COMPARATIVE EFFICIENCY OF DIFFERENT PHOSPHATIC FERTILIZERS IN RAINFED NENDRAN BANANA

BY

SHEEJA V. G.

THESIS

SUBMITTED TO PARTIAL FULFILMENT OF THE REQUIREMENT

FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM

1990

DECLARATION

I hereby declare that this thesis entitled "Comparative efficiency of different phosphatic fertilizers in the rainfed Nendran banana" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
Date: 25/3/91

(SHEELA, V.G.)

CERTIFICATE

Certified that this thesis entitled "Comparative efficiency of different phosphatic fertilizers in the rainfed Nendran banana" is a record of research work done independently by Kum. Sheeja, V.C. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. K. Harikrishnan Nair,
Chairman,
Advisory Committee,
Associate Professor &
Co-ordinator,
Tribal Area Research Centre,
Amboori,
Department of Soil Science &
Agricultural Chemistry,
College of Agriculture, Vellayani.

25.3.91

Vellayani,
25.3.91

APPROVED BY

Chairman

Dr. K. Harikrishnan Nair

Members

1. Dr. R.S. Aiyer
2. Dr.(Mrs.) Lekha Sreekantan
3. Sri. C. Sundaresan Nair

External Examiner

(K. MAYALAGU)

With immense pleasure I express my profound sense of gratitude and sincere indebtedness to my respected guide and major advisor Dr. K. Harikrishnan Nair, Associate Professor & Co-ordinator, Tribal Area Research Centre, Amboori, for his valuable guidance and enthusiastic encouragement during the course of this investigation and preparation of the thesis.

I am grateful to Dr. R.S. Aiyer, Professor and Head, Department of Soil Science and Agricultural Chemistry and member of the Advisory Committee for his timely advice, encouragement, and help rendered during the entire period of the research work.

I express my sincere thanks to Dr.(Mrs.) [illegible], Associate Professor, Tribal Area Research Centre and Sri. C. [illegible] Nair, Associate Professor, Regional Agricultural Research Station, Pilicode, for the valuable suggestions and help offered in the preparation of this thesis.

I remember with gratitude Sri. P. Rajendran, Assistant Professor, Department of Soil Science and Agricultural Chemistry for his patient help rendered during the course of research work.

ACKNOWLEDGEMENT

With immense pleasure I express my profound sense of gratitude and sincere indebtedness to my respected guide and major adviser Dr. K. Harikrishnan Nair, Associate Professor & Co-ordinator, Tribal Area Research Centre, Amboori, for his valuable guidance and enthusiastic encouragement during the course of this investigation and preparation of the thesis.

I am grateful to Dr. R.S. Aiyer, Professor and Head, Department of Soil Science and Agricultural Chemistry and member of the Advisory Committee for his timely advice, encouragement, and help rendered during the entire period of the research work.

I express my sincere thanks to Dr.(Mrs.) Lekha Sreekantan, Associate Professor, Tribal Area Research Centre and Sri. C. Sundaresan Nair, Associate Professor, Regional Agricultural Research Station, Pilicode, for the valuable suggestions and help offered in the preparation of this thesis.

I remember with gratitude Sri. P. Rajendran, Assistant Professor, Department of Soil Science and Agricultural Chemistry for his patient help rendered during the course of research work.

I have received much help from Smt. C.R. Sudharmai Devi, and P.R. Usha, Junior Assistant Professors of Department of Soil Science and Agricultural Chemistry, and Smt. V.L. Sheela, Assistant Professor of Department of Horticulture, throughout the course of investigation.

I wish to place on record my sincere thanks to Miss. Brijit Joseph, Assistant Professor and Sri. C.E. Ajithkumar, Junior Programmer, Department of Agricultural Statistics for their excellent and patient help and encouragement offered for the statistical analysis of the data.

It is my present duty to express my gratitude and indebtedness to some of my junior students of B.Sc.(Ag.) for their generous help and whole hearted co-operation during the course of work.

The valuable suggestions, encouragement and co-operation by all staff members and students of Department of Soil Science and Agricultural Chemistry is also greatly acknowledged.

My sincere thanks are also due to Mr. Natarajan who helped me a lot in the neat and timely typing of the manuscript.

I also like to express my boundless gratitude and indebtedness to my parents and brothers for their constant inspiration and help.

I am extremely grateful to the Rajasthan State Mines and Minerals Ltd. for the financial assistance offered me for the present investigation.

