POTASSIUM NUTRITION IN RAINFED BANANA
Musa (AAB group) 'PALAYAN KODAN'

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Potassium nutrition in rainfed banana Musa (AAB group) 'Palayankodan'" is a bonafide record of research work done by me during the course of research work 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.

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7-11-1982.

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CERTIFICATE

Certified that this thesis is a record of research work done independently by Kumari Sheela V.L., 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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Sheela V.L.

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Introduction

INTRODUCTION

Among fruits, banana has a prominent place in Kerala, which accounts for an area of about *50,000 ha in the State. About 80 per cent of this crop is grown under rainfed conditions and the predominent cultivar is 'Palayankodan'.

Surprisingly the research work hitherto undertaken in Kerala was mainly on irrigated bananas which has resulted in little understanding of the problems concerning rainfed bananas. The cultural and manurial requirements of the rainfed bananas appear to vary considerably since the conditions under which they are grown is entirely different from irrigated bananas. The relationship between developmental physiology and fertiliser application has been well established in bananas (Croucher and Mitchell, 1940). As far as irrigated bananas are concerned this aspect has been worked in detail. The results of these works however have little application on bananas grown under rainfed conditions. Understanding the physiology and nutrient uptake pattern of a crop is a prerequisite to work out the proper fertiliser schedule and time of application of nutrients. The earlier work of nitrogen nutrition

*Source: Farm guide 1981

conducted in the Department of Pomology (Valsamma Mathew, 1980) has indicated the necessity for indepth study of various aspects of nutritional uptake in rainfed banana. The present work in potassium nutrition was taken up mainly with the purpose of obtaining additional information on potassium needs of rainfed bananas. The basic studies on nutritional requirements of rainfed bananas will be ultimately useful for working out the fertiliser schedule as well as the time of application. The present study was therefore undertaken with the following objectives.

1. to study the effect of different levels of potassium on growth yield and quality of fruits
2. to study the uptake and distribution of nutrients at different phases of growth and development, and
3. to find out the optimum dose of potassium for rainfed bananas.

Review of Literature

REVIEW OF LITERATURE

The pertinent research work in the potassium nutrition in banana is briefly reviewed below.

Potassium in banana nutrition

Manurial experiments as early as in 1921 had revealed that nitrogen and potassium were required in large amounts by banana (Fawcett, 1921). Norris and Ayyar (1942) reported that banana plants required large quantities of potassium, moderate quantities of nitrogen and relatively little phosphorus for optimum production.

An increase in the yield of banana was observed by Wood (1939) by the application of farm yard manure and potash. Bowman and Eastwood reported in 1940 that in Grosmichel banana potash at three lb per stool and nitrate of soda at 20z per month per plant increased the yield by two per cent and 30 per cent respectively. No response to phosphoric acid was observed. They obtained best results in Cavendish bananas by using 14.40 oz of nitrate of soda and 3.5 oz of sulphate of potash per plant per year.

Croucher and Mitchell (1940) observed that in banana an increase in yield could be secured only by the application of nitrogen in soils which were rich in available P_2O_5 and K_2O. Similar results were obtained by Butler (1960) and Wardlaw (1961)

In sandy soils marked increase in production was obtained by K application and slight increases by N and P (Decuncha and Fraga, 1963). For these soils 60 g N, 40 g P_2O_5 and 325 g K_2O per plant was recommended for getting increased yields. Twyford (1967) found that amount of potash was always the highest of the nutrients analysed being between 2.2 and 4.6 times as the contents of nitrogen and critical manuring could be done in 4 : 1: 14 ratio of N, P and K. Lahav (1973) suggested that atleast 1200 kg/ha of potassium chloride is required to ensure better yields. Twyford and Walmsley (1974) recommended a ratio of 9:9:35 of NPK which should be applied at the rate of 6.25 tonnes/ha and for ratoon 0.65 tonnes/ha. Optimum K_2O rates recommended by Samuel et al. (1977) for increased number and weight of plantains were 420 and 405 kg/ha respectively. For bananas grown from suckers under drip irrigation optimum fertiliser rates were found to be 1000 kg/ha KNO_3 for plots without organic manure and 2000 kg/ha for manured plots (Lahav et al., 1981).

In Queensland having red basaltic soils Summerville (1944) found that there was considerable response to nitrogen and potassium when applied together than when these were applied separately. Application of phosphorus to these soils had no effect on growth. Under French cameroon conditions increased yields were obtained by applying 105 kg N, 190 kg P_2O_5 and 550 kg K_2O/ha (Borel, 1952). In French Guinea Pelegrin (1953) suggested that fertilisers should be rich in potassium, a ratio of 6:3:28 of N, P_2O_5 and K_2O being suitable. Studies in Jamaica and Honduras by Butler (1960) revealed that economic response to fertilising can be expected only from the use of nitrogen. But according to Banana Board Research Department potassium also was found to induce better yields in many localities in Jamaica (Anon, 1961). For New South Wales conditions an annual dose of 225 kg N, 55 - 110 kg P_2O_5 and 500 kg K_2O/ha was recommended by Turner and Bull (1970). In Madagascar yield rose with increasing K_2O application. The greatest response was for the highest dose tried namely 1325 kg/ha (Moreau and Robin, 1972).

Investigations by Koen *et al.* (1976) in Levebu area revealed that an annual application of 230 to 450 g of potassium ammonium nitrate and 110 to 230 g superphosphate and 130 to 350 g potassium chloride was adequate for optimum yields and good quality fruits.

In India, Gandhi (1951) reported that in the Poona region nitrogen application was found to be highly beneficial, whereas addition of phosphorus and potassium produced no additional yield. Gopalan Nair (1953) reported that under wet heavy clay soils of Aduthurai there was no response to the addition of K or P. The cultivar used for trial was 'Poovan'. In West Bengal investigations with Martman variety by Bhan and Majumdar (1956) gave a similar result. Plants cropped earlier and yielded better when heavy applications of N were used, but did not respond to P or K. K added to a low basal application of N also increased the number of fingers upto the level of that produced by plants receiving heavy applications of N. Trials in U.P. in Cavendish banana by Teaotia et al. (1971) revealed that growth and yield were highest when plants were supplied with 300 g ammonium sulphate, 600 g superphosphate and 300 g potassium sulphate per plant. The treatments had no marked effect on quality. Sarma and Roy (1971) reported from experiments on Dwarf

Cavendish cv. Jahajee in Gauhati that 600 kg N, 320 kg P_2O_5 and 320 kg K_2O per hectare gave the greatest profit.

In a five year trial in Kerala on Nendran banana by Pillai et al. (1977) it was found that yields were greatest at N and K_2O at 191 and 301 g per plant per year respectively. There was little or no response to P.

Effect of potassium on growth

Croucher and Mitchell (1940) found that plant growth was increased by application of nitrogen along with P_2O_5 and K_2O. Summerville (1944) showed that whilst in the very early stages of growth significant increased were associated with the presence of added potash, no difference was found later. Bresesowsky and Van Biesen (1962) reported that the treatment with 60:64:450 lb/acre of NPK produced significantly more leaves than treatments 60:64:150 and 120:64:150 lb/acre. Jagirdar and Ansari (1966) found that in Basrai variety of banana, stem girth was increased when P was applied alone or with K at the rate of 48 and 96 lb/acre respectively. In a green house study with Grosmichel bananas Hernadez Medina and Lugo Lopez (1967) found that high K favoured better plant development. Lacoevilhe (1973) clearly indicated that K application influenced the number of functional leaves.

Effect of potassium on yield and yield attributes

Ballion *et al.* (1933) obtained increased yields with nitrogen and potash applications in banana. Bhangoo *et al.* (1962) found that a 350-160-180 formulation of N, P_2O_5 and K_2O greatly increased yields, bunch weight, number of hands per bunch and marketing quality as compared with 350 lb N alone. Jagirdar and Ansari (1966) reported that Basrai variety of banana receiving 96 lb/acre of K_2SO_4 alone, gave the highest yield in terms of bunch weight, number of fingers per unit area and the highest monetary returns per lb of fertilizer applied. Melin (1970) found that KCl at 2 kg per plant and N at 250 g per plant caused marked increases in growth, earliness, bunch weight and yield.

Yang and Pao (1962) studied the effect of K on Fairyman banana. They reported that increased dose of K exerted a favourable effect on nearly every feature of fruit growth and quality. The average weight of the bunch increased by 3.2 to 36.8 per cent in the first year and 53.8 to 72.1 per cent in the second year.

The difference in bunch weight between potash applied, (1600 kg/ha) and potash depleted soil was highly significant. The average weight of the finger was increased by potash by 15 to 27 per cent during first year and 27 to 48 per cent in second year, likewise the weight of flesh, weight of peel, thickness of rind and length and circumference of the finger was found increasing.

Osborne and Hewitt (1963) found that the total weight of the fruit per acre as well as the average bunch weight showed appreciable increase with increased dose of potash.

Veeraraghavan (1972) reported that significant increase was observed 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.

Effect of potassium on fruit quality

In an experiment by Ho (1968 a) in Taiwan increasing supplies of K increased the number of hands and weight of finger, rind thickness and finger length and circumference. Increased K also markedly improved fruit condition as observed after 20 days storage. Potash at 450 to 600 g or more per plant was recommended for Taiwan.

Teaotia *et al.* (1972) reported that quality of fruits was not influenced by the amount of fertilizer applied. According to Koen,(1976) optimal yields of high quality fruits were obtained with an annual application of 370 g potassium ammonium nitrate, along with 450 g potassium chloride per plant. Yields and fruit quality were lowered by higher application rates or when the latter treatment was supplimented with 250 g magnesium sulphate.

Studies conducted by Venkatarayappa *et al.*(1976) on the effect of post shooting applications of potassium dihydrogen phosphate revealed that the treatments significantly increased the volume and weight of fruits. The volume of fruits increased by 26.88 and 32.6 per cent respectively in Giant Cavendish and Dwarf Cavendish bananas. There was an increase of 62.5 per cent in Giant Cavendish and 32.6 per cent in Dwarf Cavendish in the weight of fruits. The ripening of the fruit was delayed in both the clones. Treatments in general were found to lower acidity.

Singh *et al*. (1977) reported a presaging effect of higher dose of fertilizer on quality parameters of the variety Basrai Dwarf in U.P. in addition to increased yield and higher number of fingers. A dose of 150 g N, 90 kg P_2O_5 and 170 kg K_2O supplemented with 20 kg compost per plant was recommended.

Split application of potassium

Fertiliser application must follow the potential growth of the plant. Generally earlier applications before shooting decides the bunch size and number of fingers and totally the yield.

Summerville (1944) stated that the time of application of fertiliser was obviously important and for better results it should be applied during the early stages of the crop. Osborne and Hewitt (1963) found no significant difference in yield between applications of the fertiliser made once in a year or three times in a year. Twyford (1967) reported that K supply in the first two months had a greater influence on the number of hands produced, while potash applied after shooting did not influence the finger size. According to Ho (1968 b) earlier applications of K_2O was most beneficial to plant growth and fruit yield.

Shanmugham and Velayudham (1972) stated that K could be applied in three split doses viz., 1st, 3rd and 5th month after planting along with nitrogen in Tamil Nadu. According to them, fertilizers did not help in increasing the yield if applied after the sixth month. In Assam three split applications of 900 kg N, 480 kg P_2O_5 and 480 kg K_2O per hectare were given for Dwarf Cavendish (Sarma and Roy, 1971). Veeraraghavan (1972) reported that for Nendran banana in Kerala, application of 228 g N, 278 g P_2O_5 and 450 g K_2O per plant during second and fourth month after planting in two equal split doses was effective along with a single dose of one kg CaO.

Uptake and distribution of nutrients

Norris and Ayyar (1942) worked on the mineral requirement of banana and found that K and Ca were the chief substances in the different parts. Jacob and Uexkull (1960) found that the nutrient removal by a 30 tonne crop was to the turne of 50 to 75 kg N, 15 to 20 kg P_2O_5 and 175 to 220 kg K_2O respectively. Martinprevel

(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 M tonnes per hectare per 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 requirement of nitrogen and potassium and a low phosphorus.

According to Joseph (1971) a banana crop producing 16.25 tonnes of fruits required a fertilizer dose of 38 kg N, 5 kg P_2O_5 and 285 kg K_2O per acre. Shanmugham and Velayudham (1972) estimated the uptake of nutrients by banana plants as 300 kg N, 80 kg P_2O_5 and 800 kg K_2O/ha. Studies on nutrient uptake by Jauhari *et al.* (1974) revealed that in the first few months of planting there was rapid uptake of N, P_2O_5 and K_2O. K content in leaves and roots decreased with age but that in rhizome and pseudostem increased, pseudostem was the richest in potassium.

Twyford and Walmsley (1974) conducted an exhaustive uptake study with robusta variety. At the sucker stage the potassium content of the corm was found to be higher than that of pseudostem. At the early and late vegetative stages, pseudostem was always the greatest repository of potassium, followed by the leaves and the corm. At shooting pseudostem and leaves had the highest potassium, with corm and usually the internal fruit stalk next. At the shot stage fruits contained most of the plant's potassium, petioles and infloresecence contained the least K. At harvest the general order was fruits, followed by pseudostem. Other organs varied in ranks with external fruit stalk, petioles and inflorescence lowest. This study showed that a high yield was associated with very high uptake of K_2O than with high uptake of other nutrients.

Veeranna *et al.* (1976) reported that Robusta required N, P_2O_5 and K_2O at the rate of 325, 75 and 1195 kg per hectare respectively, while the requirement for poovan was 408, 35 and 1285 kg of N, P_2O_5 and K_2O respectively. They further reported that nitrogen and potassium were absorbed more in pre-flowering stage in 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.

Critical levels of nutrients in banana

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 practical aim of leaf tissue analysis is to determine the nutritional status of the plant at various growth stages, remedy deficiencies or excesses or imbalances discovered and thereby improve final yield. Leaf analysis results may be applied with great precision for establishing interrelationship between (a) the amount of fertilizer applied to soil in which the crop is grown (b) the concentration of major elements in leaf tissue of the crop after the fertilizer has been added (c) fruit yield of the crop. The relationship will help in predicting fertilizer rates for desired optimum level of nutrient concentration in leaf tissue and subsequent fruit yield (Randhawa et al., 1973).

Leaf analysis in banana was standardised by Hewitt (1955) in Lacatan banana. He determined NPK concentrations of 3rd, 5th and 7th leaves and decided to adopt the third leaf as the standard one for sampling, as 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. He also observed that 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. Murray (1960) found that the leaves of the plants supplied with K showed very little fall in K content with increasing age. This was in contrast to K deficient plants, where not only the expected low level but the gradient with increasing age was very much pronounced. He also confirmed the choice of third leaf as satisfactory. The critical levels reported by him for N, P_2O_5 and K_2O respectively. According to Boland, (1960) the levels of 2.8 to 3.0 per cent 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.

In Israel, Hagin *et al.* (1964) found no significant correlation between yield responses and various levels of available nutrients in the soil and the nutrient content in the leaves with regard to N and P. But in the case of K there was an apparent relationship between yield responses and nutrient levels in leaves. They recommended addition of nutrients when the leaf content fell below 0.19 per cent for P, 3.3 per cent for K_2O and 3.2 per cent for nitrogen. Twyford (1967) standardised the fourth youngest leaf to assess the critical level of nutrients. The critical level for N was shown to be 2.9 per cent in most soils and 2.6 per cent in very light soils. For P_2O_5 it was 0.29 per cent to 0.48 per cent and for K_2O it was 3.8 per cent. The concentration for nitrogen and potassium were constant and were recommended for wide adoption.

Hewitt and Osborne (1962) working on Lacatan variety of banana observed that for securing high yields, the leaf tissue should have 2.6 per cent N, 0.40 per cent P_2O_5 and 4.0 per cent K_2O respectively. Potash application rapidly increased leaf K and heavy application decreased leaf nitrogen. Twyford and Coulter (1964) reported that adequacy levels for

N, P_2O_5 and K_2O was found to be 2.0, 2.29 to 0.48 and 3.8 per cent respectively. Ho (1969) established significant positive correlations between K concentrations in third leaf in one hand, and stem circumference, height, number of fingers, yield and bunch weights on the other. Lacoevilhe and Martin prevel (1971) analysed banana leaves for K concentration in third and fourth leaves (combined) and expressed as percentage of dry matter during flowering stage. During flowering and cutting stages the levels of K_2O were 4.3 and 8.5 per cent respectively whereas K deficient plants showed 2.65 and 1.8 per cent during the same stage.

Sunder Singh (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 optimum for the variety Robusta for high yield. Randhawa <u>et al.</u> (1973) reported that the K content of leaf tissue was not influenced by the varying levels of nitrogen and phosphorus at any stage. Increased levels of potash increased the K concentration in leaf tissues in Robusta banana.

Effect of potassium deficiency

The occurrence of premature yellowing in 8 to 10 month old Lasatan bananas was associated with low leaf content of K caused by a low content of K in the dry soil (Hasselo, 1961). On chinchina series soils K_2O at 200 or 400 kg per hectare controlled premature yellowing (Garcia, 1970). According to Cassidy (1960) in declining banana plantations the first deficiency to appear was that of potassium. This was followed by the dominance of paragrass, the bananas then becoming worthless. Murray (1960) observed that visual deficiency symptoms of K occurred at levels considerably lower than those at which growth was reduced.

Interaction of potassium with nitrogen, phosphorus, calcium and magnesium in banana

Increase or decrease of one element may increase or decrease substantially the other element thereby causing complete deprivation of one particular element to the plant. Such antagonism or synergism between nutrient elements affect growth and development of banana plant considerably.

Hewitt and Osborne (1962) studied the nutrition of Lacatan banana and reported that application of K was reflected in rapid increase in the content of 'K' in the leaf and high dressings brought about depression of nitrogen in the leaf. Ho (1969) reported that K application lowered the leaf C_a, Mg and N contents. According to Lahav (1973), K had a marked effect on the base metals. There is antagonism between K and Mg and K and Ca, as also between K and N and K and Na. But a synergestic relation was observed between K and P.

