REGULATION OF MAJOR PLANT NUTRIENTS AND ORGANIC MATTER FOR IMPROVING THE NUTRITIVE QUALITY OF BANANA GROWN IN LATERITE SOILS

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled '**Regulation of major plant nutrients and organic matter for improving the nutritive quality of banana grown in laterite soils**' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
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CERTIFICATE

Certified that this thesis entitled ` **Regulation of major plant nutrients and organic matter for improving the nutritive quality of banana grown in laterite soils'** is a record of research work done independently by **Smt. Binu Thomas**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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BINU THOMAS

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LIST OF ABBREVIATIONS

ppm	- parts per million
mg	- milligram
kg	- kilogram
ha	- hectare
g	- gram
FYM	- farmyard manure
t	- tonne
m	- metre
cm	- centimeter
ml	- millilitre
MAP	- Months after planting
N	- Nitrogen
P	- Phosphorus
K	- Potassium

Introduction

INTRODUCTION

Banana is one of the most important fruit crops of India with a productivity of 55 t/ha. Its fruits are available throughout the year unlike other fruits which are seasonal. Due to its high nutritive value and low market price it is popularly known as poor mans fruit. India is the home of multitudes of varieties of banana which are distributed throughout the country. In respect of area and production banana ranks second only to mango in this country.

Bananas are put into varied uses in India. Almost every part of the plant is used some way or other. The fruits are used for dessert purpose as well as culinary purposes. The pseudostem which bears peduncle is used as vegetable. The corm rich in carbohydrate is also cooked and eaten. The peel of the unripe fruit is used for making dehydrated products.

Banana requires adequate amounts of fertilizer through out its growth period. The proper fertilization of banana is essential to increase crop yield, to reduce crop duration, for increasing the number of marketable bunches and to improve the quality of produce.

The present study was aimed at to find out the effect of fertilizer application on the quality parameters of banana crop. Singh *et al.* (1977) observed presaging effects of higher dose of fertilizers on the quality parameters of banana cv. Basrai.

Among the three major nutrients potassium had more effect on the quality of banana. Fruit quality was highly improved by application of treatments having K combination (Singh *et al.*, 1972; Mustaffa, 1988; Kulasekharan, 1993).

Nitrate accumulation is a detrimental effect of fertilizer application. In vegetables, increasing the level of nitrogen increases the nitrate concentration (Barker and Maynard, 1971).

The present study was aimed at the information about the changes in food nutrients under varying levels of organic matter, nitrogen, phosphorus and potassium in banana.

The objectives of this study were

(1) to find out the change in the nutrient content under varying levels of organic matter, nitrogen, phosphorus and potassium

(2) to produce better quality banana by regulating major nutrients and organic matter

(3) to find out the effect of organic matter and major nutrients on the accumulation of toxic materials in banana.

Review of Literature

REVIEW OF LITERATURE

Banana requires adequate amounts of fertilizer throughout its growth period. In Kerala a recommendation of 190:115:300 g N, P_2O_5 and K_2O per plant and farmyard manure 10 kg/plant is usually adopted. This is applied in six splits which coincides with all the major stages of crop growth.

Yield and quality of banana is very much affected by the nutrition of the crop. But the application of fertilizer will have some impact on the quality of banana. Fertilizers have some detrimental effects on plant environment (Philips, 1972). Also nitrate accumulation is affected by fertilizer management. Effect of different combinations of plant nutrients and organic matter on the content of food nutrients have not been studied so far. A precise knowledge of the effect of major nutrients and organic matter on the yield and quality of food nutrients in banana is essential to understand the changes in the quality with the treatments of fertilizers and organic matter.

1 Effect of major nutrients on the yield and yield contributing characters of banana

Singh *et al.* (1972) studied the effect of nitrogen and potassium on the physico-chemical characters of Robusta banana (*Musa* Cavendish Lambert). When N at 168 g/plant, K at 336 g/plant and P at 84 g/plant was applied an increased yield was obtained. The number of hands and fingers were increased by the application of N while the response to K was in the increased weight, volume and density of the fruit.

Nambiar *et al.* (1979) obtained greater bunch weight for banana plants receiving N and P_2O_5 225 g/plant each and K_2O 450 g/plant applied in two split doses at 30 and 50 days after planting.

Pillai *et al.* (1980) obtained heaviest bunches from plants receiving 250 kg N, 100 kg P_2O_5 and 1000 kg K_2O per hectare in a work conducted at TNAU.

Mustaffa (1983) studied the effect of spacing and nitrogen nutrition on growth, yield and quality of hill banana and obtained maximum yield from closely planted plots receiving N at the rate of 250 g/plant/year.

Obeifuna (1984) reported that the optimum dose of potassium was 300 g/plant applied at 19th/20th leaf stage i.e., 4-5 months after planting. Kohli *et al.* (1984) reported that the optimum dose of N for Robusta banana was 300 g/plant.

In a four year trial on the effect of various NPK doses on the growth and production of Basrai banana, Shaikh *et al.* (1985) reported that the optimum dose of N:P_2O_5 and K_2O were 786:393:786 kg/ha.

Chattopadhyay and Bose (1986) studied the effect of various levels of N:P_2O_5 and K_2O on dwarf Cavendish banana and reported that maximum fruit yield was obtained with highest dose of N:P_2O_5 and K_2O at 240, 90 and 480 g/plant.

Dagade (1986) reported that maximum yield was obtained for Basrai banana with N 100 g, P_2O_5 40 g and K_2O 100 g/plant.

Mustaffa (1987) studied the effect of 0, 50, 150, 200, 250, 300 and 400 g K_2O/plant on banana var. Robusta under rainfed conditions and obtained highest fruit yield of 45.4 t/ha with 300 g K_2O/plant which was 35 per cent higher than in the no potassium treatment.

Obiefuna and Onycle (1987) conducted an experiment on nutrition of plantains and reported that annual application of 200 g N and 500 g K/plant produced the heaviest bunch weights and was the most economic.

Yadav *et al.* (1988) conducted an experiment on the response of banana to different levels and frequencies of K application and reported that KCl at 300 g/plant applied in three split doses gave the maximum yield.

Mustaffa (1988) studied the effect of spacing and nitrogen on fruit yield of Robusta banana grown under rainfed conditions. The plants received N at 0 to 250 g/plant which was applied in two splits i.e., five and eight months after planting, highest yields were obtained from plots receiving 150 g N/plant.

In another study on the effect of increasing doses of K (0 to 400 g/plant) fertilizer on rainfed hill banana, highest bunch weight was obtained with K 350 g/plant. The fruit yield was 65 per cent higher than that in the control. The response curve between K level and bunch weight indicated an optimum dose of 315 g/plant (Mustaffa, 1988).

Ram and Prasad (1988) reported that maximum plant growth was measured by the application of 300 g N, 120 g phosphorus and 200 g potassium/plant in dwarf Cavendish banana.

Dave *et al.* (1990) conducted an experiment on the nutritional requirement of banana cv. Basrai in South Gujarat. The treatments included the application of N, P_2O_5 and K_2O at 45:45:45, 180:180:180 and 270:270:270 g/plant. They reported that fruit yield can be increased by increasing nutrient application. Application of 180:180:180 g $N:P_2O_5:K_2O$ per plant is recommended for banana.

Murthy and Iyengar (1990) opined that basal application at planting either as full or half dose resulted in quicker absorption of fertilizer P, meeting the P requirement of Robusta banana during early stages of growth.

Natesh *et al.* (1993) reported that the recommended dose of fertilizers viz., 190:115:300 g NPK per plant when applied in four splits for Nendran banana, favoured yield, than when the same dose was applied in two splits.

As per the package of practice recommendations (KAU, 1993) 190:115:300 g NPK per plant has to be applied for Nendran in six split doses.

Absorption of fertilizer N applied at early and late vegetative stages was faster but decreased gradually at harvest in Robusta banana. Nitrogen was applied in five equal splits of 50 g each at early vegetative phase, late vegetative phase bud differentiation and shooting stages of plant growth (Murthy *et al.*, 1995).

According to Sheela (1995) application of 300 g N and 450 g potassium per plant gave the highest yield in tissue culture Nendran banana. The optimum nitrogen and potassium dose was found to be 299.5 g and 465.5 g per plant respectively.

Robinson (1996) reported that banana has high demand for nitrogen and potassium. Nitrogen should be applied at short intervals during growth whereas potassium should be applied at planting and perhaps twice a year and phosphorus was required only at planting.

2 Effect of farmyard manure on quality of banana

Philips (1972) opined that fertilizers have some detrimental effects on plant environment.

Herath *et al.* (1977) reported that the application of 8.25 t cattle manure per hectare every four months increased total bunch weight, number of hands/bunch and number of fruits per bunch. Cerna (1980) reported that application of nitrogen and potassium in the absence of FYM retarded formation of vegetative organs and subsequently reproductive organs.

According to Joseph (1985) the lowest rotting percentage of oriental pickling melon was registered when the crop was supplied with farmyard manure and wood ash.

Perchova and Prugar (1986) studied the nitrate content of lettuce in relation to fertilizer and climatic factors and reported that farmyard manure positively affected nitrification process in soil and nitrate accumulation in the crop.

Termine *et al.* (1987) conducted an experiment to find out the effect of mineral and organic fertlizers on the content of nitrates in leaks and turnips and observed that crop nitrate content was significantly low with organic fertilizer like compost and sheep manure than with bone meal or mineral fertilizer application. The lowest nitrate content were observed in the treated controls.

Gomes *et al.* (1988) obtained highest yield from banana plots receiving both FYM and NPK fertilizers than the plots without FYM application. Paydas *et al.* (1988) reported that FYM had a better effect on the nutrient uptake and fruit yield in Dwarf Cavendish banana.

Meier *et al.* (1989) reported that the use of biogenic waste gave superior results with regard to storage, quality, content of desirable nutrients like vitamin C, sugar and undesirable constituents like nitrates in tomato and cabbage.

Ogabadu and Easman (1989) studied the effect of inorganic and organic fertilizers on the chemical composition of three egg plant cultivars and the results revealed that fertilizer application increased crude fibre, acidity and vitamin C.

Leclere *et al.* (1991) studied the vitamin and mineral content of carrot and celeries grown under mineral and organic fertilizers. Organically grown carrots had more β carotene, while organically grown celery had more vitamin and less nitrate than conventionally grown crops.

Based on another study by Voghtmann *et al.* (1993) reported that composts significantly reduced nitrate content in vegetables.

3 Changes occurring during ripening of banana

Lal *et al.* (1974) observed that ripening cause an increase in sugar and protein content of the fruit. Singh *et al.* (1985) also observed that protein content was increased during ripening of banana fruit.

Marriott *et al.* (1981) reported that total sugar was 23 per cent in fully ripe and over ripe bananas, but in plantains it increased from 20 per cent at full ripe stage to 27 per cent at over ripe stage.

Tripathy *et al.* (1981) observed the changes during ripening in banana fruit. The pulp:peel ratio increased during ripening. Acidity, protein and sugar content increased while ascorbic acid decreased during ripening.

Marriott *et al.* (1983) studied the changes in composition during ripening of plantain and reported that total sugar content continued to increase after full maturity and was still increasing in over ripe fruits. Ripe plantains fully yellow but showing no blackening contained 3-12 per cent starch and 18-28 per cent total sugars.

Abdullah *et al.* (1985) observed an increase in sugar content whereas pH and remains more or less same, in banana on ripening.

Fernandez *et al.* (1985) reported that proteins increased quantitatively and qualitatively during ripening from a content of 0.5 mg/ml to 0.9 mg/ml in Dwarf Cavendish banana.

Munasque and Mendoza (1990) observed that during ripening total sugar and titratable acidity increased.

Almazan (1991) reported that the pulp:peel ratio increased during ripening. Total acid crude, fibre, percentage of protein and sugar content also increased.

Collin and Dalnic (1991) obtained a decrease in starch content, an increase in acidity and total sugar during ripening. The increase in pulp acidity is due to an increase in citric acid.

Giami and Alu (1994) reported that ripening increased the crude protein and total ash content but decreased the carbohydrate and fat content of the pulp.

4 Effect of major nutrients on sugars, acidity and vitamin C contents

Reuther and Smith (1951) studied the effect of fertilizers on the fruit quality of valencia orange and reported that acidity of the fruit increased with increasing levels nitrogen. Ali (1952) conducted an experiment on the manuring of citrus and concluded that nitrogen had no effect in the quality of citrus. The percentage of total sugar in fruits was more under higher levels of potassium in combination with high level of phosphorus.

Webber *et al.* (1956) reported that acidity of the lime fruits increased with increasing levels of nitrogen.

Schuphan and Postel (1958) opined that added N decreased the vitamin C content of Spinach.

Singh and Agarwal (1960) studied the nitrogen requirement of citrus and reported that nitrogen had no effect on the quality of citrus. The percentage of total sugar increased with increasing levels of nitrogen and phosphorus. Another study conducted by Bunneman and Gruppe (1961) revealed that phosphorus had very little effect on the sugar content of fruits, but higher dose of K increased the sugar and acid content in strawberries.

Roy and Seth (1971) reported that ascorbic acid content increased with application of nutrients.

Ramasamy and Muthukrishnan (1972) studied the effect of leaf nitrogen on the composition and quality of Robusta banana (*Musa cavendishii* Lamp.). The acidity of peel and pulp varied with growth, amount of N applied and leaf N content. A progressive increase in reducing sugars in the fruit peel and pulp was noted in response to increasing N application. Nitrogen at 170 g/plant compared to 0, 85 or 255 g/plant gave the highest percentage of reducing sugars.

Nachaiva (1973) observed the highest ascorbic acid content in tomato fruits receiving N and K or N and P fertilizers.

Jambulingam *et al.* (1975) studied the effect of potassium on robusta banana and reported that potassium had a pronounced effect on fruit titratable acids and soluble solids.

Sistrunk and Dradley (1975) reported that addition of nitrogen decreased ascorbic acid content in turnip.

Vadivel and Shanmughavelu (1978) conducted an experiment on the effect of increasing rates of potassium on the quality of banana cv. Robusta. Total soluble solid content of banana increased with an increase in the level of K_2O application (upto 300 g/plant) particularly with split applications. Reducing, non-reducing and total sugar contents increased with increased rates of K_2O while acidity decreased and the sugar/acid ratio was enhanced. Fruit ascorbic acid content also increased with K_2O application.

Khatua *et al.* (1981) studied the effect of $N:P_2O_5:K_2O$ on the growth, yield and quality of pineapple var. Kew and reported that P had no effect on the sugar content of fruits. Henry *et al.* (1984) studied the effect of NPK on yield and fruit quality of country pear. The N rates were 0, 50 and 100 g/plant, P_2O_5 rates were 0, 25 and 50 g/plant and K_2O rates were 0, 50 and 100 g/plant. Application of 600 g N, 150 g P_2O_5 and 300 g K_2O resulted in higher yield and fruit T.S.S. The acid content was lowest in treatment with 600 g N, 150 g P_2O_5 and 600 g K_2O per plant.

Mitra and Bose (1985) studied the effect of varying levels of nitrogen, phosphorus and K_2O on yield and quality of guava. They reported that total soluble solids, sugar, acid and vitamin C content of fruits were found to increase with higher levels of potassium. Higher levels of nitrogen adversely affected the quality of fruits whereas different levels of P had no marked effect on fruit quality.

Patil and Patil (1986) studied the effect of NPK and its method of application on ascorbic acid content of radish and reported that an inverse relationship existed between N application and ascorbic acid content. Phosphorus and potassium application enhanced the accumulation of ascorbic acid.

Singh *et al.* (1986) reported that application of N decreased ascorbic acid content of amaranthus.

Chattopadhyay and Bose (1986) studied the effect of NPK nutrition on growth, yield and quality of Dwarf Cavendish banana and reported that acidity of the fruit showed a reduction with increase in K levels.

Mustaffa (1987) conducted an experiment on the effect of 0, 50, 150, 200, 250, 300 and 400 g K_2O/plant on bananas (var. Robusta) under rainfed conditions and reported that potassium improved the quality of the fruit by raising the T.S.S. and ascorbic acid content and reducing acidity.

Zhang *et al.* (1988) studied the effect of combined use of organic and inorganic fertilizer on the yield and quality of tomato and reported that application of both organic and inorganic fertilizers in a balanced manner resulted in better growth of tomato plants, higher yield and better fruit quality.

Mustaffa (1988) studied the effect of K fertilizer on growth, yield and quality of an hill banana. K fertilizer was applied at 0 to 400 g/plant. The fruit quality was improved due to an increase in T.S.S. and ascorbic acid content and reducing acidity for plots receiving K at 300 g/plant.

In another study by Ram and Prasad (1988) on the effect of N, P and K on fruit quality of banana cv. Camperganj local (Musa ABB), obtained the maximum T.S.S. from plots with NPK at 200:80:200 g/plant and total sugar with 300:120:100 g/plant.

Ghosh *et al.* (1989) conducted a study on the effect of nitrogen on growth, yield and quality of banana cv. Giant Governer. The rates included N 90 g, 120 g and 240 g. The fruit quality in terms of T.S.S. and ascorbic acid contents was high with 120 g N, fruit acidity and sugar content also increased with increasing N application.

Another study was conducted to find out the influence of inorganic and organic fertilizers on the chemical composition of egg plant. The results revealed that fertlizer application increased crude fibre, titratable acidity and ascorbic acid (Ogabadu and Easman, 1989).

Montagu and Ghu (1990) concluded that fruit vitamin C concentration decreased when any one of N fertlizers was applied based on their study on the effect of two inorganic and two organic nitrogenous fertilizer on yield and quality of tomato.

Singh *et al.* (1992) conducted an experiment on the effect of nitrogen on the quality of banana (*Musa paradisiaca*) and obtained highest T.S.S., sugar and ascorbic acid with two per cent urea spray.

Pimpini *et al.* (1992) compared poultry manure and mineral fertilizers with non-fertilized control and reported that all the fertilizer treatments decreased the acidity of spinach.

5 Effect of major nutrients on carotene, protein, fibre and carbohydrate contents

Schuphan and Postel (1958) opined that added N increased the crude protein content of spinach due to enhanced absorption of added nitrogen and direct participation of nitrogen in protein synthesis. The carotene content was found to increase as the content of nitrogen in the plant increased.

Sistrunk and Dradley (1975) reported that addition of nitrogen increased the carotene content of turnip.

Akochi (1977) studied the effect of nitrogen and potassium on yield and quality of sugar beet and reported that nitrogen and potassium improved the crude protein content in sugar beet.

Subbiah and Ramanathan (1983) studied the influence of nitrogen and potassium on the crude protein and carotene content of amaranthus and reported that added nitrogen enhanced the quality such as crude protein and carotene. Potassium application have no marked effect on carotene content, but it improved the crude protein content.

Singh *et al.* (1985) studied the effect of split application of N on certain qualitative characters of amaranthus and reported that increasing levels of nitrogen from 20-60 kg/ha decreased the crude fibre content.

Singh *et al.* (1986) reported that application of N significantly increased crude protein and carotene content in amaranthus.

Another study was conducted to find out the influence of inorganic and organic fertilizers on the chemical composition of egg plant. It revealed that fertilizer application increased crude fibre and total protein content (Ogabadu and Easman, 1989).

Florescu *et al.* (1991) studied the effect of manuring with urban waste compost on the yield and quality of cucumbers and found that fruits grown with compost had higher content of carbohydrates.

In an experiment, poultry manure and mineral fertilizers were compared with non-fertilized control in spinach. Compared to control all the fertilizer treatments had more protein content (Pimpini *et al.*, 1992).

Singh *et al.* (1992) conducted an experiment on the effect of nitrogen on the quality of banana (*Musa paradisiaca*) and obtained highest protein content with two per cent spray of nitrogen.

6 Effect of major nutrients on nitrate content of banana

Nitrate is a natural constituent in plants and the concentration within plants vary with a number of environmental and genetic factors.

Minotti and Stanskey (1973) observed a straight forward relationship between the nitrate concentration of outer leaves of head lettuce and the amount of fertilizer N applied and it was also found that summer crop accumulated more nitrate than spring crop.

Maynard *et al.* (1976) studied the factors affecting nitrate accumulation in vegetables and reported that nitrate concentration in plants depends on the availability of nitrate in the root zone and the amount of fertilizer N applied and also reported that the process of absorption, translocation and assimilation of nitrate are affected by factors like light, moisture and nitrogen availability.

The relationship between nutrient supply and nitrate accumulation has been well documented by Commoner (1970). The amount of nitrogen fertilizer applied and the time and method of application govern the nitrate accumulation in vegetables. Increasing the level of nitrogen nutrition usually increases the nitrate concentration in vegetables (Baker and Maynard, 1971; Peek *et al.*, 1971; Schmidth *et al.*, 1971; Trevino and Murray, 1975).

Barker *et al.* (1971) showed that urea, ammonium nitrate and potassium nitrate side dressed to a spinach crop increased the nitrate concentration and that urea gave the least increase and potassium nitrate gave the greatest increase.

According to Schmidt (1971) amaranthus grown on highly fertile soil had 125 per cent more nitrate than those grown in medium fertile soils.

Sarah (1986) reported that nitrate accumulation increased with increasing levels of N in amaranthus. Custic *et al.* (1994) reported that increased nitrogen fertilization led to increased nitrate content in lettuce without significantly increasing the yield, although all the nitrate contents were below the maximum prescribed limit of FAO.

Doikova *et al.* (1986) studied the effect of fertilization on the productivity and total nitrogen and nitrate content of capsicum. The treatments included four rates of nitrogen with or without FYM 50 t/ha. The highest application rate of nitrogen i.e., 360 kg/ha with or without farmyard manure produced the highest total nitrogen and nitrate content in green fruits.

Materials and Methods

MATERIALS AND METHODS

1 Experiment details

1.1 Location

The experiment was laid out at Banana Research Station, Kannara of Kerala Agricultural University, in a deep well drained laterite soil which enjoyed a humid tropical climate.

1.2 Design and layout

Design - Second order rotatable surface design

The treatments included five levels of the four factors i.e., five levels of farmyard manure, nitrogen, phosphorus and potassium. If we go for 5^4 factorial experiment for banana, the experiment become too complicated and unhandy. Due to this, treatments were so chosen that only a few combinations need be tested and for that second order rotatable surface design was selected. There was an absolute control treatment and the total number of treatments was 18. The treatments were replicated twice. Thus there were only 36 plots for the experiment.

No. of replications	- 2
Crop/variety	- Banana - Nendran
Pit size	- 50 x 50 x 50 cm^3
Spacing	- 2 x 2 m^2
Plot size	- 4 x 4 m^2
No. of plant/plot	- 4

Treatment details

The details of treatments as follows:

1) Levels of Farmyard manure - 5 viz., 5.0, 7.97, 12.5, 17.13, 20.00 kg/plant

2) Levels of N - 5 viz., 100.00, 138.27, 200.00, 261.73, 300.00 g/pt

3) Levels of P - 5 viz., 50.00, 78.70, 125.00, 171.30, 200.00 g P_2O_5/pt

4) Levels of K - 5 viz., 100.00, 176.54, 300.00, 423.46, 500.00 g K_2O/pt

1.3 Treatment combinations

The treatment combinations were as follows:

Treatment	FYM kg/plant	N g/plant	P_2O_5 g/plant	K_2O g/plant
T_1	5.00	200.00	125.00	176.54
T_2	5.00	200.00	125.00	423.46
T_3	7.97	100.00	125.00	300.00
T_4	7.97	300.00	125.00	300.00
T_5	12.50	138.27	50.00	300.00
T_6	12.50	200.00	78.70	100.00
T_7	12.50	200.00	78.70	500.00
T_8	12.50	200.00	125.00	300.00
T_9	12.50	200.00	171.30	100.00
T_{10}	12.50	200.00	171.30	500.00
T_{11}	12.50	261.73	50.00	300.00
T_{12}	12.50	261.73	200.00	300.00
T_{13}	12.50	261.73	200.00	300.00
T_{14}	17.13	100.00	125.00	300.00
T_{15}	17.13	300.00	125.00	300.00
T_{16}	20.00	200.00	125.00	176.54
T_{17}	20.00	200.00	125.00	423.46
T_{18}	00.00	000.00	000.00	000.00

1.4 Application of treatments

Almost uniform sword suckers were selected for planting. The wet weight of suckers ranged from 3 to 3.5 kg. The planting was done on 19th August, 1996.

FYM was applied as single dose at the time of planting suckers. Nitrogen, P_2O_5 and K_2O were applied in two equal splits at two months and four months after planting. Other cultivation practices were carried out as per Package of Practices Recommendations of KAU (KAU, 1993).

2 Collection and preparation of samples

2.1 Soil

Soil samples were collected up to a depth of 30 cm. The samples were taken using soil auger from four different directions around the plant at varying radii within the basin of 60 cm radius. These samples were pooled to make a composite sample. The samples were dried in the shade, clods were broken using wooden mallet and sieved through 2 mm sieve.

After harvest, the plants were uprooted and separated into rhizome, pseudostem, leaves and bunch. The total weight was noted.

2.2 Plant samples

1) Unripe fruit: Samples of unripe fruits were collected from the middle finger in the top row of the second hand (D finger) (Gotteich *et al.*, 1964).
2) Pseudostem: Pseudostem samples were taken from middle one-third portion.
3) Rhizome: Samples were collected from the base of the corm.
4) Peel: Peel of the D finger was separated.
5) Ripe fruit: D finger was kept for ripening.

All the samples were chopped into small pieces and dried under shade and then dried in a hot air oven at 60-70°C. The samples were then ground in a mechanical grinder. The powdered samples were stored in polythene containers for chemical analysis.

Sample of the aforesaid portions were taken for fresh analysis like protein, vitamin C, sugars and acidity.

3 Biometric observations

Biometric observations were recorded monthly upto flowering stage.

Plant characters

1) Height of pseudostem

2) Girth of pseudostem

3) No. of functional leaves

4) Yield components

5) No. of hands/bunch

6) No. of fingers/bunch

4 Chemical analysis of samples

4.1 Soil samples

Mechanical analysis of initial soil sample was done by hydrometer method (Piper, 1942).

Soil reaction of 1:2.5 soil-water suspension was determined by pH meter. Electrical conductivity of the supernatent liquid of soil-water suspension used for pH determination was read in conductivity meter (Jackson, 1958).

The organic carbon content was determined by Walkley and Black method as described by Jackson (1958). Total nitrogen was determined by modified microkjeldahl digestion-distillation method (Hesse, 1971).

For the total elemental analysis of P, K, Ca, Mg, S, Fe, Mn, Cu and Zn, the samples were extracted with a diacid mixture (HNO_3 and $HClO_4$ in 2:1 ratio). Total P was determined colorimetrically by ascorbic acid blue colour method. For the content of total K, the extract was diluted and read in EEL flame photometer. Total content of Ca, Mg, Fe, Mn, Cu and Zn were determined in atomic absorption spectrophotometer. Total S was estimated by turbidimetry (Hesse, 1971).

Available N content was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available P was extracted using the Bray No.1 extract (0.03N NH_4F in 0.025N HCl) and the P content was estimated colorimetrically (Watanabe and Olsen, 1965).

4.2 Farmyard manure

Samples of farmyard manure used for the experiment were analysed for total content of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and Zn.

4.3 Plant samples

Fresh samples were used for the estimation of protein, vitamin C, sugars and acidity.

4.3.1 Carbohydrate

The total carbohydrate content was determined by phenol sulphuric acid method suggested by AOAC (1980). Hundred mg of the sample was hydrolysed by hydrochloric acid. After neutralising with sodium carbonate, the volume was made upto 100 ml. Yellow colour was developed with phenol and concentrated sulphuric acid. The colour was read at 490 nm using spectrophotometer. The total carbohydrate content was expressed as percentage.

4.3.2 Protein

Protein was estimated by Lowry's method described by AOAC (1980). 500 mg of the sample was ground using 10 ml of TRIS buffer centrifuged and the supernatent was used for protein estimation by blue colour developed by Folin-ciocalteau reagent. The intensity of the colour was read at 660 nm uv-vis spectrophotometer. The amount of protein was expressed as mg of protein in 100 g of samples.

4.3.3 Fat

The fat content of the sample was extracted in petroleum ether using soxhlet extraction apparatus. A known weight of the sample packed in filterpaper was kept in the butt-tube of the soxhlet apparatus. The extracting medium used was petroleum ether. After six hours of distillation the fat content of the sample was collected in the pre-weighed receiver of the apparatus. The petroleum ether was evaporated and the fat content was estimated and expressed as percentage.

4.3.4 Total sugars

The total sugars was estimated as per the method described by AOAC (1980). It was expressed as percentage.

4.3.5 Reducing sugars

Reducing sugar was estimated by Fehling solution method (AOAC, 1980).

To 10 gm of fruit juice, distilled water was added. After thorough mixing the solution was clarified with neutral lead acetate and potassium oxalate and made upto 250 ml volume. The solution was filtered and an aliquot of this solution was titrated against a mixture of fehling solution A and B, using methylene blue as indicator. The reducing sugar was expressed in percentage.

4.3.6 Non-reducing sugar

The difference between total sugar and reducing sugars was worked out and expressed as per cent of non-reducing sugar.

4.3.7 Acidity

Acidity was estimated by method described by AOAC (1980). Ten gram of macerated sample was digested with boiling water and made up to a known volume. An aliquot of the filtered solution was titrated against 1N NaOH using phenolphthalien as indicator. The acidity was expressed as per cent of citric acid.

