766.0	-	1240.6	202.0	1773.5	-
	Harvest	255.1	-	898.6	117.0	1082.1	-
200	5th	122.6	2.96	107.5	20.6	203.7	8.13
	6th	223.8	1.56	267.0	56.0	416.2	5.77
	7th	341.6	-	605.7	124.7	940.0	2.85
	8th	591.5	-	976.0	170.9	1416.6	2.63
	9th	841.3	-	1346.4	217.1	1904.9	-
	Harvest	298.2	-	940.4	124.1	1092.8	-
300	5th	162.4	4.68	113.5	21.6	240.6	10.38
	6th	275.8	1.48	282.2	64.4	478.3	6.08
	7th	352.5	-	618.9	125.0	964.1	3.75
	8th	671.7	-	994.9	180.6	1413.3	3.54
	9th	990.9	-	1370.9	238.2	2062.5	-
	Harvest	355.9	-	1091.3	130.9	1253.7	-
400	5th	172.6	5.15	124.5	25.3	264.0	11.64
	6th	299.6	1.75	292.9	62.4	530.8	7.76
	7th	491.5	-	707.1	127.4	1099.2	4.02
	8th	746.2	-	1110.5	154.4	1676.2	4.14
	9th	1000.8	-	1514.0	241.5	2253.9	-
	Harvest	364.9	-	1214.0	158.0	1469.2	-

able 15b. Effect of levels of nitrogen on dry matter content of different organs at different stages of plant growth, g/plant

evels f itrogen, /plant	Month of sampling	Organs				
		Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud*
0	8th	193.1	-	-	-	-
	9th	307.7	252.5	-	-	-
	Harvest	-	177.6	109.7	2078.7	60.0
100	8th	210.4	-	-	-	-
	9th	320.8	279.3	-	-	-
	Harvest	-	182.8	124.9	2258.6	68.9
200	8th	213.7	-	-	-	-
	9th	325.9	312.1	-	-	-
	Harvest	-	200.0	136.7	2333.2	64.9
300	8th	231.5	-	-	-	-
	9th	348.3	314.5	-	-	-
	Harvest	-	240.2	127.8	2311.5	66.6
400	8th	259.6	-	-	-	-
	9th	366.2	327.5	-	-	-
	Harvest	-	243.2	129.9	2234.7	64.7

* The male buds were pruned when the bunch formation was completed.

accumulation of dry matter was maximum in the laminae and the least in the petiole. At harvest maximum dry matter accumulation was contributed by the fruits, the rest of the organs showing a similar trend as in previous phases.

With respect to the levels of nitrogen the dry matter increased with the levels of nitrogen in vegetative plant parts. But in the reproductive organs, viz., in the fruit and external stalk total dry matter increased upto the level of 200 g N while further increase in nitrogen levels resulted in a decline. Analysis of the male bud for their dry matter accumulation showed that the dry matter increased only upto 100 g N/plant. In all the plant parts irrespective of the levels of nitrogen, there was a steady increase in dry matter upto shooting (9th month) which however, declined at harvest.

A comparative study of dry matter accumulation between the vegetative and reproductive phases clearly showed the effect of different levels of nitrogen. Upto 200 g N/plant the reproductive parts contributed the major part of the dry matter. At the level 300 and 400 g N the reverse was the case, vegetative parts contributing the maximum dry matter.

Table 15c. Effect of nitrogen on dry matter content in the different organs at different stages of growth

Summary

Levels of nitrogen, g/plant	Dry matter content, g/plant										
	Corm	Meri-stem	Pseudo-stem	Petiole	Lami-nae	Inter-nal leaf	Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
0	356.07	1.43	604.83	96.68	799.55	3.74	250.37	215.04	109.74	2078.73	59.95
100	375.60	1.90	640.32	106.92	897.27	4.21	265.70	231.05	124.87	2258.59	68.91
200	403.18	2.26	707.03	118.86	995.70	4.85	264.81	256.03	136.71	2333.17	64.86
300	468.20	3.08	745.28	126.78	1068.75	5.94	289.94	277.33	127.78	2311.47	66.58
400	512.60	3.45	827.15	133.17	1215.55	6.89	312.91	285.36	129.88	2234.65	64.71
Month of sampling											
5th	144.72	3.41	110.20	21.26	217.34	7.07	-	-	-	-	-
6th	239.72	1.44	254.30	53.46	408.38	5.46	-	-	-	-	-
7th	368.44	-	577.30	116.76	867.46	3.27	-	-	-	-	-
8th	610.38	-	957.94	165.70	1391.88	3.07	221.68	-	-	-	-
9th	868.24	-	1338.56	215.00	1904.44	-	331.80	251.77	-	-	-
Harvest	307.12	-	991.48	126.72	1182.70	-	-	208.75	125.80	2243.32	65.00

7. DISTRIBUTION OF NITROGEN

7.1. Nitrogen percentage

The data presented in Tables 16a and b represent the percentage distribution of nitrogen in various organs as influenced by levels of nitrogen and periods of growth. The summary is furnished in Table 16c. The different levels of nitrogen had significant influence on the nitrogen content of the various plant parts. The nitrogen percentage in the plant parts increased with increasing levels of nitrogen. However, between the two higher levels the difference was not significant. At all levels of nitrogen, maximum nitrogen content was found in the internal leaf.

With respect to periods of growth, the nitrogen percentage in plant parts in general decreased with the age of the crop. At harvest the nitrogen content of the organs were significantly lower than that at the earlier periods. During vegetative phase the internal leaf had the highest content of nitrogen followed by laminae. During shooting also maximum nitrogen content was noted in laminae followed by inflorescence and pseudostem. At harvest, nitrogen content was recorded maximum in external stalk (1.50 per cent) followed by laminae (1.40 per cent) and internal stalk(1.28 per cent). Among the reproductive organs the male bud had the highest nitrogen content.

Table 16a. Effect of nitrogen on the N content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Inter-nal leaf
0	5th	1.11	1.76	1.23	0.84	1.94	1.73
	6th	0.91	2.14	1.48	1.01	2.21	2.35
	7th	0.95	-	0.89	1.10	2.08	2.12
	8th	0.88	-	0.93	0.89	1.91	1.73
	9th	0.82	-	0.97	0.97	1.74	-
	Harvest	0.97	-	0.69	0.80	1.41	-
100	5th	1.46	2.27	1.25	1.29	2.20	2.24
	6th	1.09	2.35	1.57	1.28	2.55	2.52
	7th	1.21	-	1.32	1.33	2.23	3.03
	8th	1.17	-	1.18	1.13	2.12	2.44
	9th	0.96	-	1.03	0.79	2.21	-
	Harvest	1.10	-	0.69	1.06	1.18	-
200	5th	1.59	2.33	1.57	1.73	2.69	2.71
	6th	1.25	2.48	1.74	1.72	2.87	2.93
	7th	1.32	-	1.56	1.55	2.71	3.14
	8th	1.19	-	1.33	1.27	2.69	2.71
	9th	1.07	-	1.09	0.85	2.27	-
	Harvest	1.03	-	0.86	1.07	1.39	-
300	5th	1.67	2.39	1.70	1.63	2.73	2.73
	6th	1.32	2.77	1.81	1.98	3.31	2.97
	7th	1.58	-	1.73	1.70	2.61	3.04
	8th	1.41	-	1.60	1.39	2.47	2.69
	9th	1.24	-	1.46	1.26	2.34	-
	Harvest	1.13	-	1.04	1.06	1.56	-
400	5th	1.71	2.40	2.11	1.71	2.88	2.82
	6th	1.33	2.80	2.32	1.85	3.43	3.01
	7th	1.43	-	1.69	1.79	2.90	3.30
	8th	1.40	-	1.53	1.49	2.69	2.98
	9th	1.36	-	1.37	1.16	2.48	-
	Harvest	1.12	-	0.97	1.10	1.44	-

16b. Effect of nitrogen on the N content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Infloresecence	Internal stalk	External stalk	Fruit	Male bud
	8th	1.18	-	-	-	-
0	9th	1.39	0.32	-	-	-
	Harvest	-	1.17	1.31	0.77	1.56
	8th	1.76	-	-	-	-
100	9th	1.74	0.73	-	-	-
	Harvest	-	1.23	1.30	0.80	1.61
	8th	1.88	-	-	-	-
200	9th	2.06	0.84	-	-	-
	Harvest	-	1.36	1.36	0.98	1.69
	8th	2.02	-	-	-	-
300	9th	1.99	1.04	-	-	-
	Harvest	-	1.30	1.67	1.09	1.72
	8th	2.66	-	-	-	-
400	9th	1.85	1.15	-	-	-
	Harvest	-	1.34	1.87	1.31	1.78

Table 16c. Effect of nitrogen on the N content of different plant organs at different stages of growth, N% on moisture free basis

Summary

Levels of nitrogen, g/plant	N% on moisture free basis										
	Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Inter-nal leaf	Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
0	0.94	1.95	1.03	0.94	1.88	1.98	1.29	0.75	1.31	0.77	1.56
100	1.17	2.31	1.17	1.15	2.08	2.56	1.75	0.98	1.30	0.80	1.61
200	1.24	2.41	1.36	1.37	2.44	2.87	1.97	1.10	1.36	0.98	1.69
300	1.39	2.58	1.56	1.50	2.50	2.88	2.01	1.17	1.67	1.09	1.72
400	1.39	2.60	1.50	1.52	2.64	3.03	2.26	1.25	1.87	1.31	1.78
C.D (5%)	0.18	-	0.17	0.20	0.22	0.31	-	-	-	-	-
SEm ±	0.06	-	0.06	0.07	0.08	0.11	-	-	-	-	-
Month of sampling											
5th	1.50	2.23	1.37	1.44	2.49	2.45	-	-	-	-	-
6th	1.18	2.51	1.78	1.57	2.60	2.76	-	-	-	-	-
7th	1.30	-	1.44	1.49	2.50	2.93	-	-	-	-	-
8th	1.21	-	1.31	1.23	2.38	2.51	1.90	-	-	-	-
9th	1.09	-	1.18	1.01	2.21	-	1.81	0.82	-	-	-
Harvest	1.07	-	0.85	1.02	1.40	-	-	1.28	1.50	0.99	1.67
C.D (5%)	0.19	-	0.18	0.22	0.24	0.03	-	-	-	-	-
SEm ±	0.07	-	0.07	0.08	0.09	0.10	-	-	-	-	-

7.2. Total uptake of nitrogen

The data furnished in Table 17 (Fig. 11) revealed that total uptake of nitrogen was significantly influenced by the levels of nitrogen applied. The higher levels of nitrogen, namely n_3 and n_4 resulted in increased uptake and the highest uptake was noticed at the highest level of nitrogen in all stages of growth. The difference between n_3 and n_4 was not statistically significant during 5th, 6th, 9th months and at harvest.