Materials and Methods

MATERIALS AND METHODS

The present investigation was carried out to study the effect of different levels of potassium on growth, development, dry matter accumulation, yield, fruit quality and uptake of nutrients in rainfed banana Musa (AAB group) 'Palayankodan'. The experiment was conducted in the Department of Pomology, College of Horticulture, Vellanikkara, Trichur.

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-1. The daily maximum temperature during the cropping period ranged from 26 to 36.9°C. and the minimum from 21.3 to 27.2°C. The range of maximum and minimum relative humidity was from 57.7 to 93.7 per cent and 32.09 to 86.5 per cent respectively. There were 110 rainy days during the period of 363 days which was the duration of the crop. The total rainfall received during the

Table 1. Chemical characteristics of the soil

Constituents	Content in soil (%)	Analytical method used
Total nitrogen	0.13	Microkjeldahl (Jackson,1958)
Available phosphorus	0.001	In Bray-1 extract; chlorostannous reduced molybdophosphoric blue colour method (Jackson, 1958)
Available potassium	0.01	In 1 N neutral ammonium acetate extract; flame photometric (Jackson, 1958)
pH	5.3	1:2.5 soil:water ratio; using a pH meter
EC (Specific conductivity)	0.1 millimhos/cm	1:2.5 soil:water ratio; using electrical conductivity bridge

period was 3034.9 mm. The maximum rainfall was received during the month of June 1981. During planting and at harvest, practically there was no rainfall and the temperature was comparatively high. The period of crop establishment (April-May) was also during hot summer. The average monthly rainfall was 121 mm. Pot watering at the rate of 9 litres per plant was done at fortnightly intervals from the first week of planting till three months for the establishment of the crop. The maximum rainfall was received during the pre-shooting period from June to August.

Cultivar

The cultivar selected for study was "Palayankodan" coming under the sub group Poovan with AAB genome. This is a popular cultivar of banana in Kerala being of hardy nature and having average fruit qualities. This is mainly grown as a rainfed crop.

Suckers of uniform size and age (3 months old) were selected and the pseudostem was cut back to a height of 60 cm before planting. By taking five random samples the nutrient content of corm and pseudostem of the suckers were estimated before planting.

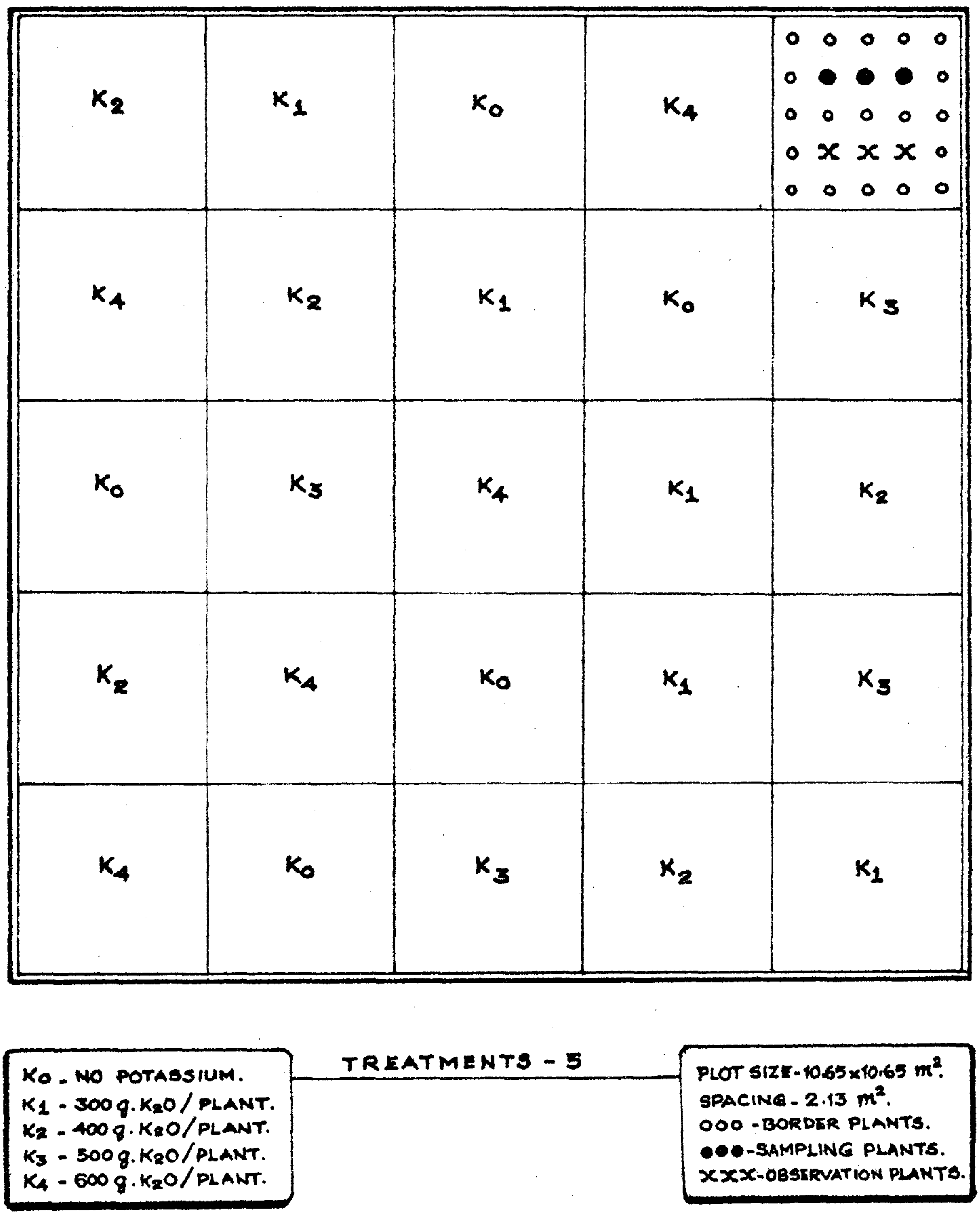
Field preparation

Pits of size 50 cm^3 were dug at a spacing of 2.13 m x 2.13 m, after thorough ploughing and levelling. Suckers were planted on 3rd March 1982. 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 K_2O) was also incorporated into each pit. Twenty five g of thimet granule was also applied in the pits before planting as a prophylatic measure against rhizome weevils and aphids. Uniform cultural operations and crop management were adopted during the cropping period.

Experimental design and layout

The experiment was laid out adopting the randomised block design, with five treatments and five replications. In each plot there were five rows spaced at 2.13 m. Five suckers each were planted at 2.13 m in the row. Thus there were twenty five plants per plot as shown in figure-I. For recording morphological characters three plants were selected as indicated in the

Fig. 1 - LAYOUT PLAN



lay out plan, and three plants for nutrient uptake studies. All remaining plants were kept as border plants. Nutrient uptake studies before fertiliser application was done uprooting five plants at random from among the border plants

Treatments

K_0 - Control

K_1 - Potassium at the rate of 300 g/plant

K_2 - Potassium at the rate of 400 g/plant

K_3 - Potassium at the rate of 500 g/plant

K_4 - Potassium at the rate of 600 g/plant

Potassium was given in the form of muriate of potash (KCl). Nitrogen and phosphorus were applied at the rate of 200 g per plant of N and 200 g per plant P_2O_5 in the form of urea and super phosphate respectively. The doses that were followed earlier were taken as a basis for fixing N and P_2O_5 (Valsamma Mathew, 1980).

All the fertilisers were applied in two equal split doses 90th and 150th day of planting taking advantage of summer and pre-monsoon showers.

Observations

Morphological characters

Observations on various morphological characters were recorded at monthly intervals from 90th day of planting to shooting adopting the method of Yang and Pao (1962).

Plant characters

Height

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

Girth

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

Number of leaves

Fully opened functional leaves present at each observation were counted.

Length of lamina

Lamina length was measured from its base to the tip.

Width of lamina

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

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 0.08).

Duration of the crop

The number of days taken from planting to shooting and from shooting to harvest was recorded. The total number of days from planting to harvest was also computed.

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 the inflorescence one sucker per plant was retained.

Bunch characters

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

Weight of the bunch

Weight of the bunch including the peduncle was recorded.

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.

Number of hands and fingers

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

Average weight of a hand

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

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 (Gyottreich 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.

Girth and length of the finger

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

Studies on nutrient uptake and dry matter production

To assess the nutrient uptake plant samples were collected before fertilizer application (3 months after planting) at the late vegetative phase (5 months after planting) at shooting time and also at harvest. Sampling was done following the method of Twyford and Walmsley (1973). At each stage one plant was uprooted from each treatment replication-wise and separated into different plant parts excluding roots.

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

Sampling of different organs

Period of sampling	Organs sampled
1. Early vegetative phase (Before fertiliser application)	Corm, meristem, pseudostem, petiole, laminae and internal leaf
2. Late vegetative phase	Corm, meristem, pseudostem, laminae, internal leaf
3. Shooting time	Corm, pseudostem, petiole, laminae inflorescence
4. Harvest	Corm, pseudostem, petiole, laminae internal stalk, external stalk fruit and male bud.

Each part was weighed and sampled as given below.

Internal leaf

The whole tissue

Emerged leaves

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

Petioles

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

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.

Meristem

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

Corm

As for meristem

Inflorescence

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

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.

Internal fruit stalk

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

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.

Fingers

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

Chemical analysis

Plant parts

Nitrogen

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

Phosphorus

One gram 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).

Potassium

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

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.

Total soluble solids

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

Acidity

Ten grams 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).

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 Fehlings A and B solutions using methylene blue as indicator. The content of reducing sugar was expressed as percentage.

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.

Non-reducing sugars

This was computed using the values obtained for total and reducing sugars.

Sugar/acid ratio

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

Statistical analysis

The data collected on different plant characters were analysed by applying the technique of analysis of variance for randomised block design.

Variation in levels of K was decomposed into linear and quadratic components and tested for significance (Snedecor and Cochran, 1967). As the quadratic effect was found to be nonsignificant no attempt was made to fit the quadratic response function in order to obtain the optimum level. A linear response function of the form $Y = a+bx$ where Y is the yield and x is the dose of K was fitted to describe the relationship between dose of K tried and responses achieved.

Results

RESULTS

The results are presented under the following heads with appropriate tables and illustrations.

EFFECT OF POTASSIUM ON GROWTH PARAMETERS

Height of pseudostem

Data on the mean height of plants at early vegetative phase, late vegetative phase and at shooting are furnished in Table 2.

The height of the pseudostem at late vegetative phase and at shooting showed significant difference between treatments. At late vegetative phase the plants which received 500 g K_2O showed maximum height, while at shooting, the maximum height was found in plants where 400 g K_2O was applied.

Girth of pseudostem

The different levels of potassium had no significant influence on the girth of the pseudostem at any of the stages of plant growth (Table 3).

Table 2. Effect of potassium on plant height at different stages of growth (cm)

Levels of potassium (g/plant)	Stage of plant growth		
	Early vegetative phase	Late vegetative phase	Shooting
0	65.36	143.06	211.47
300	63.99	149.06	242.50
400	68.21	149.66	245.96
500	64.89	155.06	237.73
600	65.86	154.53	244.13
C.D.(5%)	-	3.48	13.70
SEm ±	-	2.50	4.57

Table 3. Effect of potassium on plant girth at different stages of growth (cm)

Levels of potassium (g/plant)	Stage of plant growth		
	Early vegetative phase	Late vegetative phase	Shooting
0	22.97	44.53	58.14
300	22.93	44.47	61.98
400	23.53	46.00	62.70
500	23.13	44.50	61.86
600	22.84	44.73	61.59
C.D.(5%)	-	N.S.	N.S.
SEm ±	-	1.43	1.80

Number of functional leaves

The total number of functional leaves per plant at various stages of growth under different treatments (vide Table 4) showed that the treatments did not show significant effect on the number of functional leaves. A tendency for higher leaf number with the highest level of K_2O was however noticed.

Total leaf area

The total leaf area as influenced by the treatments in the three stages of growth are presented in Table 5. Leaf area was not significantly affected by the different levels of potassium. But increasing levels of K_2O tended to result in increased leaf area.

Sucker production

The data on sucker production presented in Table 6 showed that there was no significant difference in the number of suckers produced at shooting due to different levels of potassium.

FLOWERING AND FRUIT MATURITY

Table 7 presents data on the number of days from planting to shooting, shooting to harvest and planting to harvest.

Table 4. Effect of potassium on number of functional leaves at different stages of growth

Levels of potassium (g/plant)	Stage of plant growth		
	Early vegetative phase	Late vegetative phase	Shooting
0	5.00	10.47	9.55
300	3.93	10.93	9.59
400	4.01	10.93	9.19
500	4.26	10.97	9.50
600	5.06	11.02	10.00
C.D.(5%)	-	N.S.	N.S.
SEm ±	-	0.25	0.39

Table 5. Effect of potassium on total leaf area at different stages of growth (m^2)

Levels of potassium (g/plant)	Stage of plant growth		
	Early vegetative phase	Late vegetative phase	Shooting
0	0.839	6.914	9.240
300	0.734	7.208	9.820
400	0.802	7.352	9.960
500	0.101	7.780	10.684
600	1.050	7.990	10.822
C.D.(5%)	-	N.S.	N.S.
SEm ±	-	0.499	0.406

Table 6. Effect of potassium on production of suckers at shooting

Levels of potassium (g/plant)	Suckers at shooting
0	3.87
300	4.50
400	3.93
500	4.33
600	5.00
C.D.(5%)	N.S.
SEm ±	0.49

Table 7. Effect of potassium on duration of the crop

Number of days

Levels of potassium (g/plant)	Planting to shooting	Shooting to harvest	Planting to harvest
0	258.46	97.68	358.55
300	245.87	97.86	343.33
400	241.06	95.62	336.68
500	237.37	96.63	333.99
600	235.42	96.57	334.00
C.D. (5%)	13.44	N.S.	14.00
SEm ±	4.49	1.16	4.67

Significant variation was observed between treatments in respect of the number of days taken from planting to shooting. Higher levels of potassium recorded the minimum days for shooting (235.4) compared to control (258.5 days).

However there was no significant difference between treatments with regard to the days taken from shooting to harvest which ranged from 95.6 for 400 g K_2O per plant to 97.7 for control. With increasing levels of potassium, the number of days taken from planting to harvest significantly decreased, control plants recording the maximum duration (358.5 days).

BUNCH CHARACTERS

The data relating to various bunch characters as influenced by different levels of potassium are presented in Table 8.

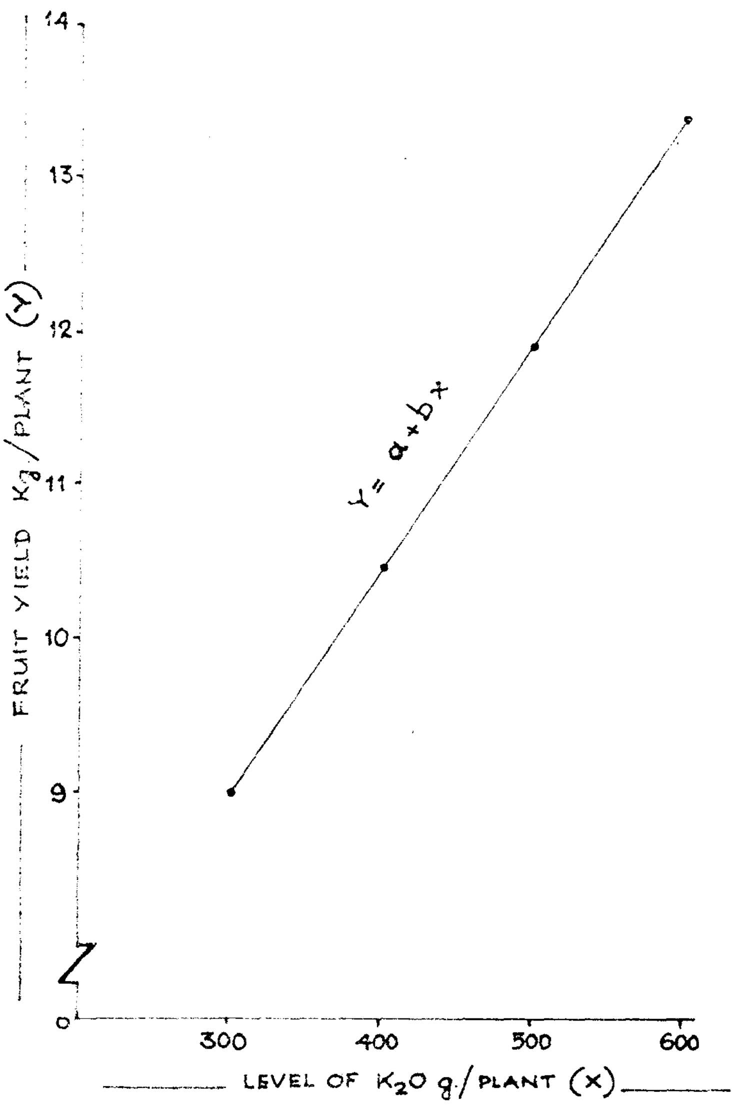
Weight of the bunch

Levels of potassium significantly influenced the weight of the bunch. The highest weight (13.6 kg) was recorded at the highest level of K_2O and the lowest in the control (7.83 kg).

Table 8. Effect of potassium on bunch characters

Levels of potassium (g/plant)	Weight of bunch (kg)	Length of bunch (cm)	Number of hands per bunch	Weight of hand (kg)	Number of fingers	Length of finger (cm)	Girth of finger (cm)	Weight of finger (g)
0	7.83	44.35	10.33	0.804	154.02	13.93	9.67	50.29
300	9.41	49.52	11.91	0.991	189.86	15.32	10.90	59.98
400	11.33	50.01	11.70	1.064	187.93	14.38	10.55	59.73
500	11.57	50.79	12.19	1.119	183.83	14.67	10.98	60.74
600	13.60	53.37	12.74	1.126	202.50	14.40	10.90	60.11
C.D.(5%)	1.02	4.07	0.63	0.084	14.28	N.S.	0.57	4.75
SEm ±	0.34	1.49	0.21	0.028	4.763	0.34	0.19	1.59

Fig. 2 - EFFECT OF LEVELS OF POTASSIUM ON THE YIELD OF BANANA



Length of the bunch

The length of the bunch also varied significantly between different treatments. Higher levels of potassium resulted in increased length of the bunch (53.37 cm) differing significantly from control (43.35 cm).