Oven dried samples were used for the estimation of carbohydrate, fat, total minerals, calcium, nitrogen, phosphorus, potassium, carotene, fibre and nitrate.

4.3.8 Nitrate

Nitrate content of the samples was determined by extracting with 3,4 dimethyl phenol and distillating it. The distillate was read at 430 nm using spectrophotometer using NaOH (Marderosian *et al.*, 1980).

One gram of the sample was extracted in 100 ml water for 30 minutes in a shaker. The filtrate was treated with 3,4 dimethylphenol and H_2SO_4. Then steam distillation was done and 25 ml of distillate was taken and read at 430 nm, after the addition of NaOH.The nitrate content was expressed as percentage.

4.3.9 Fibre

The fibre content of the fat free sample was determined after treating with H_2SO_4 and NaOH (AOAC, 1980). The air dried fat free sample was boiled for 30 minutes in H_2SO_4 and filtered to remove the acid soluble materials. The filtrate was then boiled in NaOH for 30 minutes to remove the alkali soluble constituents. Again the filtrate was treated with alcohol and ether, weighed and heated in a muffle furnace. It was then cooled and weighed and the loss in weight was expressed as percentage.

4.3.10 Carotene

The carotene content of dried fruit sample was estimated using spectrophotometer at 438.5 nm after extracting with water saturated n-butanol (AOAC, 1980).

4.3.11 Total minerals

The total minerals or ash content of the sample was determined by ashing the sample in a muffle furnace (Jackson, 1958). A known weight of the oven dried sample was taken in a pre-weighed crucible. The crucible was kept in the muffle furnace and the temperature was gradually raised to 500-600°C for six hours. After that the sample was taken out and weight was found out. The total minerals was expressed as percentage.

4.3.12 Nitrogen

The total N was determined by microkjeldhal method (Jackson, 1958).

4.3.13 Phosphorus

For the determination of phosphorus, the sample was extracted with a diacid mixture (HNO_3 and $HClO_4$ in 2:1 ratio). The P content was determined colorimetrically by the Vanadomolybdo phosphoric acid yellow colour method in HNO_3 system (Jackson, 1958).

4.3.14 Potassium

The potassium content of the sample was determined by extracting with a diacid mixture (HNO_3 and $HClO_4$ in 2:1 ratio). The extract was diluted and read in a flame photometer.

4.3.15 Calcium

The calcium content of the oven dried sample was determined by extracting with a diacid mixture (HNO_3 and $HClO_4$ in 2:1 ratio) and estimated using atomic absorption spectrophotometer (Jackson, 1958).

4.3.16 Vitamin C

Vitamin C was estimated as per the method suggested by AOAC (1980). Vitamin C extracted by oxalic acid reduces the oxidation-reduction indicator dye 2, 6, dichlorophenol indophenol to colourless solution. The content of vitamin C was expressed as mg of vitamin C in 100 g of sample.

5 Statistical analysis

The results of various parameters obtained from the experiment were analysed statistically for test of significance using M Stat C Package at College of Horticulture, Vellanikkara. The correlations were worked out using the procedure as described by Snedecor and Cochran (1967). The methods as described by Singh and Chaudhary (1977) was followed for path analysis.

Results

RESULTS

The present study was conducted to find out the changes in food nutrients under varying levels of organic matter, nitrogen, phosphorus and potassium in banana. In order to achieve the objective, a field experiment was laid out at Banana Research Station, Kannara, Thrissur district of Kerala Agricultural University. Soil samples were taken before and after the crop and analysed for physical and chemical properties. Biometric observation were recorded monthly upto the flowering stage. Plant samples were taken from different parts like ripe fruit, unripe fruit, unripe peel pseudostem and rhizome. The results of this experiment are narrated in this chapter.

1 Biometric observations

1.1 Height of pseudostem

The effect of various treatments on the height of pseudostem is depicted in Table 1. The height of the plants did not differ significantly during the different stages of growth studied. However the effect of fertilizer application was observed by increasing trends in the height of the pseudostem when compared to the control treatment at all the stages except at 2 MAP as at this stage some of the treatments have recorded lower values compared to absolute control.

1.2 Girth of pseudostem (cm)

The effect of various treatments on the girth of the pseudostem is depicted in Table 2. Girth of pseudostem was found non-significant during the early stage of growth. However significant difference between treatments was observed at fifth and sixth months and the lowest value was recorded by T_{18} (Control) from third month onwards.

Table 1. Effect of treatments on the height (cm) of pseudostem of banana cv. Nendran at different periods of growth

Treatment	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	142.6	187.6	238.1	296.5	357.1	377.4
T_2	126.4	183.4	206.8	276.5	339.8	387.0
T_3	140.9	168.5	230.6	296.5	350.5	379.9
T_4	138.5	170.8	197.5	277.5	331.0	361.1
T_5	112.4	160.3	245.0	308.5	366.5	427.1
T_6	133.9	174.0	219.3	335.0	389.6	415.7
T_7	138.3	174.0	233.2	301.9	368.5	389.5
T_8	156.9	190.6	228.2	336.9	395.0	464.6
T_9	109.6	169.4	217.7	263.2	305.1	344.6
T_{10}	145.1	192.8	229.1	279.4	326.7	382.0
T_{11}	125.7	177.4	236.3	303.1	356.0	437.9
T_{12}	150.1	292.2	228.6	308.8	325.2	407.7
T_{13}	158.3	203.9	249.2	296.7	354.3	402.9
T_{14}	153.4	168.2	206.2	300.4	394.3	408.2
T_{15}	148.1	183.0	214.4	280.8	376.0.	392.2
T_{16}	166.6	196.5	229.4	290.9	356.3	379.3
T_{17}	162.1	199.4	223.8	300.3	367.3	392.7
T_{18}	139.9	152.4	160.4	201.0 .	253.0	282.2
Mean	141.6	185.0	221.9	291.9	350.6	390.7
CD	NS	NS	NS	NS	57.29*	59.3*

MAP - Months after planting
* - Significant at 5% level

Table 2. Effect of treatments on the girth (cm) of pseudostem of banana cv. Nendran at different periods of girth

Treatment	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	20.9	27.5	38.3	46.7	53.4	56.2
T_2	22.0	29.2	37.9	49.3	55.8	63.4
T_3	20.5	27.8	37.9	49.3	56.9	61.3
T_4	21.8	27.3	37.6	46.3	54.4	62.1
T_5	20.9	28.4	43.1	49.9	55.4	61.6
T_6	21.6	30.2	38.8	49.5	55.1	63.7
T_7	21.0	28.5	39.7	48.5	55.1	59.7
T_8	23.6	31.3	42.3	49.5	59.7	67.6
T_9	20.9	27.2	36.8	44.9	50.7	58.3
T_{10}	23.6	34.0	42.7	48.4	58.9	65.1
T_{11}	22.4	29.6	39.3	53.0	55.5	65.9
T_{12}	23.8	29.9	39.4	47.6	58.3	59.7
T_{13}	25.0	30.4	35.7	49.3	55.0	64.1
T_{14}	20.3	25.8	38.3	45.8	55.4	60.1
T_{15}	21.1	28.5	38.3	47.2	55.4	62.2
T_{16}	25.4	32.6	38.1	44.8	55.2	58.1
T_{17}	21.0	29.8	40.6	50.4	57.8	62.3
T_{18}	22.1	24.4	28.1	32.9	37.8	44.3
Mean	22.1	29.0	38.5	47.4	51.7	60.9
CD	NS	NS	NS	7.89*	6.90**	NS

* Significant at 5% level

**Significant at 1% level

MAP - Months after planting

1.3 Number of functional leaves

The effect of treatments on the number of functional leaves at different stages of growth are given in Table 3.

Significant differences in the number of functional leaves between treatments were observed from fifth month onwards. At 5 MAP the treatment T_8 recorded the maximum number of functional leaves (13.9) and the minimum (9) was recorded by T_{18} (Control). At fifth and seventh month T_8 recorded the maximum value. At sixth month T_8 is on par with T_2 and T_{17} which have recorded the maximum value. The lowest value was recorded by T_{18} at all the stages of growth. From fifth month onwards all the treatments have recorded significant higher values compared to control.

1.4 Yield and yield attributes of banana

The data on yield and yield attributes are presented in Table 4.

There was significant difference in the biomass yield of banana at the time of harvest between various treatments. The treatment T_8 recorded the highest value of biomass yield (85.91 kg) which was on par with T_{13} (84.27 kg). The absolute control recorded the lowest value of 48.14 kg.

In the case of bunch weight also there was significant difference between treatments. The absolute control (T_{18}) got the lowest bunch weight of 3.75 kg whereas the highest bunch weight was recorded by T_2 (9.52 kg). The increase in yield of T_2 was 154 per cent more over the control.

The number of hands did not differ significantly among treatments. There was significant difference in the number of fingers per bunch. The highest number

Table 3. Effect of treatments on the number of functional leaves of banana cv. Nendran at different periods of growth

Treatment	2 MAP	3 MAP	4 MAP	5 MAP	6 MAP	7 MAP
T_1	6.5	7.9	9.6	11.1	12.6	13.9
T_2	6.5	8.3	10.2	12.6	14.5	15.4
T_3	6.8	8.5	8.6	12.4	13.3	13.9
T_4	6.5	7.5	9.4	10.8	12.0	13.5
T_5	6.8	8.3	10.3	11.8	13.0	13.0
T_6	6.9	8.3	9.8	12.5	14.0	13.8
T_7	7.0	7.8	9.5	11.5	12.3	13.8
T_8	6.9	8.1	10.0	13.9	14.4	15.8
T_9	6.4	7.1	9.8	11.4	13.6	13.3
T_{10}	7.0	8.1	9.3	12.3	12.4	13.8
T_{11}	6.4	8.3	10.8	12.0	14.3	14.8
T_{12}	6.6	7.5	10.0	12.1	13.5	13.4
T_{13}	6.9	8.6	9.8	11.8	13.4	13.5
T_{14}	6.8	7.9	9.8	13.0	13.6	13.6
T_{15}	7.3	8.6	10.1	12.0	13.3	13.0
T_{16}	6.5	8.0	10.1	11.5	12.1	13.0
T_{17}	6.8	9.3	10.0	11.1	14.5	14.9
T_{18}	6.3	6.8	8.4	9.0	10.1	11.2
Mean	6.7	8.1	9.8	11.8	13.2	13.8
CD	NS	NS	NS	1.03**	0.88**	1.54**

**Significant at 1% level

MAP - Months after planting

Table 4. Effect of treatments on the yield and yield attributes of banana cv. Nendran

Treatment	Biomass yield (kg)	Bunch yield (kg)	No.of hands/ bunch	No.of fingers/ bunch
T_1	71.50	8.23	5	47.6
T_2	77.29	9.52	5	52.6
T_3	70.61	9.00	6	52.2
T_4	71.81	8.21	5	47.9
T_5	72.79	8.67	5	52.0
T_6	75.53	8.67	5	49.3
T_7	68.55	8.24	5	44.8
T_8	85.91	9.47	6	50.2
T_9	70.05	8.87	5	45.8
T_{10}	74.68	8.32	5	49.1
T_{11}	76.14	9.28	5	50.4
T_{12}	67.33	8.74	5	47.8
T_{13}	84.27	9.34	5	52.8
T_{14}	67.80	8.80	6	49.0
T_{15}	77.40	9.16	5	51.8
T_{16}	68.13	8.87	5	47.3
T_{17}	74.26	9.04	5	48.4
T_{18}	48.14	3.75	4	29.5
Mean	72.34	8.57	5.1	48.25
CD	3.58*	1.13**	NS	7.58**

* Significant at 5% level

**Significant at 1% level

of fingers per bunch was recorded by the treatment T_{13} and the lowest number of fingers per bunch was recorded by the treatment T_{18} (Control) with a value of 29.5.

2 Analysis of plant samples

2.1 Carbohydrate content (per cent)

The effect of treatments on the carbohydrate content of ripe and unripe fruit, unripe peel, rhizome and pseudostem is depicted in Table 5.

The carbohydrate content of ripe banana fruit was maximum in T_5 (14.63%) and minimum in T_{18} (10.47%). The treatments showed significant difference in the carbohydrate content of ripe fruits.

There was significant difference in the carbohydrate content of unripe fruits of banana. Maximum carbohydrate content was recorded in T_{10} (25.08%) which was on par with T_2, T_6, T_7, T_8, T_{11} and T_{12}.

The treatments did not differ significantly in the carbohydrate content of peel of unripe fruits. However T_{13} recorded a maximum content of 12.46 per cent which was about 25 per cent higher than the absolute control (T_{18}).

The treatments did not differ significantly in the carbodydrate content of the rhizome also. However the maximum content of carbohydrate was recorded in T_{14} (14.62%). The minimum content was obtained in the absolute control (T_{18}) (11.5%).

The treatments did not differ significantly in the carbohydrate content of pseudostem also. However the treatment T_{16} recorded the highest value (14.13%) and absolute control recorded lowest value (11.94%).

Table 5. Effect of treatments on the carbohydrate content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	13.19	21.60	10.42	12.60	12.24
T_2	12.94	22.35	10.34	12.76	13.35
T_3	11.49	21.87	11.42	13.31	13.55
T_4	12.79	21.68	11.95	12.96	13.43
T_5	14.63	22.11	11.23	13.07	13.43
T_6	13.49	22.99	10.70	12.49	13.38
T_7	11.89	22.50	10.47	12.40	12.95
T_8	11.11	22.80	11.08	12.81	13.06
T_9	13.08	20.49	11.83	13.38	11.98
T_{10}	14.35	25.08	10.27	12.53	12.15
T_{11}	13.75	23.13	11.36	12.46	13.12
T_{12}	13.92	23.01	11.64	12.52	12.48
T_{13}	14.07	21.08	12.46	12.55	13.86
T_{14}	13.33	21.55	12.39	14.62	12.85
T_{15}	13.63	21.44	10.83	12.61	13.67
T_{16}	12.01	21.94	11.11	13.38	14.13
T_{17}	11.19	20.97	12.12	11.99	12.57
T_{18}	10.47	20.54	10.07	11.55	11.94
Mean	12.85	22.06	11.04	12.08	13.00
CD	2.43*	2.84*	NS	NS	NS

* Significant at 5% level

RF - Ripe fruit

UF - Unripe fruit

2.2 Protein content

The protein content (mg/100 g) of the different parts as influenced by the treatments is presented in Table 6.

There was significant difference in the protein content of ripe fruit. The highest content of protein was recorded in T_{16} (127.81) which was on par with T_{13} (121.29). The lowest value (48.81) was recorded in T_{18} (control). The protein content of T_{16} was 160 per cent higher than that of the absolute control which showed that fertilizer application has much influence in the protein content of ripe banana.

There was significant difference in the protein content of unripe fruits also. The treatment T_{16} as in the case of ripe fruit recorded maximum content (88.35) of protein. This treatment was on par with T_{13}. Absolute control recorded the lowest value of 36.67 per cent and it is significantly lower than all other treatments.

The treatments showed significant difference in the protein content of peel. The maximum content (94.85) was recorded in T_{16} and minimum value (45.38) in T_{18}.

The highest content of protein in rhizome was recorded by the treatment T_{17} (40.33) which was on par with all other treatments except control which have recorded the lowest value of 24.49 mg/100 g.

The treatments showed significant differences among themselves in the protein content of pseudostem. The highest value was recorded in the treatment T_{11} (65.73) which was on par with T_9 and T_{13}. The lowest value (30.94) was recorded for absolute control.

Table 6. Effect of treatments on the protein content (mg/100g) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	82.49	73.75	80.82	31.37	32.23
T_2	79.08	59.88	66.52	37.58	44.89
T_3	67.89	52.27	72.31	34.72	39.46
T_4	85.36	62.74	78.39	37.46	39.46
T_5	64.59	54.11	80.12	39.32	43.33
T_6	81.16	65.60	59.34	38.01	54.78
T_7	81.89	78.16	72.36	37.72	33.16
T_8	80.28	61.77	75.80	29.78	64.99
T_9	67.73	52.99	63.76	31.71	31.56
T_{10}	66.89	53.71	57.97	37.91	47.92
T_{11}	67.65	60.24	64.09	40.08	65.73
T_{12}	70.36	53.23	83.07	30.26	45.45
T_{13}	121.29	81.50	79.87	39.87	63.61
T_{14}	112.37	78.54	65.24	33.75	34.75
T_{15}	82.93	65.00	63.47	40.10	44.15
T_{16}	127.81	88.35	94.85	37.95	35.92
T_{17}	84.11	55.27	59.56	40.33	37.61
T_{18}	48.81	36.67	45.38	24.49	30.94
Mean	81.89	62.98	70.01	35.68	43.88
CD	9.48**	8.43**	13.27*	14.01*	10.23*

* Significant at 5% level
** Significant at 1% level
RF - Ripe fruit
UF - Unripe fruit

2.3 Fat content

The effect of treatments on the fat content (%) of ripe and unripe fruit, unripe peel, rhizome and pseudostem is presented in Table 7.

The treatments did not differ significantly in the fat content of ripe fruit. However the treatments T_7 and T_{15} recorded maximum contents of fat (0.500) in the ripe fruit and the lowest value was recorded for absolute control (0.175) along with treatments T_2, T_5 and T_9.

The treatments showed significant difference in the fat content of unripe fruit. The treatment T_{15} recorded maximum value of 0.675 per cent. Absolute control recorded the lowest value of 0.225 per cent.

There was significant difference in the fat content of peel also. The treatment T_{12} recorded highest content of fat (3.210) which was on par with T_{11}. Absolute control recorded the lowest value of 0.188 per cent. The fat content of T_{12} was 70 per cent more than that in the absolute control.

The treatment showed significant difference in the fat content of rhizome also. The highest content of fat was recorded in T_{17} (0.49). The treatment T_{18}, absolute control recorded lowest content of fat (0.175). The treatment T_{17} recorded 180 per cent more fat than absolute control.

The treatments varied significantly in the fat content of pseudostem. The maximum value was recorded in T_5 (0.965) which was on par with T_3, T_4, T_{11} and T_{14}. Absolute control recorded the lowest value of 0.525 per cent.

Table 7. Effect of treatments on the fat content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.250	0.300	2.110	0.300	0.625
T_2	0.175	0.350	1.910	0.410	0.750
T_3	0.400	0.425	2.875	0.275	0.815
T_4	0.475	0.300	2.785	0.250	0.795
T_5	0.175	0.325	2.265	0.365	0.965
T_6	0.350	0.450	2.330	0.415	0.655
T_7	0.500	0.525	2.550	0.475	0.550
T_8	0.400	0.450	2.785	0.450	0.820
T_9	0.175	0.375	2.800	0.450	0.650
T_{10}	0.400	0.500	2.655	0.405	0.625
T_{11}	0.300	0.400	3.130	0.475	0.725
T_{12}	0.300	0.425	3.210	0.325	0.540
T_{13}	0.350	0.475	2.755	0.450	0.650
T_{14}	0.425	0.475	2.605	0.440	0.800
T_{15}	0.500	0.675	2.330	0.420	0.550
T_{16}	0.350	0.375	2.130	0.475	0.550
T_{17}	0.250	0.315	1.980	0.490	0.675
T_{18}	0.175	0.225	0.188	0.175	0.525
Mean	0.330	0.409	2.411	0.391	0.681
CD	NS	0.133**	0.200*	0.240*	0.264*

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

2.4 Total sugar

The changes in total sugar content (%) of ripe and unripe fruit, unripe peel, rhizome and pseudostem as influenced by the treatments are depicted in Table 8.

The treatments showed significant difference in the total sugar content of ripe fruit. The treatment T_{16} recorded maximum total sugar content of 29.5 per cent and it was on par with T_{14}. Absolute control (T_{18}) recorded the least value of 7.18 which was on par with T_1.

There was significant difference between treatments in the content of sugar in the unripe fruit. The treatment which recorded maximum total sugar content was T_7 (9.22%) which was on par with T_2, T_{10} and T_{16}. Absolute control (T_{18}) recorded lowest value of 1.52.

The total sugar content of the unripe fruit peel showed significant difference between treatments. The treatment T_{12} recorded maximum content of total sugar (4.25%). Absolute control recorded the lowest value of 0.70 per cent.

The treatment did not differ significantly in the total sugar content of rhizome. However the maximum content was recorded by T_{15}. Absolute control recorded the lowest value of 0.320 per cent.

The treatments showed significant difference in the content of total sugar in the pseudostem. The treatment T_7 recorded the maximum total sugar content of 3.30. Absolute control (T_{18}) recorded the lowest value of 1.075 per cent.

2.5 Reducing sugar

The data on the effect of treatments on the reducing sugar content of the ripe and unripe fruit, unripe peel, rhizome and pseudostem is presented in Table 9.

Table 8. Effect of treatments on the total sugar content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	9.14	3.96	2.99	0.525	1.320
T_2	14.68	7.23	3.98	0.909	1.175
T_3	17.25	4.12	3.50	0.960	1.650
T_4	17.34	6.02	3.72	0.850	1.570
T_5	18.93	5.76	2.01	0.790	1.390
T_6	23.75	6.15	3.20	0.735	2.155
T_7	19.33	9.22	3.20	0.550	3.300
T_8	22.65	3.92	3.20	0.625	1.440
T_9	15.24	3.82	2.60	0.875	1.400
T_{10}	22.63	7.55	3.80	0.950	1.255
T_{11}	18.36	4.63	3.89	1.000	1.850
T_{12}	25.23	5.12	4.25	0.940	1.120
T_{13}	24.75	4.49	2.25	0.965	1.550
T_{14}	27.34	5.00	2.03	0.970	1.215
T_{15}	23.15	4.94	2.41	1.360	1.850
T_{16}	29.50	8.99	3.23	0.910	2.995
T_{17}	13.82	5.10	2.30	0.615	1.650
T_{18}	7.18	1.52	0.43	0.320	1.075
Mean	19.36	5.54	2.94	0.810	1.664
CD	3.10**	2.07**	0.18**	NS	0.120**

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

Table 9. Effect of treatments on the reducing sugar content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	4.35	1.56	1.42	0.090	0.730
T_2	7.68	1.02	1.08	0.330	0.375
T_3	10.25	1.57	1.40	0.345	0.755
T_4	10.34	1.14	0.99	0.075	0.550
T_5	11.00	1.85	0.90	0.270	0.585
T_6	13.75	1.99	0.82	0.410	0.885
T_7	9.00	2.58	1.00	0.060	1.845
T_8	12.65	1.90	0.78	0.070	0.845
T_9	7.24	2.35	0.90	0.195	0.705
T_{10}	12.63	2.51	0.90	0.065	0.760
T_{11}	8.36	1.33	0.37	0.075	0.730
T_{12}	15.00	1.25	1.96	0.270	0.570
T_{13}	14.75	1.47	1.06	0.215	0.895
T_{14}	16.67	1.70	1.08	0.135	0.620
T_{15}	13.00	1.11	1.91	0.395	0.995
T_{16}	16.70	1.56	0.72	0.130	1.350
T_{17}	6.82	1.75	1.02	0.090	0.780
T_{18}	4.08	0.50	0.20	0.055	0.670
Mean	10.79	1.68	1.028	0.181	0.813
CD	2.14*	0.94**	NS	NS	0.48**

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

The treatments showed significant difference in the sugar content of ripe fruit. The treatment T_{16} recorded maximum value of 16.70 per cent in the content of reducing sugar content which was on par with T_{12}, T_{13} and T_{14}. Absolute control recorded the lowest value of 4.08 which was on par with T_1.

The treatments showed significant difference in the reducing sugar content of unripe fruit. The treatment, T_7 recorded the maximum content of 2.58 per cent of reducing sugar which was on par with T_{10}. Absolute control recorded the lowest value of 0.50 per cent.

The reducing sugar content of the unripe fruit peel did not differ significantly with the treatments. The treatment T_{12} recorded the maximum content of 1.96 per cent reducing sugar. Absolute control recorded the lowest value of 0.20 per cent.

The treatments did not differ significantly in the reducing sugar content of rhizome. However, the treated plots showed increasing trend in the content of reducing sugar.

The treatments showed significant difference in the content of reducing sugar in the pseudostem. The treatment T_7 recorded the maximum total sugar content (1.845%) which was on par with T_{16}. Absolute control recorded lowest value of 0.67 per cent.

2.6 Nonreducing sugar

The changes in nonreducing sugar content of ripe and unripe fruit, unripe peel, rhizome, pseudostem as influenced by the treatments is presented in Table 10.

Table 10. Effect of treatments on the non reducing sugar content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	4.79	2.40	1.57	0.435	0.590
T_2	7.00	6.21	2.90	0.579	0.800
T_3	7.00	2.55	2.10	0.615	0.895
T_4	7.00	4.88	2.73	0.775	1.020
T_5	7.93	3.91	1.11	0.520	0.805
T_6	10.00	4.16	2.38	0.325	1.270
T_7	10.33	6.64	2.20	0.490	1.455
T_8	10.00	2.02	2.42	0.555	0.595
T_9	8.00	1.47	1.70	0.680	0.695
T_{10}	10.00	5.04	2.90	0.885	0.495
T_{11}	10.00	3.30	3.52	0.925	1.120
T_{12}	10.23	3.87	2.29	0.670	0.550
T_{13}	10.00	4.02	1.19	0.750	0.655
T_{14}	10.67	3.30	0.95	0.835	0.595
T_{15}	10.15	3.83	0.50	0.965	0.855
T_{16}	12.80	7.43	2.51	0.780	1.645
T_{17}	7.00	3.35	1.28	0.525	0.870
T_{18}	3.00	1.02	0.23	0.265	0.405
Mean	8.66	3.23	1.91	0.643	0.795
CD	1.98*	1.55**	0.23**	NS	0.21**

* Significant at 5% level
** Significant at 1% level
RF - Ripe fruit
UF - Unripe fruit

The treatments showed significant difference in the content of nonreducing sugar of ripe fruit of banana. The treatment T_{16} recorded the maximum value of 12.8 per cent. The lowest value (3%) was recorded by absolute control T_{18}.

The treatments showed significant difference in the nonreducing sugar content of unripe fruit. The treatment T_{16} recorded the maximum nonreducing sugar content of 7.43 per cent which was on par with T_2 and T_7. The treatment absolute control recorded the lowest value of 1.02 per cent.

The nonreducing sugar content of unripe fruit peel showed significant difference between treatments. The treatment T_{11} recorded maximum content of (3.52%) nonreducing sugar. Absolute control recorded the lowest value (0.23).

The treatments did not differ significantly in the nonreducing sugar content of rhizome. However, there was an increasing trend in the treated plots in the content of nonreducing sugar.

The treatments showed significant difference in the nonreducing sugar content of the pseudostem. The highest content of 1.645 was recorded by T_{16} which was on par with T_7. Absolute control (T_{18}) recorded the lowest value of 0.405 per cent.

2.7 Acidity

The data on the acidity of the ripe and unripe fruit, unripe peel, rhizome and pseudostem of banana as influenced by the treatments are tabulated in Table 11.

The treatments differ significantly in the acidity of ripe banana fruit. The highest acidity of 0.938 per cent was recorded by T_{17}. The lowest value of 0.486 per cent was recorded by absolute control (T_{18}).

Table 11. Effect of treatments on the acidity (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.880	0.141	0.095	0.058	0.042
T_2	0.875	0.159	0.105	0.065	0.030
T_3	0.535	0.170	0.095	0.039	0.055
T_4	0.752	0.162	0.105	0.033	0.048
T_5	0.758	0.180	0.105	0.060	0.049
T_6	0.765	0.118	0.110	0.030	0.033
T_7	0.738	0.168	0.100	0.044	0.045
T_8	0.810	0.170	0.110	0.045	0.055
T_9	0.871	0.210	0.175	0.050	0.045
T_{10}	0.785	0.240	0.150	0.035	0.041
T_{11}	0.890	0.208	0.167	0.039	0.045
T_{12}	0.830	0.223	0.179	0.050	0.047
T_{13}	0.810	0.220	0.180	0.045	0.055
T_{14}	0.930	0.200	0.180	0.040	0.045
T_{15}	0.875	0.215	0.175	0.027	0.055
T_{16}	0.815	0.255	0.161	0.027	0.033
T_{17}	0.938	0.250	0.188	0.165	0.062
T_{18}	0.486	0.090	0.037	0.020	0.029
Mean	0.796	0.184	0.134	0.048	0.045
CD	0.152*	0.067*	0.066*	0.041*	NS

* Significant at 5% level
RF - Ripe fruit
UF - Unripe fruit

The content of acidity showed significant difference among treatments. The maximum value of acidity (0.255%) was recorded in T_{16} which was on par with treatments T_{17}. The lowest value of 0.09 per cent was recorded in absolute control (T_{18}).

The treatments showed significant difference in the acidity of the unripe fruit peel of banana. The maximum acidity was recorded in T_{17} (0.188%) and the treatment was on par with treatments T_9 to T_{16}. The lowest value (0.037%) was recorded for absolute control (T_{18}).

The acidity of the rhizome showed significant difference with the treatments. The treatment T_{17} recorded the maximum value (0.165) whereas absolute control recorded the lowest value (0.02).

The treatments did not differ significantly in acidity of pseudostem. However, there was an increasing trend in acidity in the plots receiving treatments.

2.8 Nitrate content

The data on the effect of treatments on the nitrate content of ripe and unripe fruit, unripe peel, rhizome and pseudostem is depicted in Table 12.

The treatments showed significant difference in the nitrate content in ripe fruit. The maximum content of 0.496 per cent was recorded in T_4 which was on par with T_{12}, T_{13} and T_{15}. The lowest value of 0.048 per cent was recorded in the absolute control (T_{18}).