The data also revealed the influence of different phases on the uptake. A steady increase in the uptake of nitrogen was observed upto shooting irrespective of the dose of nitrogen applied. The nitrogen uptake however, declined at harvest. The maximum uptake of nitrogen was achieved at 9th month (shooting). There was also remarkable intake of nitrogen by the crop during the period from 5th to 6th month. The mean nitrogen uptake value of 10.17 g recorded at 5th month shot upto 20.75, an increase of 100.20 per cent over the previous period. From 6th to 7th month, 7th to 8th and 8th to 9th month the percentage of increase was 80.53, 67.48 and 31.73 respectively.

7.3. Nitrogen uptake in different organs

The data on the nitrogen uptake in various organs as affected by different levels of nitrogen and periods of growth are furnished in Tables 18a and b and their summary in Table 18c.

Table 17. Effect of nitrogen on total uptake of nitrogen, g/plant

Levels of nitrogen, g/plant	Period, month of sampling					
	5th	6th	7th	8th	9th	Harvest
0	6.49	11.70 (80.00)	29.91 (78.63)	38.62 (84.70)	51.07 (32.24)	44.95
100	8.36	15.08 (80.38)	28.29 (87.60)	49.24 (74.05)	68.75 (39.62)	47.83
200	9.74	20.48 (110.27)	41.27 (101.51)	63.88 (54.79)	78.42 (22.76)	55.53
300	12.13	26.40 (117.64)	43.23 (63.75)	67.26 (55.59)	92.34 (37.29)	68.22
400	14.14	30.09 (112.73)	51.50 (71.15)	81.50 (58.25)	103.30 (26.75)	74.97
C.D (5%)	3.09	6.21	7.32	10.99	20.60	11.60
SEm ±	1.03	2.07	2.44	3.67	6.87	3.87

Note: The figures in parenthesis indicate the rate of increase in total uptake of nitrogen at each time interval,%

As evident from the data, the levels of nitrogen influenced the uptake of the element in all plant parts. In the case of corm the n_4 and n_3 levels were on par and were significantly superior to n_0 with respect to uptake. In pseudostem the levels n_3 and n_4 were significantly superior to n_0, n_1 and n_2 while n_3 and n_4 were on par. In laminae highest level of applied nitrogen significantly increased the uptake of nitrogen than other levels. The nitrogen uptake in the internal leaf significantly increased with the doses of nitrogen. The levels of nitrogen had no significant effect on the uptake in the petiole.

With respect to the periods of growth, the nitrogen uptake of the organs in general decreased with the age of the crop. The nitrogen uptake of organs viz., corm, pseudostem and laminae at harvest were significantly lower than that of the other periods. During vegetative and shooting phases, laminae always had the highest uptake of nitrogen followed by pseudostem and corm. At harvest however, maximum nitrogen uptake was met within fruits followed by laminae and pseudostem. The uptake of nitrogen in vegetative organs steadily increased upto 9th month of planting and thereafter showed a marked decline towards harvest.

Table 18a. Effect of nitrogen on the N uptake of different plant organs at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meri-stem	Pseu-dostem	Petiole	Laminae	Inter-nal leaf
0	5th	1.46	0.03	1.27	0.16	3.45	0.11
	6th	1.59	0.02	2.94	0.41	6.65	0.09
	7th	3.04	-	4.08	1.13	12.59	0.05
	8th	4.57	-	7.84	1.22	22.63	0.04
	9th	5.91	-	11.92	1.10	27.13	-
	Harvest	3.62	-	5.55	0.83	14.39	-
100	5th	2.02	0.06	1.29	0.25	4.49	0.24
	6th	2.45	0.03	3.81	0.58	8.11	0.10
	7th	3.92	-	6.84	1.37	16.06	0.09
	8th	6.10	-	10.06	1.74	27.50	0.07
	9th	6.91	-	12.63	1.81	39.71	-
	Harvest	3.02	-	6.84	1.24	13.26	-
200	5th	1.97	0.07	1.67	0.35	5.47	0.23
	6th	2.73	0.04	4.75	1.01	11.78	0.17
	7th	4.45	-	9.46	1.91	25.36	0.09
	8th	7.01	-	13.01	2.17	37.53	0.07
	9th	8.62	-	14.65	2.16	43.64	-
	Harvest	2.95	-	7.86	1.33	14.91	-
300	5th	2.76	0.11	1.92	0.35	6.71	0.28
	6th	3.55	0.04	5.15	1.27	16.22	0.18
	7th	5.58	-	10.37	2.18	24.99	0.11
	8th	9.42	-	15.92	2.49	34.72	0.10
	9th	12.21	-	20.18	2.55	47.31	-
	Harvest	3.95	-	12.09	1.28	19.69	-
400	5th	3.03	0.12	2.66	0.43	7.56	0.33
	6th	3.95	0.05	6.62	1.13	18.11	0.23
	7th	6.89	-	11.89	2.32	30.27	0.14
	8th	10.49	-	16.69	2.72	44.57	0.12
	9th	13.52	-	20.55	2.81	55.94	-
	Harvest	3.99	-	11.87	1.75	21.16	-

Table 18b. Effect of nitrogen on the N uptake of different plant organs at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Inflorescence	Internal stalk	External stalk	Fruit	Male bud
0	8th	2.33	-	-	-	-
	9th	4.25	0.77	-	-	-
	Harvest	-	2.09	1.48	16.05	0.94
100	8th	3.76	-	-	-	-
	9th	5.64	2.04	-	-	-
	Harvest	-	2.23	1.61	18.57	1.11
200	8th	4.09	-	-	-	-
	9th	6.72	2.62	-	-	-
	Harvest	-	2.75	1.85	22.79	1.09
300	8th	4.61	-	-	-	-
	9th	6.90	3.20	-	-	-
	Harvest	-	3.10	2.06	24.90	1.15
400	8th	6.91	-	-	-	-
	9th	6.83	3.66	-	-	-
	Harvest	-	3.26	2.42	29.37	1.14

Table 18c. Effect of nitrogen on the N uptake of different plant organs at different stages of growth

Summary

Levels of nitrogen, g/plant	Uptake of nitrogen, g/plant										
	Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Inter-nal leaf	Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
0	3.37	0.03	5.60	0.81	14.47	0.07	3.29	1.43	1.48	16.05	0.94
100	4.07	0.05	6.91	1.17	18.19	0.13	4.70	2.14	1.61	18.57	1.11
200	4.62	0.06	8.53	1.49	23.12	0.14	5.41	2.69	1.85	22.79	1.09
300	6.25	0.08	10.94	1.69	24.94	0.17	5.76	3.15	2.06	24.90	1.15
400	6.98	0.09	11.71	1.86	29.60	0.21	6.87	3.46	2.42	29.37	1.14
C.D (5%)	2.59	-	2.38	NS	3.80	0.04	-	-	-	-	-
SEm ±	0.48	-	0.80	0.73	1.38	0.02	-	-	-	-	-
Month of sampling											
5th	2.25	0.08	1.76	0.31	5.54	0.24	-	-	-	-	-
6th	2.85	0.04	4.65	0.88	12.17	0.15	-	-	-	-	-
7th	4.78	-	8.53	1.78	21.85	0.10	-	-	-	-	-
8th	7.52	-	12.70	2.00	33.39	0.10	4.34	-	-	-	-
9th	8.88	-	15.99	2.09	42.75	-	5.96	2.46	-	-	-
Harvest	3.51	-	8.84	1.29	16.68	-	-	2.69	1.88	22.34	1.09
C.D (5%)	1.54	-	2.59	NS	4.16	0.04	-	-	-	-	-
SEm ±	0.52	-	0.88	0.79	1.51	0.01	-	-	-	-	-

8. DISTRIBUTION OF PHOSPHORUS

8.1. Phosphorus percentage

The data on the effect of different levels of nitrogen and periods of growth on phosphorus content of various organs are tabulated in Tables 19a and b and their summary furnished in Table 19c.

The results showed that the levels of nitrogen had no marked influence on the percentage of phosphorus in corm, pseudostem, petiole, laminae and internal leaf. Unlike in the case of nitrogen, phosphorus percentage did not show a steady increase in its distribution with increasing levels of nitrogen except in meristem and internal leaf. On the other hand the period of growth significantly influenced the concentration of phosphorus in corm, pseudostem and petiole. However, the values failed to indicate any definite trend with increasing periods of growth. In general the phosphorus percentage of corm, pseudostem, petiole, laminae and internal leaf was higher in the early periods. In laminae and the internal leaf the period of growth had no significant influence on the phosphorus content.