Number of hands per bunch

The levels of potassium also had a significant effect on the mean number of hands per bunch. There was an increase in the mean number of hands per bunch with increasing levels of potassium, the highest number of hands being recorded at 600 g K_2O per plant (12.74), followed by 500 g K_2O per plant and the lowest in the control (10.33).

Weight of hand

There was significant variation between treatments with respect to mean weight of hand. The three higher levels of potassium namely 400, 500 and 600 g K_2O per plant recorded significantly higher mean weight of hand (1.064, 1.119, 1.126 kg) compared to control (0.804 kg).

Number of fingers

The number of fingers showed significant variation between treatments. The highest level of potassium resulted in the highest number of fingers (202.50 and the least was recorded in control (154.02).

Length of finger

Levels of potassium did not significantly influence the length of the finger. The mean values ranged from 13.93 cm (K_0) to 14.7 cm (K_3).

Girth of finger

Data on the mean girth of finger showed that the effect due to potassium application was significant. The treatments K_1, K_2, K_3 and K_4 were on par and they differed significantly from control. The highest girth of the finger (10.98 cm) was recorded in the treatment K_3 followed by K_4 (10.90 cm).

Weight of finger

Significant difference was observed between treatments with respect to the weight of finger. The highest weight of the finger was recorded in the treatment K_3 (60.74 g) followed by K_4 (60.11 g) and the least in control (50.29 g).

FRUIT CHARACTERS

Data pertaining to physical characteristics of the fruit are furnished in Table 9.

Weight of fruit

The different levels of potassium showed significant differences with regard to weight of the fruit. All the treatments showed significant increase over the control. The highest weight was obtained in K_4 (58.65 g) and the least in control (47.42 g).

Weight of the pulp

Increasing levels of potassium resulted in significant increase in the weight of pulp. Maximum pulp weight of 45.52 g was noticed in 600 g K_2O per plant.

Weight of peel

Levels of potassium significantly influenced peel weight. Treatments K_0, K_1 and K_2 were on par whereas K_3 and K_4 gave significantly higher peel weight.

Pulp/peel ratio

The pulp peel ratios showed significant variation between levels of potassium. K_4, K_3 and K_2 were

Table 9. Effect of potassium on fruit characters

Levels of potassium (g/plant)	Fruit weight (g)	Pulp weight (g)	Peel weight (g)	Pulp/peel ratio
0	47.42	35.02	11.90	2.95
300	50.60	37.53	12.28	3.15
400	55.04	43.15	12.31	3.50
500	56.13	43.34	12.98	3.34
600	58.65	45.52	13.17	3.45
C.D.(5%)	1.81	1.36	0.63	0.07
SEm ±	0.60	0.45	0.21	0.07

on par but these differed significantly from K_1. Control recorded the lowest pulp/peel ratio.

FRUIT QUALITY

The data on fruit quality are presented in Table 10.

Total soluble solids

TSS was significantly influenced by the levels of K. The highest TSS of 29.82 per cent was observed at K_4 followed by K_3 and K_2. There was no significant difference between K_0 and K_1 with regard to TSS.

Reducing sugars

Data on reducing sugar content of the fruits (vide Table 10) showed that the effects due to different levels of potassium were significant. K_2, K_3 and K_4 which were on par showed higher percentages of reducing sugars than the rest of the treatments.

Non reducing sugars

There was no significant difference in non reducing sugars due to different levels of potassium. However, increasing levels of K tended to increase the percentage of non reducing sugars.

Table 10. Effect of potassium on fruit quality

Levels of potassium (g/plant)	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Sugar acid ratio	Total soluble solids (%)
0	0.502	14.85	13.82	1.03	29.54	25.76
300	0.453	15.38	14.25	1.04	33.71	25.58
400	0.427	17.68	16.58	1.16	40.01	27.70
500	0.485	17.95	16.83	1.21	36.92	28.52
600	0.485	19.98	16.68	1.33	37.08	29.82
C.D. (5%)	0.009	0.52	0.35	N.S.	1.99	0.47
SEm ±	0.003	0.17	0.12	0.097	0.66	0.16

Total sugars

There was significant difference between different treatments in the percentage of total sugars. K_4 gave the highest percentage of total sugars (19.98 per cent), K_3 and K_2 were on par (17.95 per cent and 17.68 per cent) and differed significantly from K_1. There was significant difference between K_1 and K_0 (15.38 and 14.85 per cent).

Sugars/acid ratio

Significant differences were observed in sugar/acid ratio between different treatments. K_3 gave the highest ratio (40.00) followed by K_2 and K_4 (37.92 and 37.08) which were on par. Control gave the lowest value (29.54).

Acidity

Acidity of fruits were significantly influenced by levels of potassium. Control showed the highest acidity (0.502 per cent). The lowest acidity was obtained at K_2 (0.427 per cent) followed by K_3 and K_4 which were on par (0.485 per cent each).

DRY MATTER PRODUCTION

The data on total dry matter content at planting and at four different stages of growth viz., early and late vegetative phases, shooting phase and at harvest are furnished in Table 11.

The total dry matter content progressively increased with age of plants (Fig.3 and Fig.4). From planting to early vegetative phase there was on an average an increase of 188.36 per cent. A further increase of 33.29 per cent was noticed between early and late vegetative phases. During the period between late vegetative phase and shooting time a spectacular increase in the production of dry matter i.e. 699.54 per cent was observed. Between shooting and harvest also the dry matter content continued to increase but the rate of increase was very low (27.94 per cent) compared to the previous stages.

In general the increasing levels of potassium increased the total dry matter content. The highest dry matter content at late vegetative phase was obtained in K_4 (497.08 g per plant) followed by K_3 (489.10 g per plant). But at shooting time K_2 recorded

Table 11. Effect of potassium on total dry matter production

Levels of potassium (g/plant)	Stage of sampling				
	Planting	Early vegetative phase	Late vegetative phase	Shooting	Harvest
	(g/plant)				
0	122.70	360.91	477.02	3743.40	4577.96
		(194.13)	(32.17)	(684.76)	(22.29)
300	135.60	364.34	473.36	3928.60	4782.72
		(168.69)	(29.92)	(729.94)	(21.74)
400	125.18	355.21	485.89	3899.60	5008.32
		(183.76)	(36.79)	(702.56)	(28.45)
500	124.35	379.86	489.10	3903.00	5094.58
		(205.48)	(28.76)	(698.00)	(30.53)
600	123.59	358.10	497.08	3888.80	5315.80
		(189.75)	(38.81)	(682.33)	(36.69)

Note: The figures in parantheses indicate the percentage of increase in dry matter production compared to the previous stage.

Fig-3. EFFECT OF POTASSIUM ON TOTAL DRY MATTER PRODUCTION

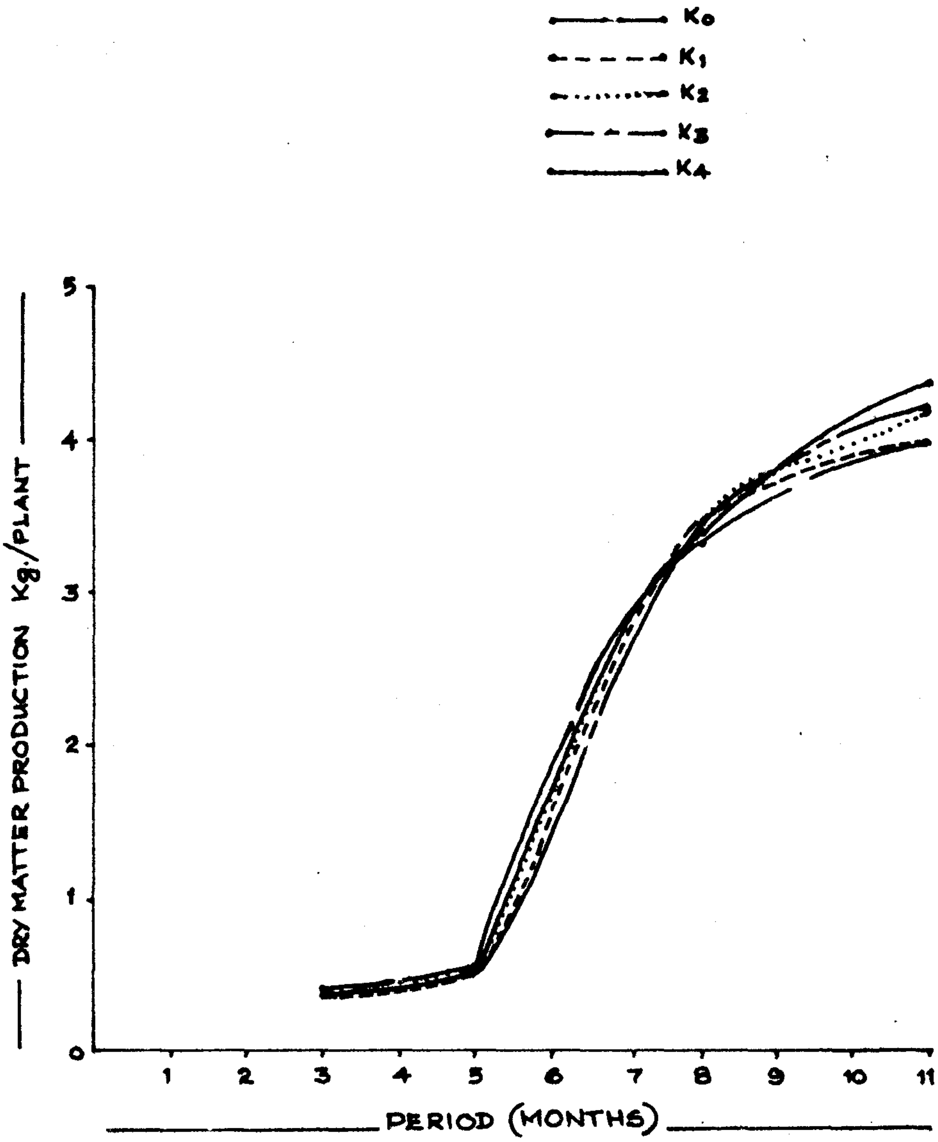
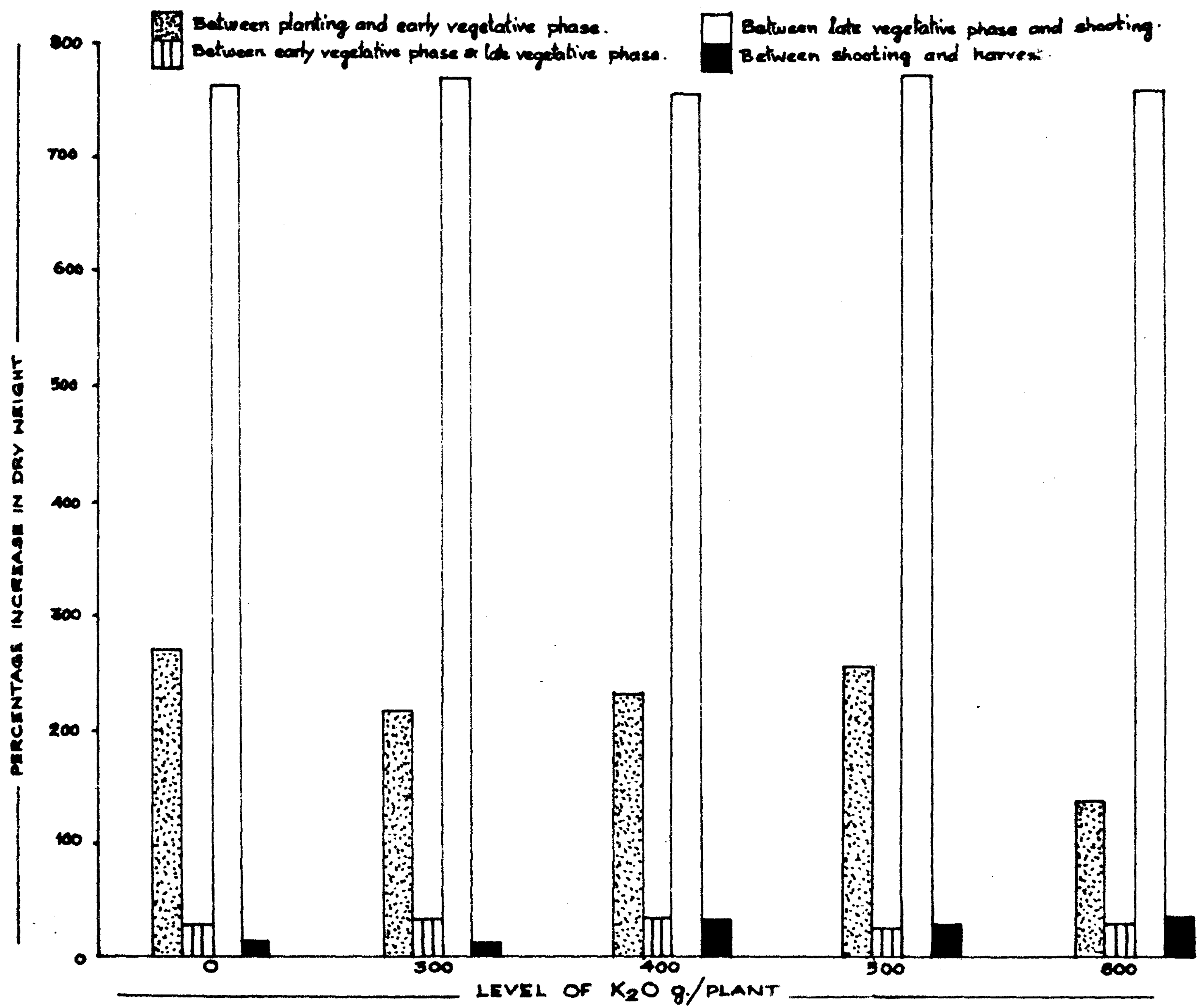


Fig. 4. EFFECT OF POTASSIUM ON THE PERCENTAGE INCREASE IN DRY MATTER PRODUCTION BETWEEN DIFFERENT STAGES OF GROWTH.



the maximum dry weight which was 3928.6 g per plant, when there was an increase of 729.94 per cent in production of dry matter compared to the previous stage viz., late vegetative phase. At harvest however, K_4 recorded the highest dry matter content (5315.8 per plant) as well as the highest per cent of increase over the shooting phase which was 36.69 per cent. Both at shooting and at harvest the lowest weight of dry matter was obtained in the case of control.

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

The dry matter content of various organs as influenced by various levels of potassium are given in Table 12 and their mean values summarised in Table 13.

At planting dry matter accumulation was maximum in corm (88.56 g per plant), compared to pseudostem (36.60 g per plant) and meristem (0.864 g per plant). At early and late vegetative phases as well as at shooting dry matter accumulation was concentrated in the lamina. In the early vegetative phase 42.19 per cent of the total dry weight was contributed by the lamina. In the late vegetative phase and at shooting the share of lamina in the total dry matter content of the plant

Table 12. Effect of potassium on the dry matter content at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meristem	Pseudostem	Petiole	Laminae
			(g/plant)			
0	Planting	88.5	0.7	33.5	-	-
	Early vegetative phase	116.5	1.2	58.9	15.3	164.5
	Late vegetative phase	138.2	2.2	125.0	20.8	184.4
	Shooting	628.0	-	1306.0	153.0	1359.2
	Harvest	252.6	-	833.8	113.2	1001.3
300	Planting	92.3	0.8	42.5	-	-
	Early vegetative phase	114.5	1.4	76.3	14.4	153.5
	Late vegetative phase	139.5	2.1	121.0	20.6	1427.2
	Shooting	675.6	-	1355.2	155.8	1427.2
	Harvest	271.0	-	829.0	113.2	1013.4
400	Planting	85.9	1.0	38.3	-	-
	Early vegetative phase	108.9	1.3	78.5	13.7	148.3
	Late vegetative phase	137.5	2.3	123.0	21.2	195.6
	Shooting	690.6	-	1352.0	155.4	1377.6
	Harvest	304.8	-	845.8	109.8	1156.0
500	Planting	86.8	1.1	36.5	-	-
	Early vegetative phase	123.7	1.4	79.5	14.1	157.2
	Late vegetative phase	142.4	2.6	123.0	21.0	193.9
	Shooting	705.4	-	1355.8	155.0	1373.8
	Harvest	332.8	-	862.2	109.6	1239.4
600	Planting	89.3	0.8	33.5	-	-
	Early vegetative phase	116.5	1.4	80.2	12.5	143.5
	Late vegetative phase	140.2	2.2	131.2	20.6	16.6
	Shooting	698.8	-	1340.6	155.0	1373.0
	Harvest	348.0	-	859.2	112.0	1303.0

continued

Table 12. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Internal leaf	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
		(g/plant)					
0	Planting	-	-	-	-	-	-
	Early vegetative phase	[illegible]	-	-	-	-	-
	Late vegetative phase	6.4	-	-	-	-	-
	Shooting	-	297.2	-	-	-	-
	Harvest	-	-	195.0	121.4	1999.8	60.8
300	Planting	-	-	-	-	-	-
	Early vegetative phase	4.3	-	-	-	-	-
	Late vegetative phase	6.1	-	-	-	-	-
	Shooting	-	314.8	-	-	-	-
	Harvest	-	-	200.4	123.8	2169.2	62.7
400	Planting	-	-	-	-	-	-
	Early vegetative phase	4.6	-	-	-	-	-
	Late vegetative phase	6.3	-	-	-	-	-
	Shooting	-	324.0	-	-	-	-
	Harvest	-	-	199.6	122.0	2208.2	62.11
500	Planting	-	-	-	-	-	-
	Early vegetative phase	4.0	-	-	-	-	-
	Late vegetative phase	6.2	-	-	-	-	-
	Shooting	-	313.0	-	-	-	-
	Harvest	-	-	198.8	122.4	2168.0	62.4
600	Planting	-	-	-	-	-	-
	Early vegetative phase	4.0	-	-	-	-	-
	Late vegetative phase	6.3	-	-	-	-	-
	Shooting	-	321.4	-	-	-	-
	Harvest	-	-	205.8	122.8	2303.8	61.2

Table 13. Effect of potassium on dry matter content at different stages of growth/summary

Levels of potassium (g/plant)	Dry matter content (g/plant)					
	Corm	Meri-stem	Pseudo-stem	Petiole	Laminae	Internal leaf
0	244.75	1.35	471.44	60.46	541.89	5.50
300	258.57	1.44	484.80	60.79	555.64	5.20
400	265.57	1.53	487.52	60.00	575.50	5.44
500	278.22	1.71	491.40	59.93	592.86	5.08
600	278.55	1.45	488.94	60.02	603.22	5.18
Stage of sampling						
Planting	88.56	0.86	36.60	-	-	-
Early vegetative phase	116.02	1.39	74.68	13.98	153.40	4.28
Late vegetative phase	139.54	2.29	124.64	20.82	190.92	6.28
Shooting	679.68	-	1341.92	154.84	1382.16	-
Harvest	301.84	-	846.00	111.56	1142.64	-

(Contd.)