The treatments showed significant difference in the unripe fruit also. Maximum nitrate content was recorded in T_4 and which was on par with T_{11}, T_{12}, T_{13} and T_{15} and the lowest content was recorded in absolute control (T_{18}) which was on par with T_1.

Table 12. Effect of treatments on the nitrate content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.052	0.178	0.721	0.423	0.645
T_2	0.284	0.301	0.683	0.615	0.608
T_3	0.234	0.630	0.738	0.323	0.583
T_4	0.496	0.791	0.828	0.851	0.934
T_5	0.098	0.298	0.620	0.684	0.605
T_6	0.182	0.328	0.643	0.416	0.240
T_7	0.382	0.334	0.743	0.604	0.212
T_8	0.084	0.363	0.481	0.793	0.683
T_9	0.389	0.650	0.788	0.602	0.591
T_{10}	0.091	0.338	0.704	0.381	0.484
T_{11}	0.215	0.698	0.695	0.410	0.606
T_{12}	0.484	0.784	0.801	0.804	0.874
T_{13}	0.436	0.758	0.809	0.864	0.814
T_{14}	0.146	0.299	0.504	0.262	0.605
T_{15}	0.486	0.788	0.838	0.884	0.906
T_{16}	0.283	0.310	0.732	0.515	0.689
T_{17}	0.134	0.641	0.632	0.363	0.384
T_{18}	0.048	0.087	0.241	0.204	0.192
Mean	0.251	0.476	0.677	0.555	0.592
CD	0.092**	0.103*	0.114*	0.108*	0.121*

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

The nitrate content in the unripe fruit peel showed significant difference between treatments. The maximum value was recorded in T_{15} (0.838%). The absolute control (T_{18}) recorded the lowest value of 0.241 per cent.

The treatments showed significant difference in the nitrate content of rhizome. The treatment T_{15} recorded the maximum content of nitrate (0.884%) in the rhizome and this treatment was on par with T_4, T_8, T_{12} and T_{13}. Absolute control recorded the lowest value (0.204%) for the nitrate content of rhizome.

In the case of pseudostem also the treatments showed significant difference in the content of nitrate. The treatment T_4 recorded the maximum nitrate content (0.934%) in the pseudostem which was on par with T_{12}, T_{13} and T_{15}. Absolute control recorded the lowest value of 0.192 per cent.

2.9 Fibre content

The changes in fibre content of ripe and unripe fruit, unripe peel, rhizome, pseudostem as influenced by the treatments are depicted in Table 13.

The treatments showed significant difference in the fibre content of ripe fruit. The treatment T_{14} recorded the highest content of fibre in ripe fruit and the lowest content of 0.075 per cent was recorded by T_{18} (absolute control).

The treatments did not differ significantly in the fibre content of unripe fruit, unripe peel, rhizome and pseudostem. However the plants receiving the treatments showed increasing trends in fibre content. When the mean values of the content of fibre in various edible parts were examined, maximum fibre content was observed in pseudostem followed by rhizome, peel, ripe fruit and unripe fruit.

Table 13. Effect of treatments on the fibre content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	1.065	0.175	5.10	8.16	8.35
T_2	0.975	0.100	5.08	8.46	8.17
T_3	1.140	0.130	5.38	7.75	9.12
T_4	1.200	0.175	5.37	6.99	8.44
T_5	1.500	0.125	5.74	7.72	8.36
T_6	1.450	0.175	5.48	7.99	8.42
T_7	1.295	0.125	5.26	7.41	8.89
T_8	1.215	0.110	5.53	8.97	8.40
T_9	1.075	0.135	5.03	8.29	8.17
T_{10}	1.680	0.100	5.46	8.90	8.45
T_{11}	1.475	0.165	5.47	9.01	8.75
T_{12}	1.215	0.175	5.21	8.30	8.92
T_{13}	1.370	0.175	5.30	7.69	8.20
T_{14}	1.785	0.185	5.46	8.15	8.47
T_{15}	1.430	0.175	5.76	8.68	8.76
T_{16}	1.310	0.130	5.04	9.30	8.81
T_{17}	1.235	0.140	5.06	8.90	9.18
T_{18}	0.075	0.095	4.95	6.18	8.12
Mean	1.249	0.143	5.32	8.15	8.53
CD	0.529*	NS	NS	NS	NS

* Significant at 5% level
RF - Ripe fruit
UF - Unripe fruit

2.10 Carotene content

The effect of treatments on the carotene content of ripe and unripe fruit, unripe peel, pseudostem and rhizome is depicted in Table 14.

The treatments showed significant difference in the carotene content of ripe fruit. The treatment T_9 recorded the highest value of 78.24 ppm and absolute control recorded the lowest value of 28.67 ppm.

The treatments showed significant difference in the carotene content of unripe fruit also. The treatment T_6 recorded the maximum content (17.23 ppm) carotene and absolute control (T_{18}) recorded the lowest value of 6.17 ppm.

The carotene content of the peel of unripe fruit varied significantly with treatments. The highest value (64.15 ppm) was recorded in T_8 which was on par with T_6 and T_7 and the treatment absolute control recorded the lowest value of 30.67 ppm.

In the case of rhizome and pseudostem also, the treatments showed significant difference. The treatment T_8 recorded the highest value of 62.79 ppm in the case of rhizome and the treatment T_{10} recorded the highest value of 32.17 ppm in the case of pseudostem. The lowest values were recorded by absolute control treatment (T_{18}) in both the parts.

2.11 Total minerals

The effect of treatments on the total mineral content of ripe and unripe fruit, unripe peel, rhizome and pseudostem of banana is presented in Table 15.

The treatments showed significant difference in the total mineral content of ripe fruit. The treatment T_{13} recorded the highest value of 2.82 per cent and the absolute control (T_{18}) recorded the lowest value of 1.97 per cent.

Table 14. Effect of treatments on the carotene content (ppm) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	31.36	15.99	43.53	50.36	23.03
T_2	71.84	14.46	31.49	49.59	21.05
T_3	49.20	8.61	32.51	33.23	25.85
T_4	64.66	13.35	37.08	52.83	15.92
T_5	72.96	16.02	42.05	60.66	15.24
T_6	36.08	17.23	59.60	49.22	17.50
T_7	58.42	6.53	61.65	55.81	21.50
T_8	38.50	16.28	64.15	62.79	23.93
T_9	78.24	16.54	37.58	48.73	28.48
T_{10}	38.95	16.10	44.54	55.29	32.17
T_{11}	40.59	6.92	35.62	59.20	25.32
T_{12}	39.66	12.53	45.60	45.47	28.19
T_{13}	30.57	10.60	52.50	49.37	25.38
T_{14}	64.73	13.59	54.51	62.39	16.49
T_{15}	43.89	9.17	46.33	50.43	24.48
T_{16}	45.45	15.17	39.01	41.19	17.08
T_{17}	32.13	7.22	57.12	49.94	28.17
T_{18}	28.67	6.17	30.67	31.72	14.88
Mean	48.10	12.36	45.30	50.45	22.48
CD	10.27*	5.10*	5.50*	4.80*	3.80*

* Significant at 5% level
RF - Ripe fruit
UF - Unripe fruit

Table 15. Effect of treatments on the total mineral content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	2.15	2.42	5.00	5.38	6.05
T_2	2.35	2.68	3.65	5.06	6.99
T_3	1.99	2.48	3.87	6.52	7.01
T_4	2.24	2.98	3.28	6.39	7.62
T_5	2.30	2.65	4.50	7.39	7.62
T_6	2.56	2.52	3.15	7.60	6.80
T_7	2.67	2.26	3.88	7.05	7.49
T_8	2.66	2.50	3.09	7.94	8.11
T_9	1.99	2.28	4.63	6.62	8.42
T_{10}	2.11	2.45	3.49	6.03	7.50
T_{11}	1.99	3.06	4.00	8.20	7.02
T_{12}	1.98	2.47	4.63	5.61	7.63
T_{13}	2.82	2.43	3.98	7.06	6.86
T_{14}	2.32	2.40	3.40	7.87	6.34
T_{15}	2.08	2.43	3.91	8.17	9.84
T_{16}	2.37	2.41	4.49	7.06	7.87
T_{17}	2.46	2.38	4.91	8.03	6.68
T_{18}	1.97	2.09	2.99	5.02	4.59
Mean	2.27	2.49	3.93	6.83	7.24
CD	0.22*	NS	0.63*	0.62*	0.81*

* Significant at 5% level

RF - Ripe fruit

UF - Unripe fruit

The treatments did not differ significantly in the total mineral content of unripe fruit. However, there was a tendency for mineral accumulation in the treated plots.

The treatments showed significant difference in the content of mineral matter of the unripe peel between treatments. The treatment T_1 recorded maximum value of 5.0 per cent and the treatment T_{18} recorded the lowest value of 2.99 per cent.

Treatments showed significant difference in the total mineral content of rhizome. The maximum content was recorded in T_{11} (8.2) which was on par with T_6, T_8, T_{14}, T_{15} and T_{17}. The lowest value of 5.02 per cent was recorded by T_{18} which was on par with T_1, T_2 and T_{12}.

The treatments also showed significant difference in the total mineral content of pseudostem also. The treatment T_{15} recorded the highest value of 9.84 per cent and the treatment T_{18} (absolute control) recorded the lowest value of 4.59 per cent.

2.12 Nitrogen content

The data on the nitrogen content of ripe and unripe fruit, unripe peel, rhizome and pseudostem are presented in Table 16.

The treatments showed significant difference in the nitrogen content of ripe fruit of banana. The treatments T_2, T_7 and T_{11} recorded the highest value of 0.756 per cent. The treatment T_{18} (absolute control) recorded the lowest value of 0.250 per cent.

The treatments differed significantly in the nitrogen content of unripe fruit. The treatment T_9 and T_{15} recorded maximum value for the nitrogen content

Table 16. Effect of treatments on the nitrogen content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.251	0.578	1.320	0.630	1.512
T_2	0.756	0.630	1.012	1.008	0.252
T_3	0.504	1.012	1.385	1.200	1.080
T_4	0.252	0.630	0.756	0.756	0.756
T_5	0.252	0.630	2.520	1.516	1.134
T_6	0.252	0.756	2.016	0.756	0.504
T_7	0.756	0.756	1.764	1.331	0.202
T_8	0.252	0.756	0.882	1.260	1.134
T_9	0.630	1.260	1.890	1.260	1.008
T_{10}	0.282	0.756	1.016	1.504	0.882
T_{11}	0.756	1.134	1.260	0.630	1.008
T_{12}	0.554	0.504	1.764	1.504	1.890
T_{13}	0.252	0.552	1.260	1.277	2.142
T_{14}	0.252	0.630	1.890	1.252	1.260
T_{15}	0.252	1.260	1.512	0.882	1.008
T_{16}	0.504	0.882	1.764	0.882	1.260
T_{17}	0.252	1.008	1.572	0.756	0.504
T_{18}	0.250	0.204	0.630	0.504	0.110
Mean	0.403	0.774	1.456	1.050	0.980
CD	0.0944**	0.296*	0.975*	0.499*	NS

* Significant at 5% level
** Significant at 1% level
RF - Ripe fruit
UF - Unripe fruit

(1.26%). absolute control (T_{18}) recorded the lowest value of 0.204 per cent for the nitrogen content.

There was significant difference between treatments in the content of nitrogen in unripe fruit peel. Highest content of nitrogen was recorded by the treatment T_5 (2.52%) and lowest value by absolute control, T_{18} (0.630%).

The nitrogen content in the rhizome also differed significantly with treatments. The maximum content was recorded by T_5 (1.516%) and the lowest by absolute control T_{18} (0.504%).

The treatments did not differ significantly in the nitrogen content of pseudostem. However, the maximum content was recorded by T_{15} (2.142%) and the lowest by absolute control T_{18} (0.110%).

2.13 Phosphorus content

The changes in the phosphorus content of ripe and unripe fruit, unripe peel, rhizome and pseudostem are presented in Table 17.

The treatments showed significant difference in the phosphorus content of ripe fruit of banana. The treatment T_6 recorded the highest content of phosphorus (0.099%). Absolute control (T_{18}) recorded the lowest content of 0.055 per cent.

There was significant difference between treatments in the content of phosphorus in unripe fruit of banana. The maximum content was recorded by T_{14} (0.105%) and minimum content was recorded by T_{18} (absolute control (0.048%).

The phosphorus content in the peel also differed significantly with treatments. The highest value was recorded by T_{13} (0.178%) and lowest value by absolute control, T_{18} (0.085%).

Table 17. Effect of treatments on the phosphorus content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.081	0.070	0.151	0.430	0.079
T_2	0.068	0.076	0.168	0.460	0.067
T_3	0.083	0.101	0.140	0.510	0.058
T_4	0.067	0.071	0.134	0.420	0.080
T_5	0.067	0.082	0.144	0.550	0.086
T_6	0.099	0.089	0.110	0.440	0.088
T_7	0.079	0.065	0.130	0.540	0.078
T_8	0.074	0.082	0.146	0.410	0.073
T_9	0.072	0.075	0.097	0.400	0.070
T_{10}	0.095	0.066	0.099	0.540	0.091
T_{11}	0.074	0.083	0.099	0.320	0.078
T_{12}	0.079	0.072	0.100	0.340	0.078
T_{13}	0.085	0.076	0.178	0.580	0.077
T_{14}	0.090	0.105	0.103	0.540	0.085
T_{15}	0.085	0.069	0.163	0.350	0.087
T_{16}	0.084	0.080	0.148	0.410	0.086
T_{17}	0.072	0.086	0.119	0.580	0.071
T_{18}	0.055	0.048	0.085	0.180	0.041
Mean	0.078	0.078	0.129	0.444	0.076
CD	0.0075*	0.035*	0.0667*	NS	0.013**

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

The treatments did not differ significantly in the phosphorus content of rhizome. However, the maximum content was recorded by T_{13} and T_{17} (0.580%) and lowest value by absolute control, T_{18} (0.180%).

The treatments showed significant difference in the phosphorus content of pseudostem. The treatment T_{10} recorded the highest value of 0.091 per cent and absolute control (T_{18}) recorded the lowest value (0.041%).

2.14 Potassium content

The data on the potassium content of ripe and unripe fruit, unripe peel, rhizome and pseudostem are presented in Table 18.

The treatments showed significant difference in the potassium content of ripe fruit of banana. The maximum content was recorded by the treatment T_2 (0.995%) and the minimum value was recorded by absolute control T_{18} (0.750%).

There was significant difference between treatments in the content of potassium in ripe fruit of banana. The treatment T_5 recorded the maximum content (2.238%) and absolute control recorded the lowest content (0.787%).

The treatments did not differ significantly in the potassium content of unripe peel. However, the treatment T_8 recorded the maximum value (4.225%) and absolute control, the lowest content (1.85%).

There was significant difference between treatments in the content of potassium in the rhizome and pseudostem of banana. The highest content was recorded by the treatment T_1 (3.32% and 4.83%) and the lowest content was recorded by absolute control (1.90% and 2.92%).

Table 18. Effect of treatments on the potassium content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.765	0.955	3.487	3.32	4.83
T_2	0.995	1.325	3.950	2.80	3.47
T_3	0.928	1.075	3.488	2.70	2.35
T_4	0.967	1.238	3.100	2.96	2.72
T_5	0.875	2.238	2.225	2.82	2.96
T_6	0.775	0.980	2.462	1.99	3.39
T_7	0.873	1.087	3.262	2.39	3.01
T_8	0.930	1.650	4.225	2.46	3.34
T_9	0.765	0.855	2.725	2.63	3.63
T_{10}	0.865	0.862	3.950	2.01	4.63
T_{11}	0.892	1.363	2.350	3.02	2.39
T_{12}	0.838	1.913	3.038	2.53	3.26
T_{13}	0.825	0.988	2.750	3.04	3.03
T_{14}	0.795	1.762	2.925	2.55	3.13
T_{15}	0.908	1.200	3.365	2.13	3.21
T_{16}	0.815	1.925	3.775	2.54	3.19
T_{17}	0.813	1.303	3.375	2.52	4.05
T_{18}	0.750	0.787	1.850	1.90	2.02
Mean	0.854	1.305	3.128	2.57	3.256
CD	0.094**	0.296*	NS	0.633**	0.743*

* Significant at 5% level

** Significant at 1% level

RF - Ripe fruit

UF - Unripe fruit

2.15 Calcium content

The data on the calcium content of ripe and unripe fruit, unripe peel, rhizome and pseudostem of banana as influenced by the treatments is tabulated in Table 19.

The treatments showed significant difference in the calcium content of ripe fruit. The highest value (0.159%) was recorded by the treatment T_{17}. The treatment T_{18} (absolute control) recorded the lowest value (0.032%).

The calcium content of unripe fruit also differed significantly with treatments. The treatment T_7 recorded the maximum content of calcium (0.159%). Absolute control (T_{18}) recorded the lowest content (0.011%).

There was significant difference between treatments in the content of calcium in the peel. The treatment T_9 recorded the highest content for calcium (0.184%) and absolute control recorded the lowest value (0.009%).

The treatments showed significant difference in the calcium content of rhizome. The treatment T_{16} recorded the highest content of calcium (0.301%) and absolute control the lowest value (0.163%).

The treatment did not differ significantly in the calcium content of pseudostem.

2.16 Vitamin C content

The data on the vitamin C content of ripe and unripe fruit, unripe peel, rhizome and pseudostem of banana are depicted in Table 20. In the case of ripe fruit of banana the highest value was recorded by T_{14} (17.5 mg/100 g) and the lowest value of 14.0 mg/100 g was recorded by T_{18} (absolute control).

Table 19. Effect of treatments on the calcium content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	0.011	0.023	0.032	0.206	0.269
T_2	0.020	0.035	0.125	0.122	0.171
T_3	0.022	0.020	0.098	0.148	0.183
T_4	0.023	0.081	0.082	0.201	0.187
T_5	0.020	0.030	0.080	0.191	0.158
T_6	0.027	0.141	0.041	0.199	0.262
T_7	0.028	0.159	0.143	0.292	0.314
T_8	0.028	0.030	0.103	0.170	0.167
T_9	0.030	0.108	0.184	0.191	0.202
T_{10}	0.030	0.044	0.124	0.159	0.228
T_{11}	0.035	0.020	0.089	0.166	0.153
T_{12}	0.042	0.026	0.043	0.182	0.211
T_{13}	0.044	0.022	0.045	0.142	0.274
T_{14}	0.081	0.027	0.115	0.194	0.189
T_{15}	0.108	0.028	0.084	0.202	0.200
T_{16}	0.141	0.028	0.106	0.301	0.187
T_{17}	0.159	0.042	0.092	0.150	0.194
T_{18}	0.032	0.011	0.009	0.163	0.151
Mean	0.044	0.049	0.088	0.187	0.205
CD	0.004*	0.006*	0.008*	0.007*	NS

* Significant at 5% level
RF - Ripe fruit
UF - Unripe fruit

Table 20. Effect of treatments on the vitamin C content (per cent) of edible parts of banana cv. Nendran

Treatment	RF	UF	Unripe peel	Rhizome	Pseudostem
T_1	14.50	16.80	7.00	10.00	4.00
T_2	15.92	22.50	8.65	7.33	4.17
T_3	15.30	17.50	7.16	4.92	3.70
T_4	15.78	18.00	8.00	4.00	6.00
T_5	17.00	23.50	9.16	5.33	6.50
T_6	16.50	20.04	8.16	5.00	7.00
T_7	16.50	22.27	6.72	5.00	5.00
T_8	16.00	23.65	8.00	6.00	5.50
T_9	17.00	25.00	9.00	5.50	6.20
T_{10}	16.50	22.50	8.16	5.50	6.34
T_{11}	16.00	24.50	10.85	9.25	6.17
T_{12}	14.80	21.67	14.85	9.00	6.35
T_{13}	15.50	25.00	10.00	4.00	9.00
T_{14}	17.50	19.00	9.00	5.00	7.00
T_{15}	17.03	19.83	10.16	5.50	5.66
T_{16}	16.50	20.00	11.50	7.50	6.25
T_{17}	15.00	22.00	6.00	4.00	5.50
T_{18}	14.00	16.50	5.00	3.80	3.20
Mean	15.96	21.12	8.74	5.90	5.75
CD	2.2*	2.3**	NS	NS	NS

* Significant at 5% level
** Significant at 1% level
RF - Ripe fruit
UF - Unripe fruit

There was also significant difference in the vitamin C content of unripe banana fruit. The treatments T_9 and T_{13} recorded the highest value of 25.00 mg/100. Absolute control (T_{18}) recorded the lowest value of 16.5 mg/100 g.

The treatments did not differ significantly in the content of vitamin of rhizome, pseudostem and unripe peel of banana. However, there was a tendency to increase the vitamin C content in the plots receiving the treatments of nitrogen and farmyard manure.

3 Correlation studies between major nutrients and yield and quality of banana fruit

3.1 Total N in the soil, yield and biochemical qualities of banana fruit

Correlation studies were conducted between total nitrogen content of soil at different stages and protein content of ripe banana fruit. A highly significant positive correlation was obtained between protein content and total nitrogen content of soil at 6 MAP (r = 0.4428**) followed by P_2 (2 MAP) (r = 0.4253**). Also the total N content at P_3 (4 MAP) had a positive correlation (r = 0.4337) with P_2 (2 MAP) and P_4 (6 MAP) (r = 0.6832**) (Table 21).

The total content of N in the soil when correlated with the sugar content of ripe banana fruit, significant correlations were obtained at two stages of growth of the crop (Table 22). A highly significant positive correlation was obtained at P_2 (2 MAP) (r = 0.6355**) followed by that at P_4 (6 MAP) (r = 0.4815**). The correlation studies conducted with the sugar content of unripe fruit, no significant relations were obtained (Table 23).

Correlation studies conducted on the carotene content of fruits and the total N content of the soil revealed an insignificant relation with respect to ripe fruit and significant positive relations with regard to unripe fruit (Tables 24 and 25). The correlation was found mostly significant at P_2 (2 MAP) (r = 0.6988**) followed by that of P_4 (6 MAP) (r = 0.4470**) and P_3 (4 MAP) (r = 0.4202) for the unripe banana fruit.

The nitrate content of the ripe fruit was found to be positively correlated with the total N content of the soil at P_4 (6 MAP) (r = 0.5792**) and P_3 (4 MAP) (r = 0.4049**) (Table 26). The nitrate content of unripe fruit also showed a similar trend. The highest correlation was observed for P_4 (6 MAP) (r = 0.6028**) followed by P_3 (4 MAP) (r = 0.4186**) (Table 27).

Significant positive correlations were obtained for total N content of the soil at different stages and vitamin C content of unripe fruit. The content of N at P_2 (2 MAP) showed the maximum correlation (r = 0.5328**) followed by that at P_4 (6 MAP) (r = 0.4978**) and P_3 (4 MAP) (r = 0.4677**) (Table 28).

The total content of N in the soil when correlated with the yield of banana showed highly significant positive correlation with different stages of growth of the crop. The highest correlation was obtained at P_4 (6 MAP) (r = 0.5542**) followed by P_3 (4 MAP) (r = 0.4522**) and P_2 (2 MAP) (r = 0.3593*) (Table 29).

3.2 Available N content of soil, yield and biochemical qualities of banana fruit

The content of available nitrogen in soil was correlated with the protein content of ripe and unripe banana fruit. A highly significant positive correlation was obtained between the protein content of ripe banana fruit and available nitrogen content of soil whereas protein content of unripe banana fruit showed nonsignificant correlation except at P_5. The maximum correlation was obtained at P_4 (6 MAP) (r = 0.5848**) followed by P_3 (4 MAP) (r = 0.4121**) and P_2 (2 MAP) (r = 0.3449*) (Tables 30 and 31).

Correlation studies were carried out between the available nitrogen content of soil and the sugar content and total minerals of ripe fruit. There was a significant positive correlation at P_3 (4 MAP) (4 = 0.3986*) and P_4 (6 MAP) (r = 0.3803*) while total mineral content showed significance only at P_4 (6 MAP) (r = 0.3766*) (Tables 32 and 33).

The available nitrogen content of soil at P_4 (6 MAP) (r = 0.6297**) and P_3 (4 MAP) (r = 0.4988**) showed high positive correlation with vitamin C content of unripe banana fruit. Correlation studies conducted on the carotene content of unripe banana fruit and the available N content revealed an insignificant relation (Tables 34 and 35).

Yield of the banana crop was correlated with available N content of soil and a highly significant correlation was obtained at P_3, P_4 and P_2. Maximum correlation was observed at P_3 (4 MAP) (r = 0.5338**) followed by P_4 (6 MAP) (r = 0.4884**) and P_2 (2 MAP) (r = 0.3889*) (Table 36).

3.3 Total P content of soil, yield and biochemical qualities of banana fruit

Correlation studies were carried out between the total P content of soil at different stages of growth with the yield and biochemical qualities of banana (Table 37). A highly significant positive correlation was obtained between the total P content of soil at P_3 (4 MAP) (r = 0.7213**) and P_4 (6 MAP) (r = 0.5551**) and yield of banana. Total mineral content of ripe banana showed a significant positive correlation with the total P content of soil. Maximum correlation was observed at P_4 (6 MAP) (r = 0.4949**) followed by P_3 (4 MAP) (r = 0.3109*) (Table 38).

In the case of unripe banana fruit, significant positive correlations were obtained at all stages of crop growth for vitamin C content (Table 39). Maximum value was observed at P_3 (4 MAP) (r = 0.4073*) followed by P_2 (2 MAP) (r = 0.3908*), P_5 (r = 0.3216*) and P_4 (6 MAP) (r = 0.3174*). The total P content of soils at P_2 (2 MAP) (r = 0.3924*) and P_1 (r = 0.3153*) showed positive correlation with carotene content of unripe fruits (Table 40).

3.4 Available P content of soil, yield and biochemical qualities of ripe banana fruit

Correlation studies were conducted between available P content of soil at different stages and biochemical properties of ripe banana fruit. A highly significant positive correlation was obtained between protein content of ripe fruit and available P content of soil at P_3 (r = 0.5948**), P_2 (r = 0.4740**) and P_4 (0.4090**) (Table 41).

Sugar content of ripe banana fruit also showed a highly positive correlation with available P content of soil at P_2, P_3 and P_4. Maximum correlation was obtained at P_2 (2 MAP) (r = 0.5628**) followed by P_4 (6 MAP) (r = 0.4835**) and P_3 (4 MAP) (r = 0.4558**) (Table 42).

A highly significant positive correlation was obtained between available P content at different stages of growth and yield (Table 43). The maximum correlation was obtained at P_4 (6 MAP) (r = 0.6115**) followed by P_3 (4 MAP) (r = 0.5131**) and P_5 (r = 0.4914**). Carbohydrate content showed highly significant positive correlation with available P content at P_5 only (r = 0.4501**) (Table 44). Nitrate content of ripe and unripe banana fruit obtained significant positive correlation at P_4 (4 MAP) (r = 0.5345**) (r = 0.5800**) and P_2 (2 MAP) (r = 0.3411*) (r = 0.3844**) respectively (Tables 45 and 46). Vitamin C content of ripe banana fruit when correlated with available P content of soil at different stages, significant positive correlation was obtained at P_3 (6 MAP) (r = 0.3918*) and P_2 (2 MAP) (r = 0.3276*) whereas vitamin C content of unripe fruit showed significant positive correlation at P_4 (6 MAP) (r = 0.4215**) and P_2 (2 MAP) (r = 0.3846*) and P3 (4 MAP) (4 = 3770*) (Tables 47 and 48).

3.5 Total K in the soil, yield and biochemical qualities of banana

Correlation studies were carried out between the total K content of soil at different periods and yield and biochemical qualities of banana. A highly significant positive correlation was obtained between total K content and yield at all stages of growth of banana. Maximum correlation was obtained between yield and total K content at P_2 (2 MAP) (r = 0.5120**) followed by P_3 (4 MAP) (r = 0.4486**) and P_4 (6 MAP) (r = 0.3569*) (Table 49).

Nitrate content of ripe fruit showed insignificant positive correlation with total K content of soil (Table 50). Vitamin C content of ripe banana fruit showed significant negative correlation with total K content of soil at P_3 (4 MAP) (r = -0.3227*) (Table 51).

Carotene content of ripe fruits when correlated with total K content of soil at different stages showed significant positive correlation at P_3 (4 MAP) (r = 0.4522**) and P_2 (2 MAP) (r = 0.3213*) (Table 52).

Protein content of unripe banana fruit showed significant positive correlation at P_2 (2 MAP) (r = 0.3567*) only whereas sugar content showed significant positive correlation at P_2 (2 MAP) (r = 0.5211**), P_5 (r = 0.3490*) and P_4 (6 MAP) (r = 0.3409*) in that order (Tables 53 and 54). Carbohydrate content obtained significant positive correlation only at P_5 (0.4576**) (Table 55).

3.6 Exchangeable K content of soil, yield and quality of banana

Exchangeable K content of soil when correlated with yield of banana showed significant positive correlations at all stages of growth. Maximum correlation was obtained at P_3 (4 MAP) (r = 0.5806**) followed by that at P_5 (r = 0.5454**), P_2 (2 MAP) (r = 0.5186**) and P_4 (6 MAP) (r = 0.4294**) (Table 56).