Throughout the vegetative phase, the unemerged leaf had a higher phosphorus concentration than other parts, while at shooting the inflorescence recorded the maximum percentage of phosphorus. At harvest the maximum level of phosphorus however, was noted in the external stalk followed by internal

Table 19a. Effect of nitrogen on the P content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf
0	5th	0.15	0.15	0.14	0.10	0.17	0.40
	6th	0.10	0.57	0.17	0.09	0.17	0.51
	7th	0.08	-	0.20	0.11	0.14	0.60
	8th	0.07	-	0.13	0.09	0.15	0.53
	9th	0.06	-	0.08	0.08	0.15	-
	Harvest	0.08	-	0.08	0.08	0.16	-
100	5th	0.16	0.18	0.15	0.17	0.19	0.36
	6th	0.08	0.50	0.18	0.11	0.21	0.54
	7th	0.16	-	0.23	0.16	0.22	0.62
	8th	0.10	-	0.16	0.12	0.18	0.58
	9th	0.05	-	0.08	0.08	0.14	-
	Harvest	0.08	-	0.08	0.09	0.17	-
200	5th	0.12	0.24	0.15	0.13	0.22	0.37
	6th	0.10	0.55	0.15	0.08	0.20	0.52
	7th	0.10	-	0.15	0.11	0.20	0.57
	8th	0.08	-	0.11	0.09	0.17	0.52
	9th	0.05	-	0.07	0.08	0.15	-
	Harvest	0.06	-	0.07	0.07	0.15	-
300	5th	0.16	0.28	0.22	0.14	0.19	0.26
	6th	0.12	0.55	0.22	0.07	0.19	0.58
	7th	0.10	-	0.21	0.12	0.23	0.58
	8th	0.07	-	0.13	0.09	0.19	0.51
	9th	0.05	-	0.06	0.06	0.14	-
	Harvest	0.07	-	0.08	0.07	0.14	-
400	5th	0.16	0.50	0.20	0.12	0.20	0.61
	6th	0.08	0.37	0.15	0.08	0.19	0.57
	7th	0.09	-	0.19	0.10	0.18	0.61
	8th	0.07	-	0.14	0.08	0.16	0.52
	9th	0.05	-	0.05	0.07	0.14	-
	Harvest	0.06	-	0.06	0.08	0.15	-

Table 19b. Effect of nitrogen on the P content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Infloresecence	Internal stalk	External stalk	Fruit	Male bud
	8th	0.26	-	-	-	-
0	9th	0.34	0.15	-	-	-
	Harvest	-	0.16	0.19	0.13	0.32
	8th	0.25	-	-	-	-
100	9th	0.30	0.12	-	-	-
	Harvest	-	0.18	0.26	0.12	0.28
	8th	0.22	-	-	-	-
200	9th	0.28	0.13	-	-	-
	Harvest	-	0.15	0.16	0.11	0.30
	8th	0.24	-	-	-	-
300	9th	0.28	0.13	-	-	-
	Harvest	-	0.12	0.14	0.12	0.30
	8th	0.26	-	-	-	-
400	9th	0.31	0.12	-	-	-
	Harvest	-	0.17	0.20	0.12	0.29

Table 19c. Effect of nitrogen on P content of different plant organs at different stages of growth

Summary

Levels of nitrogen, g/plant	P% on moisture free basis										
	Corm	Meri-stem	Pseudo-stem	Petiole	Lami-nae	Inter-nal leaf	Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
0	0.09	0.36	0.13	0.09	0.16	0.51	0.30	0.16	0.19	0.13	0.32
100	0.11	0.34	0.15	0.12	0.19	0.53	0.28	0.15	0.26	0.12	0.28
200	0.09	0.40	0.12	0.09	0.18	0.50	0.26	0.13	0.16	0.11	0.30
300	0.10	0.42	0.15	0.09	0.18	0.48	0.26	0.13	0.14	0.12	0.30
400	0.09	0.44	0.13	0.09	0.17	0.58	0.29	0.15	0.20	0.12	0.30
C.D (5%)	NS	-	NS	NS	NS	NS	-	-	-	-	-
SEm ±	0.01	-	0.01	0.01	0.04	0.09	-	-	-	-	-
Month of sampling											
5th	0.15	0.27	0.17	0.13	0.19	0.40	-	-	-	-	-
6th	0.10	0.51	0.17	0.09	0.19	0.54	-	-	-	-	-
7th	0.11	-	0.20	0.12	0.19	0.60	-	-	-	-	-
8th	0.08	-	0.13	0.09	0.17	0.52	0.25	-	-	-	-
9th	0.05	-	0.07	0.07	0.14	-	0.30	0.13	-	-	-
Harvest	0.07	-	0.07	0.08	0.15	-	-	0.16	0.19	0.12	0.30
C.D (5%)	0.02	-	0.04	0.03	NS	NS	-	-	-	-	-
SEm ±	0.01	-	0.01	0.01	0.04	0.08	-	-	-	-	-

stalk, laminae and fruit. It is interesting to observe that the Phosphorus content of male bud was invariably high at all levels of nitrogen as compared to other reproductive organs of the plant.

8.2. Total uptake of phosphorus

Observations on the total uptake of phosphorus are furnished in Table 20 (Fig. 12).

From the data it is evident that the levels of nitrogen had significant influence on the uptake of phosphorus, except during 6th and 9th months. The higher levels of nitrogen (n_3 and n_4) showed significantly superior values in the 5th, 7th, 8th months and at harvest compared to lower doses (n_2, n_1 and n_0). In all the six stages of growth the control recorded the lowest phosphorus uptake.

The age of the plant also influenced the uptake of phosphorus. The uptake values progressively increased with increasing period of crop growth. As in the case of nitrogen, the maximum rate of uptake of phosphorus was also found to be during 7th month, after which gradual reduction was noticed. The rate of increase from shooting to harvest was only upto 13.6 per cent.

8.3. Phosphorus uptake in different organs

The data on the uptake of phosphorus in different organs

Table 20. Effect of nitrogen on total uptake of phosphorus, g/plant

Levels of nitrogen, g/plant	Period, month of sampling					
	5th	6th	7th	8th	9th	Harvest
0	0.68	1.09 (60.29)	2.15 (97.25)	3.91 (81.86)	5.20 (32.99)	5.76 (10.77)
100	0.89	1.32 (48.31)	3.02 (128.79)	4.86 (60.92)	5.32 (9.46)	6.53 (22.78)
200	0.82	1.63 (98.78)	3.30 (102.45)	4.67 (41.52)	5.70 (22.06)	5.91 (3.68)
300	1.04	1.92 (86.40)	3.99 (107.81)	5.17 (29.57)	5.67 (9.67)	6.21 (9.52)
400	1.19	1.66 (39.50)	3.89 (134.34)	5.38 (38.30)	6.10 (13.38)	7.30 (19.67)
C.D (5%)	0.21	NS	0.62	0.75	NS	0.69
SEm ±	0.07	0.19	0.21	0.25	0.27	0.23

Note: The figures in parenthesis indicate the rate of increase in total uptake of phosphorus at each time interval,%

in relation to the different levels of nitrogen and period of growth are given in Tables 21a and b and their summary in Table 21c.

The results showed that the levels of nitrogen had a significant influence in the uptake of phosphorus in organs like corm, pseudostem and laminae, while in petiole and internal leaf the effect was not significant.

The variation in the uptake of phosphorus in organs in relation to the increasing age of the crop was rather inconsistent. In general, uptake of phosphorus in corm, pseudostem and petiole were at its peak during 8th month whereas in laminae inflorescence and internal stalk the uptake was maximum during 9th month.

In the vegetative phase, maximum uptake was recorded in the laminae followed by pseudostem, corm and petiole compared to meristem and internal leaf. Similar was the trend at shooting. At harvest maximum uptake of phosphorus was noted in fruits followed by laminae and pseudostem as in the case of nitrogen.

A comparison of the phosphorus content in the vegetative and reproductive plant parts at the time of harvest revealed that at all the levels of nitrogen, the reproductive parts contributed higher phosphorus content compared to vegetative plant parts.

Table 21a. Effect of nitrogen on the P uptake of different plant organs at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meri-stem	Pseu-dostem	Petiole	Laminae	Inter-nal leaf
0	5th	0.20	0.002	0.14	0.02	0.29	0.02
	6th	0.18	0.006	0.34	0.04	0.52	0.02
	7th	0.28	-	0.90	0.11	0.85	0.01
	8th	0.36	-	1.14	0.13	1.76	0.01
	9th	0.43	-	0.92	0.13	2.30	-
	Harvest	0.18	-	0.63	0.08	1.57	-
100	5th	0.22	0.015	0.22	0.03	0.38	0.03
	6th	0.17	0.006	0.42	0.04	0.67	0.02
	7th	0.28	-	1.18	0.17	1.37	0.02
	8th	0.51	-	1.36	0.18	2.27	0.02
	9th	0.38	-	0.99	0.16	2.48	-
	Harvest	0.22	-	0.89	0.10	1.80	-
200	5th	0.14	0.007	0.16	0.03	0.46	0.03
	6th	0.22	0.008	0.39	0.16	0.82	0.03
	7th	0.33	-	0.92	0.16	1.88	0.02
	8th	0.44	-	1.09	0.16	2.49	0.01
	9th	0.44	-	0.98	0.17	2.81	-
	Harvest	0.16	-	0.69	0.09	1.62	-
300	5th	0.26	0.011	0.24	0.03	0.46	0.03
	6th	0.33	0.007	0.60	0.05	0.90	0.04
	7th	0.34	-	1.26	0.15	2.23	0.02
	8th	0.47	-	1.34	0.16	2.63	0.02
	9th	0.46	-	0.78	0.14	2.91	-
	Harvest	0.26	-	0.82	0.09	1.72	-
400	5th	0.29	0.026	0.25	0.03	0.53	0.07
	6th	0.24	0.005	0.43	0.05	0.88	0.04
	7th	0.45	-	1.30	0.13	1.99	0.03
	8th	0.51	-	1.33	0.15	2.70	0.02
	9th	0.48	-	0.82	0.16	3.13	-
	Harvest	0.22	-	0.76	0.13	2.20	-

Table 21b. Effect of nitrogen on the P uptake of different plant organs at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Inflore-scence	Internal stalk	External stalk	Fruit	Male bud
	8th	0.51	-	-	-	-
0	9th	1.03	0.39	-	-	-
	Harvest	-	0.29	0.20	2.62	0.19
	8th	0.53	-	-	-	-
100	9th	0.97	0.34	-	-	-
	Harvest	-	0.32	0.33	2.68	0.19
	8th	0.48	-	-	-	-
200	9th	0.90	0.40	-	-	-
	Harvest	-	0.30	0.21	2.65	0.19
	8th	0.55	-	-	-	-
300	9th	0.99	0.40	-	-	-
	Harvest	-	0.27	0.17	2.67	0.20
	8th	0.66	-	-	-	-
400	9th	1.12	0.39	-	-	-
	Harvest	-	0.41	0.24	3.15	0.19

Table 21c. Effect of nitrogen on the P uptake of different plant organs at different stages of growth