Table 13. (Contd.)

Levels of potassium (g/plant)	Dry matter content (g/plant)				
	Infloresc-cence	Internal stalk	External stalk	Fruit	Male bud
0	297.20	195.00	121.40	1999.80	60.82
300	314.80	200.40	123.80	2169.20	62.68
400	324.00	199.60	122.00	2208.20	62.12
500	313.00	198.80	122.40	2168.06	61.38
600	321.40	205.80	122.80	2303.80	61.20
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	314.08	-	-	-	-
Harvest	-	199.92	122.48	2169.80	61.64

was 39.41 per cent and 35.69 per cent respectively. It was seen that 31.89 per cent of the total dry weight in the early vegetative phase and 28.80 per cent in the late vegetative phase was found to be concentrated in the corm. Pseudostem had 10.07 per cent of the total dry matter content at the early vegetative phase and this increased to 15.41 per cent in the late vegetative phase. The dry weight of pseudostem continued to increase and at shooting time 34.65 per cent of the total dry weight was contributed by this organ. At this stage only 17.55 per cent of the total weight was due to corm. Inflorescence was responsible for 8.12 per cent of the total dry weight.

At harvest 43.78 per cent of dry matter content was contributed by the fruits. The mean dry weight of fruits was 2169.8 g per plant. Vegetative parts showed a declining trend in the production of dry matter at harvest. The dry weight of lamina continued to increase with age until the time of shooting but recorded a drop in it from 1382.16 g per plant at shooting time to 1142.64 g per plant at harvest i.e. a decrease of 17.32 per cent. Only 23.05 per cent of the total dry weight at harvest was due to lamina.

Potassium had a positive influence in dry matter accumulation. With increasing doses of potassium the content of dry matter also increased in most of the plant organs. In the case of corm K_4 recorded the highest dry matter content (278.55 g per plant) and control the lowest (244.75 g per plant) the percentage of increase being 13.81. The same pattern was exhibited by pseudostem also with K_4 giving the highest dry weight which was 4.23 per cent higher than that of the control which gave the lowest value. The dry weight of lamina also was highest at K_4 being 11.31 per cent more than that of control. The highest dry weight of fruit was observed at K_4 2303.8 g per plant and the lowest in control 1999.8 g per plant. The increase was 15.2 per cent.

But certain organs like meristem, petiole and internal leaf did not show consistent increase in dry weight with increased levels of potassium. The dry weight of meristem continued to increase from K_0 to K_3 and declined thereafter. The dry weight at K_3 was 1.71 g per plant. K_2 recorded the highest dry weight (60.79 per cent) in the case of petiole. With respect to internal leaf there was no definite pattern of relationship between levels of potassium and the dry matter content.

NUTRIENT UPTAKE

DISTRIBUTION OF NITROGEN

Nitrogen percentage

The data presented in Table 14 represent the percentage distribution of nitrogen in various organs as influenced by levels of potassium and periods of growth. The summary is given in Table 15.

At the time of planting meristem had the highest percentage of nitrogen (1.73 per cent). In the early vegetative phase internal leaf (2.09 per cent) and lamina (1.85 per cent) were rich in nitrogen. Petiole had the lowest percentage of nitrogen (0.99 per cent). At the late vegetative phase lamina meristem and internal leaf had 2.18, 2.17 and 2.14 per cent of nitrogen respectively. In all these organs the percentage of nitrogen increased during the interval between early and late vegetative phase. In petiole also there was an increase in the percentage of nitrogen though it still recorded the lowest value compared to the other plant organs (1.22 per cent). At the time of shooting there was a significant reduction in the percentage of nitrogen in lamina (2.00 per cent), corm (1.2 per cent). Pseudostem

Table 14. Effect of potassium on the nitrogen content at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meristem	Pseudostem	Petiole	Laminae
		(% N on moisture free basis)				
0	Planting	1.05	1.56	1.08	-	-
	Early vegetative phase	1.18	1.61	1.08	1.07	1.98
	Late vegetative phase	1.40	2.19	1.21	1.24	-
	Shooting	1.25	-	1.13	1.12	2.00
	Harvest	1.10	-	0.62	1.05	1.38
300	Planting	1.28	1.97	1.02	-	-
	Early vegetative phase	1.17	1.71	0.97	0.97	1.86
	Late vegetative phase	1.39	2.10	1.23	1.24	-
	Shooting	1.31	-	1.17	1.19	2.01
	Harvest	1.13	-	0.59	1.05	1.41
400	Planting	1.16	1.68	0.87	-	-
	Early vegetative phase	1.21	1.82	0.88	1.13	1.58
	Late vegetative phase	1.39	2.21	1.19	1.22	2.19
	Shooting	1.29	-	1.19	1.14	2.04
	Harvest	1.12	-	0.60	1.09	1.39
500	Planting	1.18	1.69	1.05	-	-
	Early vegetative phase	1.17	1.71	1.07	0.89	1.96
	Late vegetative phase	1.43	2.19	1.19	1.20	2.16
	Shooting	1.28	1.19	1.20	2.16	2.15
	Harvest	1.08	-	0.59	1.04	1.39
600	Planting	1.17	1.73	0.93	-	-
	Early vegetative phase	1.23	1.83	1.02	0.92	1.87
	Late vegetative phase	1.39	2.14	1.22	1.19	2.17
	Shooting	1.25	-	1.20	1.14	2.00
	Harvest	1.10	-	0.59	1.07	1.40

(Continued)

Table 14. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Internal leaf	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
		(% N on moisture free basis)					
0	Planting	-	-	-	-	-	-
	Early vegetative phase	1.98	-	-	-	-	-
	Late vegetative phase	2.15	-	-	-	-	-
	Shooting	-	1.67	-	-	-	-
	Harvest	-	-	1.24	1.34	0.80	1.64
300	Planting	-	-	-	-	-	-
	Early vegetative phase	2.08	-	-	-	-	-
	Late vegetative phase	2.15	-	-	-	-	-
	Shooting	-	1.69	-	-	-	-
	Harvest	-	-	1.21	1.31	0.80	1.61
400	Planting	-	-	-	-	-	-
	Early vegetative phase	2.17	-	-	-	-	-
	Late vegetative phase	2.15	-	-	-	-	-
	Shooting	-	1.70	-	-	-	-
	Harvest	-	-	1.23	1.23	0.82	1.64
500	Planting	-	-	-	-	-	-
	Early vegetative phase	2.12	-	-	-	-	-
	Late vegetative phase	2.15	-	-	-	-	-
	Shooting	-	1.74	-	-	-	-
	Harvest	-	-	1.23	1.26	0.82	1.62
600	Planting	-	-	-	-	-	-
	Early vegetative phase	2.14	-	-	-	-	-
	Late vegetative phase	2.09	-	-	-	-	-
	Shooting	-	1.71	-	-	-	-
	Harvest	-	-	1.17	1.35	0.82	1.63

Table 15. Effect of potassium on the nitrogen content at different stages of growth - Summary.

Leaves of potassium (g/plant)	Corm	Meri-stem	Pseudo-stem	Peti-ole	Lami-nae	Inter-nal leaf	Info-rescence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
	(% N on moisture free basis)										
0	1.22	1.89	0.99	1.10	1.85	2.13	1.68	1.24	1.34	0.80	1.64
300	1.24	1.85	0.99	1.12	1.86	2.12	1.69	1.21	1.31	0.80	1.61
400	1.24	1.89	0.99	1.11	1.87	2.13	1.70	1.23	1.30	0.82	1.64
500	1.23	1.89	0.99	1.11	1.85	2.12	1.75	1.23	1.26	0.82	1.62
600	1.22	1.87	1.00	1.10	1.86	2.10	1.71	1.17	1.36	0.82	1.63
C.D.(5%)	-	-	-	-	-	-	-	-	0.05	-	-
SEm ±	0.05	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.01	0.45
Stage of sampling											
Planting	1.17	1.13	0.99	-	-	-	-	-	-	-	-
Early vegetative phase	1.19	1.74	1.00	0.99	1.85	2.09	-	-	-	-	-
Late vegetative phase	1.40	2.17	1.20	1.22	2.18	2.14	-	-	-	-	-
Shooting	1.28	-	1.18	1.15	2.00	-	1.71	-	-	-	-
Harvest	1.10	-	0.60	1.06	1.39	-	-	1.21	1.31	0.81	1.63
C.D.(5%)	-	-	0.09	-	0.13	-	-	-	-	-	-
SEm ±	-	-	0.03	0.02	0.04	-	-	-	-	-	-

(1.18 per cent) and petiole (1.15 per cent). The inflorescence contained 1.71 per cent of nitrogen.

In lamina and pseudostem the percentage of nitrogen declined to 1.39 per cent and 0.6 per cent respectively. At this stage male bud had the highest percentage of nitrogen (1.63 per cent). The nitrogen in external stalk and internal stalk were 1.31 and 1.21 per cent respectively. Fruits had 0.81 per cent nitrogen.

The different levels of potassium had no significant effect on the N content of any of the plant organs studied.

Total uptake of nitrogen

Table 16 gives data on the total uptake of nitrogen at four different stages of growth (early and late vegetative phases, shooting phase and at harvest).

The uptake of nitrogen increased progressively with the growth of the plant till the shooting time. Between shooting and harvest there was a decline (Fig.5 and Fig.6). On an average 2.11 g of N was taken up by the plant, at the early vegetative phase. The total uptake of nitrogen at the late vegetative phase was 8.12 g per plant. Between the two stages there was an

Table 16. Effect of potassium on total uptake of nitrogen

Levels of potassium (g/plant)	Stage of sampling			
	Early vegetative phase	Late vegetative phase	Shooting	Harvest
	(g/plant)			
0	2.14	7.89 (268)	57.80 (633)	43.92
300	2.10	7.89 (275)	60.8 (671)	45.87
400	2.02	8.11 (300)	60.7 (641)	48.48
500	2.32	8.18 (252)	57.56 (604)	49.96
600	2.28	8.52 (274)	59.06 (593)	52.20
C.D.	-	-	-	-
SEm ±	-	0.25	1.55	0.81

Note: The figures in parantheses indicate the percentage of increase in total uptake of nitrogen compared to the previous stage.

Fig-5 EFFECT OF POTASSIUM ON TOTAL UPTAKE OF NITROGEN

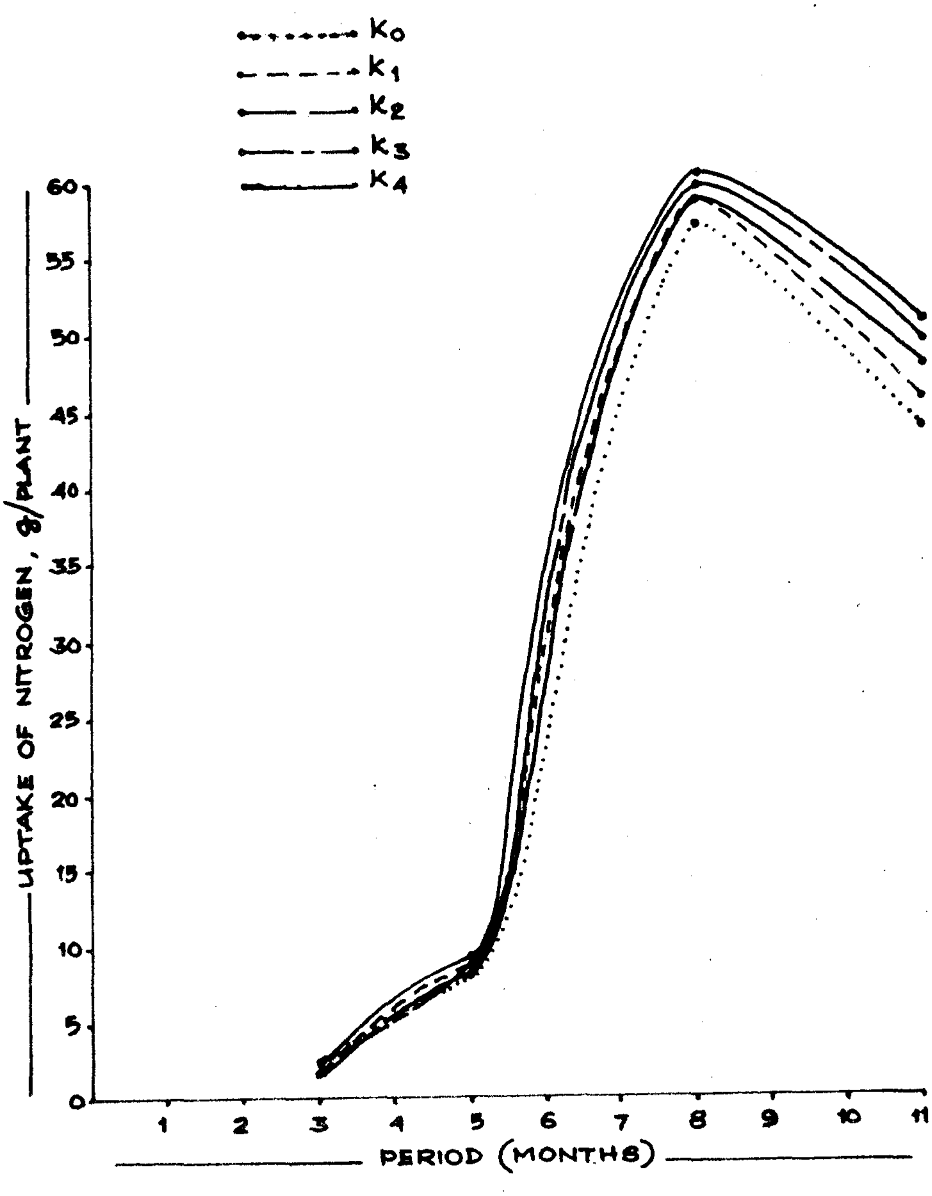
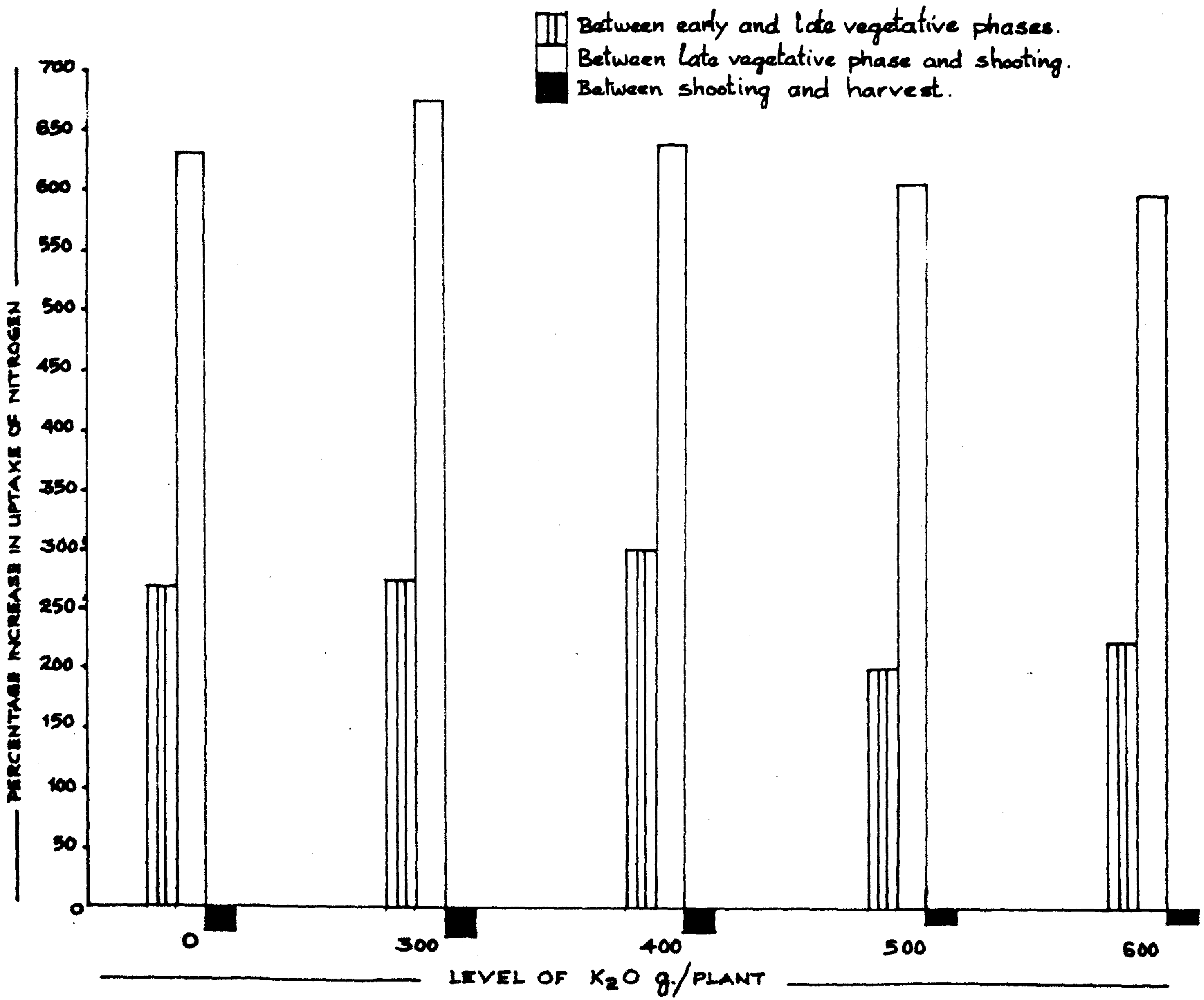


Fig. 6 - EFFECT OF POTASSIUM ON THE PERCENTAGE INCREASE IN THE UPTAKE OF NITROGEN BETWEEN DIFFERENT STAGES OF GROWTH



increase of 273.8 per cent. The total uptake of N rose to 59.06 g per plant at the shooting time, the percentage of increase being as high as 628.4 per cent. At harvest a decrease in the total uptake was observed (48.06 g per plant).