Sugar content of ripe banana fruit showed significant positive correlation with exchangeable K content only at P_5 (r = 0.3107*) (Table 57). Carotene content of ripe banana when correlated with exchangeable K obtained significant positive correlation only at P_2 (2 MAP) (r = 0.4290**) (Table 58). But in the case of unripe banana fruit, significant positive correlations were obtained at P_2 (2 MAP) (r = 0.3697*), P_5 (r = 0.3426*) and at P_4 (6 MAP) (r = 0.3160*) (Table 59). Protein content of unripe banana fruit showed significant positive correlation only at P_2 (2 MAP) (r = 0.3767*) (Table 60).

3.7 Water soluble K in the soil, yield and quality of banana

Correlations were worked out between water soluble K content of soil and yield of banana. Significant positive correlations were obtained at P_5 (r = 0.4390**), at P_3 (4 MAP) (r = 0.4387**) and at P_4 (6 MAP) (r = 0.4195**) for yield (Table 61). For ripe fruit significant positive correlation was obtained for sugar content only at P_5 (r = 0.4040*). While for carbohydrate content it was at P_4 (6 MAP) (r = 0.3954*) (Tables 62 and 63). Carotene content of unripe banana fruit showed negative significant correlations at P_2 (2 MAP) (r = -0.4418**), followed by at P_3 (4 MAP) (r = -0.3984*) and at P_1 (r = -0.3525*) (Table 64). Water soluble K content and total minerals content of unripe fruit showed positive significant correlation only P_4 (6 MAP) (r = 0.4249**) (Table 65).

3.8 Interaction of major nutrients and yield and quality of banana

Correlation studies were carried out between the major nutrients and yield and quality of banana at different growing stages. At P_2 (2 MAP), yield is correlated with potassium significantly (r = 0.4294**) (Table 66). Sugar content of ripe banana fruit has got high positive correlation with total nitrogen content of soil (r = 0.6855**) (Table 67). Total nitrogen and phosphorus has got negative insignificant correlation with carotene content whereas potassium has got positive significant correlation (r = 0.4290**) (Table 68.). Nitrogen and phosphorus has got positive significant correlation with carotene content of unripe banana fruit (r = 0.6488** and 0.3924*) (Table 69). Total nitrogen and phosphorus has got positive significant correlation on vitamin-C content of unripe fruits (Table 70).

At P_3 (4 MAP) all the three major nutrients has got significant positive correlation on yield. Maximum correlation was observed for phosphorus (r = 0.7213**) followed by K (r = 0.5188**) and nitrogen (r = 0.4522**). Vitamin-C content of unripe fruit is highly correlated with all major nutrients at P_3 (4 MAP). Maximum correlation was obtained for N and K (r = 0.4677**) followed by phosphorus (r = 0.4073**) (Table 72).

At P_4 yield is highly correlated with all major nutrients. Potassium has got maximum correlation (r = 0.5806**) followed by P (r = 0.5551**) and N (r = 0.5542**). Protein and sugar contents are highly influenced by nitrogen at P_4 (r = 0.4428** and 0.4815**) (Tables 74 and 75). Total phosphorus content of soil at P_4 has got significant positive correlation on the total mineral content of ripe banana fruit (r = 0.4949**) (Table 76). Total nitrogen and potassium have significant positive correlation with nitrate content of ripe and unripe banana fruit (Tables 77 and 78). Vitamin-C content of unripe banana fruit is significantly correlated with all the major nutrients (N r = 0.4978**, P r = 0.5174** and K r = 0.4750**) (Table 79). Carotene content of unripe fruit is highly correlated with total nitrogen content of soil at P_4 (r = 0.4470**) (Table 80).

Interaction of available nutrients on yield and quality of banana

At P_2 (2 MAP) yield is significantly correlated with potassium and phosphorus (r = 0.5924** and 0.3405*, respectively) (Table 81). Protein content of ripe banana fruit is highly correlated with nitrogen and phosphorus (r = 0.3449* and 0.4740**) (Table 82). Sugar content of ripe banana fruit is highly correlated

3.10 Uptake of nutrients and yield and quality of banana

Correlation studies were carried out between yield and quality of banana and uptake of major nutrients. Yield was significantly correlated with the uptake of all the three major nutrients. Maximum correlation was obtained for potassium (r = 0.7702**) followed by phosphorus (r = 0.6129**) and nitrogen (r = 0.5681**) (Table 99).

Among the quality parameters, vitamin C content of both ripe and unripe fruit was highly correlated with the uptake of major nutrients (Tables 100 and 101). Maximum correlation was obtained for potassium followed by phosphorus and nitrogen. Protein content of ripe banana fruit showed significant positive correlation with all the three major nutrients, the maximum value was for nitrogen (Table 102). Similar results were obtained for sugar and total mineral contents of ripe fruits (Tables 103 and 104). Maximum correlation was obtained for nitrogen followed by potassium and phosphorus.

Table 21. Correlation matrix for the total content of N in the soil at different periods and protein content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Protein content	-0.2830	0.4253**	0.0794	0.4428**	-0.0525	1.0000

Table 22. Correlation matrix for the total content of N in the soil at different periods and sugar content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Sugar content	-0.2598	0.6355**	0.1875	0.4815**	0.1915	1.0000

Table 23. Correlation matrix for the total content of N in the soil at different periods and sugar content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Sugar content	-0.3684	-0.2564	0.2936	0.1828	0.3440*	1.0000

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

Table 24. Correlation matrix for the total content of N in the soil at different periods and carotene content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Carotene content	-0.2188	-0.3048	-0.1028	-0.1000	0.1015	1.0000

Table 25. Correlation matrix for the total content of N in the soil at different periods and carotene content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Carotene content	0.0622	0.6988*	0.4202**	0.4470**	0.2292	1.0000

Table 26. Correlation matrix for the total content of N in the soil at different periods and nitrate accumulation in ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Nitrate content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Nitrate content	-0.2029	0.1041	0.4049*	0.5792**	0.2375	1.0000

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

Table 27. Correlation matrix for the total content of N in the soil at different periods and nitrate content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Nitrate content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Nitrate content	-0.2129	0.2084	0.4186**	0.6028**	0.2415	1.0000

Table 28. Correlation matrix for the total content of N in the soil at different periods and Vitamin C content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Vitamin-C content	-0.22924	0.5328**	0.4677**	0.4978**	0.1755	1.0000

Table 29. Correlation matrix for the total content of N in the soil at different periods and yield of banana

	P_1	P_2	P_3	P_4	P_5	Yield content
P_1	1.0000					
P_2	-0.2548	1.0000				
P_3	-0.2488	0.4337**	1.0000			
P_4	-0.4497**	0.6515**	0.6832**	1.0000		
P_5	-0.1369	0.3858*	0.5115**	0.3588*	1.0000	
Yield	0.0913	0.3593*	0.4522**	0.5542**	0.2387	1.0000

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

Table 30. Correlation matrix for the available N content of soil at different periods and protein content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8576**	1.0000		
P_5	0.1211	-0.0796*	0.0711	0.1402	1.0000	
Protein content	0.0074	0.3449*	0.4121**	0.5848**	0.0188	1.0000

Table 31. Correlation matrix for the available N content of soil at different periods and protein content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8576**	1.0000		
P_5	0.1211	-0.0796*	0.0711	0.1402	1.0000	
Protein content	0.2302	-0.0411	-0.1617	-0.0907	0.3901*	1.0000

Table 32. Correlation matrix for the available N content of soil at different periods and sugar content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8575**	1.0000		
P_5	0.1211	-0.0796	0.0711	0.0188	1.0000	
Sugar content	-0.1895	0.2735	0.3986*	0.3803*	0.1272	1.0000

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

Table 33. Correlation matrix for the available N content of soil at different periods and total mineral content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Total mineral content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8575**	1.0000		
P_5	0.1211	-0.0796	0.0711	0.0188	1.0000	
Total mineral content	0.2903	0.2033	0.1575	0.3766**	0.1235	1.0000

Table 34. Correlation matrix for the available N content of soil at different periods and Vitamin C content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8575**	1.0000		
P_5	0.1211	-0.0796*	0.0711	0.1402	1.0000	
Vitamin C	-0.1136	0.3002	0.4988**	0.6297**	0.1601	1.0000

Table 35. Correlation matrix for the available N content of soil at different periods and carotene content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8575**	1.0000		
P_5	0.1211	-0.0796*	0.0711	0.1402	1.0000	
Carotene	-0.5423	0.0620	0.1023	0.1412	-0.0683	1.0000

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

Table 36. Correlation matrix for the available N content of soil at different periods and yield banana

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	-0.0768	1.0000				
P_3	0.0997	0.4052*	1.0000			
P_4	0.0978	0.3695*	0.8576**	1.0000		
P_5	0.1211	-0.0796*	0.0711	0.1402	1.0000	
Yield	0.0804	0.3889*	0.5338**	0.4884**	0.1824	1.0000

Table 37. Correlation matrix for the total P content of soil at different periods and yield of banana fruit

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	0.3912*	1.0000				
P_3	0.3040	0.4109**	1.0000			
P_4	0.1094	0.2976	0.3753*	1.0000		
P_5	0.1966	0.3706*	0.7618**	0.5205**	1.0000	
Yield	0.0542	0.2883	0.7213**	0.5551**	0.1705	1.0000

Table 38. Correlation matrix for the total P content of soil at different periods and total mineral content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Total mineral content
P_1	1.0000					
P_2	0.3912*	1.0000				
P_3	0.3040	0.4109**	1.0000			
P_4	0.1094	0.2976	0.3753*	1.0000		
P_5	0.1966	0.3706*	0.7618**	0.5205**	1.0000	
Total mineral content	0.0287	0.1551	0.3109*	0.4949**	0.1934	1.0000

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

Table 39. Correlation matrix for the total P content of soil at different periods and vitamin C content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	0.3912*	1.0000				
P_3	0.3040	0.4109**	1.0000			
P_4	0.1094	0.2976	0.3753*	1.0000		
P_5	0.1966	0.3706*	0.7618**	0.5205**	1.0000	
Vitamin C content	0.1866	0.3908*	0.4073*	0.3174*	0.3216*	1.0000

Table 40. Correlation matrix for the total P content of soil at different periods and carotene content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	0.3912*	1.0000				
P_3	0.3040	0.4109**	1.0000			
P_4	0.1094	0.2976	0.3753*	1.0000		
P_5	0.1966	0.3706*	0.7618**	0.5205**	1.0000	
Carotene content	0.3153*	0.3924*	0.1761	-0.1273	0.1013	1.0000

Table 41. Correlation matrix for the available P content of soil at different periods and the protein content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001*	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Protein content	0.1394	0.4740**	0.5948**	0.4090*	0.1571	1.0000

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

Table 42. Correlation matrix for the available P content of soil at different periods and the sugar content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Sugar content	0.2389	0.5628**	0.4558**	0.4835*	0.2349	1.0000

Table 43. Correlation matrix for the available P content of soil at different periods and yield of banana fruit

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Yield	-0.0886	0.3405*	0.5131**	0.6115**	0.4914**	1.0000

Table 44. Correlation matrix for the available P content of soil at different periods and carbohydrate content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carbohydrate content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Carbohydrate content	-0.1423	0.0842	0.2575	0.2786	0.4501**	1.0000

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

Table 45. Correlation matrix for the available P content of soil at different periods and nitrate content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Nitrate content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Nitrate content	0.0056	0.2023	0.3411*	0.5345**	0.1200	1.0000

Table 46. Correlation matrix for the available P content of soil at different periods and nitrate content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Nitrate content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Nitrate content	0.0089	0.2825	0.3844*	0.5800**	0.1090	1.0000

Table 47. Correlation matrix for the available P content of soil at different periods and vitamin C content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Sugar content	0.1788	0.3276*	0.3918*	0.2360	0.0361	1.0000

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

Table 48. Correlation matrix for the available P content of soil at different periods and vitamin C content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	0.1545	1.0000				
P_3	0.1577	0.5001**	1.0000			
P_4	0.1689	0.4888**	0.8294**	1.0000		
P_5	-0.0347	0.3653*	0.3754*	0.3625*	1.0000	
Vitamin C content	0.586	0.3846*	0.3770*	0.4215**	0.4719**	1.0000

Table 49. Correlation matrix for the total K content of soil at different periods and the yield banana

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Yield	0.1720	0.5120**	0.4486**	0.3569*	0.0879	1.0000

Table 50. Correlation matrix for the total K content of soil at different periods and the nitrate content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Nitrate content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Nitrate content	-0.4010*	-0.0908	0.0901	0.0139	-0.1124	1.0000

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

Table 51. Correlation matrix for the total K content of soil at different periods and the vitamin C content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Vitamin C content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Vitamin C content	-0.2139	0.2112	-0.3227*	0.0920	0.0922	1.0000

Table 52. Correlation matrix for the total K content of soil at different periods and the carotene content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Carotene content	0.0285	0.3213*	0.4522**	-0.0459	-0.0869	1.0000

Table 53. Correlation matrix for the total K content of soil at different periods and the protein content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Protein content	0.2124	0.3567*	0.2091	-0.0304	-0.2167	1.0000

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

Table 54. Correlation matrix for the total K content of soil at different periods and the sugar content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Sugar content	0.2145	0.5211**	0.0740	0.3405*	0.3490*	1.0000

Table 55. Correlation matrix for the total K content of soil at different periods and the carbohydrate content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carbohydrate content
P_1	1.0000					
P_2	0.4365**	1.0000				
P_3	0.2602	0.2858	1.0000			
P_4	0.2157	0.1844	0.4678**	1.0000		
P_5	0.1682	0.2670	0.4936**	0.6168**	1.0000	
Carbohydrate content	-0.2129	-0.0797	-0.1780	-0.1780	0.4576**	1.0000

Table 56. Correlation matrix for the content of exchangeable K in soil at different periods and yield of banana

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	-0.0095	1.0000				
P_3	0.1976	0.5605**	1.0000			
P_4	-0.0708	0.5276**	0.3181*	1.0000		
P_5	0.1488	0.4980**	0.6129**	0.5148**	1.0000	
Yield	-0.1045	0.5186**	0.5806**	0.4294**	0.5454**	1.0000

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

Table 57. Correlation matrix for the content of exchangeable K in soil at different periods and sugar content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	-0.0095	1.0000				
P_3	0.1976	0.5605**	1.0000			
P_4	-0.0708	0.5276**	0.3181*	1.0000		
P_5	0.1488	0.4980**	0.6129**	0.5148**	1.0000	
Sugar content	0.1535	0.1922	-0.0308	-0.0037	0.3107*	1.0000

Table 58. Correlation matrix for the content of exchangeable K in soil at different periods and carotene content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	-0.0095	1.0000				
P_3	0.1976	0.5605**	1.0000			
P_4	-0.0708	0.5276**	0.3181*	1.0000		
P_5	0.1488	0.4980**	0.6129**	0.5148**	1.0000	
Carotene content	-0.2630	0.4290**	0.1254	0.0648	0.1356	1.0000

Table 59. Correlation matrix for the content of exchangeable K in soil at different periods and carotene content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	-0.0095	1.0000				
P_3	0.1976	0.5605**	1.0000			
P_4	-0.0708	0.5276**	0.3181*	1.0000		
P_5	0.1488	0.4980**	0.6129**	0.5148**	1.0000	
Carotene content	-0.2059	0.3697*	0.1071	0.3160*	0.3426*	1.0000

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

Table 60. Correlation matrix for the content of exchangeable K in soil at different periods and protein content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Protein content
P_1	1.0000					
P_2	-0.0095	1.0000				
P_3	0.1976	0.5605**	1.0000			
P_4	-0.0708	0.5276**	0.3181*	1.0000		
P_5	0.1488	0.4980**	0.6129**	0.5148**	1.0000	
Protein content	0.1767	0.3767*	-0.1763	0.1129	0.0465	1.0000

Table 61. Correlation matrix for the content of water soluble K in soil at different periods and yield of banana

	P_1	P_2	P_3	P_4	P_5	Yield
P_1	1.0000					
P_2	0.0061	1.0000				
P_3	0.2773	0.2026	1.0000			
P_4	-0.2108	0.1250	0.2473	1.0000		
P_5	-0.0971	-0.0385	0.3414*	-0.1092	1.0000	
Yield	0.0577	0.2291	0.4387**	0.4195**	0.4390**	1.0000

Table 62. Correlation matrix for the content of water soluble K in soil at different periods and sugar content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Sugar content
P_1	1.0000					
P_2	0.0061	1.0000				
P_3	0.2773	0.2026	1.0000			
P_4	-0.2108	0.1250	0.2473	1.0000		
P_5	-0.0971	-0.0385	0.3414*	-0.1092	1.0000	
Sugar content	-0.4784**	0.1052	-0.2152	0.2020	0.4040**	1.0000

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

Table 63. Correlation matrix for the content of water soluble K in soil at different periods and carbohydrate content of ripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carbohydrate content
P_1	1.0000					
P_2	0.0061	1.0000				
P_3	0.2773	0.2026	1.0000			
P_4	-0.2108	0.1250	0.2473	1.0000		
P_5	-0.0971	-0.0385	0.3414*	-0.1092	1.0000	
Carbohydrate content	-0.0767	0.1681	-0.1399	0.3954*	0.1981	1.0000

Table 64. Correlation matrix for the content of water soluble K in soil at different periods and the carotene content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Carotene content
P_1	1.0000					
P_2	0.0061	1.0000				
P_3	0.2773	0.2026	1.0000			
P_4	-0.2108	0.1250	0.2473	1.0000		
P_5	-0.0971	-0.0385	0.3414*	0.5172**	1.0000	
Carotene content	-0.3525*	-0.4418**	-0.3984	0.1313	0.2866	1.0000

Table 65. Correlation matrix for the content of water soluble K in soil at different periods and the total mineral content of unripe banana fruit

	P_1	P_2	P_3	P_4	P_5	Total mineral content
P_1	1.0000					
P_2	0.0061	1.0000				
P_3	0.2773	0.2026	1.0000			
P_4	-0.2108	0.1250	0.2473	1.0000		
P_5	-0.0971	-0.0385	0.3414*	0.5172**	1.0000	
Total mineral content	-0.1559	0.1305	0.0790	0.4249**	-0.0290	1.0000

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

Table 66. Correlation matrix for the total content of major nutrients at P_2 (2 MAP) and the yield of banana

	N	P	K	Yield
N	1.0000			
P	0.4424**	1.0000		
K	-0.0510	0.0169	1.0000	
Yield	0.2593	0.2853	0.4294**	1.0000

Table 67. Correlation matrix for the total content of major nutrients at P_2 (2 MAP) and the sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.4424**	1.0000		
K	-0.0510	0.0169	1.0000	
Sugar content	0.6855**	0.0223	0.1922	1.0000

Table 68. Correlation matrix for the total content of major nutrients at P_2 (2 MAP) and the carotene content of ripe banana fruit

	N	P	K	Carotene content
N	1.0000			
P	0.4424**	1.0000		
K	-0.0510	0.0169	1.0000	
Carotene content	-0.3043	-0.1795	0.4290**	1.0000

Table 69. Correlation matrix for the total content of major nutrients at P_2 (2 MAP) and the carotene content of unripe banana fruit

	N	P	K	Carotene content
N	1.0000			
P	0.4424**	1.0000		
K	-0.0510	0.0169	1.0000	
Carotene content	0.6488**	0.3924*	-0.0989	1.0000

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

Table 70. Correlation matrix for the total content of major nutrients at P_2 (2 MAP) and the vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.4424**	1.0000		
K	-0.0510	0.0169	1.0000	
Vitamin C content	0.5328**	0.3924*	0.0152	1.0000

Table 71. Correlation matrix for the total content of major nutrients at P_3 (4 MAP) and the yield of banana

	N	P	K	Yield
N	1.0000			
P	0.4594**	1.0000		
K	0.3519*	0.4396**	1.0000	
Yield	0.4522**	0.7213**	0.5188**	1.0000

Table 72. Correlation matrix for the total content of major nutrients at P_3 (4 MAP) and the vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.4594**	1.0000		
K	0.3519*	0.4395*	1.0000	
Vitamin C content	0.4677**	0.4073**	0.4677**	1.0000

Table 73. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the yield of banana

	N	P	K	Yield
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Yield	0.5542**	0.5551**	0.5806**	1.0000

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

Table 74. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the protein content of ripe banana fruit

	N	P	K	Protein content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Protein	0.4428**	0.2782	0.1132	1.0000

Table 75. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Sugar content	0.4815**	0.1834	-0.0029	1.0000

Table 76. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the total mineral content of ripe banana fruit

	N	P	K	Total mineral content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Total mineral content	0.0581	0.4949**	-0.0014	1.0000

Table 77. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the nitrate content of ripe banana fruit

	N	P	K	Nitrate content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Nitrate content	0.5792**	0.1893	0.3160*	1.0000

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

Table 78. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the nitrate content of unripe banana fruit

	N	P	K	Nitrate content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Nitrate content	0.6002**	0.2005	0.3278*	1.0000

Table 79. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Vitamin C content	0.4978**	0.5174**	0.4750**	1.0000

Table 80. Correlation matrix for the total content of major nutrients at P_4 (6 MAP) and the carotene content of unripe banana fruit

	N	P	K	Carotene content
N	1.0000			
P	0.2269	1.0000		
K	0.4927**	0.3646*	1.0000	
Carotene content	0.4470**	-0.1273	0.2084	1.0000

Table 81. Correlation matrix for the content of available nutrients at P_2 (2 MAP) and yield of banana

	N	P	K	Yield
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Yield	0.1678	0.3405*	0.5924**	1.0000

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

Table 82. Correlation matrix for the content of available nutrients at P_2 (2 MAP) and the protein content of ripe banana fruit

	N	P	K	Protein content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Protein content	0.3449*	0.4740**	-0.0829	1.0000

Table 83. Correlation matrix for the content of available nutrients at P_2 (2 MAP) and the sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Sugar content	0.2935	0.5628**	-0.0782	1.0000

Table 84. Correlation matrix for the content of available nutrients at P_2 (2 MAP) and the sugar content of unripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Sugar content	0.1902	0.2060	0.5211**	1.0000

Table 85. Correlation matrix for the total content of available nutrients at P_3 (4 MAP) and yield of banana

	N	P	K	Yield
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Yield	0.3265*	0.5131**	0.4485**	1.0000

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

Table 86. Correlation matrix for the content of available nutrients at P_3 (4 MAP) and the protein content of ripe banana fruit

	N	P	K	Protein content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Protein content	0.4121**	0.5948**	0.2366	1.0000

Table 87. Correlation matrix for the content of available nutrients at P_3 (6 MAP) and the sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Sugar content	0.3986*	0.4558**	-0.0699	1.0000

Table 88. Correlation matrix for the content of available nutrients at P_3 (6 MAP) and the vitamin C content of ripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Vitamin C content	0.1250	0.3918*	-0.3227	1.0000

Table 89. Correlation matrix for the content of available nutrients at P_3 (6 MAP) and the vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Vitamin C content	0.4988**	0.3770**	0.2277	1.0000

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

Table 90. Correlation matrix for the content of available nutrients at P_3 (6 MAP) and the carotene content of ripe banana fruit

	N	P	K	Carotene content
N	1.0000			
P	0.3031	1.0000		
K	0.0905	0.1198	1.0000	
Carotene content	-0.2416	-0.1777	0.4522**	1.0000

Table 91. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and yield of banana

	N	P	K	Yield
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Yield	0.3710*	0.6115**	0.3974*	1.0000

Table 92. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and nitrate content of ripe banana fruit

	N	P	K	Nitrate content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Nitrate content	0.0581	0.5345**	0.0139	1.0000

Table 93. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and nitrate content of unripe banana fruit

	N	P	K	Nitrate content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Nitrate content	0.0384	0.5002**	0.0139	1.0000

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

Table 94. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and protein content of ripe banana fruit

	N	P	K	Protein content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Protein content	0.5858**	0.4090**	0.1275	1.0000

Table 95. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Sugar content	0.3903*	0.4835**	0.0586	1.0000

Table 96. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and total mineral content of ripe banana fruit

	N	P	K	Total mineral content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Total mineral content	0.3766*	0.0609	0.4056**	1.0000

Table 97. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Vitamin C content	0.6297**	0.4215**	0.0743	1.0000

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

Table 98. Correlation matrix for the content of available nutrients at P_4 (6 MAP) and carbohydrate content of unripe banana fruit

	N	P	K	Carbohydrate content
N	1.0000			
P	0.4600**	1.0000		
K	0.2718	0.1057	1.0000	
Carbohydrate content	0.1804	0.3080	-0.4576**	1.0000

Table 99. Correlation matrix for the uptake of major nutrients and yield of banana

	N	P	K	Yield
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Yield	0.5681**	0.6129**	0.7702**	1.0000

Table 100. Correlation matrix for the uptake of major nutrients and the vitamin C content of unripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Vitamin C content	0.3886*	0.4227**	0.5546**	1.0000

Table 101. Correlation matrix for the uptake of major nutrients and the vitamin C content of ripe banana fruit

	N	P	K	Vitamin C content
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Vitamin C content	0.5680**	0.6207**	0.6471*	1.0000

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

Table 102. Correlation matrix for the uptake of major nutrients and the protein content of ripe banana fruit

	N	P	K	Protein content
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Protein content	0.6021**	0.5384**	0.3081	1.0000

Table 103. Correlation matrix for the uptake of major nutrients and the sugar content of ripe banana fruit

	N	P	K	Sugar content
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Sugar content	0.5284**	0.4986**	0.5057**	1.0000

Table 104. Correlation matrix for the uptake of major nutrients and the total mineral content of ripe banana fruit

	N	P	K	Total mineral content
N	1.0000			
P	0.4884**	1.0000		
K	0.6664**	0.6357**	1.0000	
Total mineral content	0.4820**	0.3988*	0.3791*	1.0000

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

Discussion

DISCUSSION

The present investigation was carried out to study the effect of organic matter and major nutrients on the yield and quality of banana cv. Nendran. The data relating to various observations taken were statistically analysed and the results are discussed below.

1 Effect of treatments on the height and girth of pseudostem

During the initial four months of growth the plants did not show significant differences in the height and girth of pseudostem. In general, plant height was found to increase with increasing K levels applied. The plants getting more of nitrogen also showed an increasing trend.

The effect of treatments varied significantly at 5th, 6th and 7th months. This could be explained on the basis of differential requirement of K.

The considerable increase in height and girth of pseudostem from fifth month after planting may be due to increased hormonal activity at the flower initiation stage which occurred at this stage (Sheela, 1995). George (1994) attributed the non-significance for K treatments at the early growth stages to the initial high K content in soil and the lack of competition between plants for sunlight at the early stages.

Increased plant height as a result of enhancing the levels of K application has also been reported by many workers (Jambulingam *et al.*, 1975; Sheela, 1982; Mustaffa, 1987; Khoreiby and Salem, 1991 and George, 1994).

Positive effect of K on girth of pseudostem has been reported by Turner and Bull (1970), Lahav (1972), Jamulingam *et al.* (1975), Fabregar (1986), Mustaffa (1987), Hegde and Srinivas (1991), George (1994) and Sheela (1995).

In the present study the control plants recorded lowest plant height. This is in accordance with the finding of Freiberg and Steward (1960) and Lahav (1972).

2 Effect of treatments in the number of functional leaves

The treatments did not differ significantly in the number of functional leaves during the initial four months of growth. During the later stages of growth the number of functional leaves showed significant difference with the treatments.

The results revealed that the number of functional leaves showed an increasing trend over the entire periods of growth. However, the treatments differed significantly only after five months of age. Increased K levels showed increased number of functional leaves. Similar results were reported by Anil (1994). The positive influence of mineral nutrient on the rate of leaf production was reported by Murray (1960) and Sindu (1997).

3 Effect of treatments on yield and yield attributes of banana

The bunch weight of the treatment plots showed a significant difference over control. The control (T_{18}) got the lowest bunch weight of 3.75 kg whereas the highest yield was recorded by T_2 (9.52 kg). The increase in the yield was 154 per cent over the control. T_2 was on par with all other treatments except T_1, T_4, T_7 and T_{10}. Among the treated plots, T_4 recorded the lowest value of 8.21 which was also found to be 119 per cent more than the control. This clearly indicated that the banana plants require application of nutrients. The treatments receiving 300 g

K_2O/plant and above recorded higher bunch weights which were on par. The treatments T_1, T_7 and T_{10} recorded slightly lesser bunch weights which may be due to the lesser quantity of applied K_2O. But the treatment T_{16} eventhough received lesser quantity of K_2O exhibited better yield and this treatment received the highest quantity of FYM. The K content of FYM was 0.6 per cent. The treatment T_{14} also gave a better yield of 8.80 kg eventhough the applied N was less. Here the required N might have been taken from the farmyard manure applied. Hence a fertilizer dose of 200:125:300 g $N:P_2O_5:K_2O$/plant is sufficient for getting the maximum yield.

In the case of biomass yield, the control plot showed the lowest value. Highest yield was recorded by T_8 (85.91 kg) followed by T_{13} (84.27 kg) which was on par with it. The number of hands did not differ significantly among treatments. The number of fingers per bunch differed significantly, the treatment T_3 recorded the highest value whereas absolute control recorded the lowest value. The treated plots were highly significant over control.

4 Effect of treatments on the quality aspects of banana cv. Nendran

4.1 Carbohydrate content of edible portions of banana

The treatments differed significantly in the carbohydrate content of unripe fruit of banana. Maximum carbohydrate content was recorded in T_{10} (25.08) which was on par with T_2, T_6, T_7, T_8, T_{11} and T_{12} and the treatment absolute control (T_{18}) recorded the lowest content of carbohydrate.