Summary

Levels of nitrogen, g/plant	Uptake of phosphorus, g/plant										
	Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Inter-nal leaf	Inflore-scence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
0	0.27	0.004	0.68	0.09	1.22	0.02	0.77	0.34	0.20	2.62	0.19
100	0.30	0.011	0.84	0.11	1.50	0.02	0.75	0.33	0.33	2.68	0.19
200	0.29	0.008	0.71	0.13	1.68	0.02	0.69	0.35	0.21	2.65	0.19
300	0.35	0.009	0.84	0.10	1.81	0.03	0.77	0.34	0.17	2.67	0.20
400	0.37	0.016	0.82	0.08	1.91	0.04	0.89	0.40	0.24	3.15	0.19
C.D (5%)	0.05	-	0.13	NS	0.20	NS	-	-	-	-	-
SEm ±	0.02	-	0.37	0.02	0.07	0.02	-	-	-	-	-
Month of sampling											
5th	0.22	0.012	0.20	0.03	0.42	0.04	-	-	-	-	-
6th	0.23	0.006	0.44	0.07	0.76	0.03	-	-	-	-	-
7th	0.34	-	1.11	0.14	1.66	0.02	-	-	-	-	-
8th	0.46	-	1.25	0.16	2.37	0.02	0.55	-	-	-	-
9th	0.44	-	0.90	0.15	2.73	-	1.00	0.38	-	-	-
Harvest	0.21	-	0.76	0.10	1.78	-	-	0.32	0.23	2.75	0.19
C.D (5%)	0.06	-	0.15	0.05	0.21	NS	-	-	-	-	-
SEm ±	0.02	-	0.40	0.02	0.08	0.02	-	-	-	-	-

9. DISTRIBUTION OF POTASSIUM

9.1. Potassium percentage

Potassium content of different plant parts at different stages of growth are furnished in Tables 22a and b and their summary in Table 22c.

The varying levels of nitrogen could not bring about any significant difference in potassium content of corm, petiole and laminae. But the levels of nitrogen significantly influenced the content of potassium in the pseudostem. In this organ the level of 100 g N/plant resulted in the highest content of potassium, which was significantly superior than that of the other levels of nitrogen, except control.

An analysis of the data on the influence of periods on the potassium content of plant organs showed that the age of the plant significantly influenced the concentration of this nutrient. In general potassium concentration decreased progressively with the age of the plant in all the organs except in corm. During vegetative phase the level of potassium was found maximum in pseudostem at all levels of nitrogen followed by meristem, petiole, corm and internal leaf. But at shooting and at harvest maximum percentage of potassium was found in the internal stalk.

Table 22a. Effect of nitrogen on the K content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meri-stem	Pseu-dostem	Petiole	Laminae	Inter-nal leaf
0	5th	6.98	7.69	9.15	6.83	4.43	5.22
	6th	6.35	8.46	10.16	6.93	3.68	7.29
	7th	6.34	-	9.42	5.64	3.89	6.38
	8th	5.35	-	7.01	4.48	3.21	5.46
	9th	4.35	-	4.60	3.32	2.53	-
	Harvest	10.29	-	6.73	3.54	2.26	-
100	5th	6.18	6.97	9.38	7.59	5.77	5.42
	6th	6.33	8.65	10.33	7.35	5.70	7.51
	7th	7.34	-	9.05	6.36	4.31	5.91
	8th	5.78	-	7.11	4.88	3.64	5.79
	9th	4.22	-	4.83	3.38	2.96	-
	Harvest	9.33	-	5.89	2.55	2.07	-
200	5th	5.51	7.62	8.70	7.29	5.36	5.45
	6th	6.85	7.57	9.81	6.37	3.54	6.10
	7th	6.63	-	8.78	4.65	3.62	6.19
	8th	5.14	-	6.77	3.98	3.37	5.45
	9th	3.59	-	4.76	3.30	3.10	-
	Harvest	7.45	-	4.33	3.05	2.07	-
300	5th	6.70	6.64	9.23	6.97	3.64	4.86
	6th	5.44	7.41	8.97	5.46	2.79	6.01
	7th	7.74	-	8.63	6.09	3.87	6.27
	8th	5.50	-	6.82	4.32	2.97	5.36
	9th	3.67	-	4.60	2.54	2.26	-
	Harvest	6.56	-	5.20	2.53	1.87	-
400	5th	7.44	6.73	8.27	7.36	3.45	6.39
	6th	5.27	6.18	7.20	4.14	2.10	5.41
	7th	5.36	-	7.69	4.81	3.58	5.78
	8th	4.43	-	5.79	3.61	3.12	4.85
	9th	3.51	-	3.89	2.21	2.66	-
	Harvest	4.95	-	4.40	2.59	2.18	-

Table 22b. Effect of nitrogen on the K content of different plant organs at different stages of plant growth, % on moisture free basis

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Inflore-scence	Internal stalk	External stalk	Fruit	Male bud
	8th	7.29	-	-	-	-
0	9th	5.09	5.35	-	-	-
	Harvest	-	10.56	7.46	1.80	4.21
	8th	7.31	-	-	-	-
100	9th	4.79	5.67	-	-	--
	Harvest	-	11.43	8.53	1.60	4.32
	8th	6.84	-	-	-	-
200	9th	4.63	4.59	-	-	-
	Harvest	-	9.80	6.38	1.67	4.12
	8th	6.77	-	-	-	-
300	9th	4.33	4.45	-	-	-
	Harvest	-	7.50	7.08	1.52	4.32
	8th	6.29	-	-	-	-
400	9th	4.36	3.92	-	-	-
	Harvest	-	8.08	6.50	1.37	3.90

Table 22c. Effect of nitrogen on the K content of different plant organs at different stages of growth

Summary

Levels of nitrogen, g/plant	K % on moisture free basis										
	Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
0	6.61	8.08	7.77	5.12	3.33	6.09	6.19	7.96	7.46	1.80	4.21
100	6.53	7.81	7.85	5.35	3.74	6.16	6.05	8.55	8.53	1.60	4.32
200	5.86	7.60	7.19	4.77	3.51	5.78	5.74	7.20	6.38	1.67	4.12
300	5.94	7.03	7.20	4.65	2.90	5.63	5.55	5.98	7.08	1.52	4.32
400	5.16	6.46	6.21	4.12	2.85	5.61	5.33	6.00	6.50	1.37	3.90
C.D (5%)	NS	-	0.45	NS	NS	0.10	-	-	-	-	-
SEm ±	0.40	-	0.16	0.31	0.35	0.29	-	-	-	-	-
Month of sampling											
5th	6.56	7.13	8.95	7.21	4.53	5.47	-	-	-	-	-
6th	6.04	7.65	9.24	6.05	3.16	6.46	-	-	-	-	-
7th	6.68	-	8.71	5.51	3.85	6.11	-	-	-	-	-
8th	5.24	-	6.70	4.25	3.26	5.38	6.90	-	-	-	-
9th	3.87	-	4.54	2.95	2.70	-	4.64	4.80	-	-	-
Harvest	7.72	-	5.31	2.85	2.09	-	-	9.47	7.19	1.59	4.17
C.D (5%)	1.28	-	0.25	1.02	1.13	0.81	-	-	-	-	-
SEm ±	0.44	-	0.17	0.35	0.39	0.20	-	-	-	-	-

9.2. TOTAL UPTAKE OF POTASSIUM

The data on the total uptake of potassium are presented in Table 23 (Fig. 13). The various levels of nitrogen failed to show any response on the uptake of potassium during 6th, 9th months and also at harvest. However, during the 5th, 7th and 8th months the highest level of nitrogen found to exert significant influence on the uptake.

With respect to the stages of growth the highest rate of uptake of potassium was seen during 7th month (mean increase of 115.28 per cent over the previous period). The same was the trend with nitrogen and phosphorus also. Towards harvest the potassium uptake declined at all levels of nitrogen except in the control.

9.3. Potassium uptake in different organs

The data on the uptake of potassium in different organs as influenced by different levels of nitrogen and the stages of growth are furnished in Tables 24a and b and their summary in Table 24c.

The data indicated that the potassium uptake in the various vegetative plant parts except in pseudostem were significantly influenced by different levels of nitrogen.

Table 23. Effect of nitrogen on total uptake of potassium, g/plant

Levels of nitrogen, g/plant	Period, month of sampling					
	5th	6th	7th	8th	9th	Harvest
0	26.55	45.15 (41.20)	94.51 (109.32)	144.61 (53.01)	161.51 (6.12)	171.40
100	29.94	52.77 (76.25)	107.57 (103.85)	160.59 (49.29)	180.69 (12.52)	175.61
200	27.00	60.76 (125.04)	116.24 (91.31)	165.26 (42.17)	190.28 (15.14)	158.56
300	30.38	57.36 (88.81)	127.40 (122.10)	170.64 (33.94)	180.77 (5.94)	170.89
400	33.46	51.06 (52.60)	127.55 (149.80)	173.25 (35.83)	187.56 (8.26)	169.12
C.D (5%)	4.79	NS	22.03	18.28	NS	NS
SEm ±	1.59	4.52	7.35	6.10	12.67	8.47

Note: The figures in parenthesis indicate the rate of increase in total uptake of potassium at each time interval.

There was increased uptake of potassium in corm, meristem, laminae, internal leaf and inflorescence at the highest levels of nitrogen applied. But in other organs no such trend was observed.

The data on the effect of periods of growth on the potassium content of organs indicated that age of the plant significantly influenced the uptake of this element. In general, potassium uptake decreased progressively with the age of the plant. The uptake of the vegetative organs at harvest were significantly lowest as compared to the values at other periods.

During vegetative and shooting phases potassium uptake was maximum in pseudostem followed by laminae and corm. At harvest maximum potassium content was contributed by pseudostem followed by fruits, laminae and corm.

On a general analysis of N, P and K uptake it will be seen that nitrogen and phosphorus uptake were maximum in the leaves during vegetative phase and in fruits during reproductive phase. But in the case of potassium, the maximum uptake was noted in pseudostem both in the vegetative and reproductive phase.