Levels of potassium had no significant influence on the total uptake of nitrogen as can be seen from the data presented in Table 16. At late vegetative phase and at harvest higher levels of K tended to result in higher uptake. Such a tendency was not noticed at the time of shooting. The highest uptake 8.52 g per plant observed at the late vegetative phase was in K_4. However, at the time of shooting K_2 recorded the highest uptake (60.8 g per plant). At harvest K_4 with 52.2 g N per plant had the highest uptake of potassium. In all the three stages control recorded the lowest uptake.

Nitrogen uptake in different organs

The data on the nitrogen uptake in various organs as affected by different levels of potassium and periods of growth are furnished in Table 17 and their summary in Table 18.

Table 17. Effect of potassium on the nitrogen uptake at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meristem	Pseudostem (g/plant)	Petiole	Laminae	Internal leaf
0	Early vegetative phase	1.49	0.019	6.46	0.16	3.25	0.09
	Late vegetative phase	1.93	0.048	1.51	0.26	4.03	0.14
	Shooting	8.18	-	14.73	1.71	27.14	-
	Harvest	2.72	-	5.18	1.18	13.82	-
300	Early vegetative phase	1.34	0.024	0.74	0.12	2.86	0.08
	Late vegetative phase	1.94	0.044	1.48	0.25	4.02	0.13
	Shooting	8.87	-	15.81	1.84	26.69	-
	Harvest	3.05	-	4.94	1.20	14.26	-
400	Early vegetative phase	1.31	0.023	0.69	0.15	2.34	0.10
	Late vegetative phase	1.99	0.051	1.46	0.26	4.27	0.14
	Shooting	8.95	-	14.89	1.77	26.08	-
	Harvest	3.41	-	5.04	1.19	15.84	-
500	Early vegetative phase	1.45	0.024	0.84	0.13	3.08	0.08
	Late vegetative phase	2.05	0.058	1.53	0.25	4.19	0.13
	Shooting	9.02	-	16.12	1.80	27.27	-
	Harvest	3.56	-	5.08	1.19	17.27	-
600	Early vegetative phase	1.43	0.025	0.81	0.12	2.68	0.09
	Late vegetative phase	1.75	0.049	1.58	0.25	4.36	0.13
	Shooting	8.74	-	16.05	1.78	27.52	-
	Harvest	3.83	-	5.06	1.20	18.24	-

(Continued)

Table 17. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Inflore-scence	Internal stalk (g/plant)	External stalk	Fruit	Male bud
0	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	4.98	-	-	-	-
	Harvest	-	2.41	1.62	15.98	0.99
300	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	5.33	-	-	-	-
	Harvest	-	2.41	1.62	17.38	1.00
400	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	5.45	-	-	-	-
	Harvest	-	2.45	1.59	17.84	1.00
500	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	5.58	-	-	-	-
	Harvest	-	2.45	1.55	18.06	0.99
600	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	5.31	-	-	-	-
	Harvest	-	2.41	1.67	18.85	0.99

Table 18. Effect of potassium on nitrogen uptake at different stages of growth - Summary

Levels of potassium (g/plant)	Corm	Meristem	Pseudo-stem (g/plant)	Petiole	Laminae	Internal leaf
0	3.06	0.029	4.50	0.79	12.17	0.115
300	3.26	0.027	4.66	0.80	11.96	0.111
400	3.34	0.029	4.50	0.84	12.26	0.113
500	3.42	0.033	4.78	0.83	12.91	0.111
600	3.38	0.029	4.81	0.84	13.24	0.111
C.D. (5%)	0.16	0.003	-	-	-	-
SEm ±	0.17	0.052	0.12	0.03	0.38	0.13
Stage of sampling						
Planting	-	-	-	-	-	-
Early vegetative phase	1.51	0.02	0.74	0.14	2.84	0.08
Late vegetative phase	1.85	0.049	0.15	0.25	4.18	0.13
Shooting	8.76	-	16.52	1.78	26.94	-
Harvest	3.32	-	5.03	1.18	15.85	-
C.D. (5%)	0.38	-	0.84	0.04	1.32	-
SEm ±	0.13	-	0.28	0.09	0.42	-

(Continued)

Table 18 (Contd.)

Levels of potassium (g/plant)	Infloresecence	Internal stalk	External stalk (g/plant)	Fruit	Male bud
0	4.99	2.41	1.62	15.99	0.99
300	5.33	2.42	1.62	17.38	1.00
400	5.45	2.45	1.59	17.84	1.00
500	5.59	2.45	1.55	18.06	0.99
600	5.33	2.41	1.67	18.85	0.99
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	5.34	-	-	-	-
Harvest	-	2.43	1.61	17.62	0.99
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-

With respect to the period of growth the nitrogen uptake of organs increased with the age of the plant upto shooting time, after which there was a decline. At the early vegetative phase the highest uptake of nitrogen was noticed in the lamina (2.84 g per plant) followed by corm (1.51 g per plant). At late vegetative phase the lamina contained 4.18 g per plant which increased to 26.94 g per plant at shooting. Corm recorded an uptake of 1.85 g per plant in the late vegetative phase and 8.76 g per plant at the time of shooting. In corm, pseudostem,petiole and lamina there was significant increase in the uptake of nitrogen between early and late vegetative phases as well as between late vegetative phase and shooting. At harvest highest uptake was observed in fruits i.e., 17.62 g per plant which was 36.68 per cent of the total uptake. At this stage lamina recorded an uptake 15.85 g per plant (33 per cent of the total uptake).

Levels of potassium had significant effect on the uptake of nitrogen by some plant organs. In corm increasing levels of potassium increased the uptake of nitrogen upto 500 kg K_2O per plant. The highest uptake was at K_3 3.42 g per plant compared to

3.06 g per plant in control. In meristem also the uptake of nitrogen was maximum at K_3 (0.033 g per plant). In pseudostem, petiole and lamina the uptake was not significantly influenced by the level of potassium. In the case of inflorescence and internal stalk the uptake was highest at K_3 (5.59 g per plant and 2.45 g per plant respectively). In fruit as the levels of potassium increased the uptake of nitrogen also increased, the highest being at K_4 (18.85 g per plant) and lowest at K_0 (15.99 g per plant). Of the various organs sampled fruits had the highest uptake of nitrogen.

DISTRIBUTION OF PHOSPHORUS

Phosphorus percentage

Results of the study on the effect of different levels of potassium and periods of growth on the percentage of phosphorus in various organs are presented in Table 19 and their summary in Table 20.

At the time of planting pseudostem had the highest content of phosphorus (0.17 per cent). At the early vegetative phase and also at late vegetative phase

Table 19. Effect of potassium on the phosphorus content at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meri- stem	Pseudo- stem	Petiole	Lami- nae	Inter- nal leaf
		(% P on moisture free basis)					
0	Planting	0.05	0.07	0.17	-	-	-
	Early vegetative phase	0.06	0.09	0.19	0.10	0.15	0.29
	Late vegetative phase	0.09	0.32	0.21	0.13	0.19	0.38
	Shooting	0.09	-	0.13	0.10	0.14	-
	Harvest	0.05	-	0.07	0.05	0.12	-
300	Planting	0.05	0.05	0.19	-	-	-
	Early vegetative phase	0.05	0.06	0.20	0.10	0.08	0.27
	Late vegetative phase	0.12	0.33	0.27	0.14	0.23	0.40
	Shooting	0.10	-	0.15	0.09	0.17	-
	Harvest	0.07	-	0.08	0.06	0.15	-
400	Planting	0.06	0.08	0.20	-	-	-
	Early vegetative phase	0.07	0.05	0.20	0.12	0.12	0.27
	Late vegetative phase	0.13	0.34	0.22	0.15	0.21	0.48
	Shooting	0.11	-	1.48	0.10	0.15	-
	Harvest	0.09	-	0.09	0.07	0.16	-
500	Planting	0.08	0.09	0.15	-	-	-
	Early vegetative phase	0.04	0.06	0.17	0.11	0.13	0.28
	Late vegetative phase	0.14	0.35	0.23	0.16	0.23	0.51
	Shooting	0.12	-	0.15	0.16	0.17	-
	Harvest	0.10	-	0.10	0.07	0.15	-
600	Planting	0.04	0.05	0.14	-	-	-
	Early vegetative phase	0.05	0.05	0.18	0.12	0.09	0.28
	Late vegetative phase	0.16	0.33	0.22	0.18	0.22	0.57
	Shooting	0.13	-	0.15	0.10	0.18	-
	Harvest	0.11	-	0.09	0.08	0.17	-

(Continued)

Table 19. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Inflo-rescence	Inter-nal stalk	External stalk	Fruit	Male bud
		(% P on moisture free basis)				
0	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.31	-	-	-	-
	Harvest	-	0.17	0.17	0.14	0.31
300	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.35	-	-	-	-
	Harvest	-	0.18	0.18	0.15	0.30
400	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.38	-	-	-	-
	Harvest	-	0.19	0.18	0.16	0.31
500	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.40	-	-	-	-
	Harvest	-	1.20	0.19	0.16	0.33
600	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.41	-	-	-	-
	Harvest	-	0.20	0.22	0.16	0.33

Table 20. Effect of potassium on the phosphorus content at different stages of growth - Summary

Level of potassium (g/plant)	Corm	Meristem	Pseudo-stem	Petiole	Laminae	Internal leaf
	(% P	on moisture free basis)				
0	0.065	0.150	0.150	0.092	0.142	0.327
300	0.077	0.150	0.160	0.100	0.166	0.337
400	0.088	0.160	0.160	0.105	0.158	0.382
500	0.093	0.160	0.170	0.109	0.167	0.392
600	0.101	0.160	0.160	0.113	0.171	0.426
C.D. (5%)	0.009	-	-	0.001	0.016	0.018
SEm ±	0.003	0.005	0.005	0.004	0.017	0.006
Stage of sampling						
Planting	0.056	0.070	0.170	-	-	-
Early vegetative phase	0.094	0.060	0.188	0.100	0.114	0.280
Late vegetative phase	0.123	0.330	0.216	0.152	0.163	0.470
Shooting	0.117	-	0.148	0.093	0.412	-
Harvest	0.082	-	0.100	0.069	0.150	-
C.D. (5%)	0.016	-	0.240	0.013	0.023	-
SEm ±	0.005	-	0.008	0.004	0.008	-

(Continued)

Table 20. (Contd.)

Levels of potassium (g/plant)	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
	(% P on moisture free basis)				
0	0.308	0.174	0.170	0.138	0.308
300	0.353	0.176	0.176	0.152	0.298
400	0.379	0.178	0.178	0.158	0.310
500	0.396	0.198	0.198	0.164	0.326
600	0.412	0.196	0.216	0.156	0.332
C.D. (5%)	0.004	-	-	-	-
SEm ±	0.014	-	-	-	-
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	0.370	-	-	-	-
Harvest	-	0.190	0.190	0.150	0.310
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-

the percentage of phosphorus was highest in internal leaf (0.28 per cent and 0.47 per cent respectively). At both these stages next to internal leaf pseudostem had the highest content of phosphorus (0.19 per cent and 0.22 per cent respectively). Lamina had the highest content of phosphorus at the time of shooting (0.41 per cent), followed by inflorescence (0.37 per cent). When the plants were in the stage of harvest the highest percentage of phosphorus was recorded in male bud (0.31 per cent), while fruits had only 0.15 per cent phosphorus. When the different stages of growth are considered, the content of phosphorus increased upto the late vegetative phase and decreased thereafter in organs like corm, pseudostem and petiole. Lamina, internal leaf and meristem showed an increase in the percentage of phosphorus till the time of shooting but between shooting and harvest there was a significant decline.

The levels of potassium had a significant effect on the content of phosphorus in corm, petiole, lamina, internal leaf and inflorescence. In these organs as the level of potassium increased the percentage of phosphorus also increased. In corm the increase was significant between all levels of K; K_4 recording the highest percentage of phosphorus (0.1 per cent). The highest content of phosphorus noted in lamina was at K_4 viz., 0.17 per cent. Of all the organs sampled internal leaf and inflorescence were the richest in phosphorus content, the highest values recorded being 0.43 per cent and 0.41 per cent respectively both at K_4.

Total uptake of phosphorus

Observations on total uptake of phosphorus are furnished in Table 21.

As the plants advanced in age the uptake of phosphorus also increased (Fig.7 and Fig.8). At the early vegetative phase plants absorbed on an average 0.42 g of phosphorus. An increase of 137.57 per cent was noticed in the total uptake of phosphorus between the early and late vegetative phase, the total uptake at the latter phase being 0.981 g per plant. At the time of shooting the total uptake rose to 6.75 g per plant. The percentage of increase in the total uptake observed between the late vegetative phase and shooting time was 593.61 per cent. During the interval between shooting and harvest there was no marked increase in the total uptake. The total uptake of phosphorus at the stage of harvest was 7.00 g per plant, thereby showing an increase of 3.7 per cent over the previous stage.

Table 21. Effect of potassium on the total uptake of phosphorus

Levels of potassium (g/plant)	Stages of sampling			
	Early vegetative phase	Late vegetative phase	Shooting	Harvest
	(g/plant)			
0	0.48	0.81 (70.31)	5.97 (637.94)	5.73
300	0.37	0.94 (153.65)	6.57 (602.99)	6.55
400	0.45	0.95 (110.59)	6.82 (614.88)	7.18
500	0.46	0.01 (117.67)	7.20 (612.87)	7.63
600	0.36	1.20 (225.57)	7.18 (499.30)	7.92
C.D. (5%)	-	0.14	0.64	0.79
SEm ±	-	0.14	0.22	8.30

Note: The figures in parantheses indicate the percentage of increase in the total uptake of phosphorus compared to the previous stage.

Fig-7 EFFECT OF POTASSIUM ON TOTAL UPTAKE OF PHOSPHORUS

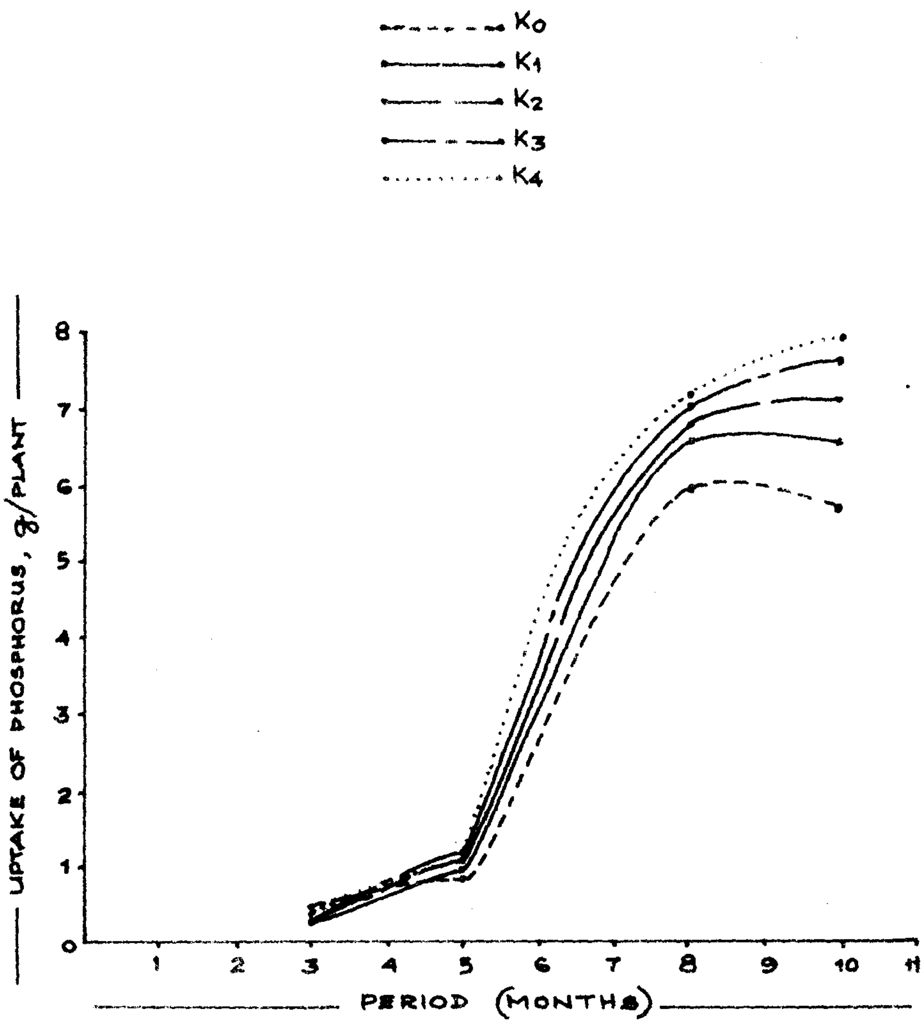
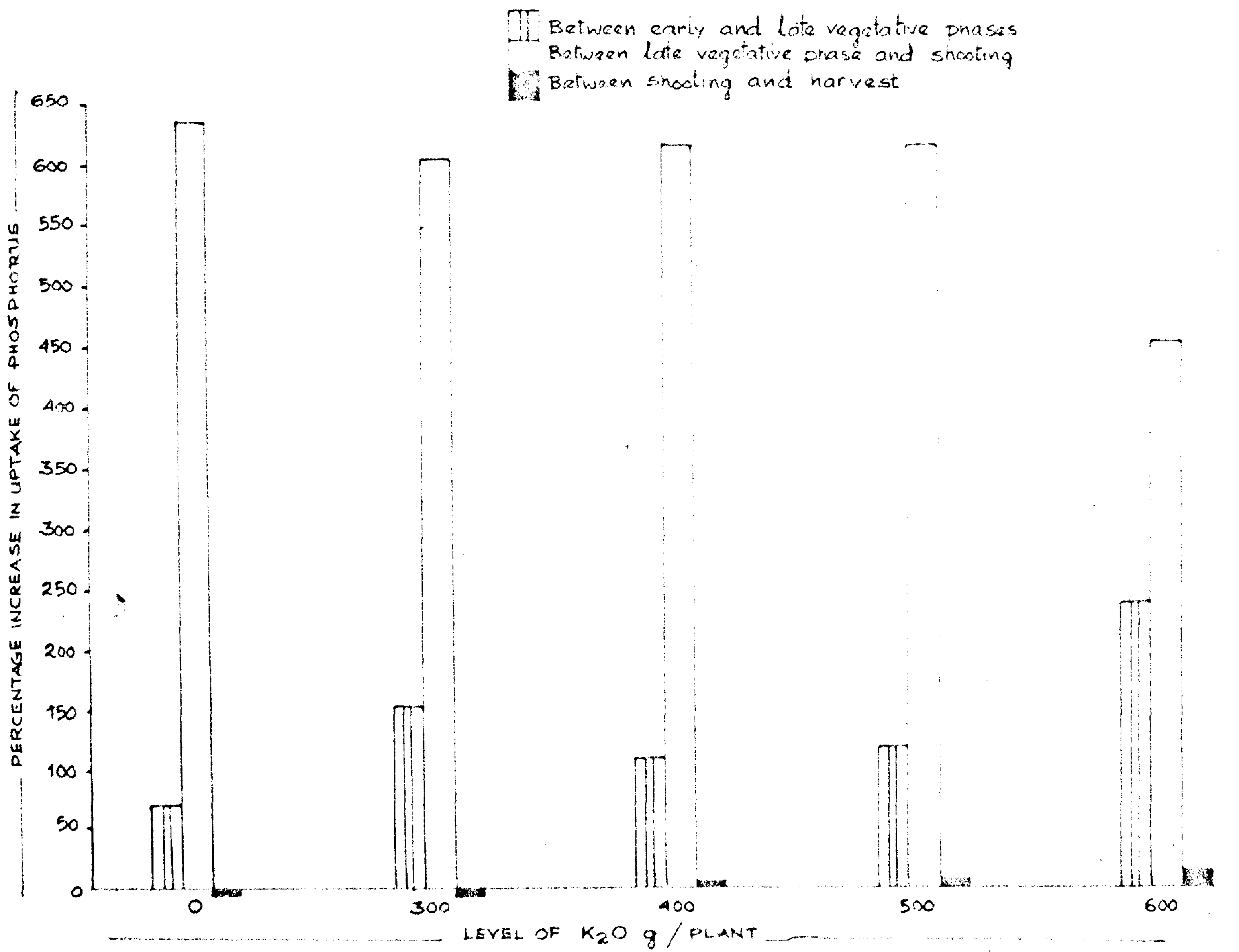