The carbohydrate content of ripe fruit also showed similar trends. The treatment T_{10} recorded the highest value (14.63%) which was 43 per cent more than that in the absolute control (T_{18}).

The treatments receiving medium level of FYM, and nitrogen (T_{10}, T_{11}, T_{12}) recorded higher values of carbohydrate content. The K levels of the above treatments were different which shows that K has least influence on carbohydrate content.

The treatments did not differ significantly in the carbohydrate content of peel. The carbohydrate content of rhizome and pseudostem did not differ significantly with treatments.

On ripening carbohydrate content of banana decreased due to the conversion of carbohydrate to sugar (Giami and Alu, 1994).

4.2 Effect of treatments on the protein content of edible portions of banana

The treatments differed significantly in the protein content of ripe fruit. Absolute control (T_{18}) recorded the lowest value of protein. The highest content of protein was recorded in T_{16} which was on par with T_{13}. The protein content of T_{16} was 160 per cent higher than the absolute control which shows that the fertilizer has much influence in the protein content of ripe fruit.

Schuphan and Postel (1958) found that added nitrogen increased the crude protein content of spinach due to enhanced absorption of added nitrogen and direct participation of nitrogen in protein synthesis.

Increased protein content of banana fruit by application of fertilizers especially nitrogen and potash has been reported by many workers (Akochi, 1977; Subbiah and Ramanathan, 1983; Singh *et al.*, 1985; Pimpini *et al.*, 1992).

The protein content of unripe fruit of banana also differed significantly with the treatments. The highest content of Protein was recorded in T_{16} (88.35 mg/100 g) which was 141 per cent more than the absolute control. The protein content of unripe-fruit peel was maximum for T_{16} (94.85 mg/100 g) and minimum (45.38 mg/100 g) for absolute control. All the fertilized plots recorded higher protein content than the control plot. This trend was also observed in rhizome and pseudostem of banana.

4.3 Fat content of edible portions of banana cv. Nendran

The treatments did not differ in the fat content of ripe banana fruit.

The fat content of unripe banana fruit varied significantly with treatments. The treatment T_{15} recorded the maximum value of 0.675 per cent which was 200 times more than absolute control (T_{18}). All the treated plots obtained higher content of fat compared to the absolute control. This shows that application of fertilizer might have some influence on the fat content of banana fruit. The plots receiving 17 kg/plant farmyard manure recorded highest value for fat content which implies that farmyard manure accelerates fat content of banana fruit. The trend is observed in the ripe fruit also.

The fat content of peel, rhizome and pseudostem of banana differed significantly with treatments. All the treated plots obtained more fat content than the absolute control which recorded the lowest fat content.

4.4 Effect of treatments on the sugar content of edible portions of banana

The sugar content of ripe banana fruit differed significantly with treatments. The treatment T_{16} recorded maximum total sugar (29.5%), reducing (16.7%) and nonreducing (12.8%) sugars. The treatment T_{16} was on par with T_{14}. Absolute control (T_{18}) recorded the lowest values.

The treatment T_{16} recorded 300 times more sugar content than the unfertilized control. All the treated plots obtained higher values for sugars which indicates that fertilizer application enhances the sugar content of fruits and thus quality is much improved.

Effect of nitrogen nutrition on the sugar content of banana was studied by many workers. A progressive increase in reducing sugars was observed in response to increasing nitrogen application (Ramasamy and Muthukrishnan, 1972; Ram and Prasad, 1988; Ghosh *et al.*, 1989).

Application of potassium also enhanced the quality of banana fruit by increasing the sugar content (Vadivel and Shanmugavelu, 1978).

The sugar content of unripe fruit also varied significantly with treatments. Fertilized plots recorded higher contents of sugar compared to absolute control.

Ripening causes an increase in sugar content of banana fruit. Sugar content was raised from 8.99 to 29.50 per cent in T_{16} by ripening. Generally total sugar content raised 150-200 times in ripe fruit during ripening. The increase in sugar content during ripening may be due to the conversion of carbohydrate and starch to sugar. Similar trend has been observed by many workers (Lal *et al.*, 1974; Marriot *et al.*, 1981; Tripathy *et al.*, 1981; Marriot *et al.*, 1983; Collin and Dalnic, 1991).

The treatments differed significantly in the sugar content of the peel of unripe fruit. In the case of unripe fruit the highest value was recorded by T_{12} (4.25%) which was on par with T_2. Absolute control (T_{18}) recorded the lowest value of 0.43 per cent. The juice of pseudostem also differ significantly in the sugar content. The treatment T_7 recorded the highest value of 3.3 per cent and absolute control (T_{18}) recorded the lowest value of 1.075 per cent.

The treatments did not differ significantly in the sugar content of rhizome.

4.5 Effect of treatments on the content of acidity of edible portions of banana cv. Nendran

Acidity is an important character which affects quality, taste and acceptability of banana fruit. Acidity of ripe fruit pulp showed a significant difference between treatments. The treatment T_{17} (0.938%) and T_{14} (0.930%) recorded highest values and absolute control (T_{18}) recorded the lowest value of 0.486 per cent. The treatment T_{17} contains 93 per cent of more acid than the absolute control (T_{18}). All the plots receiving high FYM and N recorded higher values for acidity. Nitrogen application always increases acidity of the fruit (Reuther and Smith, 1951).

The treatments receiving higher doses of K fertilizers also recorded higher values for acidity. Bunemann and Gruppe (1961) reported that higher dose of K increased the acid content of fruits.

The acidity of the unripe fruit pulp also differed significantly with treatments. Here also highest value was recorded by T_{16} (0.255%) and T_{17} (0.250%) and the lowest value of 0.090 per cent by the absolute control (T_{18}). In T_{17} and T_{14} the quantity P applied remains same which shows that P has the least influence on the acidity of the fruit. This was in accordance with the finding of Bunemann and Gruppe (1961).

The acidity of peel and rhizome also differed significantly in the content of acidity whereas the content of acidity in pseudostem did not differ significantly between treatments. In all the cases the treatment T_{17} recorded the highest value and absolute control (T_{18}) recorded the lowest value.

On ripening the acidity of the fruit pulp increased considerably about 200-300 times. Ripening also increases the sugar content. Hence the sugar acid ratio remains more or less constant in the fruit on ripening. Similar findings were reported by many workers (Tripathy *et al.*, 1981; Munasque and Mendoza, 1990; Collin and Dalnic, 1991).

Desai and Deshpande (1975) reported an increase in titratable acidity of banana pulp during ripening. They stated that the increased acidity in banana fruits during ripening might be resulting from an obstruction in proton transfer process as the fruits ripen.

4.6 Effect of treatments on the nitrate content of edible portions of banana

Nitrate accumulation in plants is a natural phenomenon resulting from the uptake of nitrate in excess quantities and resultant accumulation in plant. The concentration of nitrate in plants vary with a number of environmental and genetic factors. Plant parts eaten and the amount of nitrate available in soil appear to be a major factor whether or not a plant product will be high in nitrate.

The nitrate content of ripe banana fruit differed significantly with treatments. The maximum content of nitrate was observed in T_4 (0.496%) and this treatment was on par with T_{12}, T_{13} and T_{15}. The lowest content was recorded in the absolute control (T_{18}) (0.048%). The nitrate content of unripe fruit also showed similar trends.

The treatments which recorded highest value for the nitrate content of both ripe and unripe fruit received the highest dose of nitrogen i.e., 300 g N/plant. Nitrate accumulation in plants is dependent on the amount of nitrogenous fertilizer applied. Absolute control which received no nitrogen fertilizer recorded the lowest value.

The nitrate content of peel, rhizome and pseudostem also differed significantly with treatments. The treatment T_{15} recorded the highest value of nitrate and absolute control lowest value.

Increased application of nitrogenous fertilizer increases the net rate accumulation in plant (Barker and Maynard, 1971; Peek *et al.*, 1971; Schmidt *et al.*, 1971).

The treatments T_4, T_{12}, T_{13} and T_{15} which received highest doses of nitrogen and farmyard manure generally recorded highest contents of nitrate in the various parts of banana studied. Similar results were obtained by Doikova *et al.* (1986).

The nitrate content was found to decrease in ripe banana compared to unripe banana. This may be due to the conversion of nitrate nitrogen to protein, aminoacids and other nitrogenous compounds. Nitrate is assimilated by reduction to ammonium, followed by incorporation into organic forms (Russel, 1973).

4.7 Effect of treatments on the fibre content of edible portion of banana cv. Nendran

The treatments differed significantly in the fibre content of ripe fruit of banana. The treatment T_{14} recorded the highest value of 1.785 per cent and absolute control (T_{18}) recorded the lowest value of 0.075 per cent. All the fertilized plots obtained higher contents of fibre compared to unfertilized control. This indicates that the fertilizer application has favourable influence in increasing the fibre content of banana.

Ogabadu and Easman (1989) reported that fertilizer application increased crude fibre content. Singh *et al.* (1986) studied the effect of nitrogen a qualitative character of amaranthus and reported that increasing levels of nitrogen decrease crude fibre content.

The fibre content of unripe fruit, peel, rhizome and pseudostem did not differ significantly with treatments.

4.8 Effect of treatments on carotene content of edible portions of banana cv. Nendran

The treatments differed significantly in the carotene content of ripe banana fruit. The highest value of 78.24 ppm was recorded by the treatment T_9 and the lowest value of 28.67 ppm was recorded by the treatment T_{18}.

In the unripe fruit, highest carotene content was recorded in T_6 (17.23 ppm).

The treatments T_9, T_2, T_4 and T_5 which received highest doses of nitrogen recorded higher values of carotene.

Increase in carotene content by increased application of nitrogen was reported by many workers (Schuphan and Postel, 1958; Sistrunk and Dradley, 1975; Subbiah and Ramanathan, 1983; Singh *et al.*, 1985).

Subbiah and Ramanathan (1983) reported that application of potassium have no marked effected as carotene content of amaranthus.

The carotene content of ripe fruit was considerably higher than that in unripe fruit.

4.9 Effect of treatments on the total mineral content of edible portions of banana

The treatments differed significantly in the total mineral content of ripe fruit.

In general, all the fertilized plots recorded higher total mineral contents compared to unfertilized control showing that fertilizer application increases total mineral content in the various edible parts of banana. The application of fertilizer might have increased the uptake and availability of nutrients resulting in higher total mineral content.

4.10 Effect of treatments on the nitrogen content of edible portions of banana

The nitrogen content of ripe banana differed significantly with treatments. The treatments T_2, T_7 and T_{11} recorded the highest value of 0.756 per cent. In these treatments quantity of nitrogen fertilizer applied was high. Absolute control (T_{18}) recorded the lowest value of 0.250 per cent.

The treatments differed significantly in the nitrogen content of unripe fruit. All the treated plots obtained higher content of nitrogen to absolute control. This trend is observed in unripe peel, rhizome and pseudostem also.

4.11 Effect of treatments on the phosphorus content of edible portions of banana

The treatments differed significantly in the phosphorus content of ripe fruit of banana. The treatment T_6 recorded the highest content of phosphorus (0.099%) and absolute control (T_{18}) recorded the lowest content (0.055%). The treatment T_6 received the highest dose of phosphatic fertilizers (200 g/plant) and this implied that application of phosphorus increases the phosphorus content of banana fruit.

The treatments showed significant difference in the phosphorus content of rhizome and peel. In the parts, the highest value was recorded by the treatment T_{13} which received the highest dose of phosphatic fertilizer (200 g/pt). Absolute control (T_{18}) recorded the lowest content of phosphorous.

4.12 Effect of treatments on the potassium conten: of edible portions of banana

The treatments showed significant difference in the potassium content of ripe fruit of banana. The highest value of 0.995 per cent was recorded by the treatment T_2. The lowest value (0.750%) was recorded by absolute control (T_{18}). In all the fertilized plots the potassium content was higher compared to absolute control. This trend is observed in the case of unripe fruit also.

The treatments did not differ significantly in the potassium content of unripe peel of banana.

The treatments differed significantly in the potassium content of rhizome. The highest value was recorded by T_1 and the lowest value was recorded by T_{18} (absolute control). Similar results were obtained for pseudostem also.

4.13 Effect of treatments on the calcium content of edible portions of banana

The treatments showed significant difference in the calcium content of ripe banana. The treatment T_{17} recorded the highest value (0.159%) and absolute control recorded the lowest value of 0.032 per cent. All the treated plots obtained higher values for the calcium content compared to absolute control. This trend is observed in unripe fruit, unripe peel and rhizome also.

The treatments did not differ significantly in the calcium content of pseudostem.

4.14 Effect of treatments on the vitamin C content of edible portions of banana

The treatments differed significantly in the vitamin C content of ripe banana fruit. The treatment T_{14} obtained the highest content of vitamin C (17.5 mg/100 g) and absolute control recorded the lowest value (14.00 mg/100 g)

The treatments showed significant difference in the vitamin C content of unripe fruit of banana also. The highest value (25.00 mg/100 g) was recorded by T_9 and T_{13} and the lowest value (16.50 mg/100 g) was recorded by absolute control. All the plots receiving higher doses of nitrogen and farmyard manure obtained higher values for the vitamin C content.

The treatments did not differ significantly in the vitamin C content of unripe peel, pseudostem and rhizome.

On ripening the vitamin C content of banana is decreasing (Tripathy *et al.*, 1981).

5 Direct and indirect effects of major nutrients on the yield and quality of banana

In order to understand the direct and indirect effect of major nutrients on the yield and quality of banana path analysis was done. The results of path analysis is presented below.

5.1 Nitrogen

The direct and indirect effects of total nitrogen on the yield was obtained by path analysis (Fig.1). The direct effect of total N on yield was maximum at P_4 (6 MAP) followed by P_3 (4 MAP). The indirect effect of P_4 through P_2 and P_3 also found to be significant. Similar trend was observed with available nitrogen also. This explains that the requirement of nitrogen is high in the early and late vegetative stages in order to get economic yield.

The direct and indirect effects of total nitrogen on the protein content of ripe banana fruit is revealed that maximum direct effect was obtained at P_4 (6 MAP) followed by P_2 (2 MAP) whereas the indirect effect was significant at P_4 through P_5 (0.3359) and P_2 (0.3203).

The residual effect of fertilizers applied at P_2 (2 MAP) and P_3 (4 MAP) resulted in an increased total N content of soil. The banana crop was at maximum vegetative growth at 6 MAP and the maximum absorption of N took place at this stage which is evident from the significant direct effect at this stage.

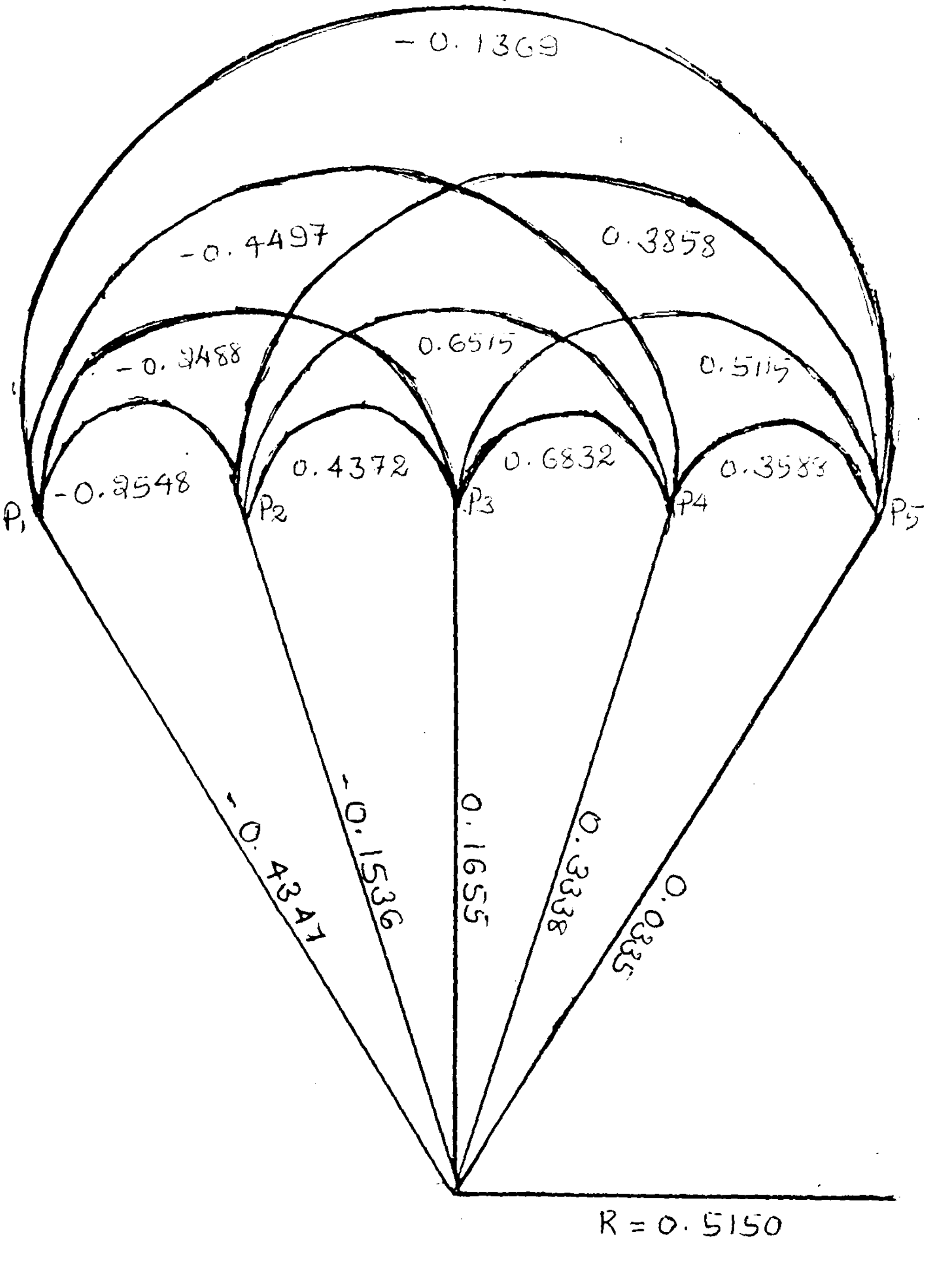

Fig. 1 Path diagram - Direct and indirect effects of total N (per cent) in soil at different periods on the yield of banana

Direct and indirect effects of available nitrogen at different stages also revealed similar trend (Fig.2). Maximum direct effect was obtained at P_4 (6 MAP). The indirect effect of P_4 through P_3 (4 MAP) and P_2 (2 MAP) were also highly significant indicating the maximum absorption of nitrogen took place at this stage.

Nitrogen which is a major structural constituent of cell also plays an important role in plant metabolism. Nitrogen is present in both protein and nucleic acid portions of nucleo proteins. Since proteins serve both as catalysists and director of metabolism, nitrogen plays an important role in metabolism. Also nitrogen is a component of chlorophyll pigments (Russel, 1973).

The sugar content of ripe fruit was found to be having a direct effect on the total N content of the soil at P_2 (2 MAP) (Fig.3). A significant positive effect was noticed ($r = 0.5579^{**}$) at this stage. The N content at P_4 (6 MAP) also manifested a positive direct effect though not significant ($r = 0.2582$). But an indirect effect of the total N content at P_4 was obtained through P_2 (2 MAP) (0.3635).

The available nitrogen did not show any significant direct effect at any stage of the growth on sugar content.

The direct and indirect effect of total nitrogen at different stages and vitamin C content of unripe fruit of banana was obtained through path analysis (Fig.4). A highly significant correlation was obtained between total nitrogen content and vitamin C at P_2 (2 MAP) (0.4258) and P_3 (4 MAP) (0.3534). This implies that the fertilizer applied at P_2 and P_3 is having favourable effect on the vitamin C content of banana fruit.

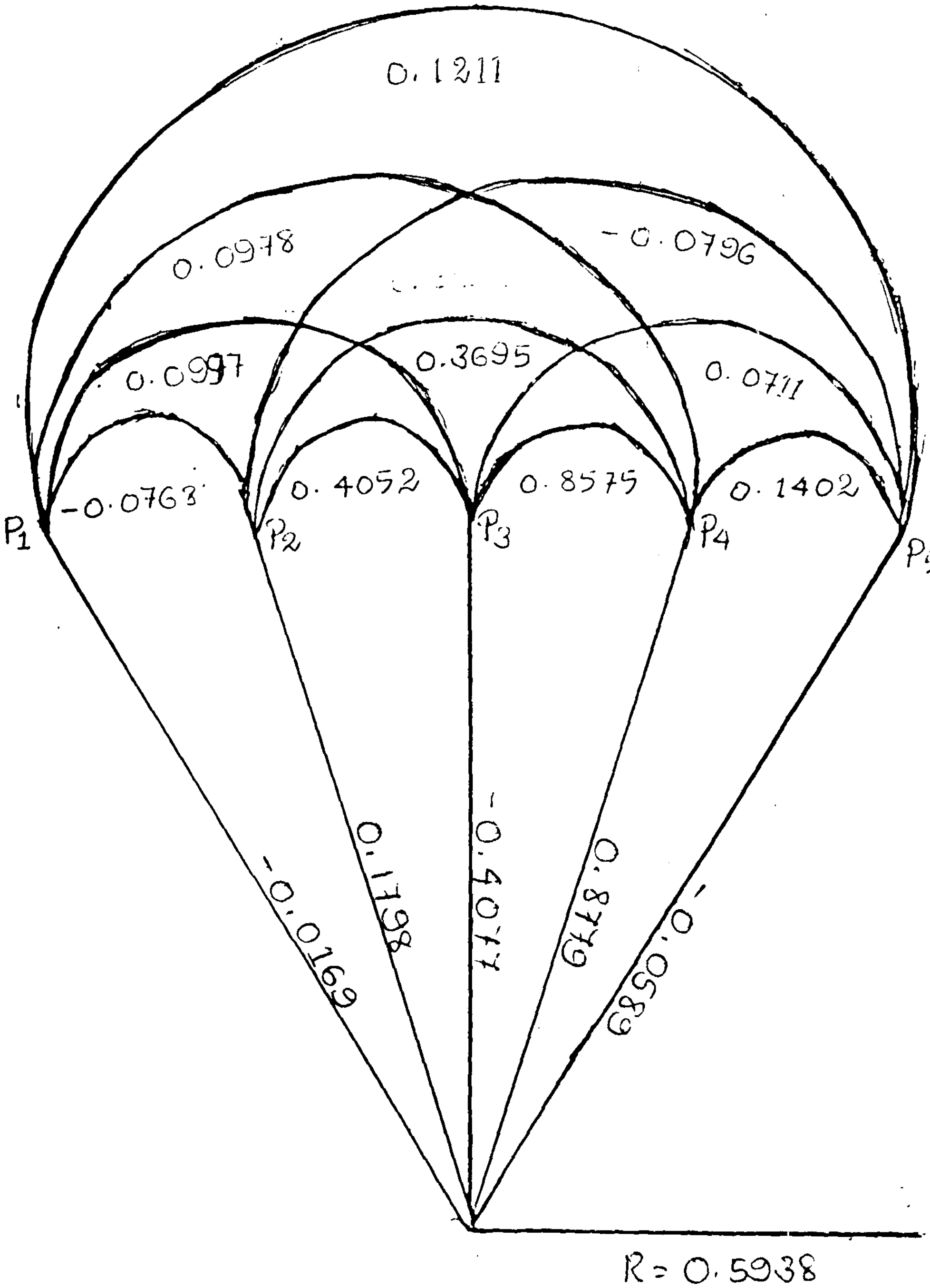

Fig. 2 Path diagram - Direct and indirect effects of available N in soil on the protein content of ripe banana

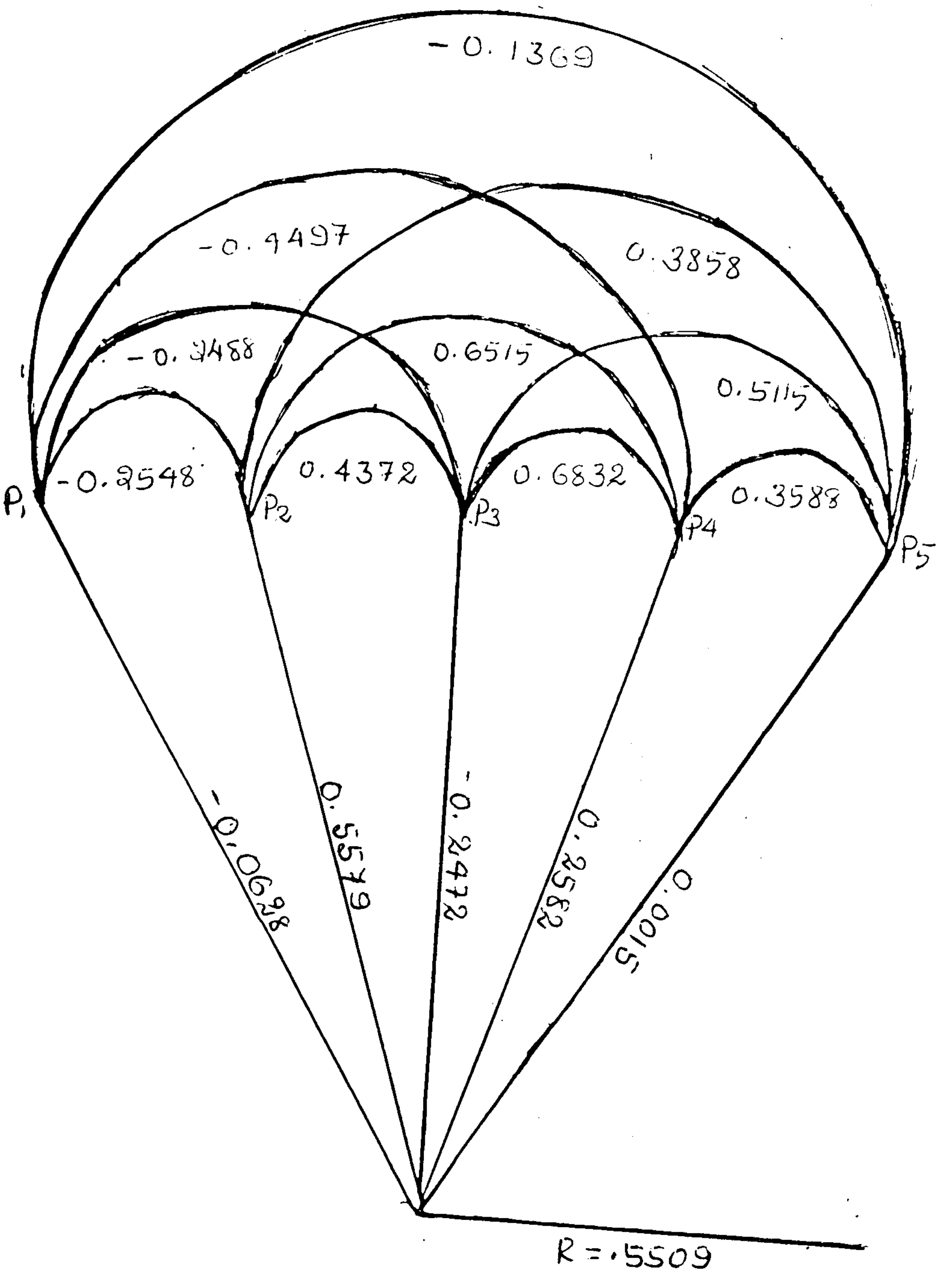

Fig. 3 Path diagram - Direct and indirect effects of total N (per cent) in soil at different periods on sugar content of ripe banana

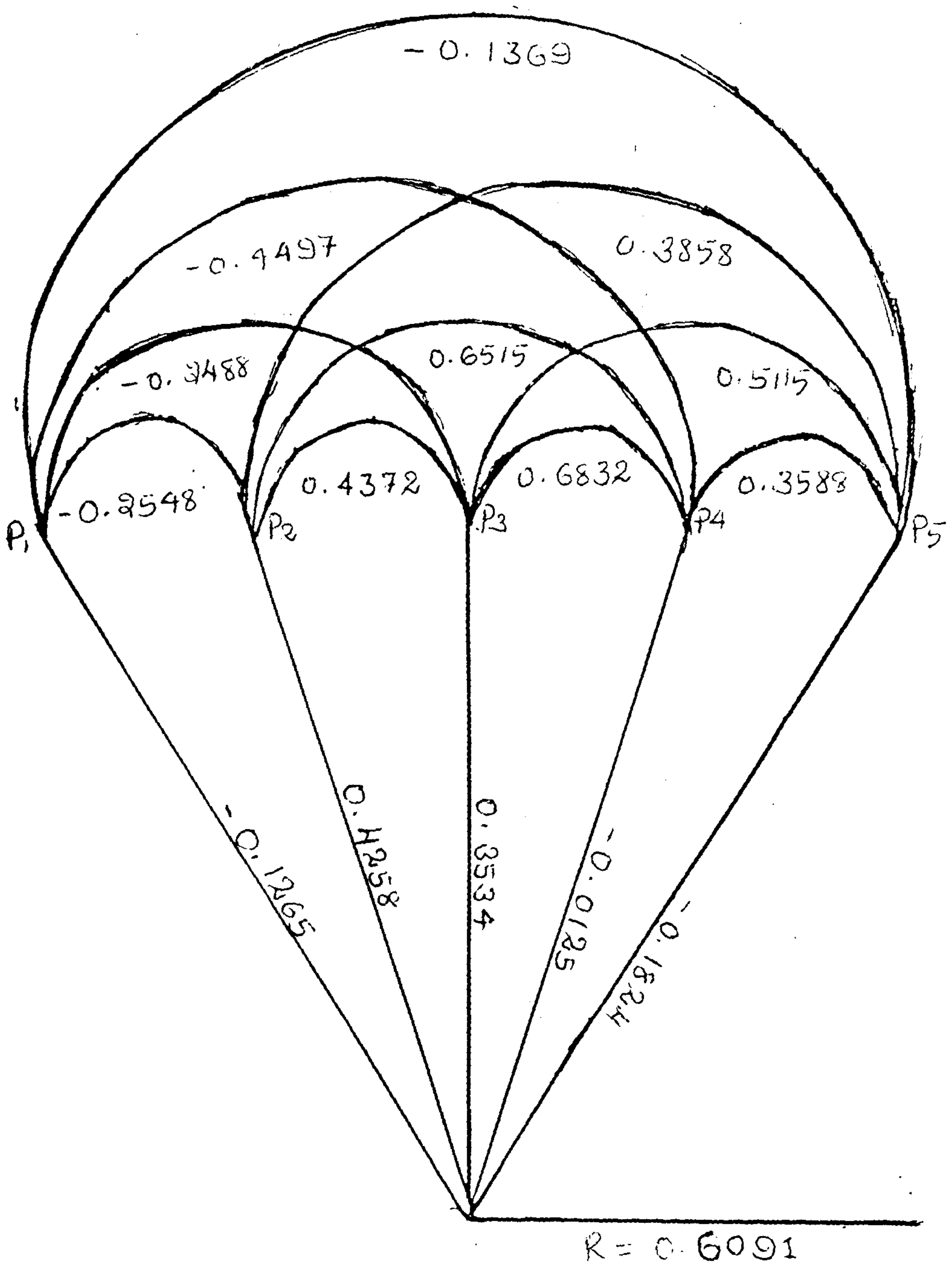

Fig. 4 Path diagram - Direct and indirect effects of total N (per cent) in soil at different periods on vitamin-C content of unripe banana

The available nitrogen has got significant direct effect on the vitamin C content of unripe banana fruit at P_4 (6 MAP). The indirect effect of nitrogen at P_4 through P_3 (0.6305) and P_2 (0.2717) are also significant (Fig.5). Residual effect of nitrogen applied at P_2 and P_3 is evident here by the maximum absorption of nitrogen at this stage.