Table 24a. Effect of nitrogen on the K uptake of different plant parts at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs					
		Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf
0	5th	9.14	0.13	7.85	1.31	7.79	0.33
	6th	11.05	0.09	20.00	2.80	11.00	0.27
	7th	21.60	-	43.15	5.73	23.85	0.16
	8th	27.80	-	58.69	6.24	37.54	0.12
	9th	32.08	-	56.04	5.89	38.70	-
	Harvest	23.40	-	54.36	3.63	23.02	-
100	5th	8.43	0.18	7.78	1.49	11.66	0.39
	6th	13.73	0.12	23.48	3.19	11.97	0.29
	7th	23.74	-	45.64	6.68	31.32	0.19
	8th	29.86	-	62.08	7.51	46.55	0.16
	9th	31.59	-	58.98	6.90	51.83	-
	Harvest	26.66	-	53.02	2.99	22.35	-
200	5th	6.79	0.21	7.19	1.48	10.90	0.43
	6th	15.32	0.12	26.51	3.58	14.88	0.35
	7th	22.93	-	53.30	5.75	34.09	0.17
	8th	30.55	-	65.79	6.79	47.78	0.14
	9th	30.20	-	63.62	7.15	59.93	-
	Harvest	22.52	-	40.16	3.80	22.39	-
300	5th	10.93	0.31	8.34	1.49	8.81	0.50
	6th	14.87	0.11	25.15	3.52	13.34	0.36
	7th	27.23	-	54.97	7.68	37.29	0.23
	8th	36.99	-	68.05	7.80	42.12	0.19
	9th	36.14	-	62.57	6.05	46.92	-
	Harvest	23.45	-	55.99	3.19	23.63	-
400	5th	12.97	0.34	9.11	1.87	8.39	0.75
	6th	15.59	0.11	21.19	2.57	11.20	0.41
	7th	26.71	-	55.03	6.14	39.44	0.23
	8th	33.04	-	64.49	6.50	52.40	0.20
	9th	35.14	-	58.43	5.52	59.59	-
	Harvest	18.26	-	53.53	4.08	32.74	-

Table 24b. Effect of nitrogen on the K uptake of different plant parts at different stages of plant growth, g/plant

Levels of nitrogen, g/plant	Month of sampling	Organs				
		Inflorescence	Internal stalk	External stalk	Fruit	Male bud
0	8th	14.21	-	-	-	-
	9th	15.65	13.16	-	-	-
	Harvest	-	18.77	8.21	37.45	2.52
100	8th	14.44	-	-	-	-
	9th	15.38	16.01	-	-	-
	Harvest	-	21.02	10.68	35.91	2.98
200	8th	14.21	-	-	-	-
	9th	15.06	14.32	-	-	-
	Harvest	-	19.38	8.83	38.81	2.67
300	8th	15.49	-	-	-	-
	9th	15.05	14.04	-	-	-
	Harvest	-	17.98	8.87	34.88	2.87
400	8th	16.61	-	-	-	-
	9th	16.02	12.87	-	-	-
	Harvest	-	18.81	8.56	30.64	2.48

Table 24c. Effect of nitrogen on the K uptake of different plant organs at different stages of growth

Summary

Levels of nitrogen, g/plant	Uptake of potassium, g/plant										
	Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
0	20.85	0.11	40.02	4.27	23.65	0.22	14.93	15.97	8.21	37.45	2.52
100	22.34	0.15	41.83	4.79	29.28	0.26	14.91	18.52	10.68	35.91	2.98
200	21.39	0.17	42.76	4.76	31.66	0.27	14.64	16.85	8.83	38.81	2.67
300	24.94	0.22	45.85	4.96	28.69	0.32	15.27	16.01	8.87	34.88	2.87
400	25.78	0.23	43.63	4.45	33.96	0.40	16.32	15.84	8.56	30.64	2.48
C.D (5%)	2.87	-	NS	0.55	4.27	0.10	-	-	-	-	-
SEm ±	1.04	-	1.61	0.20	1.55	0.03	-	-	-	-	-
Month of sampling											
5th	9.65	0.23	8.05	1.53	9.51	0.48	-	-	-	-	-
6th	14.11	0.11	23.27	3.13	12.48	0.34	-	-	-	-	-
7th	24.44	-	50.42	6.40	33.20	0.20	-	-	-	-	-
8th	31.65	-	63.82	6.97	45.28	0.16	14.99	-	-	-	-
9th	33.03	-	59.93	6.30	51.39	-	15.43	14.08	-	-	-
Harvest	22.87	-	51.41	3.54	24.83	-	-	19.19	9.03	35.54	2.70
C.D (5%)	3.12	-	4.86	0.59	4.66	0.09	-	-	-	-	-
SEm ±	1.13	-	1.76	0.21	1.69	0.03	-	-	-	-	-

10. EFFECT OF LEVELS OF NITROGEN ON THE PERCENTAGE OF N, P AND K IN INDEX LEAF (THIRD LEAF) AT SHOOTING

Results on the analysis of N, P and K concentration in the third leaf at the time of shooting are presented in Table 25.

The levels of nitrogen showed significant difference on the percentage of nitrogen in the index leaf at the time of shooting. Maximum nitrogen concentration was noted under the treatment receiving 200 g N/plant followed by 100 g N/plant which were significantly superior to control.

With respect to concentration of phosphorus although the trend was similar as in the case of nitrogen, there was no statistical difference between the treatments.

Concentration of potassium also showed significant variation among the treatments and the maximum value was noted in n_2 which was significantly superior to n_0 and n_4. Thus the maximum percentage of N, P and K was observed in plants which received 200 g N/plant.

11. YIELD RESPONSE TO DIFFERENT LEVELS OF NITROGEN

Analysis of variance for the yield response to different levels of nitrogen are presented in appendix XXI.

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Table 25. Effect of nitrogen on nutrient concentration of N, P and K in index leaf at the time of shooting, %

Levels of nitrogen, g/plant	N	P	K
0	1.33	0.14	2.12
100	2.02	0.16	2.50
200	2.08	0.17	2.76
300	1.61	0.14	2.65
400	1.47	0.15	2.05
C.D (5%)	0.55	NS	0.38
SEm ±	0.18	NS	0.13

Table 26. Economics of nitrogen application under rainfed conditions, per hectare

Levels of nitrogen, g/plant	Yield, kg	Income, @ Rs.0.80/kg	Cost of N, @ Rs.4/kg	Profit, Rs.
0	21,400.84	17,120.67	0	17,120.67
100	23,494.64	18,795.71	881.60	17,914.11
200	24,437.95	19,550.36	1,763.20	17,787.16
300	24,305.71	19,444.57	2,644.80	16,799.77
400	23,366.81	18,693.45	3,526.40	16,566.95

The response was found to be quadratic as the quadratic component of treatment sum of squares was statistically significant (Fig. 9). A quadratic response curve of the type $Y = a + bN + cN^2$ was fitted to find out the optimum dose of nitrogen. The optimum dose of nitrogen was calculated as 204.6 g/plant. The economic dose was however found to be 96 g N/plant.

11.1. Economics of nitrogen application

Economics of cultivation of palayankodan with varying levels of nitrogen under rainfed condition was worked out and the same is furnished in Table 26.

The economics of cultivation was analysed by fitting a quadratic response function so as to find out maximum profit/ha. In this analysis the quantity of nitrogen alone was taken as the input factor since all the other factors were assumed to be uniform for the plots in the lay out. The output factor consisted the bunch weight of banana.

It will be found that beyond the nitrogen level of 100 g N/plant the profit would decline considerably. The most profitable dose of nitrogen worked out for palayankodan under rainfed conditions is thus 96 g N/plant.

12. CHEMICAL ANALYSIS OF THE SOIL AFTER HARVEST OF THE CROP

Data on total nitrogen content, available phosphorus and available potassium after harvest of the crop are presented in Appendix XXII.

The results of the final soil analysis of the different treatments in relation to the analysis before the crop showed considerable depletion of nitrogen. The depletion of nitrogen was more in the control plots and in the plots which received lower levels of nitrogen application. The P and K content of the soil remained unchanged.

Discussion

DISCUSSION

Nutritional requirement of banana has been one of the major aspects of study in the past in all important banana growing regions of the world. Major emphasis, however, had been on irrigated bananas often limiting to commercial cultivars such as Gros Michel, Lacatan and Robusta. In Kerala also most of the investigations done so far in banana were on Nendran and Robusta cultivars under irrigated conditions. The fact that 80 per cent of the banana grown in Kerala are under rainfed conditions emphasises the necessity for concerted research work on rainfed bananas. Proper recommendations on nutritional needs in bananas under rainfed conditions have not been possible due to lack of adequate experimental results. Among the major elements, nitrogen and potash have been found great demand by several workers (Croucher and Mitchell, 1940; Summerville, 1944; Wardlaw, 1961 and Venkatesam, et al. 1965) for growth and development of banana. In the absence of any information on the individual nutritional needs of rainfed bananas it became necessary to commence detailed studies with individual major nutrients than with their combinations.

The present investigations on nitrogen nutrition have thrown light on the nitrogen needs and uptake pattern of rainfed banana cv. Paleyankodan. The salient results are discussed hereunder.

Effect of nitrogen on morphological characters

The effect of nitrogen is immediately manifested on the vegetative vigour of the bananas. The increased vegetative vigour of the plants in terms of height, girth of pseudostem, length of petiole, number of functional leaves and leaf area with increasing levels of nitrogen is a clear expression of the effect of nitrogen on the early phase of plant growth. Increase in plant height in banana due to nitrogen application have been reported by several workers (Croucher and Mitchell, 1940; Butler, 1960; Battikhah and Khalidy, 1962; Venkatesan et al., 1965 and Arunachalam et al., 1976).

Unlike in the case of plant height, the girth increase was evident only upto 200 g N/plant. The increase in girth due to nitrogen application has been reported by Battikhah and Khalidy (1962) and Arunachalam et al. (1976). It is interesting that the yield increase as discussed elsewhere was also found to be maximum at 200 g N/plant. The manifested vigour in terms of increased girth of the plant thus appears to be a factor responsible for yield increase. Hasselo (1961) and Venkatesan et al. (1965) also observed that the increase in girth of the pseudostem was directly related to ultimate yields in banana.

While the vegetative vigour showed a general increase with the levels of nitrogen, the expression was more evident during certain periods. The rate of increase in most of the vegetative parameters was maximum during the period commencing from 6th month onwards. The fertilizer applications were made during the third and fifth month i.e., during the vegetative phase. The factors that would have contributed for the increased vigour of plant during the above period appears to be due to the increased uptake of nutrients during this period. The soil moisture availability might also be reckoned as a factor for the increased uptake which in turn was perhaps responsible for the increased vigour of the plant. Soil moisture status improved with the receipt of showers in May.