Fig. 8 - EFFECT OF POTASSIUM ON THE PERCENTAGE INCREASE IN THE UPTAKE OF PHOSPHORUS BETWEEN DIFFERENT STAGES OF GROWTH



Levels of potassium had significant influence on the uptake of phosphorus at late vegetative phase, shooting and harvest. At the late vegetative phase the highest value was obtained at K_4 (1.198 g per plant) which was 48.08 per cent more than that of control (0.809 g per plant). When the plants were at shooting, significant difference in the uptake of phosphorus was noticed between control and treatments from K_2 onwards. The highest uptake was noticed at K_3 (7.2 g per plant) which was 20.6 per cent more than that of control (5.97 g per plant). At the time of harvest there was significant difference in total uptake between control and treatments as well as between the treatments. The highest uptake was recorded in plants receiving 600 g K_2O per plant (7.92 g per plant). There was an increase of 38.22 per cent over that of control (5.73 g per plant).

Phosphorus uptake in different organs

The data on the uptake of phosphorus in different organs in relation to different levels of potassium and the period of growth are given in Table 22 and their summary in Table 23.

In corm, pseudostem, petiole and lamina the uptake of phosphorus increased upto shooting but

Table 22. Effect of potassium on the phosphorus uptake at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf
		(g/plant)					
0	Early vegetative phase	0.076	0.006	0.112	0.015	0.247	0.018
	Late vegetative phase	0.123	0.007	0.257	0.026	0.346	0.024
	Shooting	0.504	-	0.169	0.116	1.904	-
	Harvest	0.116	-	0.598	0.060	1.240	-
300	Early vegetative phase	0.057	0.006	0.153	0.012	0.123	0.018
	Late vegetative phase	0.164	0.007	0.250	0.028	0.427	0.025
	Shooting	0.649	-	0.208	0.132	2.446	-
	Harvest	0.195	-	0.663	0.073	1.502	-
400	Early vegetative phase	0.076	0.006	0.157	0.016	0.178	0.020
	Late vegetative phase	0.182	0.008	0.270	0.031	0.411	0.031
	Shooting	0.757	-	0.200	0.149	2.114	-
	Harvest	0.255	-	0.779	0.079	1.778	-
500	Early vegetative phase	0.073	0.008	0.143	0.015	0.204	0.017
	Late vegetative phase	0.201	0.009	0.289	0.034	0.441	0.031
	Shooting	0.800	-	0.203	0.154	2.338	0.031
	Harvest	0.317	-	0.824	0.075	1.904	-
600	Early vegetative phase	0.074	0.007	0.113	0.014	0.129	0.020
	Late vegetative phase	0.243	0.008	0.288	0.036	0.445	0.036
	Shooting	0.877	-	1.872	0.144	2.426	-
	Harvest	0.373	-	0.797	0.085	0.221	-

(Continued)

Table 22. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
			(g/plant)			
0	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	0.911	-	-	-	-
	Harvest	-	0.324	0.206	2.762	0.137
300	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	1.114	-	-	-	-
	Harvest	-	0.351	0.220	3.282	0.190
400	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	1.230	-	-	-	-
	Harvest	-	0.375	0.218	3.506	0.195
500	Early vegetative phase	-	-	-	-	-
	Late vegatative phase	-	-	-	-	-
	Shooting	1.240	-	-	-	-
	Harvest	-	0.393	0.234	3.544	0.200
600	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	1.280	-	-	-	-
	Harvest	-	0.401	0.266	3.590	0.202

Table 23. Effect of potassium on the phosphorus uptake at different stages of growth - Summary

Levels of potassium (g/plant)	Corm	Meristem	Pseudo-stem	Petiole	Laminae	Internal leaf
			(g/plant)			
0	0.17	0.006	0.56	0.059	0.97	0.022
300	0.22	0.006	0.64	0.063	1.14	0.022
400	0.26	0.007	0.64	0.073	1.14	0.025
500	0.29	0.007	0.67	0.073	0.21	0.025
600	0.31	0.007	0.63	0.074	0.31	0.028
C.D. (5%)	0.03	-	-	0.001	0.14	0.002
SEm ±	1.18	-	0.04	0.003	0.045	0.002
Stage of sampling						
Every vegetative phase	0.06	0.007	0.14	0.03	0.18	0.02
Late vegetative phase	0.18	0.008	0.27	0.03	0.42	0.03
Shooting	0.72	-	1.94	0.14	2.24	-
Harvest	0.25	-	0.73	0.07	1.73	-
C.D. (5%)	0.05	-	0.10	0.03	0.13	-
SEm ±	0.43	-	0.03	0.008	0.04	-

(Continued)

Table 23 (Contd.)

Levels of potassium (g/plant)	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
	(g/plant)				
0	0.91	0.32	0.21	2.76	0.14
300	1.11	0.35	0.22	3.28	0.19
400	1.23	0.37	0.22	3.51	0.20
500	1.24	0.39	0.23	3.54	0.20
600	1.28	0.40	0.27	3.59	0.20
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	1.16	-	-	-	-
Harvest	-	0.37	0.23	3.34	0.19
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-

declined thereafter. At the early and late vegetative phases and at shooting lamina recorded the highest uptake of phosphorus, 0.176, 0.415 and 2.24 g per plant respectively. This was 41.02 per cent, 44.5 per cent and 36.12 per cent respectively of the total phosphorus uptake at the early and late vegetative phase and at shooting. Pseudostem had 31.7 per cent of total phosphorus uptake at the early vegetative phase 29.10 per cent at late vegetative phase and 31.15 per cent at shooting time.

The phosphorus content was concentrated the fruits at the time of harvest viz., 3.34 g per plant (48.26 per cent of the total uptake) compared to lamina which recorded 1.73 g per plant. Lamina contained only 25 per cent of the total uptake of phosphorus. The uptake of phosphorus by corm at harvest was 0.25 g (3.6 per cent).

Levels of potassium had a significant influence on the uptake of phosphorus by the organs like corm, petiole, lamina and internal leaf. In corm the highest uptake obtained was at K_4 which was 82.14 per cent more than that of control. In petiole an increase of 25.42 per cent was noticed in plants receiving 600 g K_2O per plant compared to control. In lamina this was 34.2 per cent while it was 26.65 per cent in the internal leaf. No significant influence was obtained in the case of pseudostem and meristem. In the reproductive parts viz., inflorescence, fruit, internal and external stalk and male bud, there was significant increase in the uptake of phosphorus with increasing levels of potassium. The percentage of increase noted over control in inflorescence was 40.05 per cent and in fruits 30.00 per cent.

At harvest all the reproductive parts had a higher phosphorus uptake compared to vegetative plant parts.

DISTRIBUTION OF POTASSIUM

Potassium percentage

The percentage of potassium in different plant parts at planting and at four different stages of growth viz., at early and late vegetative phases, shooting and harvest as influenced by different levels of potassium are furnished in Table 24 and their summary in Table 25.

Among the different organs, pseudostem had the highest content of potassium (3.16 per cent) at planting.

Table 24. Effect of potassium on the potassium content at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meristem	Pseudostem	Petiole	Laminae	Internal leaf
		(% K_2O on moisture free basis)					
0	Planting	2.51	2.97	3.16	-	-	-
	Early vegetative phase	2.15	3.23	3.75	2.98	2.65	3.25
	Late vegetative phase	3.38	3.51	5.90	3.93	3.22	4.96
	Shooting	2.81	-	3.80	3.53	2.58	-
	Harvest	3.41	-	4.24	3.47	1.71	-
300	Planting	2.61	2.93	3.15	-	-	-
	Early vegetative phase	2.05	3.16	3.24	3.21	2.82	3.76
	Late vegetative phase	4.66	4.65	7.13	5.46	3.39	5.19
	Shooting	3.52	-	4.58	3.90	2.72	-
	Harvest	4.58	-	4.84	3.22	2.13	-
400	Planting	2.23	3.15	2.98	-	-	-
	Early vegetative phase	2.93	2.95	4.05	3.31	2.98	4.15
	Late vegetative phase	5.24	5.17	8.56	7.05	4.62	6.49
	Shooting	3.44	-	5.52	4.36	3.19	-
	Harvest	4.59	-	4.82	3.42	2.68	-
500	Planting	2.41	3.21	3.25	-	-	-
	Early vegetative phase	2.43	2.93	4.16	3.26	2.73	3.83
	Late vegetative phase	6.07	6.34	10.17	8.15	5.44	8.06
	Shooting	4.20	-	7.16	6.03	3.42	-
	Harvest	4.77	-	6.93	3.75	3.06	-
600	Planting	2.25	2.71	3.23	-	-	-
	Early vegetative phase	2.52	2.73	3.95	3.12	2.91	4.05
	Late vegetative phase	6.32	7.08	11.56	8.65	6.19	8.06
	Shooting	5.09	-	7.23	7.19	3.80	-
	Harvest	5.09	-	7.53	3.85	3.16	-

(Contd.)

Table 24. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
		(% K_2O on moisture free basis)				
0	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	4.70	-	-	-	-
	Harvest	-	7.07	4.16	-	2.94
300	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	5.28	-	-	-	-
	Harvest	-	7.96	6.78	1.41	3.36
400	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	6.26	-	-	-	-
	Harvest	-	8.83	7.90	1.74	3.95
500	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	7.01	-	-	-	-
	Harvest	-	9.57	10.18	2.36	4.85
	Planting	-	-	-	-	-
	Early vegetative phase	-	-	-	-	-
	Late vegetative phase	-	-	-	-	-
	Shooting	7.98	-	-	-	-
	Harvest	-	10.21	11.68	2.45	5.19

Table 25. Effect of potassium on potassium content at different stages of growth - Summary

Levels of potassium (g/plant)	Corm	Meristem	Pseudo-stem	Petiole	Laminae	Internal leaf
	(% K_2O on moisture free basis)					
0	2.97	3.17	4.18	3.53	2.58	4.38
300	3.48	3.55	4.71	3.87	2.77	4.50
400	3.62	3.72	5.18	4.50	3.33	5.15
500	3.97	4.11	6.26	5.28	3.69	5.94
600	4.27	4.36	6.67	5.72	4.00	5.94
C.D.(5%)	0.24	0.09	0.03	0.05	0.17	0.31
SEm ±	0.10	0.03	0.08	0.15	0.06	0.10
Stage of sampling						
Planting	2.40	2.99	3.16	-	-	-
Early vegetative phase	2.41	3.00	3.83	3.17	2.82	3.81
Late vegetative phase	5.13	5.35	3.67	6.65	4.57	6.55
Shooting	3.91	-	5.58	5.01	3.13	-
Harvest	4.43	-	5.84	3.62	2.55	-
C.D. (5%)	0.33	-	0.39	0.37	0.19	-
SEm ±	0.10	-	0.14	0.10	0.14	-

(Continued)

Table 25. (Contd.)

Levels of potassium (g/plant)	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
	($\%$ K_2O on moisture free basis)				
0	4.70	7.07	4.16	1.04	2.94
300	5.28	7.96	6.78	1.41	3.36
400	6.26	8.83	7.90	1.74	3.85
500	7.01	9.57	10.18	2.36	4.85
600	7.98	10.21	11.68	2.45	5.19
C.D.(5%)	-	-	-	-	-
SEm ±	-	-	-	-	-
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	6.25	-	-	-	-
Harvest	-	8.73	8.14	1.82	4.04
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-

Meristem recorded the least (2.99 per cent). When the plants reached the early vegetative phase also, pseudostem was richest in potassium (3.83 per cent) closely followed by internal leaf (3.81 per cent). Petiole had only 3.17 per cent of potassium. At late vegetative phase the content of potassium in petiole and internal leaf increased considerably, viz., 6.65 and 6.55 per cent respectively, recording an increase of 110 per cent in the former and 72 per cent in the latter, compared to the previous stages. The potassium content in the lamina at early vegetative phase was 2.82 per cent and it increased to 4.57 per cent during the late vegetative phase. At the time of shooting significant reduction in the percentage of potassium was observed in petiole, lamina and corm. The rate of reduction being 25 per cent in petiole 32 in lamina and 24 in corm. Inflorescence (6.25 per cent) had the highest content of potassium at this stage. In pseudostem there was 52 per cent increase in the content of potassium between the late vegetative phase and shooting. This was the only vegetative part that recorded an increase between shooting and harvest (26 per cent increase) although the increase was not significant. At the time of harvest the internal stalk with 8.73 per cent of potassium and external stalk with 8.14 per cent of potassium were richest in potassium. Fruits had 1.82 per cent of the element.

The varying levels of potassium had a significant influence on the K content of almost all the plant parts. It increased with increasing levels of K. Among the vegetative parts, the percentage of increase over that of control was highest in pseudostem (60 per cent) followed by lamina (55 per cent). In the reproductive parts, in external stalk there was a difference of 181 per cent in the content of potassium between K_4 and control. In fruits this was only 77 per cent.

Total uptake of potassium

Table 26 presents data on the total uptake of potassium.

The total uptake of potassium continued to increase throughout the duration of the crop (Fig.9 and Fig.10). It was seen that 11.25 g of the element was taken up by the plants during early vegetative phase, which increased to 28.46 g per plant at the late vegetative phase, recording an increase of 153 per cent. During the interval between maximum vegetative phase and shooting the total uptake of potassium increased

Table 26. Effect of potassium on the total uptake of potassium

Levels of potassium (g/plant)	Stage of sampling			
	Early vegetative phase	Late vegetative phase	Shooting	Harvest
		(g/plant)		
0	11.10	19.20 (73)	122.22 (537)	126.74
300	9.33	23.29 (150)	147.50 (533)	146.62
400	12.54	28.82 (130)	169.28 (487)	175.10
500	11.67	34.18 (193)	204.90 (499)	212.03
600	11.62	36.83 (217)	220.11 (498)	225.00
C.D.(5%)	-	1.34	8.36	10.40
SEm ±	-	2.24	2.79	3.47

Note: The figures in parantheses indicate the percentage of increase in the total uptake of potassium compared to the previous stage.