The data was also subjected to path analysis to estimate the direct and indirect effects of the total N content at different growth stages on the carotene content of banana fruit (Fig.6). In the case of unripe fruit, the carotene content of the soil at P_2 (2 MAP) showed the maximum direct effect (0.6392**) whereas at P_3 (4 MAP) and P_4 (6 MAP) the direct effects were not significant. The indirect effect was maximum at P_4 (6 MAP) through P_2 (2 MAP) (0.4164).

The results indicate that fertilizer application has got profound influence on the carotene content of unripe banana fruit as evident from the path analysis. Increase in carotene content by increased application of nitrogenous fertilizers was reported by many workers (Subbiah and Ramanathan, 1983; Singh *et al.*, 1985).

The direct effect of total content of N in the soil on nitrate content of banana fruit is depicted in Fig.7. The direct effect was maximum at P_4 (6 MAP) (0.9639). The indirect effect of P_4 was significant through P_3 (0.6586) and P_2 (0.6280). The effect of fertilizer applied during P_2 and P_3 has got residual effect on the nitrate content of banana fruit. The more the nitrogenous fertilizer applied increased, the more was the accumulation of nitrate in the plant.

5.2 Phosphorous

Path analysis was carried out to find out the direct and indirect effect of phosphorous on yield and quality of banana based on the correlation studies.

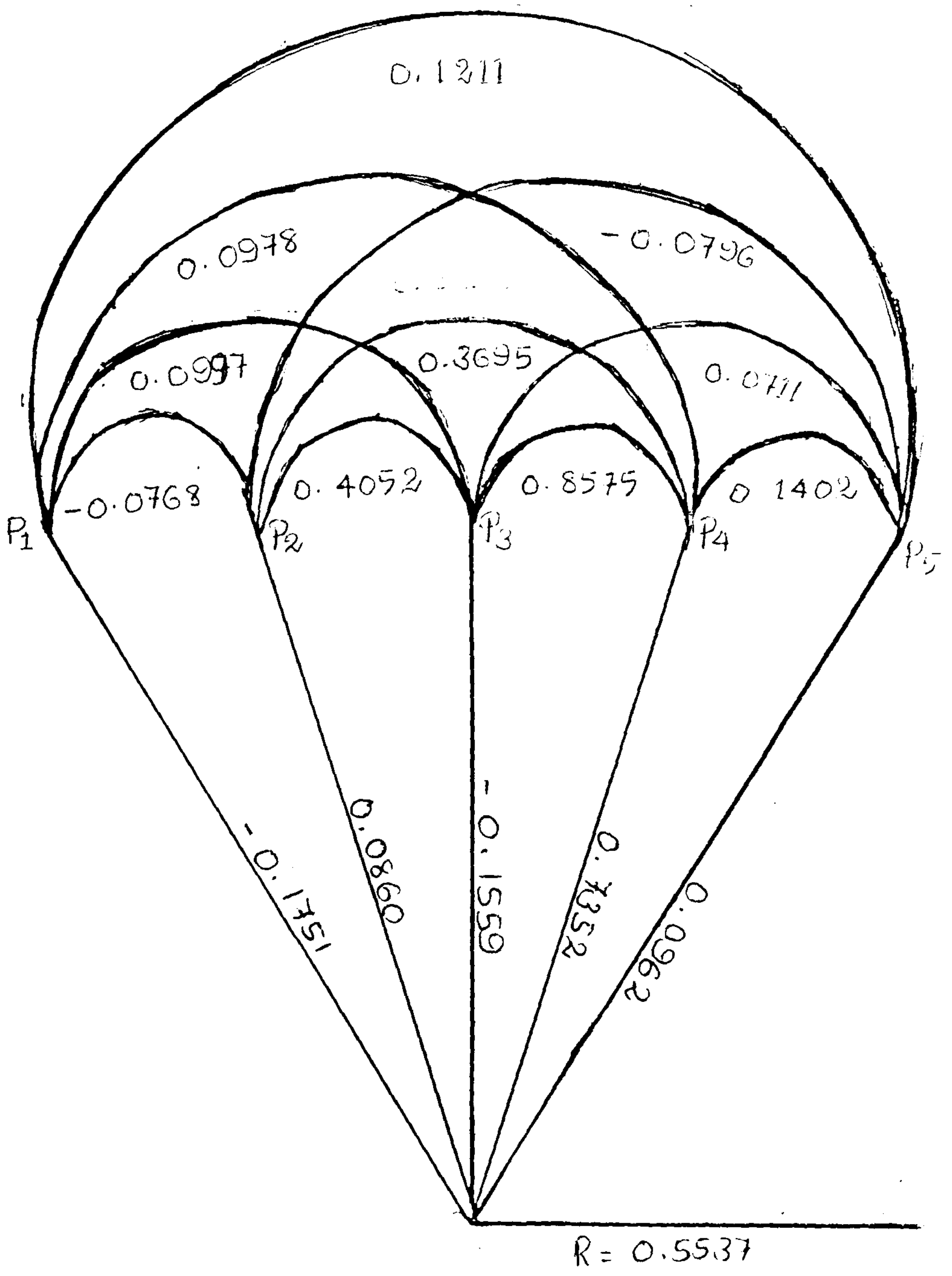

Fig. 5 Path diagram - Direct and indirect effects of available N in soil at different periods on vitamin-C content of unripe banana

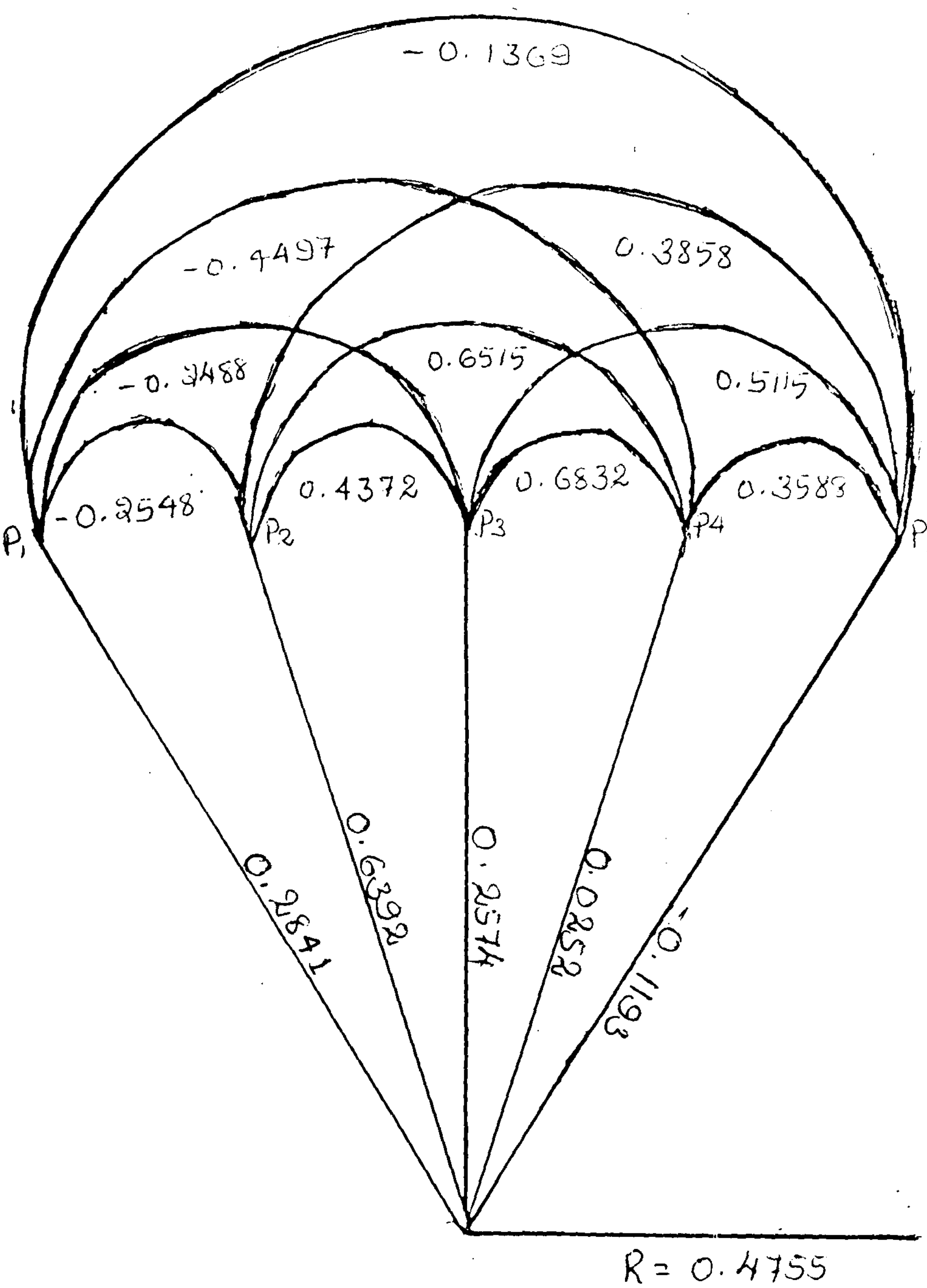

Fig. 6 Path diagram - Direct and indirect effects of total N (per cent) in soil at different periods on carotene content of unripe banana

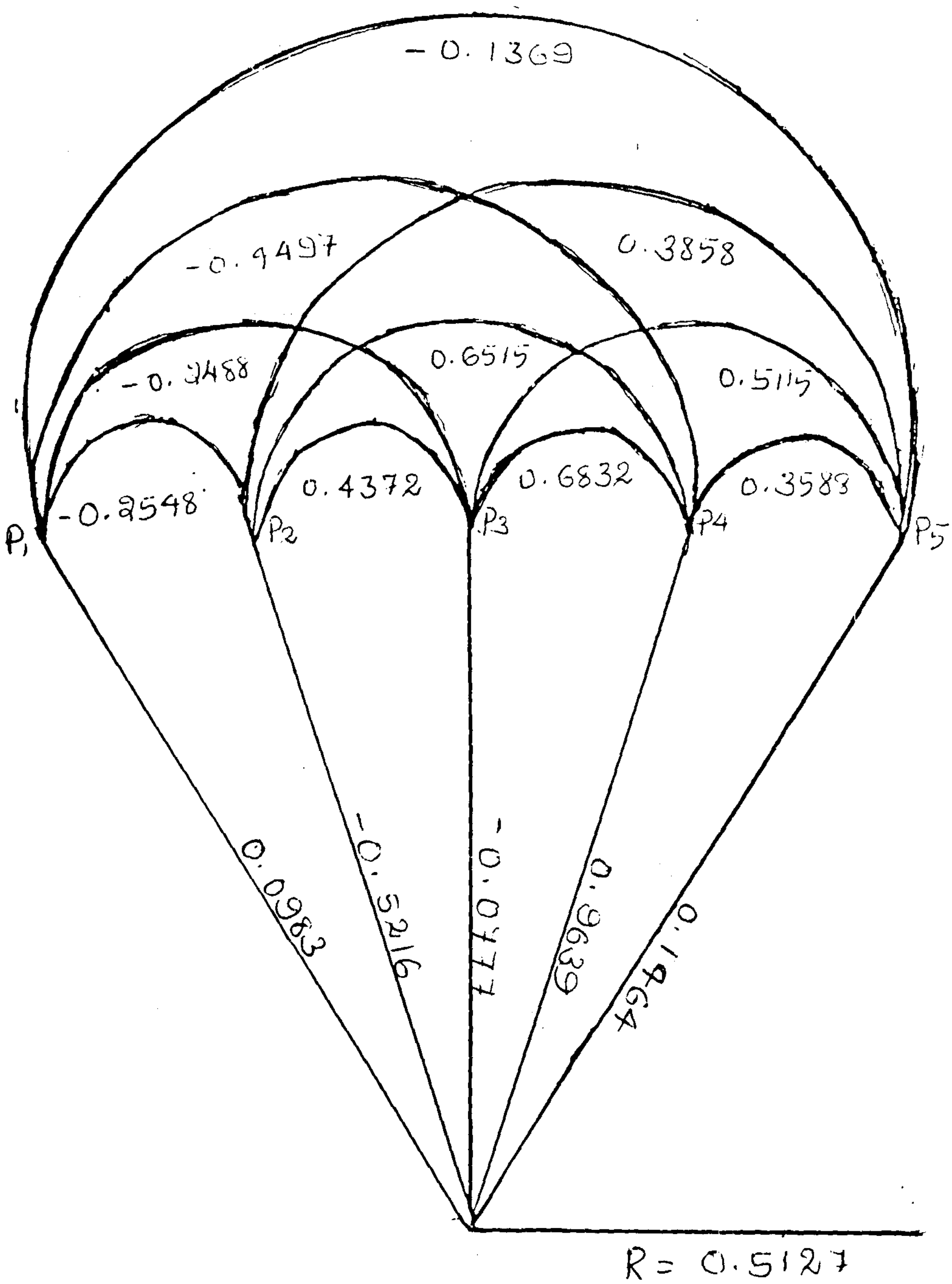

Fig. 7 Path diagram - Direct and indirect effects of total N (per cent) in soil at different periods on nitrate content of ripe banana

The direct and indirect effect of available P at different stages on the yield of banana is presented in Fig.8. The direct effect of available P was maximum at P_4 (6 MAP) (0.5669). The indirect effect of P_4 through P_3 (0.4702) and P_2 (0.2701) was also significant. The residual effect of fertilisers applied at P_2 and P_3 had influenced the yield of banana.

The direct and indirect effect of total P at different stages on the yield of banana was obtained by path analysis (Fig.9). Maximum influence was obtained at P_3 (4 MAP) (0.7630). The stage P_3 (6 MAP) has got indirect effect on yield through P_2 (0.3135) P_4 (0.2863) and P_5 (0.5813).

Phosphorus plays an important in energy transformation and metabolic processes of plants. Phosphorus is also involved in the basic reactions of photosynthesis.

Based on the significant correlations obtained, path analysis was carried out between available P content of soil at different stages and protein content of banana fruit (Fig.10). At P_4 (6 MAP) maximum direct effect was obtained (0.7565) followed by P_2 (0.2920). The indirect of P_3 through P_4 (0.6274) and P_2 (0.3783) was also found to be significant.

Phosphorus being a constituent of nucleo protein is involved in the nitrogen metabolism of plant and hence increased application of phosphorus increases the protein content as evident from path analysis of the data obtained.

Direct and indirect effect of available P in soil at different periods on the sugar content of banana fruit showed maximum effect at P_2 (0.4136) and P_4 (0.2258) (Fig.11). This indicates the influence of added phosphorus on the carbohydrate metabolism. Available P also has got direct influence on vitamin C

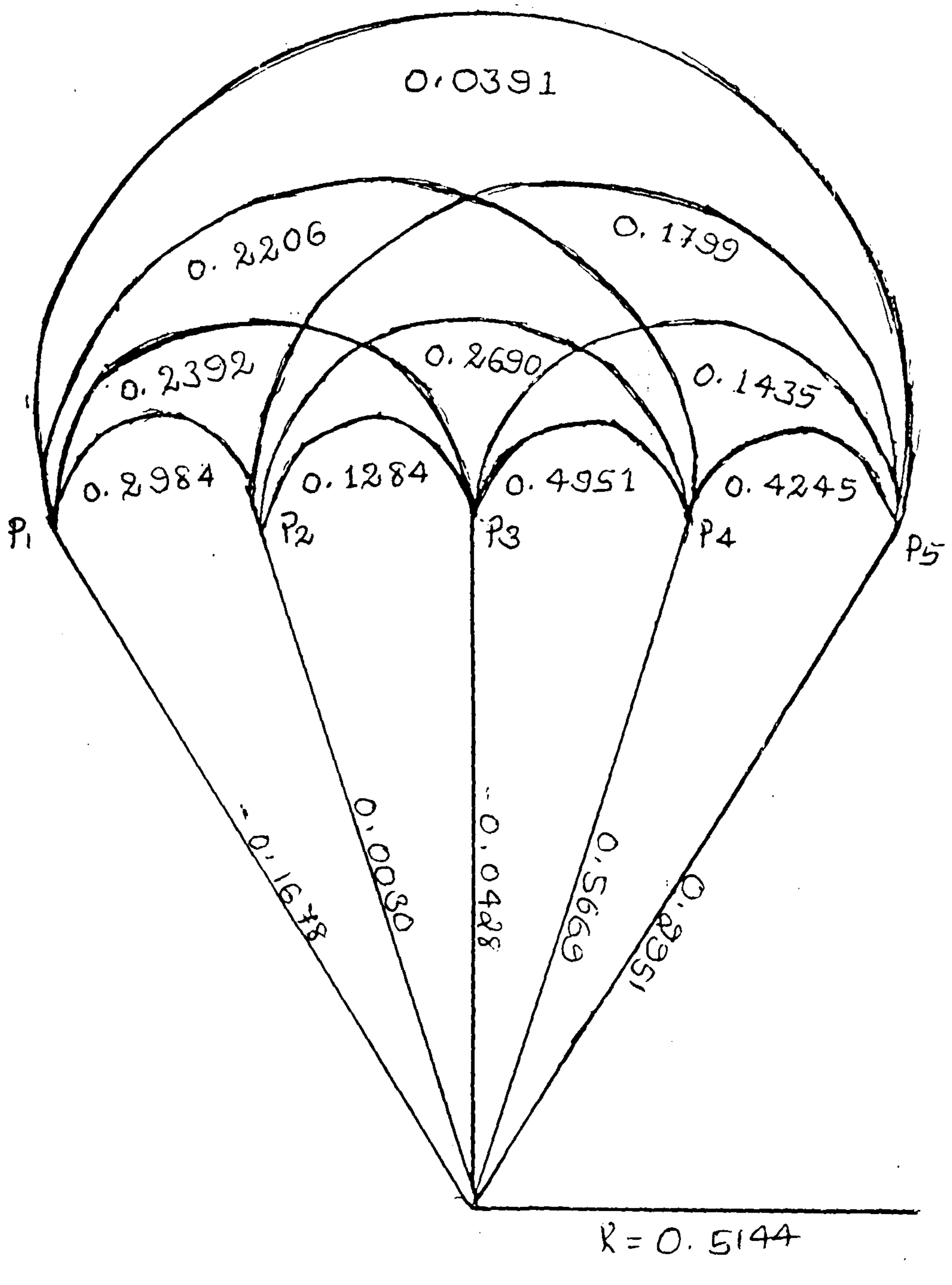

Fig. 8 Path diagram - Direct and indirect effects of available P in soil at different periods on yield of banana

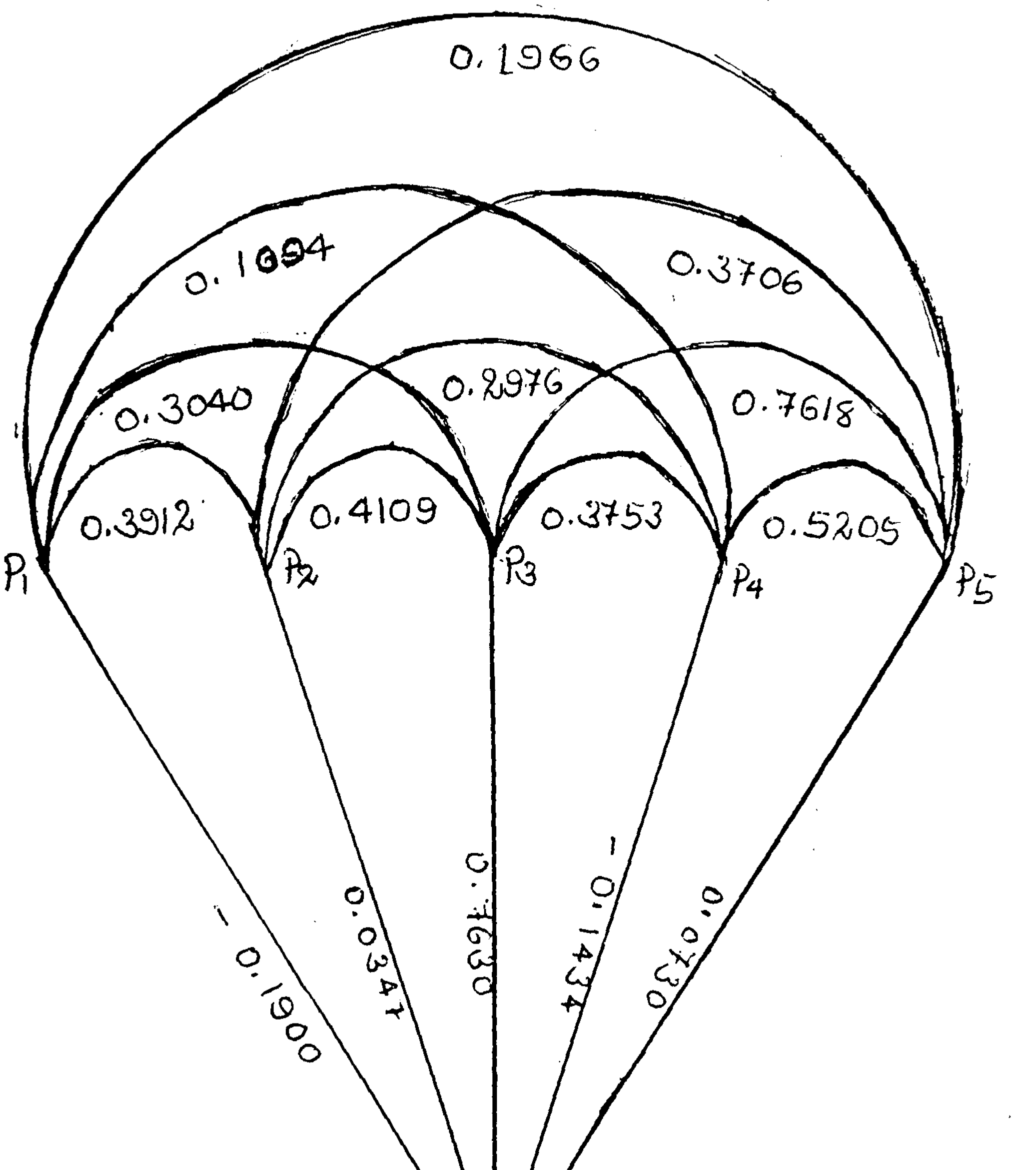

Fig. 9 Path diagram - Direct and indirect effects of total P in soil at different periods on yield of banana

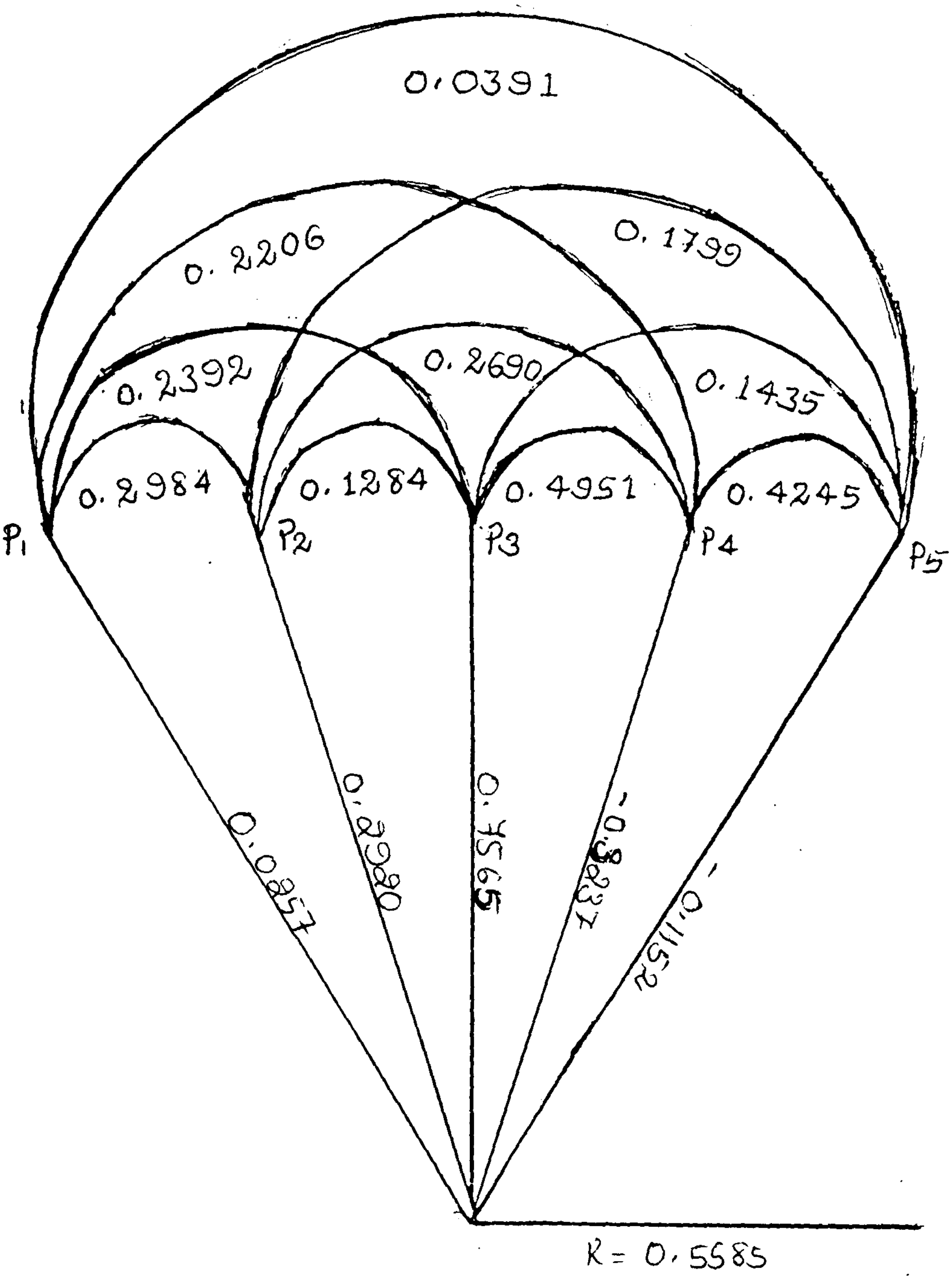

Fig. 10 Path diagram - Direct and indirect effects of available P in soil at different periods on protein content of ripe banana

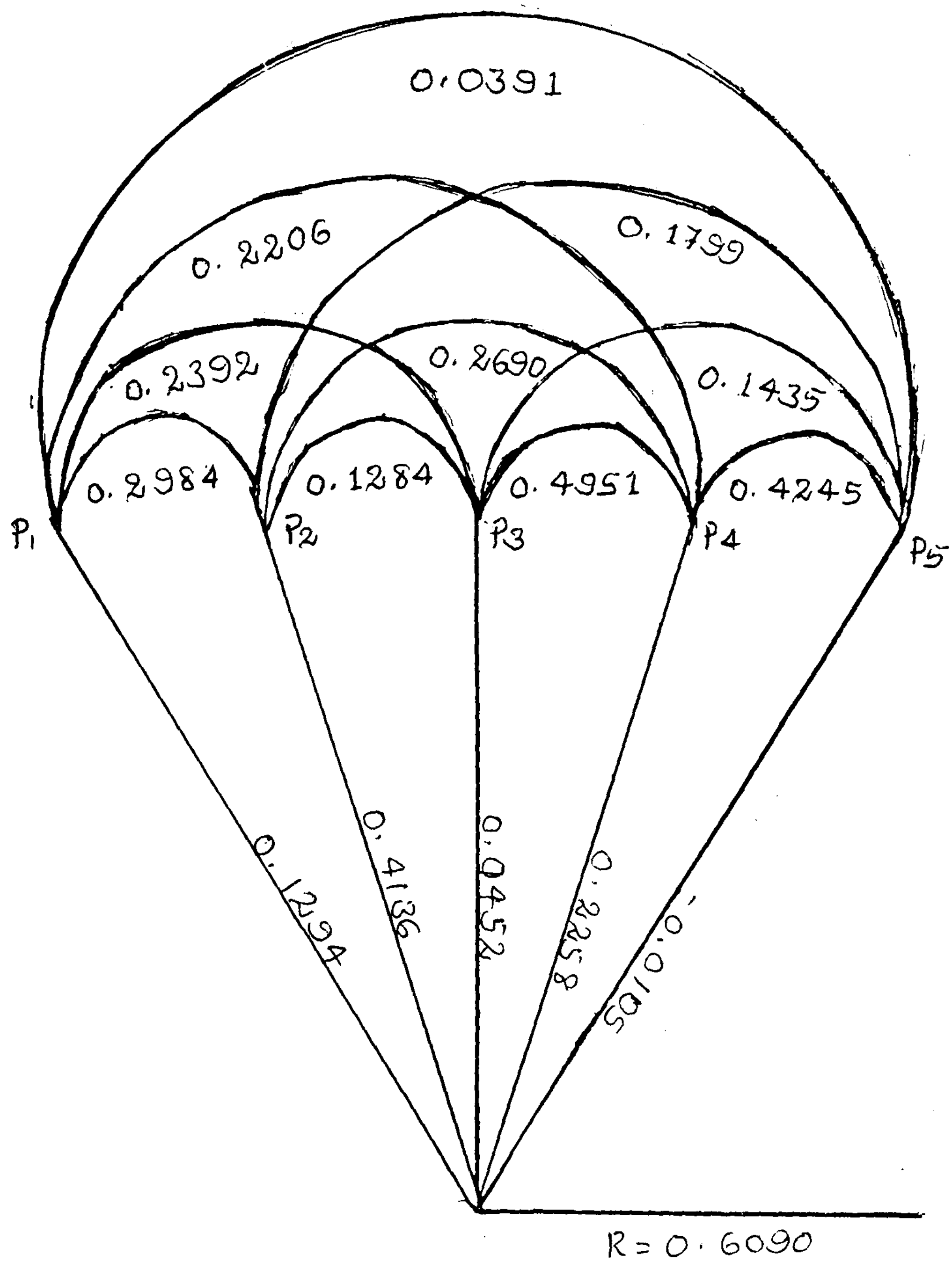

Fig. 11 Path diagram - Direct and indirect effects of available P in soil at different periods on sugar content of ripe banana

content and maximum value was at P_3 (0.5868). The indirect effect of P_3 through P_4 (0.4867) was also significant.