The functional leaf is a major parameter which contributes to the ultimate yield of a plant. In the present study it was found that the increase in leaf number was significant upto 6th month. There was no significant difference in leaf number at shooting. The factors influencing the number of leaves are the rate of leaf production and retentivity of leaves. Croucher and Mitchell (1940), Katyal and Chadha (1961), Battikhah and Khalidy (1962) and Venkatesam <u>et al</u>. (1965) observed that increase in nitrogen levels increased the number of leaves. The decrease in the functional leaves at shooting seems to have been compensated by an increased leaf area. The leaf area significantly increased during the 7th month. The increased uptake of nutrients during this stage might also have contributed to the larger leaf area. Thus the effect of nitrogen appears to be more predominant on leaf size before shooting than on the number of leaves.

It is thus clear that nitrogen markedly increased the vegetative growth, which might be attributed to the absorbed nitrogen combining with carbohydrates synthesised by leaves, which ultimately led to the formation of complex nitrogenous substance such as proteins and amides to build up new tissues (Claypool, 1936 and Childers, 1966).

Although the increased levels of nitrogen resulted in an increased vegetative growth there appears to be a limit beyond which the vigour is relatively less expressive. This is clear when the relative growth rate of pseudostem height, length of petiole and leaf area receiving different levels of nitrogen are taken into consideration. Decreased growth rate with increasing levels of nitrogen in irrigated banana was reported by Hasselo (1961) and in litchi (Sites et al., 1959 and Joiner, 1960). In the present study the relative growth rate was worked out to be maximum at 100 g N/plant beyond which on extrapolation of the growth curve a decreasing trend on growth was noticed.

The crop duration was also found to depend upon the nitrogen doses. The total crop duration was maximum with the highest level of nitrogen. The influence of higher doses of nitrogen on the crop duration was more evident between shooting and harvest than during pre-shooting period. In other words, the reproductive and fruit development phases are further pushed with increasing levels of nitrogen. The earliness of cropping in banana as reported by Croucher and Mitchell (1940), Bhan and Majumdar (1956), Simmonds (1959) and Jagirdar et al. (1963) was not found in the present study. The inevitable conclusion for the delay in harvest due to the highest level of nitrogen may be accounted for the supra optimal level of nitrogen diverting carbohydrate into vegetative growth and lowering the levels of other nutrients in the vegetative tissue (Black, 1965). Delayed fruit maturity due to higher levels of nitrogen has been reported in Robusta banana grown under irrigation by Ramaswamy and Muthukrishnan (1973) and in pineapple (Su, 1957; Yow, 1959; Kwong et al., 1966 and Gangadhara Rao et al., 1974).

Effect of nitrogen on yield and yield attributes

The effect of nitrogen on yield attributes is also clear from the present study. In bananas it is well established that the vigour during the vegetative phase has a direct relationship to the yield (Summerville, 1944). There are several reports on increased yield due to nitrogen application (Bhan and Majumdar, 1956; Simmonds, 1959; Venkatesan <u>et al</u>., 1965; Teaotia and Dubey, 1971 and Arunachalam <u>et al</u>., 1976). However, it is the optimum dose that counts for economic fertilizer application without affecting the yield. The results of the present study indicate that for rainfed bananas the nutritional requirement is comparatively low than for irrigated plants. A dose of 200 g N/plant gave maximum yield. The optimum and economic quantity of nitrogen required for the crop worked out from this experiment was 204.6 g and 96 g/plant respectively. This points out to the fact that the nutritional needs of rainfed bananas vary markedly from that of an irrigated crop. The irrigated bananas have comparatively uniform soil moisture regime during the vegetative phase which enhances the uptake of nutrients. Utilization of nitrogen when applied beyond optimum limit was perhaps used for extra vegetative growth. Excessive nitrate accumulation is another factor limiting the yield (Parr, 1967). Banana thus responds to nitrogen; but beyond a certain level the benefits are not proportional (Madhava Rao, 1978).

The yield in banana is a combined effect of factors like number of hands, number of fingers in a hand, girth and size of the fingers (Simmonds, 1959; Venkatesan *et al.*, 1965 and Arunachalam *et al.*, 1976). Any of these parameters may also play a prominent role depending upon environmental conditions. In the present study the factors that influenced the yield was found to be the weight and girth of the finger. The increase in the number of hands and fingers reported in irrigated bananas (Bhan and Majumdar, 1956 and Katyal and Chadha, 1961) was not found in the present study. This shows that in rainfed banana the possibility of increasing yield attributes like number of hands and fingers have possible limitations. The imbalanced soil moisture regime would have affected flower bud differentiation and the early phase of bunch development.

Nitrogen markedly improved the quality of fruits in respect of total soluble solids, total sugars, reducing and non-reducing sugars. An increase of 5.2 per cent in T.S.S. and 17.03 per cent in reducing sugar over control was found at 200 g N/plant. The total sugars on the other hand increased even upto the level of 300 g N/plant. The sugar/acid ratio also increased upto 200 g N/plant. The non-reducing sugar fraction was highest in the control which indicated a qualitative reduction. On an overall analysis of qualitative parameters it was found that the level of 200 g N/plant was superior than the rest. Increase in sugar content and T.S.S. due to medium dose of nitrogen has been reported in several fruits (Nijjar and Chand, 1969; Desai and Phadnis, 1979 in grapes; and Bhattacharya et al., 1973 in Kagzi lime). The qualitative improvement with nitrogen application might be attributed to the promotive effect in the process of photosynthesis and stimulated function of several enzymes in the physiological process of fruit development (Singh, 1975). The qualitative parameters like acidity and ascorbic acid content, however, were little affected by nitrogen fertilization. Moreover, they were found to be inconsistent. Such inconsistency in acidity and ascorbic acid content have been reported in several fruits. Increase in nitrogen levels resulted in increased acidity in pineapple and grapes (Tay, 1972; Nijjar and Chand, 1969 and Smith, 1967). On the contrary higher levels of nitrogen decreased the acidity in pineapple and grapes (Su, 1957; Py, 1958 and Nijjar and Singh, 1979).

Dry matter production

The pattern of growth and dry matter accumulation observed in the present study indicated that the active vegetative phase of the crop is confined to the period from 5th to 9th months during which the dry matter accumulation increased from 505.8 g to 4957.3 g/plant.

Of the different periods examined, the dry matter production between 6th and 7th months was at its maximum, the rate of increase being 101.55 per cent. The rate of growth in terms of dry matter production declined at harvest probably due to the utilization of the nutrients and the subsequent metabolic changes for the development of fruits rather than vegetative growth. Such a decrease in the rate of accumulation of dry matter during fruit development has been observed by Twyford and Walmsley (1973).

The total dry matter accumulation at harvest, in the present study ranged only from 4.59 to 5.88 kg/plant. These figures are comparatively low as compared to the dry matter accumulation of 18 kg/plant observed by Ballion et al. (1933) and 65 kg/plant recorded by Martin-Prevel (1962) in Dwarf Cavendish cultivar of banana tried under irrigated conditions. Boland (1960) also reported that in the Lacatan cultivar of banana, the dry matter accumulation ranged from 4.5 to 10 kg/plant. This discrepancy in the total dry matter accumulation observed would be assigned to the two probable reasons: (i) the cultivar tried in the present investigation namely 'Palayankodan' is of low vegetative growth as compared to the Dwarf Cavendish and Lacatan cultivars tried by the above investigators (ii) the present experiment was conducted under rainfed conditions where availability of water would have played a decisive role in the accumulation of dry matter as compared to irrigated conditions employed by the above workers.

The results revealed that the total dry matter content of the plant invariably increased with increasing levels of nitrogen in all stages of growth, the highest level of nitrogen recording 5.88 kg/plant as compared to 4.59 kg/plant at its lowest level. This profound influence of nitrogen in the production of dry matter has been observed by a number of workers (Ballion <u>et al</u>., 1933; Twyford and Walmsley, 1973 and Ashokkumar, 1977). However, it should be noticed that the proportion of dry matter accumulated as yield out of the total dry matter produced, decreased with increasing levels of nitrogen application. When the yield of fruits accounted to 45.29 per cent of the total dry matter produced in the lowest level of nitrogen application, the corresponding value at the highest level of nitrogen was only 38.01 per cent. It is an established fact that in most of the crops nitrogen increases the total dry matter out of proportion to the increase in yield (Tisdale and Nelson, 1971).

The influence of nitrogen levels and stage of growth on the distribution of dry matter content was also evident in the present study. In laminae, corm, pseudostem and petiole a steady increase in the dry matter content was noticed upto shooting which thereafter declined. Such decrease in the dry matter content in these organs after shooting has also been observed by Twyford and Walmsley (1973). After shooting the rate of growth of the vegetative organs was at a lower rate which might not be sufficient to overcome the loss of dry matter due to senescence; thus resulting in a decrease in the total dry matter content recorded at this stage.

Nutrient uptake

The uptake of nitrogen by the plants showed an increase upto shooting which declined at harvest (Table 17). Normally the uptake of nitrogen will continue to increase upto harvest though the rate of increase in the last stage may be nominal. The decrease in the uptake at harvest observed in the present study could be attributed to the loss of older dried leaves due to senescence during the last stage of crop growth. Being a mobile element translocation of nitrogen from the mother plant to its suckers especially after shooting might also possible. Ashokkumar (1977) also reported a decline in the nitrogen uptake after shooting in Robusta banana. The rate of uptake of nitrogen was the highest at 6th month (Table 17) after which it decreased with increasing period of crop growth. Similar trend of nitrogen uptake was also observed by many workers (Summerville, 1944; Twyford and Walmsley, 1974b and Veerannah et al., 1976).

As expected, nitrogen uptake increased with increasing levels of nitrogen. The increased uptake did not however correspond with yield. The increase in yield was only upto the level of 200 g N, after which there was in fact a decline. The utilization of the extra nitrogen taken by the plant was therefore evidently used only for the growth of vegetative organs.