Fig-9 EFFECT OF POTASSIUM ON TOTAL UPTAKE OF POTASSIUM

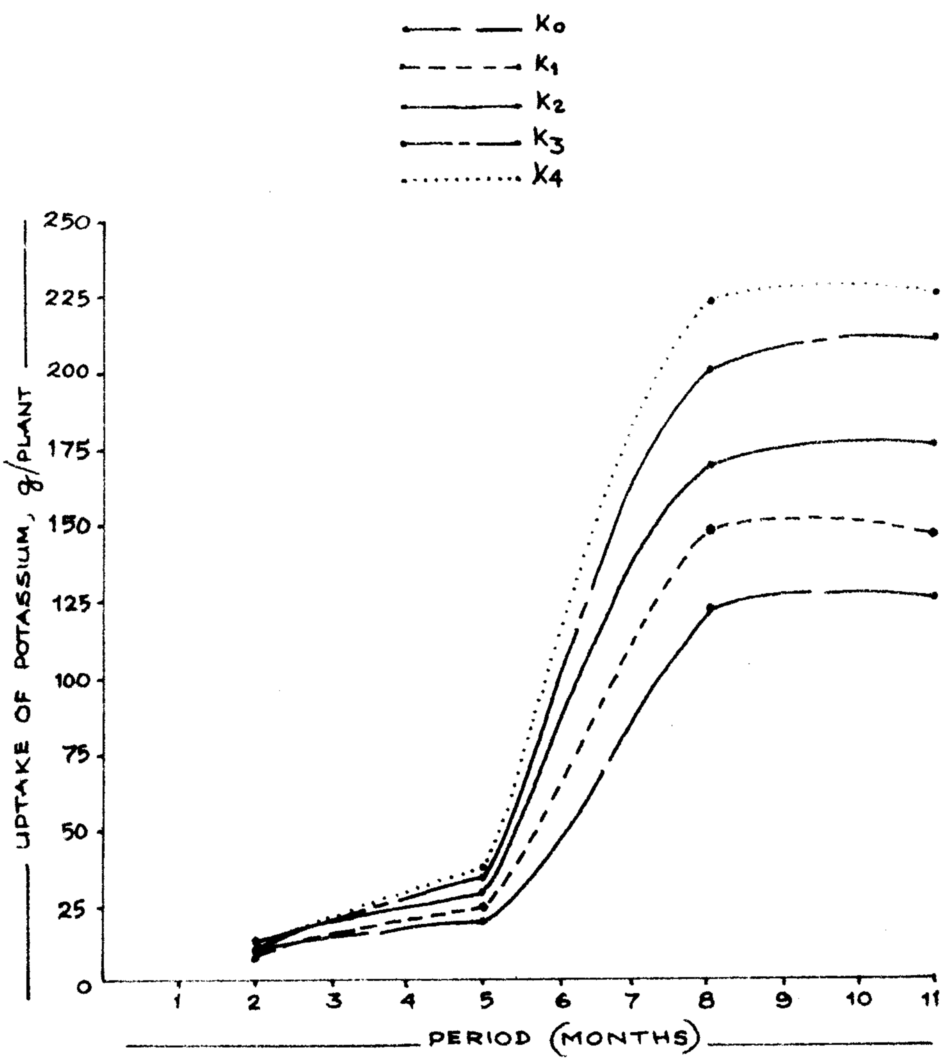
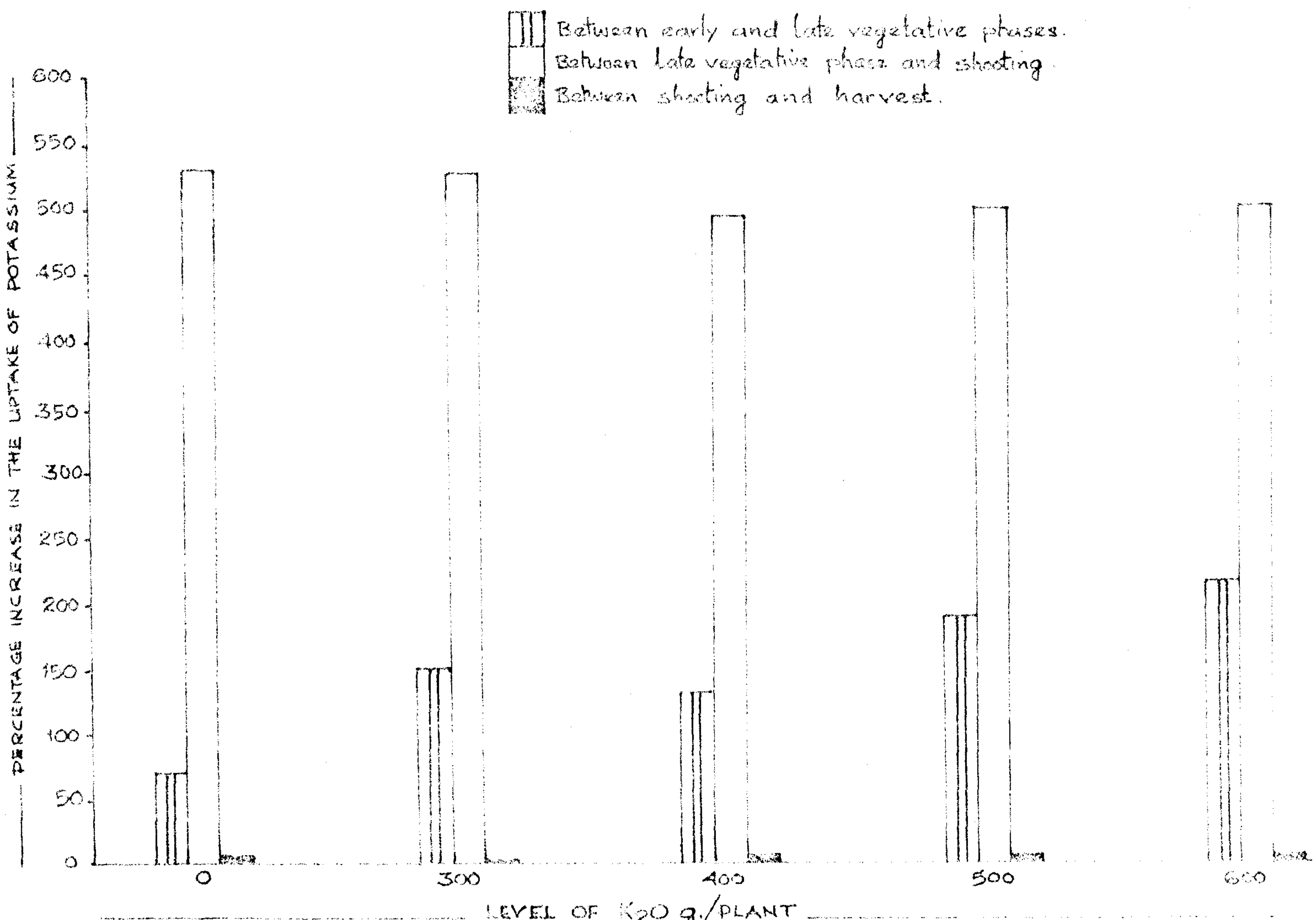


Fig. 10. EFFECT OF POTASSIUM ON THE PERCENTAGE OF INCREASE IN THE UPTAKE OF POTASSIUM BETWEEN DIFFERENT STAGES OF GROWTH



very rapidly (507 per cent increase), i.e. the total uptake recorded at the time of shooting was 172.8 g per plant. Between shooting and harvest the increase was nominal (2 per cent).

Levels of potassium significantly influenced the total uptake of potassium, at three different stages of growth after the application of the nutrients namely late vegetative phase, shooting time and harvest. increased levels of potassium invariably resulted in increased uptake. In all the three stages mentioned above the highest uptake was noticed at the highest level of potassium and the lowest in control. The difference in total uptake was maximum at the late vegetative phase where total uptake at K_4 was 92 per cent higher than that of control. At the time of shooting this was 80.09 per cent and at harvest 77.53 per cent.

POTASSIUM UPTAKE IN DIFFERENT ORGANS

Results of the study on the uptake of potassium in different organs as influenced by different levels of potassium at four different stages of growth are furnished in Table 27 and their summary in Table 28.

Stage of growth had a significant influence on the uptake of potassium by different organs. In the

Table 27. Effect of potassium on the potassium uptake at different stages of growth

Levels of potassium (g/plant)	Stage of sampling	Corm	Meri-stem	Pseudo-stem	Petiole	Laminae
		(g/plant)				
0	Early vegetative phase	2.72	0.04	2.21	0.16	4.36
	Late vegetative phase	4.66	0.08	7.35	0.82	5.95
	Shooting	17.68	-	50.47	5.38	34.75
	Harvest	8.63	-	35.33	3.92	17.11
300	Early vegetative phase	2.54	0.04	2.47	0.12	4.33
	Late vegetative phase	6.54	0.10	8.63	1.12	6.23
	Shooting	23.79	-	62.14	6.08	39.04
	Harvest	12.19	-	39.12	4.54	21.60
400	Early vegetative phase	3.17	0.04	3.18	0.15	4.42
	Late vegetative phase	7.19	0.12	10.56	1.50	8.05
	Shooting	23.72	-	74.64	6.75	43.89
	Harvest	13.96	-	40.75	3.73	30.55
500	Early vegetative phase	2.63	0.04	3.31	0.13	4.29
	Late vegetative phase	8.66	0.17	13.01	1.72	10.54
	Shooting	29.63	-	97.06	9.34	46.97
	Harvest	16.31	-	60.09	4.13	37.94
600	Early vegetative phase	2.93	0.04	3.17	0.12	4.18
	Late vegetative phase	8.86	0.15	15.19	1.78	12.42
	Shooting	35.59	-	97.02	10.46	52.20
	Harvest	17.59	-	64.74	4.31	41.22

(Continued)

Table 27. (Contd.)

Levels of potassium (g/plant)	Stage of sampling	Internal leaf	Inflo-rescence	Inter-nal stalk	Exter-nal stalk	Fruit	Male bud
		(g/plant)					
0	Early vegetative phase	0.15	-	-	-	-	-
	Late vegetative phase	0.33	-	-	-	-	-
	Shooting	-	13.97	-	-	-	-
	Harvest	-	-	13.77	5.03	23.29	1.78
300	Early vegetative phase	0.16	-	-	-	-	-
	Late vegetative phase	0.42	-	-	-	-	-
	Shooting	-	16.65	-	-	-	-
	Harvest	-	-	15.97	8.37	30.50	2.11
400	Early vegetative phase	0.19	-	-	-	-	-
	Late vegetative phase	0.41	-	-	-	-	-
	Shooting	-	20.28	-	-	-	-
	Harvest	-	-	17.64	9.63	38.44	2.38
500	Early vegetative phase	0.15	-	-	-	-	-
	Late vegetative phase	0.50	-	-	-	-	-
	Shooting	-	21.91	-	-	-	-
	Harvest	-	-	18.97	12.46	51.18	2.97
600	Early vegetative phase	0.16	-	-	-	-	-
	Late vegetative phase	0.51	-	-	-	-	-
	Shooting	-	24.83	-	-	-	-
	Harvest	-	-	20.99	14.37	56.37	3.17

Table 28. Effect of potassium on the potassium uptake of different stages of growth - Summary

Levels of potassium (g/plant)	Corm	Meristem	Pseudo-stem (g/plant)	Petiole	Laminae	Internal leaf
0	7.17	0.047	19.45	2.63	15.54	0.24
300	9.52	0.053	22.79	3.04	17.75	0.24
400	9.96	0.061	27.84	2.97	22.05	0.28
500	11.39	0.077	34.84	3.75	24.94	0.34
600	13.39	0.071	36.20	4.06	27.54	0.34
C.D. (5%)	0.071	0.009	2.75	0.55	2.18	0.04
SEm ±	0.27	0.003	0.74	0.18	0.73	0.01
Stage of sampling						
Early vegetative phase	2.76	0.04	2.87	0.41	4.31	0.16
Late vegetative phase	7.18	0.12	10.95	1.39	8.84	0.48
Shooting	26.40	-	76.27	7.60	43.44	-
Harvest	13.28	-	48.00	4.12	29.06	-
C.D. (5%)	1.21	-	3.11	0.54	1.96	-
SEm ±	0.39	-	1.01	0.18	0.64	-

(Continued)

Table 28. (Contd.)

Levels of potassium (g/plant)	Inflorescence	Internal stalk	External stalk	Fruit	Male bud
		(g/plant)			
0	13.97	13.77	5.03	23.29	1.79
300	16.65	15.97	8.37	30.50	2.12
400	20.28	17.64	9.63	38.44	2.38
500	21.91	18.97	12.45	51.18	2.97
600	24.83	20.99	14.37	56.37	3.17
C.D.(5%)	-	-	-	-	-
SEm ±	-	-	-	-	-
Stage of sampling					
Planting	-	-	-	-	-
Early vegetative phase	-	-	-	-	-
Late vegetative phase	-	-	-	-	-
Shooting	19.53	-	-	-	-
Harvest	-	17.47	9.81	39.96	2.49
C.D. (5%)	-	-	-	-	-
SEm ±	-	-	-	-	-

vegetative organs the uptake of potassium recorded a significant increase from the early vegetative phase till the time of shooting and declined thereafter. At the early vegetative phase 41 per cent of the total uptake of potassium was accounted for by the lamina. Pseudostem had 27 per cent of the total uptake and corm 26 per cent. Pseudostem recorded the highest uptake of potassium at the late vegetative phase viz., 38 per cent of the total uptake, followed by lamina (31 per cent) and corm (25 per cent). At the time of shooting also the uptake of potassium was maximum in pseudostem (44 per cent of the total uptake). Lamina came second with 25 per cent of the total uptake. Eleven per cent of the total uptake was concentrated in inflorescence. At harvest also the maximum uptake of potassium was by pseudostem (28.91 per cent). Fruits contributed to 24 per cent of the total uptake.

The uptake of potassium was significantly influenced by the levels of potassium. In all the vegetative and reproductive plant parts the uptake of potassium significantly increased with the increasing levels of potassium. Between all levels of potassium, there was significant difference with K_4 recording the highest value and control the lowest. In the case of corm K_4 took up 84 per cent more potassium than control. K_4 recorded 86 and 77 per cent more uptake than control in pseudostem and lamina. However, the difference in uptake between K_4 and control was maximum in fruits (142 per cent).

Discussion

DISCUSSION

The studies reported in this thesis are the second in series of nutritional studies on rainfed banana. Kerala ranks first in the country as far as area under banana is concerned, and of these eighty per cent are grown under rainfed conditions. Although banana research in the State dates back to 1940s, unfortunately the major emphasis was only on irrigated bananas. The studies on nitrogen in rainfed bananas, conducted earlier in the Department of Pomology, College of Horticulture (Valsamma Mathew, 1980), has emphasized the need for adequate understanding of the rainfed bananas, through detailed experimentation, so as to arrive at proper recommendation on the various nutritional needs. Nitrogen and potassium have been found to be of major importance in banana nutrition (Norris and Ayyar, 1942; Summerville, 1944; Yang and Pao, 1962; Osborne and Hewitt, 1963; Jagirdar and Ansari, 1966; Twyford, 1967; Martin-prevel, 1969; Turner and Bull, 1970; Lahav, 1973). The present investigations on potassium nutrition, have been useful to understand the uptake pattern of the major nutrients, as affected by different levels of applied potassium. The salient results are discussed here.

The investigation consisted of two parts, namely (1) the effect of potassium on morphological characters, yield and quality attributes and (2) uptake pattern of potassium and other elements as influenced by different levels of potassium.

Effect of potassium on morphological characters

The various morphological characters studied in this experiment consisted of height and girth of pseudostem, number of functional leaves and total leaf area. Potassium was not found to influence the expression of morphological characters, except the height of pseudostem, unlike in the case of nitrogen. Valsamma Mathew (1980) reported increased vegetative vigour of the plant in all the morphological characters due to application of N. According to Hernades Medina and Lugo Lopez (1967), high potassium favoured better plant development. In the present study, there was significant difference between treatments, in the height of pseudostem, highest value being at 400 g K_2O/plant and 300 g K_2O/plant during late vegetative phase and shooting respectively. Increased leaf area although not significant was noticed at 600 g K_2O per plant, in which treatment the ultimate yield was the highest. The possible correlation between leaf area and yield is thus indicated. Ho (1968a) and Teaotia *et al.* (1972), had reported that potassium increased the height and girth of pseudostem. Lacoevilhe (1973) indicated that potassium application influenced the number of leaves.

The duration of the crop was found to be markedly influenced by the amount of K_2O applied. This was mainly due to the earlier flowering noticed at higher levels of K_2O. A difference of 23 days was noticed between control and 600 g K_2O per plant. Duration between shooting and harvest was not significantly influenced by different levels of K_2O. Unlike in the case of potassium, higher levels of nitrogen was found to prolong the duration of the banana crop in earlier studies (Valsamma Mathew, 1980). In the case of nitrogen, the influence of higher doses was reported to be more evident between shooting and harvest than during pre-shooting. Apparently nitrogen exerts more influence on bunch development than potassium.

The synergic effects of nitrogen and potassium are noteworthy. While N has been responsible for delaying the crop, the effect of K_2O, as brought out by this study, has been in a reverse direction. A combination of N and K in correct proportion is therefore necessary for manipulating crop growth, which is a well established fact (Croucher and Mitchell, 1940; Summerville, 1944; Bhangoo *et al.*, 1966; Melin, 1970).

Effect of potassium on yield and yield attributes

The study has brought out clearly the effect of potassium on the yield of banana. The yield increased along with the levels of applied potassium. The earlier studies on nitrogen nutrition (Valsamma Mathew, 1980) showed a similar effect in the case of nitrogen also, but after a certain dose i.e. 200 g N per plant, the yield was found to decrease. From the present study, it could be presumed that the optimum level of potassium probably lies above the range covered. As pointed out earlier till 600 g K_2O per plant there was a linear response (Fig.2). Further studies with higher doses of K_2O must be taken up, to determine the optimum dose. Increased yield due to potassium application had been reported by various workers (Pelegrin, 1953; Yangand Pao 1962; Decunha and Fraga, 1963; Osborne and Hewitt, 1963; Moreau and Robin, 1972; Garcia *et al.*, 1980; Lahav *et al.*, 1981).

The earlier reports by Gandhi (1951), Gopalan Nair (1953), Butler (1960) and Vadivel (1976), that potassium did not influence the yield does not appear to be correct.

The attributes responsible for increase in yield, were found to be the weight of hand, number of hands, number of fingers, and average weight of finger. Thus it will be seen that all these gave increased values, by virtue of applied potassium. Jagirdar and Ansari (1966) had reported an increase in the number of fingers by application of potassium. Bhangoo et al. (1962) recorded an increase in the number of hands and Yang and Pao (1962) an increase in the average weight of fingers. The observation is of interest on a comparative basis. The earlier studies on nitrogen (Valsamma Mathew, 1980), where either the number of hands, or number of fingers were not influenced by nitrogen in rainfed bananas, thus emphasize the necessity for application of K_2O in rainfed banana, where application of nitrogen alone is usually done, by the farmers in Kerala. The necessity for the balanced application of fertilisers in irrigated bananas had been well understood (Pelegrin, 1953; Bhangoo et al., 1962; Veeraraghavan, 1972 and Pillai et al., 1977)

Fruit quality

Potassium markedly improved the quality of fruits with respect to TSS, total sugars, reducing sugars, sugar acid ratio and acidity. This was more pronounced in the case of total sugars (34.54 per cent increase at K_4 over control), and sugar acid ratio (25.53 per cent increase at K_4 over control). The lowest acidity was obtained at K_2 which was 14.94 per cent less than that of control. The highest per cent of reducing sugar was obtained at 500 g K_2O per plant. Qualitative improvement brought about by the application of potassium is thus evident which had been reported by Ho (1968b), Vadivel (1976) and Singh et al. (1977).