The total P and available P has got direct and indirect influences on the total mineral content of banana fruit due to increased uptake of nutrients.

5.3 Potassium

In order to find out the direct and indirect effect of potassium on yield and quality of banana path analysis was carried out. From the results it is clear that the total K at P_4 (6 MAP) has got maximum direct effect on yield (0.4826) followed by P_2 (2 MAP) (0.3769). Maximum indirect effect on yield was observed at P_4 (6 MAP) through P_3 (4 MAP). The direct effect of exchangeable K on yield was maximum at P_4 (6 MAP) followed by P_3. The indirect effect has highest at P_4 (6 MAP) through P_3 (4 MAP). Water soluble K also has got direct influence on yield.

The requirement of K for the crop is high throughout its growth period and hence fertilizer application should be done in splits.

Available K content of soil at different stages on protein content of ripe banana fruit has got maximum direct influence at P_3 (4 MAP) (0.4844) whereas total K had no direct influence on protein content. Sugar content of ripe fruit had maximum direct influence at P_4 for both available water soluble K.

Available K content of soil at different periods of growth has got maximum direct influence on carotene content of fruit at P_3 (4 MAP) (0.6601**) followed by P_2 (2 MAP) (0.3491*) (Fig.12). The total K content has got maximum direct influence on carotene content at P_2 (2 MAP) (0.5315**) and water soluble K had no direct effect on carotene content of the fruit.

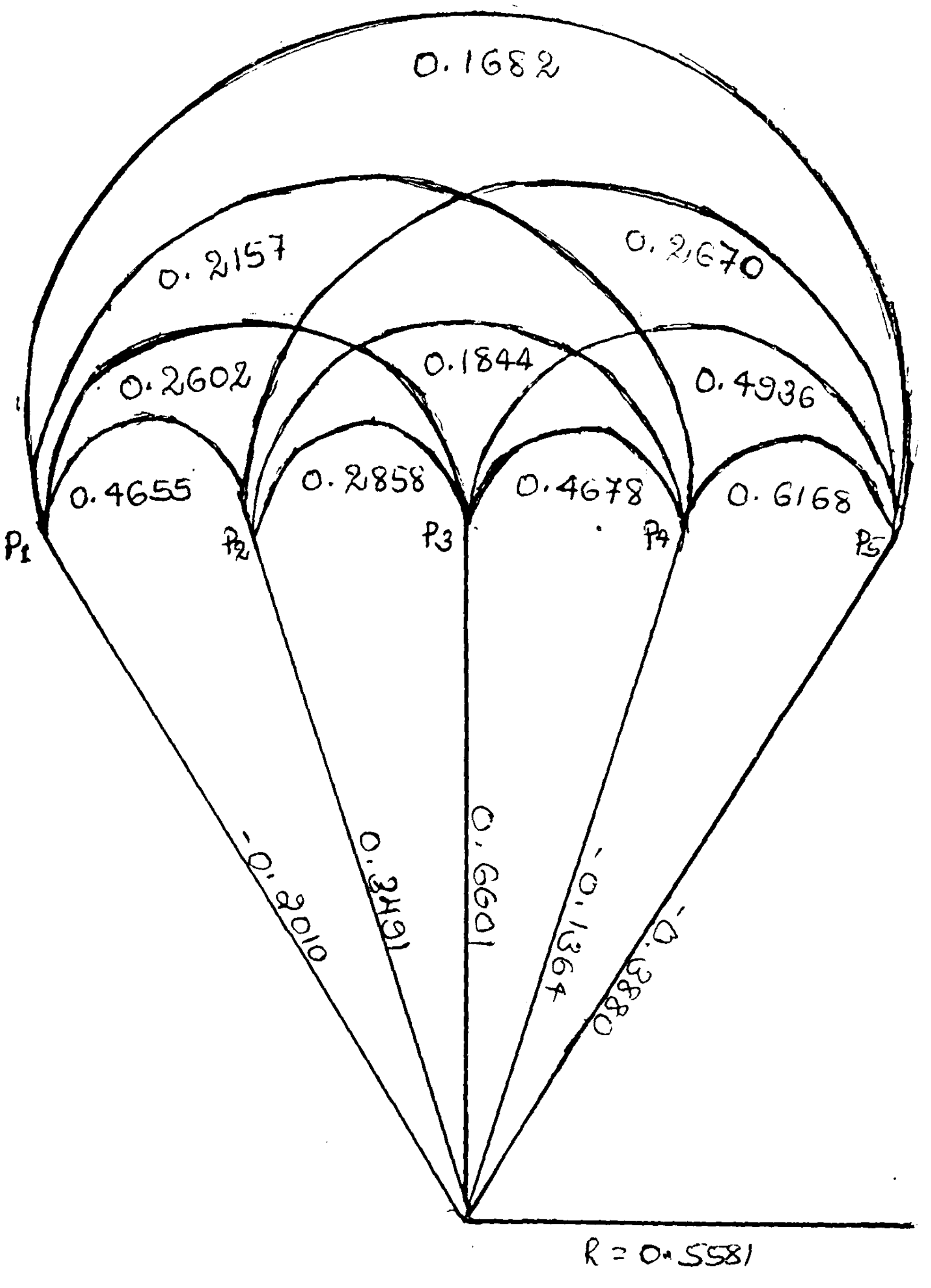

Fig. 12 Path diagram - Direct and indirect effects of exchangeable K in soil at different periods on carotene content of ripe banana

The carbohydrate content of ripe banana fruit is influenced directly by water soluble K content of soil at P_4 (6 MAP) (0.4235) followed by P_2 (2 MAP).

The sugar content of unripe banana fruit is influenced directly by exchangeable K content of soil and P_2 (2 MAP) (0.5130**) (Fig.13). The sugar content of ripe banana fruit is influenced directly by water soluble K (Fig.14).

6 Uptake of nutrients and yield and quality of banana

Path analysis was carried out to find out the direct and indirect effect on the uptake of major nutrients on yield and quality of banana.

The uptake major nutrients on yield was presented in Fig.15. The maximum direct influence on yield was obtained for potassium (0.5986**). The indirect effect of potassium through N and P was also significant.

The direct effect of the uptake of nitrogen on sugar content of ripe banana fruit was maximum followed by phosphorus. The protein content of ripe banana fruit was highly influenced by uptake of nitrogen as revealed by the path analysis (0.6324**). Phosphorus and potassium also had significant direct influence.

Vitamin C content of both ripe and unripe banana fruit was significantly influenced by potassium (0.4384**). Total mineral content of ripe banana fruit was influenced by nitrogen significantly (0.3983*).

7 Interaction of major nutrients

Path analysis was carried out to find out the direct and indirect effect of major nutrients interaction at different stages on yield and quality of banana.

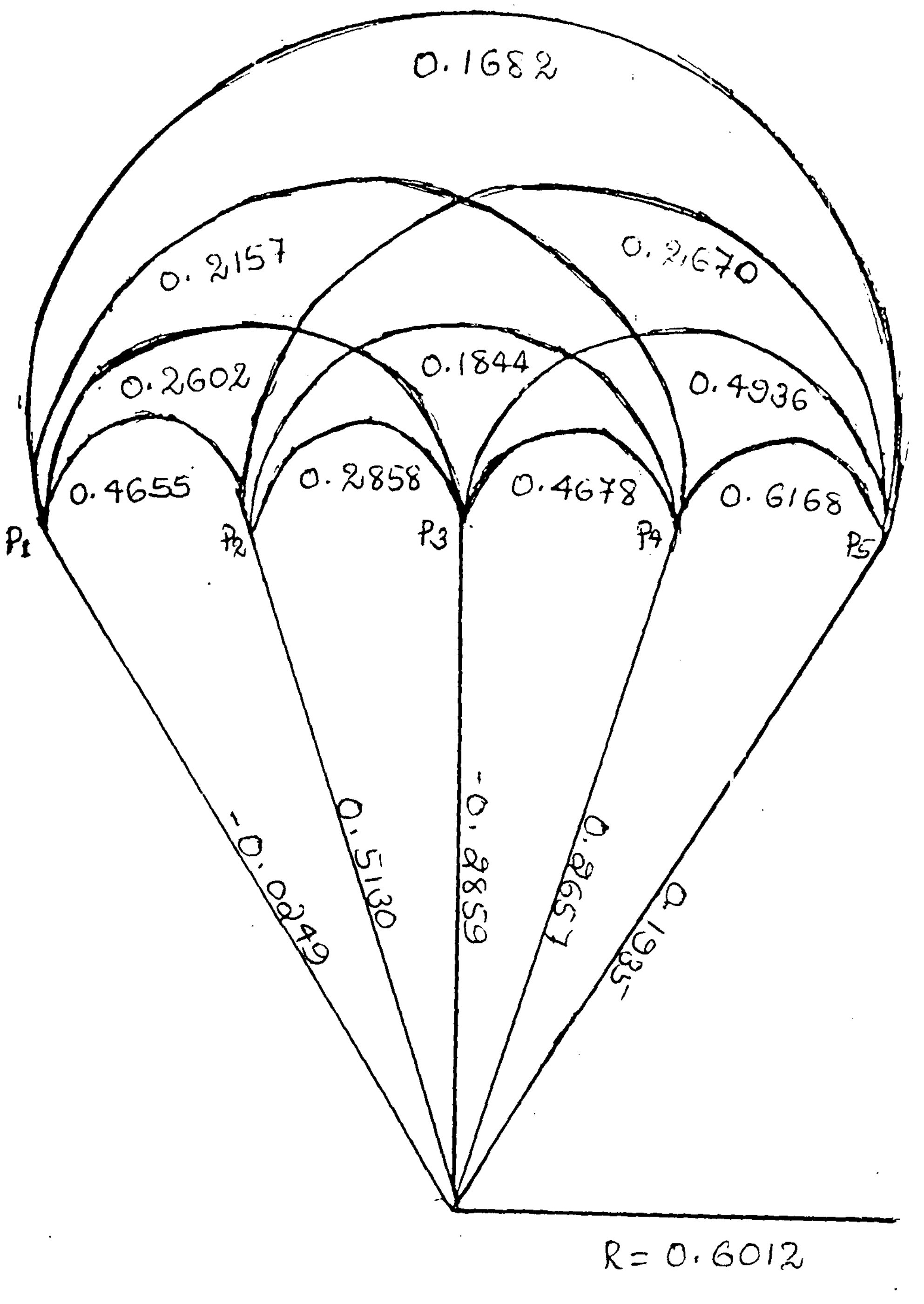

Fig. 13. Path diagram - Direct and indirect effects of exchangeable K in soil at different periods on sugar content of unripe banana

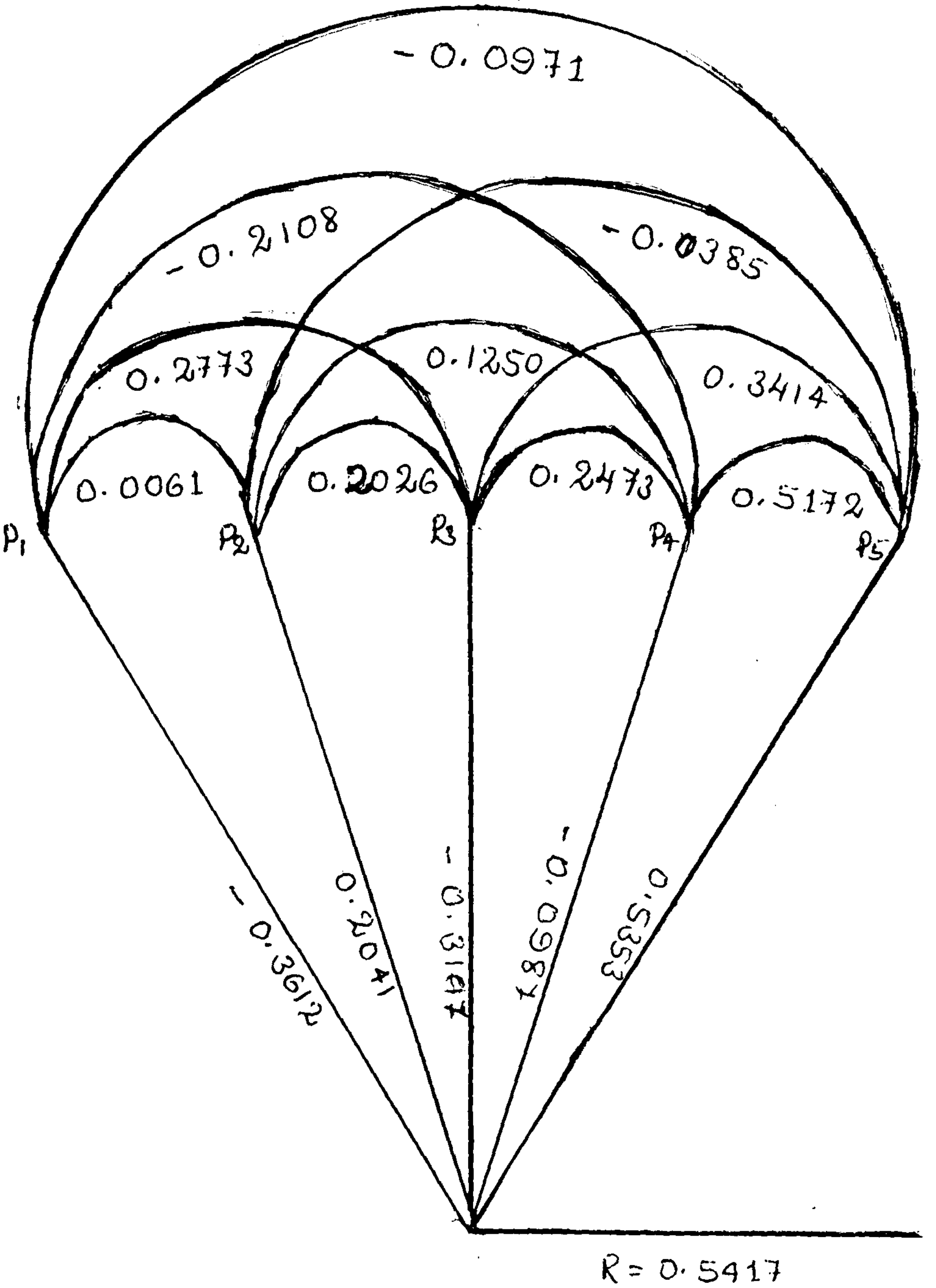

Fig.14. Path diagram - Direct and indirect effects of water soluble K (per cent) in soil at different periods on sugar content of ripe banana

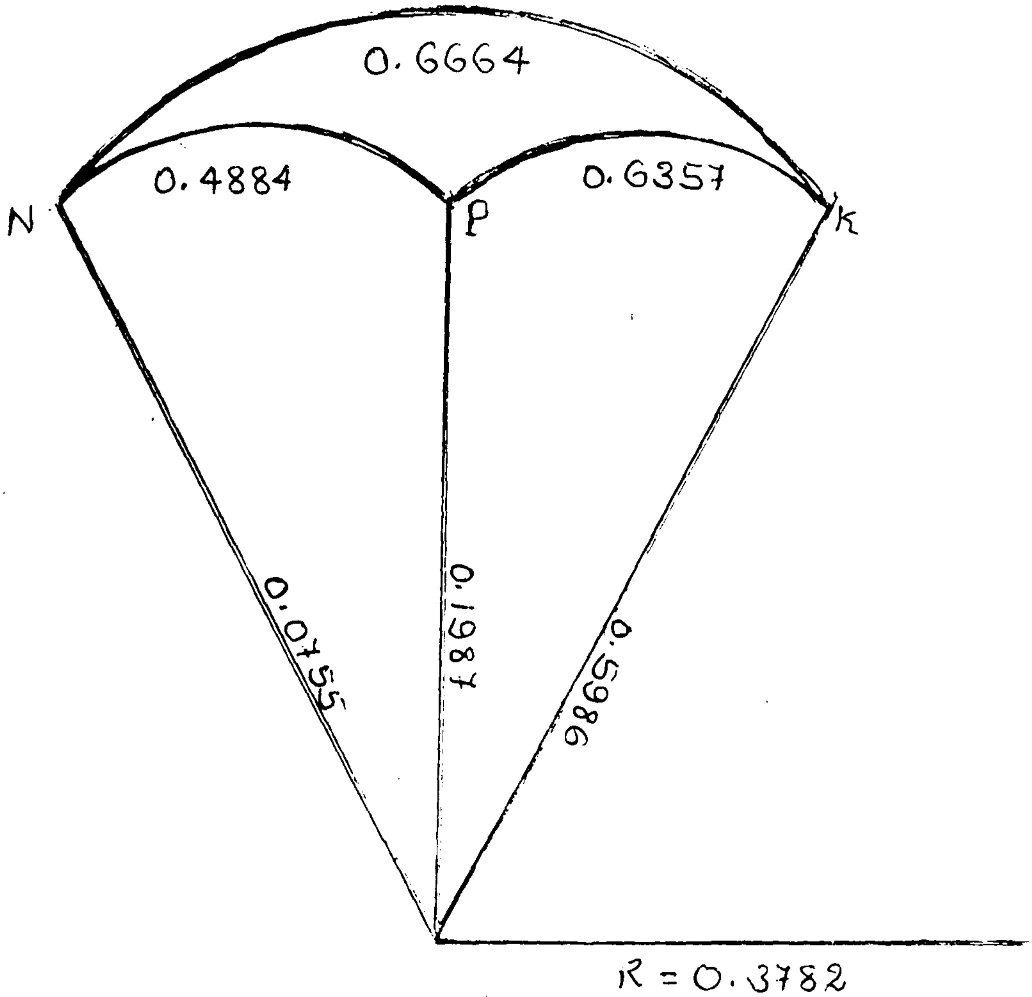

Fig. 15 Path diagram - Direct and indireet effects of uptake of nutrients on yield of banana

At 2 MAP yield of banana has got maximum direct influence with total potassium (0.4376*) followed by nitrogen (0.2121) (Fig.16). At P_3 (4 MAP) total phosphorus content of the soil has got maximum direct influence on yield (0.5701**) (Fig.17). The indirect influence of phosphorus through potassium and nitrogen was also considerably high. At P_4 (6 MAP) maximum direct influence was for total P followed by total nitrogen (Fig.18).

The sugar content of ripe banana fruit was highly influenced by total nitrogen (0.7951**) at P_2 (2 MAP) whereas the influence on sugar content of unripe banana fruit was insignificant. At P_4 (6 MAP) total nitrogen significantly influenced the sugar content of ripe fruit (0.6266**).

At P_2 (2 MAP) carotene content of unripe fruit is greatly influenced by total potassium present in soil whereas the carotene content of unripe fruit was influenced by phosphorus (0.5857**) (Fig.19). At P_4 (6 MAP) the carotene content of unripe fruit is influenced by total nitrogen content of soil (0.4709).

At 2 MAP total nitrogen content of soil has got maximum direct influence on vitamin C content of unripe banana fruit (0.4500**). Similar trend was observed at P_3 (4 MAP) and P_4 (6 MAP).

The available nutrients of soil at different periods were also correlated with yield and quality of banana. At P_2 (2 MAP) yield was greatly influenced by available potassium content of soil (0.5576**) (Fig.20). But at P_3 (4 MAP) available phosphorus has got maximum direct influence in yield (0.4633**) (Fig.21). Similar trend was observed at P_4 (6 MAP) also (Fig.22).

At P_2 (2 MAP) protein content of ripe banana fruit was highly influenced by phosphorus (0.4225**). Similar trend was observed at P_3 (4 MAP). But at P_4

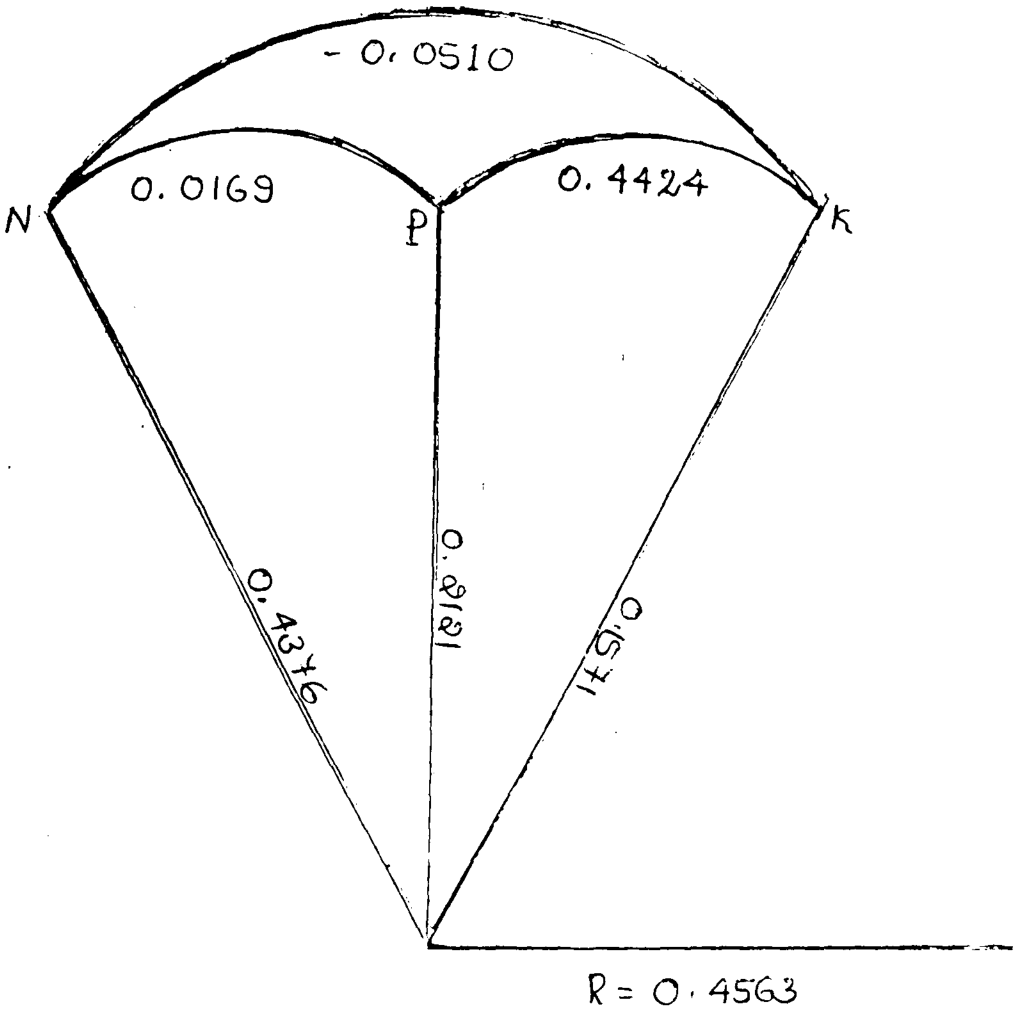

Fig.16 Path diagram - Direct and indirect effects of interaction of major nutrients at P_2 (2 MAP) on yield of banana

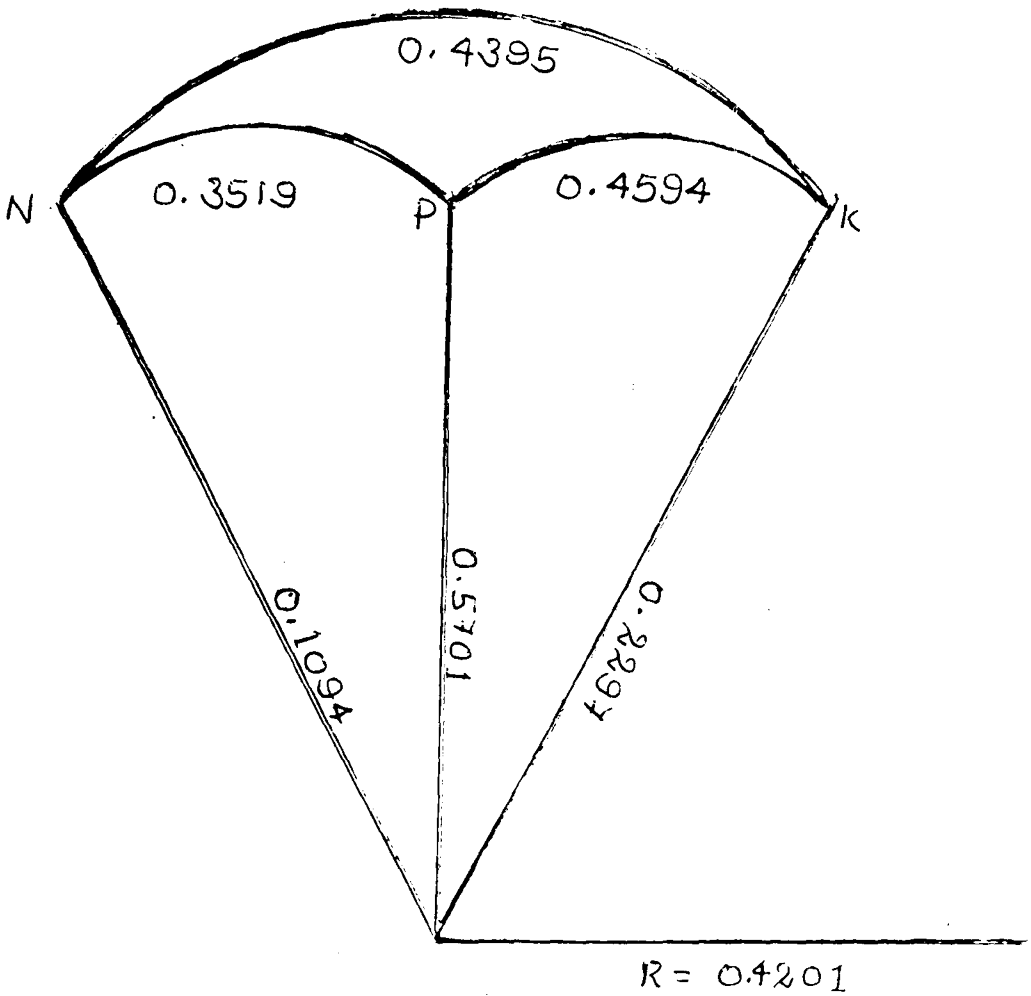

Fig.17 Path diagram - Direct and indirect effects of interaction of major nutrients at P_3 (4 MAP) on yield of banana