The distribution pattern of nitrogen in the various organs showed that the nitrogen uptake was maximum in laminae during vegetative phase. At harvest, however, fruits contributed for the maximum uptake. The developing inflorescence and fruits being powerful sinks, translocation of nutrients to these organs seems to be natural.

The uptake of phosphorus was high at shooting as well as at harvest. In general, uptake increased with the advancement of growth of plants and with nitrogen levels. The rate of phosphorus uptake as in the case of nitrogen was more in the vegetative phase and pronounced in the laminae.

Martin-Prevel (1964), Walmsley and Twyford (1968) and Veerannah et al. (1976) recorded similar results in irrigated banana and concluded that the uptake of phosphorus was more pronounced during the period from 3rd month after planting to flower initiation.

The potassium uptake of the plant was much higher compared to nitrogen and phosphorus which was an outstanding feature of the whole nutrient uptake pattern. This phenomenon could be attributed to the role of potassium in the synthesis of sugars and water transport. The uptake of potassium decreased after shooting as in the case of nitrogen. The distribution pattern of potassium showed that pseudostem is the organ where maximum accumulation occurred for this element. In all stages of growth, pseudostem tissue was distinct with its maximum uptake.

In the present study the leaf nitrogen concentration in the third leaf at shooting ranged from 1.33 to 2.08 per cent depending upon the levels of nitrogen applied. The maximum percentage of nitrogen was found at 200 g N/plant. Higher doses of nitrogen thus do not appear to influence the nitrogen status in the index leaf. In fact it caused a reduction. Ramaswamy and Muthukrishnan (1974 a) also obtained similar results for irrigated Robusta banana. The coefficient of correlation ($r = 0.107$) between the nitrogen content of the index leaf and the total yield was examined. The value was not found significant indicating that the validity of the 'index leaf' for tissue analysis in rainfed banana cv. Palayankodan is to be confirmed by further investigations.

The range of nitrogen percentage in the third leaf has been found to be influenced by agroclimatic conditions, variety and soil nutrient status. In irrigated banana the critical levels for nitrogen have been worked out as 2.6 per cent for Lacatan and Dwarf Cavendish (Hewitt, 1955; Hewitt and Osborne, 1962 and Murray, 1960). For the variety Robusta, Ramaswamy and Muthukrishnan (1974a) suggested a critical value 3.29 per cent whereas Vadivel (1976) reported 1.72 to 2.3 per cent.

As far as phosphorus was concerned its concentration was within the level of 0.14 to 0.17 per cent. In bananas phosphorus concentration in the index leaf is generally between the range of 0.07 to 0.19 per cent (Hewitt, 1955; Hewitt and Osborne, 1962; Ramaswamy and Muthukrishnan, 1974a and Vadivel, 1976). The results of the present study also indicated that phosphorus concentration in a cultivar like Palayankodan was within the normal range. The lack of response of phosphorus concentration in index leaf due to different levels of nitrogen observed in this investigation is in agreement with the results of the previous workers.

The concentration of potassium in the index leaf in the various treatments ranged between 2.05 to 2.76 per cent. The maximum percentage of potassium was found at 200 g N/plant and the potassium concentration followed a similar pattern as in the case of nitrogen. In irrigated bananas the critical level for potassium has been found to be within the range of 2.49 to 3.6 per cent (Hewitt, 1955; Hewitt and Osborne, 1962; Ramaswamy and Muthukrishnan, 1974a and Vadivel, 1976).

Summary

SUMMARY

The investigations reported in the thesis was conducted in the Department of Pomology, College of Horticulture, Kerala Agricultural University from 1979 to 1980 to study the effect of different levels of nitrogen on the growth, development, dry matter accumulation, nutrient uptake, yield and fruit quality of rainfed banana cv. Palayankodan. The salient results are summarised below.

1. Among the morphological characters studied the height of the plant, girth of the pseudostem and petiole length increased significantly with increasing levels of nitrogen.

2. The treatments did not influence the number of functional leaves and total leaf area at shooting. Sucker production was also not affected by the treatments.

3. The relative growth rate for plant height, petiole length and leaf area was maximum at 100 g N/plant whereas for girth the relative growth rate was maximum at 300 g N/plant. The highest dose of nitrogen resulted in the least growth rate for the above all parameters.

4. The crop duration was significantly altered by the applied nitrogen levels and the plants receiving 400 g N took maximum time for harvest. The delay was more pronounced in the reproductive and fruit development phases than during the vegetative phase.

5. The yield significantly increased upto a level of 200 g N/plant while a further increase to higher levels decreased the yield. The optimum and economic levels of nitrogen was worked out as 204.6 g and 96 g/plant respectively.

6. The bunch characters viz., length of the bunch, number of hands per bunch, weight of hand, number of fingers and length of finger were not significantly influenced due to nitrogen application. Girth and weight of the fingers were the attributes responsible for increase in yield.

7. Fruit and pulp weight were significantly influenced by nitrogen whereas the peel weight and pulp peel ratio were not affected by the treatments.

8. Nitrogen application significantly increased the total soluble solids, reducing sugars, non-reducing sugar, total sugars and sugar/acid ratio. Acidity and ascorbic acid content of the fruits were not however, influenced by the treatments.

9. Total dry matter production was highest at n_4 level of 400 g N/plant at all stages of growth and the least in control.

10. The pattern of distribution of dry matter content in the vegetative plant parts showed that in the vegetative and shooting phases maximum dry matter accumulation occurred in laminae while at harvest dry matter accumulation was maximum in fruits.

11. Highest uptake of nitrogen was found at the highest level of applied nitrogen. A steady increase in the uptake of nitrogen upto shooting was observed in all the treatments. Irrespective of the treatments nitrogen uptake declined after shooting.

12. Application of nitrogen enhanced the uptake of phosphorus throughout the growth period and it was at its peak at harvest.

13. The potassium uptake although increased with the stages of growth upto shooting, it did not show a corresponding increase with the levels of nitrogen applied.

14. The pattern of distribution of nitrogen and phosphorus in plant parts showed similarities. The uptake of these elements were maximum in the laminae during vegetative phase and in fruits during reproductive phase. In the case of potassium, the maximum uptake was noted in pseudostem both in the vegetative and reproductive phases.

15. The nutrient status of the 'third leaf' at shooting ranged from 1.33 to 2.08 per cent for N, from 0.14 to 0.17 per cent for P and from 2.05 to 2.76 per cent for K respectively.

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APPENDIX I

Weather data for the period from January 1979 to January 1980

Month	Temperature (°C)		Relative humidity (per cent)		Total rain-fall (mm)	Number of rainy days
	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum		
1	2		3		4	5
1979						
January	34.1	18.6	96	38	Nil	Nil
February	34.8	21.6	96	37	22.0	4
March	36.7	22.3	96	38	3.2	1
April	40.1	21.3	95	33	46.5	4
May	35.7	21.8	97	52	155.1	10
June	35.1	22.0	97	53	722.7	22
July	31.1	21.0	98	68	729.8	28
August	31.4	21.6	97	65	462.6	19
September	32.8	22.6	98	67	208.7	18
October	33.4	22.0	95	45	127.3	16
November	32.9	22.2	96	61	317.4	18
December	32.2	19.4	95	45	Nil	Nil
1980						
January	33.5	18.3	93	30	Nil	Nil

APPENDIX II

Analysis of variance for effect of nitrogen on plant height at different periods of growth

Source	Degrees of freedom	Mean squares					
		4th month	5th month	6th month	7th month	8th month	9th month
Total	24						
Block	4	14.94	430.22	923.18	441.30	179.03	176.30
Treatment	4	9.11	483.47**	325.16*	625.67**	629.70**	399.64**
Error	16	20.48	68.67	72.10	112.02	52.72	60.43

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Analysis of variance for effect of nitrogen on plant girth at different periods of growth

Source	Degrees of free-dom	Mean squares					
		4th month	5th month	6th month	7th month	8th month	9th month
Total	24						
Block	4	3.13	27.50	41.92	24.62	15.18	2.51
Treatment	4	1.26	8.00*	15.77*	7.66	6.35	20.59**
Error	16	1.48	2.31	4.92	2.70	3.29	2.92

* Significant at 5% level

** Significant at 1% level

APPENDIX IV

Analysis of variance for effect of nitrogen on functional leaves at different periods of growth

Source	Degrees of freedom	Mean squares					
		4th month	5th month	6th month	7th month	8th month	9th month
Total	24						
Block	4	3.42	1.89	1.94	2.32	2.12	0.54
Treatment	4	0.07	4.17*	7.35**	0.21	0.58	0.37
Error	16	1.17	1.00	1.14	0.26	0.20	0.27

* Significant at 5% level

** Significant at 1% level

APPENDIX V

Analysis of variance for effect of nitrogen on petiole length at different periods of growth

Source	Degrees of freedom	Mean squares					
		4th month	5th month	6th month	7th month	8th month	9th month
Total	24						
Block	4	4.74	17.36	26.90	31.77	1.15	0.42
Treatment	4	0.69	15.06*	24.26*	9.96	9.17**	15.79*
Error	16	3.11	3.25	5.58	4.35	1.46	3.91

* Significant at 5% level

** Significant at 1% level

APPENDIX VI

Analysis of variance for effect of nitrogen on total leaf area at different periods of growth

Source	Degrees of freedom	Mean squares					
		4th month	5th month	6th month	7th month	8th month	9th month
Total	24						
Block	4	0.012	0.61	11.64	8.86	2.44	17.54
Treatment	4	0.006	0.31	1.08	4.33**	2.28	3.29
Error	16	0.039	0.20	1.74	0.82	0.84	5.04

** Significant at 1% level

APPENDIX VII

Analysis of variance for effect of nitrogen on sucker production and duration of the crop

Source	Degrees of freedom	Mean squares			
		Number of suckers at shooting	Days to shoot from planting	Days to harvest from shooting	Days to harvest from planting
Total	24				
Block	4	2.70	285.60	37.15	226.84
Treatment	4	0.07	89.05	402.68**	639.10*
Error	16	0.32	84.29	81.42	200.79