Dry matter production

Dry matter production was most rapid between the late vegetative phase and shooting time, the percentage increase being 699.52. This might be because of the fact that the plant showed a very high rate of growth during this period. Increased K_2O levels always resulted in increased dry matter production. Similar results were obtained by Summerville (1944) and Vadivel (1976). Between shooting and harvest the increase in dry matter production was only nominal. The vegetative growth of the plant showed a declining trend during this period. Mobilisation of nutrients to the developing bunches and the resultant metabolic changes might have also contributed for the decreased vegetative vigour of plants. During this period the increase in dry matter production observed was due to bunch development. This is in accordance with the findings of Twyford and Walmsley (1973).

In the present study, the total dry matter content at the time of harvest ranged from 4.58 kg in control to 5.32 kg in N_4 which was comparable to the earlier experiments conducted on N nutrition (Valsamma Mathew, 1980). Ballion et al. (1933) had obtained a dry matter content of 18 kg per plant in Dwarf Cavendish banana. Martinprevel (1962) reported a dry matter accumulation of 6.5 kg per plant. In Lacatan bananas, a wide range of 4.5 to 10 kg per plant was recorded by Boland (1960). The values obtained here are low compared to these figures, but is in line with the findings of Twyford and Walmsley (1973), who recorded a dry weight of 5.15 kg in Robusta banana. The dry matter production under our condition seems to be low, which in turn might be one of the reasons for comparatively lower bunch weight.

The percentage of dry matter accumulation in fruits, out of the total dry weight of the plant ranged between 42 and 45 per cent in different treatments. Thus, it is evident that unlike nitrogen, which at higher levels caused more of vegetative growth than yield (Valsamma Mathew, 1980); higher levels of potassium did not tend to merely increase the vegetative growth, there was a proportionate increase in the yield also.

Dry matter accumulation in vegetative organs continued till shooting, but declined towards harvest. A similar trend was also reported by Twyford and Walmsley (1973) in Robusta banana. The loss in weight may be due to the decreased growth and faster senescence of vegetative organs.

Nutrient uptake

The uptake of three major elements namely, nitrogen, phosphorus and potassium by different plant organs was studied in detail. The total uptake of nitrogen increased upto the stage of shooting, and declined thereafter (Fig.4), irrespective of the amount of potassium applied. Summerville (1944), Twyford and Walmsley (1974) and Veeranna *et al.* (1976) observed that in banana, nitrogen uptake was at its peak during late vegetative phase and thereafter showed a declining trend. Ashokkumar (1977) reported that in Robusta banana a decrease in the total uptake of nitrogen was noticed after shooting. Two possible reasons for this phenomena are (1) the loss of older leaves due to drying up and (2) possible translocation of nitrogen from mother plant to suckers.

The percentage of nitrogen in the various plant parts sampled, did not show significant difference between the different treatments. Thus the depressing effect of higher levels of potassium on the uptake of nitrogen as reported by Ho (1969a), and Lahav (1973) was not evident in the present study. In this study the level of K_2O applied did not seem to have reached the maximum level, as there was a linear increase in yield upto 600 g K_2O per plant. In corm, pseudostem, petiole and lamina, the percentage of nitrogen was maximum at the late vegetative phase, and showed a decreasing trend towards shooting and reached a minimum at harvest. A similar trend in the uptake of nitrogen by vegetative organs was reported by Vadivel (1976) and Garcia et al. (1980).

The total uptake of phosphorus continued to increase throughout the duration of the crop (Fig.5). The levels of potassium significantly increased the uptake of phosphorus. Possibly this was due to synergestic relationship that existed between K and P, as reported by Lahav (1973). The uptake of phosphorus by banana was very low, compared to that of nitrogen and potassium. The phosphorus requirement of banana is much less than that of nitrogen and phosphorus (Norris and Ayyar, 1942; Jacob and Vexkull, 1960; Matin-prevel, 1964; Turner, 1969; Jauhari et al., 1974 and Vadivel, 1976). The maximum uptake of phosphorus occurred during the period between late vegetative phase and shooting time. After shooting, a decrease in the content of phosphorus in vegetative organs was observed; indicating a possibility of mobilisation of this element to the reproductive parts. Montagut and Martin-prevel (1964) had claimed that total uptake of P_2O_5 ceased at shooting and P_2O_5 was mobilised from the vegetative organs, for fruit development. With respect to the total uptake of phosphorus, the same increased till harvest as was reported by Vadivel (1976).

Among the nutrients, the uptake of potassium was the highest, compared to the other two elements. The total uptake of potassium continued to increase until harvest. A similar result was obtained by Valsamma Mathew (1980) in her studies in nitrogen nutrition. Increasing levels of potassium increased the uptake of the same element. That high applications of potassium always resulted in higher uptake of potassium had been reported by Chattopadhayay and Mallik (1977), Vincente-Chandler and Figarella (1962) and Vadivel (1976). According to Martin-prevel (1962), banana utilises one hundred per cent of potassium applied. The keyrole played by K_2O in the synthesis of sugars and maintaining a balance in the water relations of the plant might be the cause for the requirement of this element in large amounts. Luxury consumption of potassium by banana had been reported by Montagut and Martin-prevel (1965), Cooke (1974) and Vadivel (1976).

In the vegetative parts, there was a drop in the uptake of potassium after shooting. Mobilisation to fruits was at a lower pace compared to N and P_2O_5. Pseudostem had the highest content of potassium at the time of harvest.

The distribution pattern of N, P_2O_5 and K_2O in various organs were not affected by the amount of potassium applied. Vadivel (1976) also reported such a trend. Under all the treatments, the uptake of nitrogen was highest in the lamina at the late vegetative phase, shooting, and harvest. Similarly phosphorus uptake was also highest in lamina at the early and late vegetative phases and shooting. At harvest, fruits had the highest uptake of P_2O_5. A similar distribution of N and P_2O_5 was recorded by Samuel et al. (1976). Pseudostem recorded the highest uptake of potassium at late vegetative phase, shooting and harvest. Jauhari et al. (1976) and Valsamma Mathew (1980) had also recorded the highest uptake of potassium in pseudostem.

From this study, it is clear that assimilation of principal nutrients was slow when plants were in early vegetative phase, and increased rapidly between late vegetative phase and shooting. Such an uptake pattern had also been reported by Machado (1962).

According to Jauhari *et al.* (1974) and Samuel *et al.* (1976) uptake of P_2O_5 and K_2O was very rapid during the first few months of planting and decreased later on. This indicate that in banana, maximum nutrient requirements are during this period. Therefore application of fertilizer should be made well in advance of this growth phase.

With regard to the uptake of nutrients, in relation to the availability of moisture, it was seen that the maximum uptake was recorded between the late vegetative phase and shooting which coincided with the period of maximum rainfall. Thus apart from the developmental stage, soil moisture also had definite influence on nutrient uptake. In rainfed bananas, there seems to be necessity for working out soil moisture relationship, with developmental physiology, as well as nutrient uptake.

Summary

SUMMARY

The present investigations were carried out in the Department of Pomology, College of Horticulture, Kerala Agricultural University, from 1981 to 1982 to study the effect of different levels of potassium on morphological characters yield and quality attributes, drymatter accumulation and uptake of nutrients, of rainfed banana Musa (AAB group). The summary of results are presented below.

1. The morphological characters except the height of the plant were not affected by the application of potassium.

2. The treatments did not also influence the number of functional leaves, total leaf area or sucker production.

3. The duration of the crop was significantly altered by levels of potassium. Plants receiving 600 g K_2O per plant took the minimum time for harvest. The effect was mainly due to the earlier flowering noticed at higher levels of potassium.

4. The yield increased with increasing levels of potassium. There was a linear relationship between amount of potassium applied, and yield obtained, the highest yield being obtained at 600 g K_2O per plant. The optimum range of potassium required appeared to be above 600 g K_2O per plant.

5. The bunch characters viz., length of bunch, number of hands per bunch, weight of hand, number of fingers, and girth and weight of finger were significantly affected by the levels of potassium.

6. Levels of potassium significantly influenced fruit weight, pulp weight, peel weight, and pulp/peel ratio.

7. Potassium application had a significant beneficial effect on quality attributes like total soluble solids, total sugars, reducing sugars, sugar/acid ratio and acidity.

8. Total dry matter production increased with increasing levels of potassium in all the three stages of sampling.

9. During early and late vegetative phases, as well as at shooting, dry matter accumulation was

maximum in laminae. At harvest fruits had the highest dry matter accumulation.

10. Total uptake of nitrogen increased from early vegetative phase, to shooting and declined thereafter, in all the treatments. Levels of potassium had no effect on the uptake of nitrogen.

11. Total uptake of phosphorus continued to increase, throughout the duration of the crop. Increasing levels of potassium increased the uptake of phosphorus.

12. Total uptake of potassium increased with increasing levels of the same. It continued to increase until harvest. The uptake of potassium was the highest of the three major nutrients, namely nitrogen, phosphorus and potassium.

13. Distribution pattern of nitrogen, phosphorus and potassium remained the same under all the treatments. Lamina recorded the highest uptake of nitrogen at late vegetative phase, shooting and at harvest. Uptake of phosphorus was maximum in lamina at early and late vegetative phases and also at shooting. At harvest fruits recorded the highest uptake of this element. Potassium uptake was maximum in the pseudostem at late vegetative phase, shooting, and harvest.

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*Original not seen

Appendices

APPENDIX - I

Weather data for the period from March 1981 to March 1982.

Month	Temperature °C		Relative humidity (%)		Total rainfall (mm)	No. of rainy days
	Maximum	Minimum	Maximum	Minimum		
March	36.2	24.2	81.6	46.9	2.0	1
April	36.2	25.6	77.1	52.2	16.0	6
May	33.1	24.7	88.7	53.2	225.8	8
June	28.8	21.8	93.1	86.5	1124.6	25
July	26.0	22.0	92.6	79.4	512.9	20
August	29.4	21.4	93.7	80.0	407.9	17
September	29.0	22.3	93.2	80.1	528.8	19
October	29.6	22.8	91.8	69.3	136.7	13
November	31.3	22.0	90.0	60.6	80.2	5
December	31.2	21.6	79.3	46.7	Nil	-
January	32.5	24.6	61.6	45.88	Nil	-
February	36.9	21.3	57.7	32.09	Nil	-
March	35.4	27.2	78.2	69.38	Nil	-

APPENDIX - II

Analyses of variance for the effect of potassium on plant height at various stages of growth

Source	Mean sum of squares		
	Degrees of freedom	Late vegetative phase	Shooting
Blocks	4	317.32**	343.38**
Treatments	4	118.59**	1014.80**
Error	16	31.14	104.52

**Significant at 1 per cent level

APPENDIX - III

Analyses of variance for the effect of potassium on girth of pseudostem at various stages of growth

Source	Mean sum of squares		
	Degrees of freedom	Late vegetative phase	Shooting
Blocks	4	7.16	16.21
Treatments	4	2.13	16.04
Error	16	10.26	16.41

APPENDIX - IV

Analyses of variance for the effect of potassium on number of functional leaves and total leaf area

Source	Degrees of freedom	Mean sum of squares			
		Total number of functional leaves		Total leaf area	
		Late vegetative phase	Shooting	Late vegetative phase	Shooting
Blocks	4	0.6376	0.6635	1.5184	2.3165
Treatments	4	0.2923	0.4135	0.9499	2.1219
Error	16	0.3133	0.7582	1.2432	0.8246

APPENDIX - V

Analyses of variance for the effect of potassium on number of days from planting to shooting, days taken from shooting to harvest and planting to harvest.

Source	Degrees of freedom	Mean sum of squares		
		Number of days from planting to shooting	Days taken from shooting to harvest	Number of days from planting to harvest
Blocks	4	164.63**	20.27	143.15
Treatments	4	422.60**	4.18	454.26**
Error	16	100.56	6.83	109.09

**Significant at 1 per cent level

APPENDIX - VI

Analyses of variance for the effect of potassium on the production of suckers

Source	Degrees of freedom	Mean sum of squares
Blocks	4	1.79
Treatments	4	1.06
Error	16	1.19

APPENDIX - VII

Analyses of variance for the effect of potassium on bunch characters in banana

Source	Degrees of freedom	Mean sum of squares								
		Length of bunch	Length of finger	Girth of finger	Number of hands	Number of fingers	Weight of bunch	Weight of hands	No. of fingers per hand	Weight of fingers
Blocks	4	4.40	0.23	0.28	0.085	262.62	0.15	0.0213**	259.43	11.37**
Treatments	4	54.24**	1.30**	1.49**	4.030**	1628.28**	24.30**	0.088**	1520.30**	97.77**
Error	16	11.10	0.58	0.18	0.224	126.23	0.57	0.004	13.42	12.6

**Significant at 1 per cent level

APPENDIX - VIII

Analyses of variance for the effect of potassium on fruit characters in banana

Source	Degrees of freedom	Mean sum of squares			
		Fruit weight	Pulp weight	Peel weight	Pulp/peel ratio
Blocks	4	5.68*	2.51	0.45	0.022
Treatments	4	100.89**	97.84**	1.40**	0.26**
Error	16	1.82	1.03	0.22	0.024

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX - IX

Analyses of variance for the effect of potassium on fruit qualities in banana

Source	Degrees of freedom	Mean sum of squares					
		TSS	Acidity	Total sugars	Reducing sugar	Non-reducing sugar	Sugar acid ratio
Blocks	4	0.65**	0.0001	0.076	0.08	0.14	1.52
Treatments	4	16.47**	0.0045**	11.67**	10.74	0.078	79.43**
Error	16	0.12	0.00005	0.15	0.07	0.048	2.21

**Significant at 1 per cent level

APPENDIX - X

Analyses of variance for the effect of potassium on total uptake of N.

Source	Degrees of freedom	Mean sum of squares		
		Late vegetative phase	Shooting	Harvest
Blocks	4	0.53	34.06	2.31
Treatments	4	0.33	9.85	53.71
Error	16	0.28	11.92	3.30

**Significant at 1 per cent level

APPENDIX - XI

Analyses of variance for the effect of potassium on the total uptake of P_2O_5

Source	Degrees of freedom	Mean sum of squares		
		Late vegetative phase	Shooting	Harvest
Blocks	4	0.007	0.38	0.34
Treatments	4	1.006**	1.29**	3.85**
Error	16	0.010	0.23	0.35

**Significant at 1 per cent level

APPENDIX - XII

Analyses of variance for the effect of potassium on the total uptake of K_2O

Source	Degrees of freedom	Mean sum of squares		
		Late vegetative phase	Shooting	Harvest
Blocks	4	0.95	165.42**	262.60
Treatments	4	315.89**	8099.42**	8728.98**
Error	16	1.00	38.33	60.23

** Significant at 1 per cent level

APPENDIX - XIII

Analyses of variance for the linear and quadratic effects of different levels of potassium on bunch weight.

Source	Degrees of freedom	Mean sum of squares
Total	24	-
Blocks	4	0.15
Treatments	4	24.3**
Control Vs treated	1	54.46**
Between levels of K	3	14.30**
K linear	1	40.96**
K quadratic	1	0.15
Error	16	0.573

**Significant at 1 per cent level

APPENDIX - XIV

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

Levels of potassium (g/plant)	Total nitrogen (%)	Available phosphorus (%)	Available potassium (%)
0	0.130	0.001	0.0095
300	0.131	0.0009	0.0105
400	0.130	0.0009	0.0123
500	0.132	0.0008	0.0135
600	0.130	0.0008	0.0140

POTASSIUM NUTRITION IN RAINFED BANANA
Musa (AAB group) 'PALAYAN KODAN'

By

SHEELA, V. L.

ABSTRACT OF THE 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.

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ABSTRACT

The present investigation was carried out in the Department of Pomology, College of Horticulture, Vellanikkara from 1981 to 1982. This study was aimed at finding out the effect of different levels of potassium on growth, yield and quality of fruits, uptake of nutrients at different stages of growth and also to find out the optimum dose of potassium for banana under rainfed conditions. The five treatments tried were 0, 300, 400, 500 and 600 g K_2O per plant. The experiment was laid out in randomised block design with five replications.

Among the morphological characters, only the height of the pseudostem was significantly affected by the levels of potassium. The duration of the crop was significantly reduced by higher levels of potassium. The effect of potassium on duration was more evident during the preflowering stage than between shooting and harvest.

There was a linear increase in yield with the application of potassium. The yield continued to increase till the highest dose tried (600 g K_2O/plant). The optimum therefore probably lies above this range.

Total soluble solids, total sugars, reducing sugars and sugar/acid ratio increased with increasing levels of potassium. Acidity of fruits was also significantly affected by levels of potassium.

Increasing levels of potassium resulted in increased dry matter production. Dry matter accumulation was maximum in laminae during early and late vegetative phases and during shooting. But at harvest dry matter accumulation was maximum in fruits.

Uptake of nitrogen was not influenced by levels of potassium. In all the treatments the total uptake of nitrogen increased upto shooting and declined thereafter. With increasing levels of potassium, the uptake of phosphorus also increased. The total uptake of this element continued to increase till harvest. The uptake of potassium increased with increasing levels of potassium. The total uptake of potassium continued to increase till harvest. The amount of potassium taken up by the plants in all the treatments was the highest of all the nutrients studied.

Lamina recorded the highest uptake of nitrogen and phosphorus at late vegetative phase and shooting. At harvest also uptake of nitrogen was maximum in lamina but that of phosphorus was maximum in fruits. Pseudostem recorded the highest uptake of potassium at late vegetative phase, shooting and harvest.