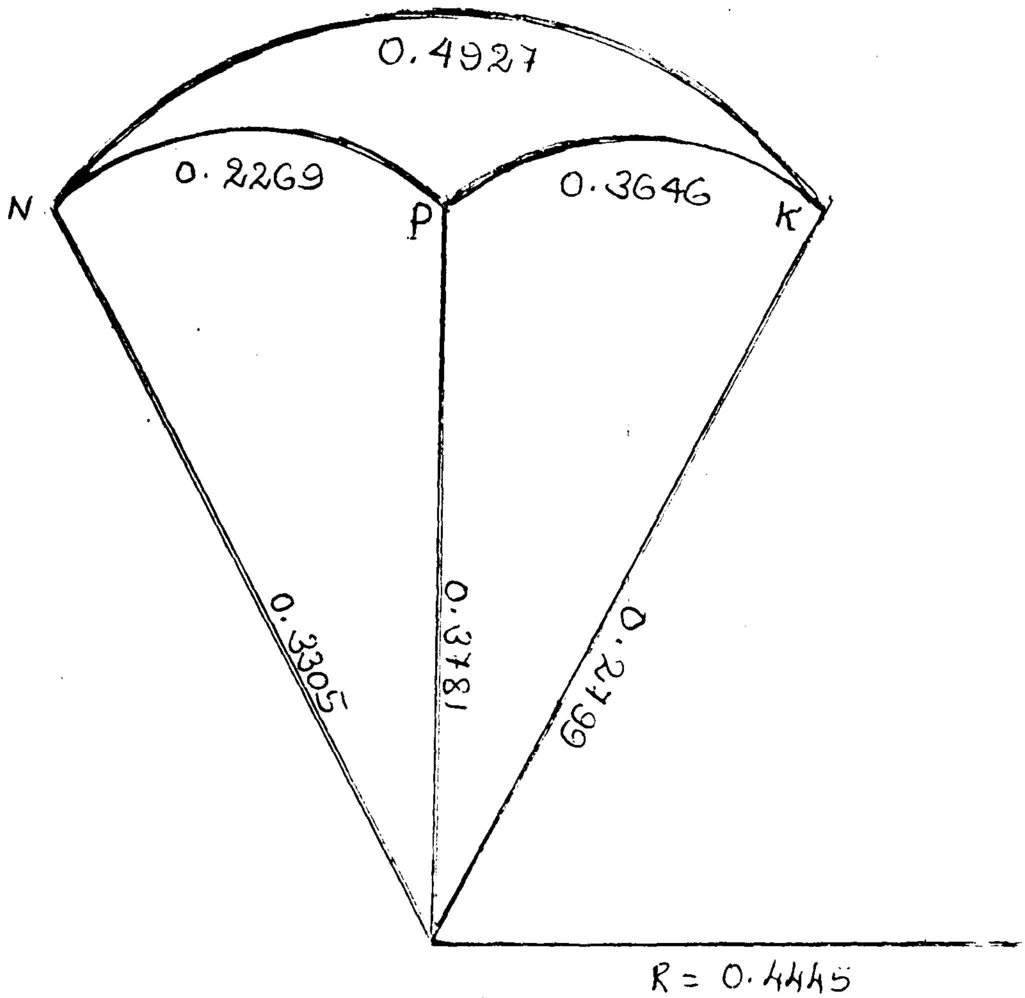

Fig. 18 Path diagram - Direct and indirect effects of interaction of major nutrients at P_4 (6 MAP) on yield of banana

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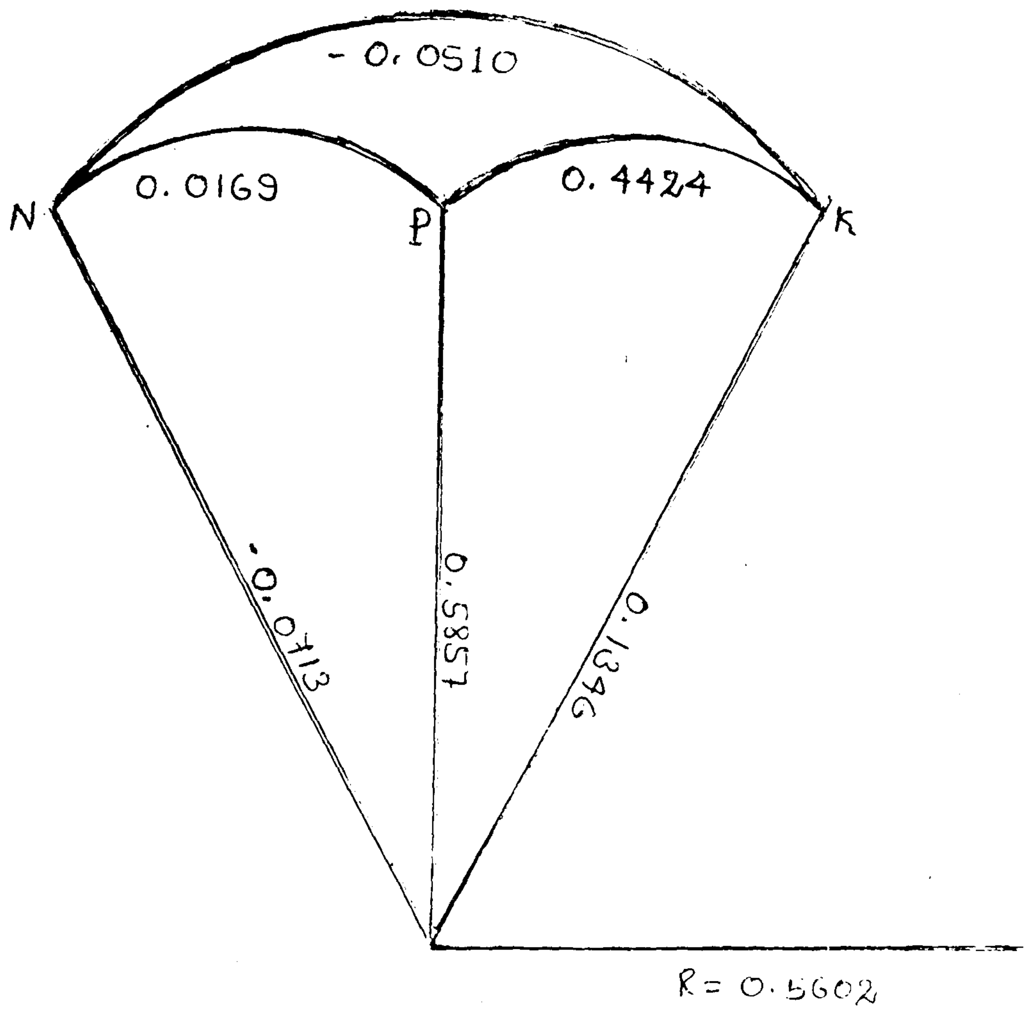

Fig. 19 Path diagram - Direct and indirect effects of interaction of major nutrients at P_2 (2 MAP) on carotene content of unripe banana

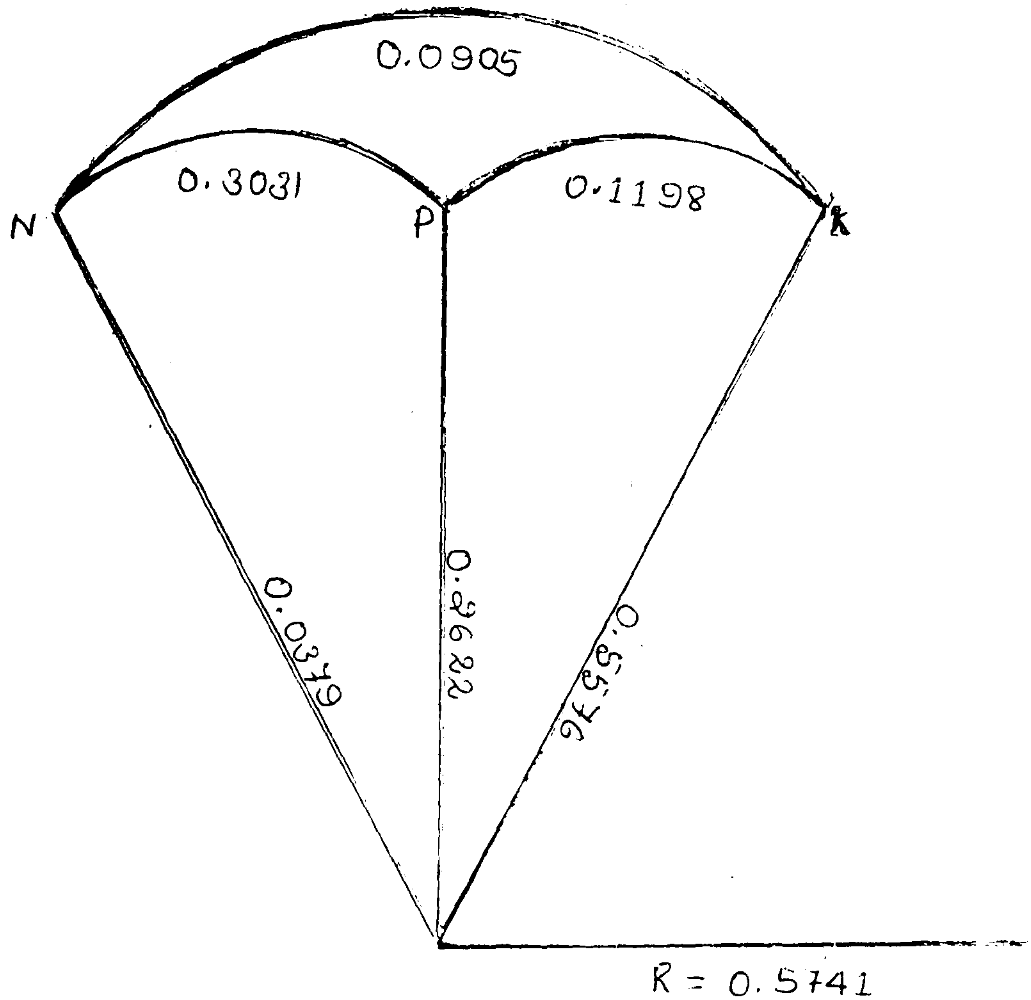

Fig. 20 Path diagram - Direct and indirect effects of interaction of available nutrients at P_2 (2 MAP) on yield of banana

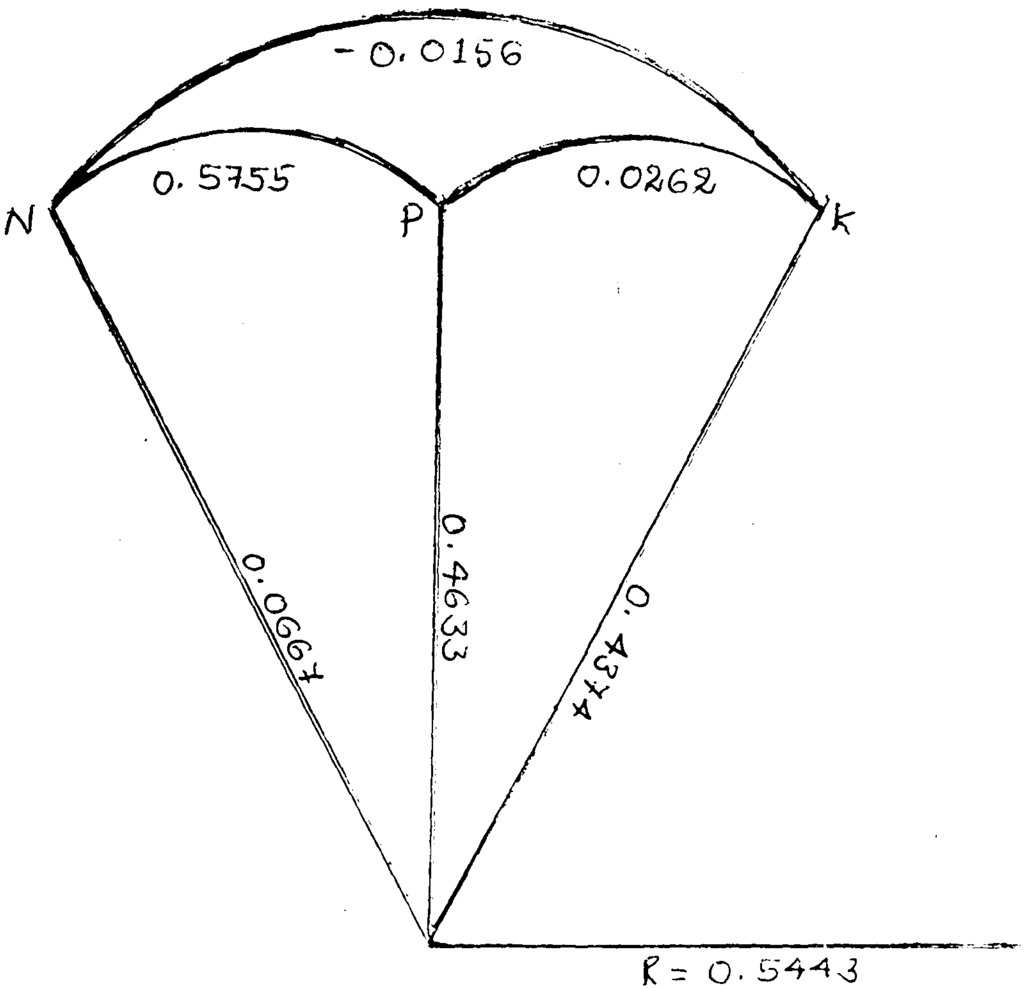

Fig. 21 Path diagram - Direct and indirect effects of interaction of available nutrients at P_3 (4 MAP) on yield of banana

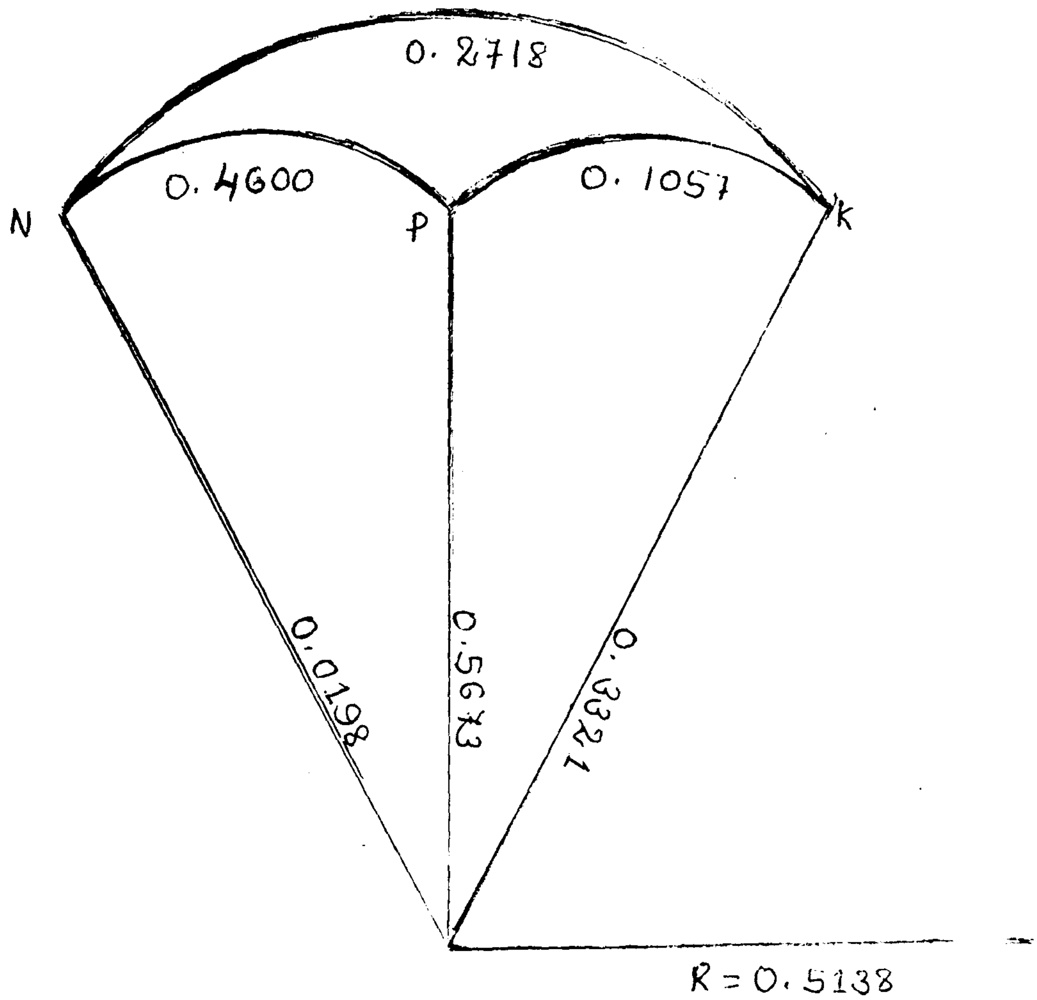

Fig. 22 Path diagram - Direct and indirect effects of interaction of available nutrients at P_4 (6 MAP) on yield of banana

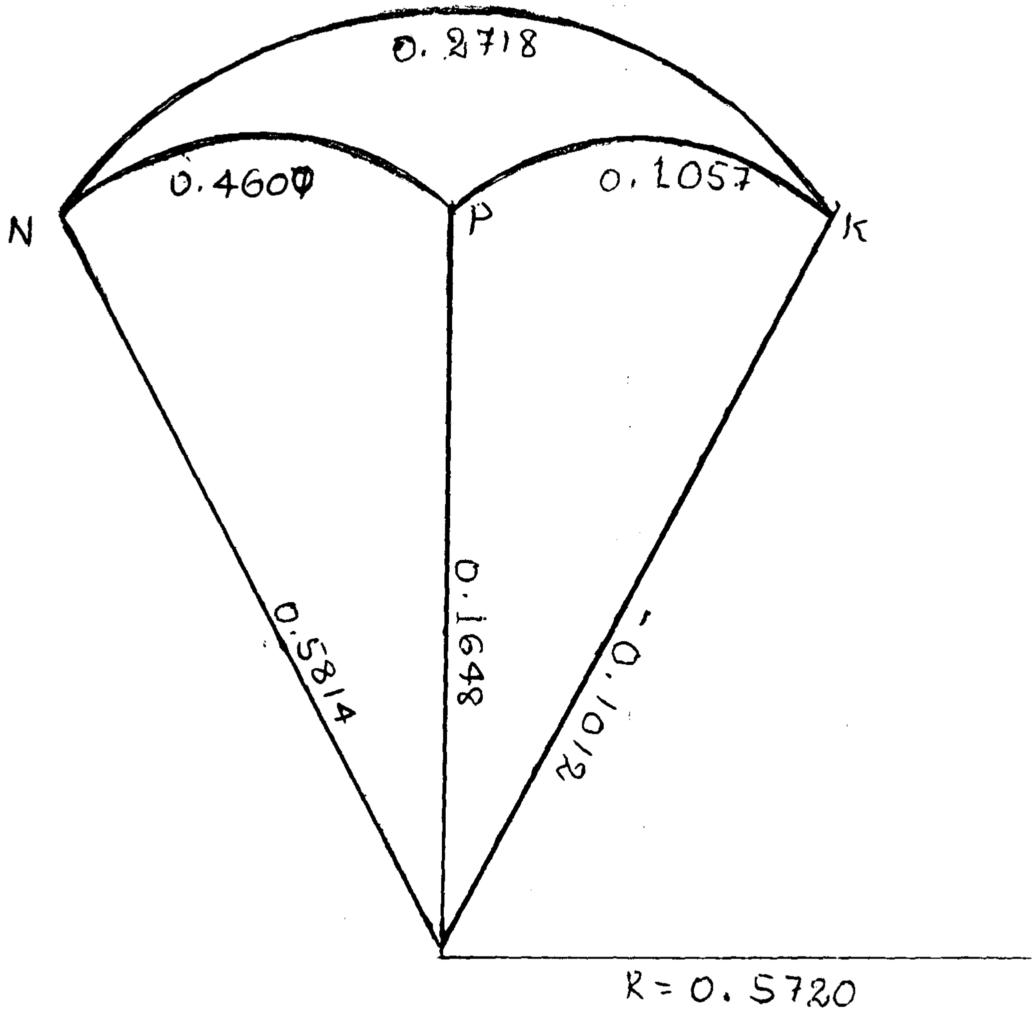

Fig. 23 Path diagram - Direct and indirect effects of interaction of available nutrients at P_4 (6 MAP) on vitman C content of unripe banana

(6 MAP) potassium has got maximum direct influence on protein content of ripe fruit (0.5117**).

The sugar content of ripe fruit was influenced by phosphorus content of the soil at P_2 (2 MAP) (0.5376**). But for unripe fruit available nitrogen has got maximum influence on sugar content at P_2 (0.4975**). At P_3 (4 MAP) phosphorus has got maximum direct influence on sugar content of ripe banana fruit (0.3425*) followed by potassium, similar trend was observed at P_4 (6 MAP) also.

At P_3 (4 MAP) vitamin C content was greatly influenced by available phosphorus content of soil (0.4959**) whereas carotene content was influenced greatly by available nitrogen content of soil (0.4515**). But the vitamin C content of unripe fruit was influenced by available K content (0.4320**) significantly. At P_4 (6 MAP) available N content of soil has got maximum direct influence on the vitamin C content of unripe banana fruit (Fig.23).

Thus the study revealed that application of fertilizers and organic matter is essential for getting better yield and quality of banana. All the food nutrients were found to be increased by applying fertilizer and hence the quality is much enhanced. Regarding bunch yield the fertilizer dose of 12.5 kg FYM, 200:125:300 g N, P_2O_5 and K_2O per plant obtained maximum yield. The treatments receiving medium level of FYM and nitrogen recorded higher content of carbohydrate. Protein content of banana was increased by the application nitrogen and potassium. Application of farmyard manure enhances the fat content of banana. Sugar content of the banana fruit is increased by the application of nitrogenous and potassium fertilizers. Acidity is increased by the application of farmyard manure and nitrogen. Nitrate accumulation in banana was high in plots receiving highest dose of nitrogen. Nitrogenous fertilizers increased the carotene content of banana. Fertilizer application enhances the total mineral content of banana due to increased uptake

SUMMARY

The present investigation was carried out in the Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara. The field experiment was laid out at Banana Research Station, Kannara on banana var. Nendran during the period of 1996 to 1997 with the following objectives.

1. To find out the changes in nutrient contents under varying levels of organic matter, nitrogen, phosphorus and potassium.
2. To produce better quality banana by regulating major nutrients and organic matter.
3. To find out the effect of organic matter and major nutrients on the accumulation of toxic materials in banana.

The following conclusions were made based on the present investigation.

1. The height of the plants did not differ significantly during the different stage of growth studied. Girth of the pseudostem did not differ significantly during the initial stages of growth. However, significant differences between treatments were observed from 5 MAP onwards. Regarding the number of functional leaves also, the treatments differed significantly from 5 MAP onwards. Increased application of K increased the vegetative growth of the plant.

2. Yield and all yield attributes showed increasing trends in the treated plots compared to control plot.

3. The carbohydrate content of ripe and unripe fruits of banana differed significantly with treatments. The treatments receiving medium level of FYM,

and nitrogen recorded higher value of total carbohydrate content. On ripening carbohydrate content of banana decreased due to the conversion of carbohydrate to sugar.

4. The protein content of all edible parts differed significantly with treatments. Application of fertilizers especially nitrogen and potasssium increased the protein content of banana.

5. The fat content of banana differed significantly with treatments. All the treated plots obtained higher content of fat compared to absolute control which showed that application of fertilizer and FYM had influenced on the fat content of banana.

6. The sugar content of edible portions of banana fruit is more in fertilized plots compared to control which indicates that fertilizer application enhances the sugar content. Application of fertilizers especially nitrogen and potassium enhanced the sugar content. Ripening increased sugar content due to the conversion of carbohydrate and starch to sugar.

7. The treatments showed significant differences in the acidity of banana. All the plots receiving high FYM and nitrogen recorded higher values for acidity. On ripening acidity of the fruit pulp increased.

8. The treatments showed significant difference in the nitrate content of banana. The treatments which received highest dose of nitrogen, 300 g N/plant recorded highest value for nitrate content.

16. The vitamin C content of ripe and unripe fruit differed significantly with treatments. All the plots receiving higher doses of nitrogenous fertilizer and farmyard manure obtained higher values for the vitamin C content.

17. Correlation studies revealed that nitrogen has got highly significant positive correlation with yield and quality parameters at all stages of growth. The nitrate content of ripe and unripe fruit were significantly correlated with nitrogen content of soil at P_4 (6 MAP) followed by P_3 (4 MAP).

18. Correlation studies conducted between phosphorus and yield and quality of banana revealed significant positive correlations at all stages of growth.

19. Potassium has got positive significant correlations with yield and quality of banana at all stages of growth indicating its requirements throughout the growth of the plant.

20. Path coefficient analysis of major nutrients with yield and quality of banana revealed highly significant direct effect at P_4 (6 MAP) followed by P_3 (4 MAP) and P_2 (2 MAP).

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* Originals not seen

Appendices

Appendix-I

Physico-chemical characteristics of the soils of the experimental site

Structure	Medium subangular blocky
Texture	Sandy clay
Coarse sand (%)	17.04
Fine sand (%)	9.27
Silt (%)	34.07
Clay (%)	41.91
Bulk density	1.44
Particle density	2.64
pH	4.85
EC (dS m^{-1})	0.050
CEC (cmol (+) kg^{-1})	3.64
Organic carbon (%)	0.485
Total nitrogen (%)	0.064
Available N (ppm)	89
Total phosphorus (%)	0.114
Available P (ppm)	26.9
Total K (%)	0.119
Available K (ppm)	359.3
Total Ca (ppm)	816.4
Exchangeable Ca (ppm)	150.2
Total Mg (ppm)	1128.9
Exchangeable Mg (ppm)	34.4
Total S(%)	412.5
Available S (ppm)	4.31
Total Fe (ppm)	1885
NH_4OAC Exchangeable Fe (ppm)	1.11
Total Mn (ppm)	896.5
NH_4OAC Exchangeable Mn (ppm)	15.4
Total Cu (ppm)	28.8
NH_4OAC Exchangeable Cu (ppm)	0.235
Total Zn (ppm)	55.3
NH_4OAC Exchangeable Zn (ppm)	0.330

Appendix-II

Content of nutrients (total and water soluble) in the farmyard manure used in the experiment

Nutrients	Total				Water soluble (ppm)			
	1	2	3	Mean	1	2	3	Mean
Nitrogen (%)	0.70	0.80	0.60	0.70	1500	2000	1800	1700
Phosphorus (%)	0.11	0.12	0.12	0.12	19.20	9.40	11.30	13.30
Potassium (%)	0.80	0.60	0.40	0.60	7.50	6.30	5.70	6.50
Calcium (%)	0.36	0.76	0.56	0.563	10.90	11.00	8.80	10.20
Magnesium (%)	0.23	0.096	0.32	0.22	3.90	2.75	2.65	3.10
Sulphur (%)	0.32	0.34	0.30	0.32	11.70	12.00	13.00	12.20
Iron (ppm)	2371	2200	2500	2357	8.75	6.80	7.75	7.80
Manganese (ppm)	17.4	16.3	16.7	16.8	1.00	1.00	1.00	1.00
Zinc (ppm)	10.0	8.5	12.1	10.2	0.81	0.63	0.74	0.73
Copper (ppm)	5.0	7.0	6.0	6.0	0.20	0.40	0.30	0.30

REGULATION OF MAJOR PLANT NUTRIENTS AND ORGANIC MATTER FOR IMPROVING THE NUTRITIVE QUALITY OF BANANA GROWN IN LATERITE SOILS

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was taken to study the regulation of major plant nutrients and organic matter for improving the nutritive qualities of banana. The expriment was laid out at Banana Research Station, Kannara, Kerala Agricultural University during the period 1996-97.

The result of this study revealed that application of fertilizer and organic matter is essential for getting better yield and quality of banana. All the food nutrients studied were increased by the application of fertilizer and hence the quality is much improved. Regarding bunch yield the fertilizer dose of 12.5 kg FYM, 200:125:300 g N, P_2O_5 and K_2O per plant obtained maximum yield. The treatments receiving medium level of FYM and nitrogen recorded higher content of carbohydrate. Protein content of banana was increased by the application nitrogen and potassium. Application of farmyard manure enhanced the fat content of banana. Sugar content of the banana fruit is increased by the application of nitrogenous and potassium fertilizers. Acidity is increased by the application of farmyard manure and nitrogen. Nitrate accumulation in banana was high in plots receiving highest dose of nitrogen. Nitrogenous fertilizers increased the carotene content of banana. Fertilizer application enhances the total mineral content of banana due to increased uptake and availability of nutrients. Fibre content was high in fertilized plots compared to absolute control. The nitrogen content of edible portions of banana was high in plots receiving higher doses of nitrogen. The treatment T_6 and T_{13} which received highest dose of phosphorus (200 g/plant) recorded highest content of phosphorus. Vitamin C content was enhanced by the application of nitrogenous fertilizer and farmyard manure. Correlation studies revealed that the content of major nutrients in soil at 2, 4 and 6 months after planting has got much influence on the quality parameters studied. Hence fertilizers should be applied in split doses commencing from 2

months after planting. Path coefficient analysis revealed that the direct effect of the three major nutrients on quality parameters was maximum at 6 months after planting. The direct effects at 2 months after planting and 4 months after planting were also significant. This indicated that the requirement of these nutrients is essential through out the growth of the plant.