* Significant at 5% level

** Significant at 1% level

APPENDIX VIII

Analysis of variance for effect of nitrogen on bunch characters

Source	Degrees of freedom	Weight of bunch	Length of bunch	Number of hands per bunch	Weight of hand	Number of fingers	Length of finger	Girth of finger	Weight of finger
Total	24								
Block	4	0.39	5.61	0.55	7906.86	130.11	0.36	0.08	29.25
Treatment	4	1.52*	8.71	0.47	2572.46	160.22	0.34	2.20**	103.22**
Error	16	0.47	6.69	0.26	5035.96	150.32	0.78	0.38	21.34

* Significant at 5% level

** Significant at 1% level

APPENDIX IX

Analysis of variance for effect of nitrogen on fruit characters

Source	Degrees of freedom	Mean squares			
		Fruit weight	Pulp weight	Peel weight	Pulp/peel ratio
Total	24				
Block	4	30.04	24.75	1.46	0.03
Treatment	4	103.44*	69.71*	2.05	0.12
Error	16	33.79	18.40	3.98	0.08

* Significant at 5% level

APPENDIX X

Analysis of variance for effect of nitrogen on fruit quality

Source	Degrees of freedom	Total soluble solids	Reducing sugar	Non-reducing sugar	Total sugars	Sugar/acid ratio	Acidity	Ascorbic acid
Total	24							
Block	4	0.18	3.10	0.13	2.73	26.74	0.004	4.79
Treatment	4	1.27**	4.99**	0.48**	2.61**	42.10**	0.003	2.51
Error	16	0.24	0.64	0.07	0.49	8.49	0.001	1.14

** Significant at 1% level

APPENDIX XI

Nutrient status and dry matter content of planting materials (suckers)

Particulars	N, %	P, %	K, %	Dry matter, g
Corm	1.12	0.06	1.38	170.64
Pseudostem	1.40	0.13	5.50	82.37

APPENDIX XII

Analysis of variance for effect of nitrogen on total dry matter production

Source	Degrees of freedom	Mean squares					
		5th month	6th month	7th month	8th month	9th month	Harvest
Total	24						
Block	4	2348.52	61300.92	112807.83	76863.75	157675.73	152174.96
Treatment	4	24313.47**	192661.04**	664271.09**	941103.01**	1708562.97**	1245669.80**
Error	16	2934.46	14417.94	23698.73	67104.58	219553.59	95187.16

** Significant at 1% level

APPENDIX XIII

Analysis of variance for effect of nitrogen on total uptake of nitrogen

Source	Degrees of freedom	Mean squares					
		5th month	6th month	7th month	8th month	9th month	Harvest
Total	24						
Block	4	1.08	18.97	88.06	126.47	853.20	51.20
Treatment	4	45.76**	291.18**	752.73**	1374.48**	2066.63**	838.51**
Error	16	5.32	21.43	29.79	67.16	236.05	74.83

** Significant at 1% level

APPENDIX XIV

Analysis of variance for effect of nitrogen and period of growth on nitrogen content and uptake of banana

Source	Degrees of freedom	Mean squares							
		N content				N uptake			
		Corm	Pseudo-stem	Petiole	Laminae	Corm	Pseudo-stem	Petiole	Laminae
Nitrogen levels	4	1.05**	2.07**	1.87**	1.95**	68.87**	195.73**	5.30	1181.01**
Periods	5	0.65**	2.34**	1.49**	5.84**	202.18**	648.88**	12.68	4734.80**
Nitrogen x periods	20	0.03	0.13	0.13	0.11	6.81*	19.29*	15.81**	83.21
Pooled error	96	0.12	0.11	0.16	0.19	3.72	9.56	0.33	56.79

* Significant at 5% level

** Significant at 1% level

APPENDIX XV

Analysis of variance for effect of nitrogen on total uptake of phosphorus

Source	Degrees of freedom	Mean squares					
		5th month	6th month	7th month	8th month	9th month	Harvest
Total	24						
Block	4	0.03	0.33	1.49	0.98	0.14	0.05
Treatment	4	0.20**	0.51	2.78**	1.59**	0.66	1.88**
Error	16	0.03	0.18	0.21	0.32	0.37	0.26

** Significant at 1% level

APPENDIX XVI

Analyses of variance for effect of nitrogen and period of growth on phosphorus content and uptake of banana

Source	Degrees of freedom	Mean squares							
		P content				P uptake			
		Corm	Pseudo-stem	Petiole	Laminae	Corm	Pseudo-stem	Petiole	Laminae
Nitrogen levels	4	0.002	0.008	0.005	0.008	0.04**	0.19*	0.010	2.22**
Periods	5	0.030**	0.060**	0.014**	0.016	0.43**	3.99**	0.066**	19.99**
Nitrogen x periods	20	0.001	0.005**	0.002**	0.050**	0.01	0.05	0.007**	0.22
Pooled error	96	0.001	0.0008	0.0005	0.0006	0.01	0.07	0.003	0.15

** Significant at 1% level

* Significant at 5% level

APPENDIX XVII

Analysis of variance for effect of nitrogen on total uptake of potassium

Source	Degrees of freedom	Mean squares					
		5th month	6th month	7th month	8th month	9th month	Harvest
Total	24						
Block	4	62.16	86.91	1432.62	592.65	106.85	205.33
Treatment	4	39.48*	179.82	984.20*	647.57*	632.10	202.37
Error	16	12.77	101.99	270.04	185.91	803.04	358.38

* Significant at 5% level

APPENDIX XVIII

Analyses of variance for effect of nitrogen on potassium content and uptake of banana

Source	Degrees of freedom	Mean squares							
		K content				K uptake			
		Corm	Pseudo-stem	Petiole	Laminae	Corm	Pseudo-stem	Petiole	Laminae
Nitrogen levels	4	10.26	11.60**	6.90	3.91	112.72*	124.72	3.47*	436.04**
Periods	5	43.99**	106.70**	65.22**	24.56**	2104.36**	11939.25**	119.14**	7286.04**
Nitrogen x periods	20	4.71**	1.26	2.96**	3.64**	37.29	77.81	1.73	90.55
Pooled error	96	0.70	0.80	0.41	0.29	32.18	77.69	1.15	71.64

** Significant at 1% level

* Significant at 5% level

APPENDIX XIX

Analyses of variance for effect of N, P and K contents and uptake of internal leaf

Source	Degrees of freedom	N content	N uptake	P content	P uptake	K content	K uptake
Nitrogen levels	4	3.58**	0.05**	0.032	0.007	1.34	0.10*
Periods	3	1.58**	0.13**	0.180	0.003	6.80*	0.55**
Nitrogen x period	12	0.18	0.007	0.161**	0.007**	1.72**	0.02*
Pooled error	64	0.24	0.005	0.007	0.0004	0.54	0.01

** Significant at 1% level

* Significant at 5% level

APPENDIX XX

Analysis of variance for effect of nitrogen on nutrient concentration of N, P and K in index leaf at the time of shooting

Source	Degrees of freedom	Mean squares		
		N	P	K
Total	24			
Block	4	0.05	0.0008	0.15
Treatment	4	0.56*	0.0003	0.51**
Error	16	0.17	0.0005	0.08

* Significant at 5% level

** Significant at 1% level

APPENDIX XXI

Analysis of variance for linear and quadratic effects of the different levels of nitrogen

Source	Degrees of freedom	Mean squares
Total	24	
Block	4	0.39
Nitrogen (N)	4	
N linear	1	2.31*
N quadratic	1	3.75**
Error	16	0.47

* Significant at 5% level

** Significant at 1% level

APPENDIX XXII

Effect of nitrogen nutrition on total nitrogen, available phosphorus and available potassium in soil after harvest of the crop

Levels of nitrogen, g/plant	Total nitrogen, %	Available phosphorus, %	Available potassium, %
0	0.130	0.001	0.012
100	0.130	0.0009	0.012
200	0.132	0.0009	0.012
300	0.133	0.0009	0.013
400	0.135	0.0009	0.013

NITROGEN NUTRITION IN RAINFED BANANA *cv.* 'PALAYANKODAN'

BY

VALSAMMA MATHEW

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the

requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of

Horticulture (Pomology & Floriculture and Landscaping)

COLLEGE OF HORTICULTURE

Vellanikkara, Trichur

1980

ABSTRACT

The present investigations were carried out in the Department of Pomology, College of Horticulture, Vellanikkara from 1979 to 1980. The object of the study was to find out the effect of different levels of nitrogen on growth, yield and quality of fruits; uptake and distribution of nutrients at different phases of growth and development and also to assess the most economic dosage of nitrogen for banana cv. Palayankodan under rainfed conditions. The treatments comprised of five levels of nitrogen viz., 0, 100, 200, 300 and 400 g/plant. The experiment was laid out in a randomised block design.

The results revealed that among the morphological characters studied only the height, girth and length of the petiole of the plants were markedly influenced by levels of nitrogen, while the number of functional leaves and total leaf area remained unaffected. Application of nitrogen significantly increased the total duration of the crop. The highest level of nitrogen (400 g N/plant) resulted in maximum crop duration. The delay was more pronounced in the reproductive and fruit development phases than during the vegetative phase.

The yield significantly increased upto a level of 200 g N/plant while a further increase to higher levels decreased the yield. The optimum and economic doses of nitrogen was worked out as 204.6 g and 96 g/plant respectively.

Nitrogen application significantly increased the total soluble solids, reducing sugars, non-reducing sugar, total sugars and sugar/acid ratio. Acidity and ascorbic acid content of the fruits were not, however, influenced by the treatments.

The total dry matter production increased with increasing levels of nitrogen at all stages of growth. The uptake pattern of major nutrients was also greatly influenced by nitrogen application. A steady increase in the uptake of nitrogen was observed in all the treatments upto shooting. Irrespective of the treatments nitrogen uptake declined after harvest. Application of nitrogen enhanced the uptake of phosphorus throughout the growth period and it was at its peak at harvest. The potassium uptake although increased with the stages of growth upto shooting, it did not show a corresponding increase with the levels of nitrogen applied.

The uptake of nitrogen and phosphorus were maximum in laminae during vegetative phase and in fruits during reproductive phase. In the case of potassium the maximum uptake was noted in pseudostem both in the vegetative and reproductive phases.

The nutrient status of the 'third leaf' at shooting ranged from 1.33 to 2.08 per cent for N, from 0.14 to 0.17 per cent for P and from 2.05 to 2.76 per cent for K respectively.