Last but not least, I thank God for all help and courage given to me for completing this work.

Vellayani (SHEEJA, V.G.)

I have received much help from Smt. C.R. Sudharmai Devi, and P.B. Usha, Junior Assistant Professors of Department of Soil Science and Agricultural Chemistry, and Smt. V.L. Sheela, Assistant Professor of Department of Horticulture, throughout the course of investigation.

I wish to place on record my sincere thanks to Miss. Brijit Joseph, Assistant Professor and Sri. C.E. Ajithkumar, Junior Programmer, Department of Agricultural Statistics for their excellent and patient help and encouragement offered for the statistical analysis of the data.

It is my present duty to express my gratitude and indebtedness to some of my junior students of B.Sc.(Ag.) for their generous help and whole hearted co-operation during the course of work.

The valuable suggestions, encouragement and co-operation by all staff members and students of Department of Soil Science and Agricultural Chemistry is also greatly acknowledged.

My sincere thanks are also due to Mr. Natarajan who helped me a lot in the neat and timely typing of the manuscript.

I also like to record my boundless gratitude and indebtedness to my parents, and brothers for their constant inspiration and help.

I am extremely grateful to the Rajasthan State Mines and Minerals Ltd. for the financial assistance offered me for the present investigation.

Last but not least, I thank God for all help and courage given to me for completing this work.

Vellayani

(Sheeja V G)

(SHEEJA, V.G.)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

With the possible exception of nitrogen, no other element is as critical in practical agriculture as phosphorus. It is involved in a wide range of processes from permitting cell division to the establishment of a well developed root system, to ensuring timely and uniform ripening of the crop. Thus, it's role in crop production is well known and needs no emphasis.

In India, the consumption rate of phosphatic fertilisers has not kept pace with that of nitrogenous fertilizers. The relatively high cost of chemically processed phosphatic fertilisers may be one of the reasons for such a trend. Direct application of cheap reactive ground rockphosphates to the soil is a fruitful attempt in this direction. Use of rockphosphate in countries like India deserves special consideration in view of the factors such as growing shortages and ever rising prices of soluble phosphates, and better residual effects of rockphosphate in soil coupled with the fact that, more than 30 per cent of the available land in India is covered by acid soils, where rockphosphate could prove a suitable source of fertiliser P.

The soil situation plays a dominant role on the release of phosphorus and in turn, the response of crops to P application. The recovery of applied phosphatic fertilizers by most of the crops ranges from 20 to 30 per cent only (Mandal and Khan, 1975). In general, ground rockphosphate is most effective when used in acid soils (pH less than 6.0) extremely deficient in available P or with high P fixing capacity. Use of rockphosphate is one of the cheapest ways to supply P to crops provided the soil has the capacity to dissolve rockphosphate and has sizeable amounts of native available P to take care of the initial stage of growth of the crop.

The information available on the utilization of cheap rockphosphate under upland acid soil conditions is very meagre. Hence the present study leys stress on the efficiency of different P sources on rainfed 'Nendran' banana.

Banana is one of the most important fruit crops of Kerala and the State ranks first in acreage accounting for about 19000 ha with a production of about 250000 tonnes (Anon., 1989). Eventhough 80 per cent of this crop is grown under rainfed conditions, only very few nutritional studies have been done in rainfed bananas especially with phosphatic fertilizers.

Various studies indicate that the addition of P_2O_5 in water soluble form in the laterite soils enhances P fixation and in turn reduces the availability of P for the crop (Tandon, 1976). But rockphosphates have been found to be suitable for acid soils; where it is first disintegrated by the soil acidity and the P ions released react with soil constituents (Mistry and Yadav, 1981; Yadav and Mistry, 1984).

The efficiency of raw rockphosphate is only 25-50 per cent as compared to superphosphate but it's efficiency can be improved by liberal application using it in conjunction with amendments like pyrite, organic matter, farmyard manure, compost (Singh et al., 1980; Marwaha and Kanwar, 1981; Nageeb, 1989). The mixing of organic matter with rockphosphate enhances the availability of P from the insoluble source by it's dissolution. The present study throws light on the influence of organic matter in the P releasing capacity of soils to which various phosphatic fertilisers are added.

Thus, the objectives of the study include;

(i) to study the comparative efficiency of different sources of phosphatic fertilisers under upland soil conditions with banana as the test crop.

(2) to find out the influence of organic matter on the release of phosphorus from different P sources.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Among the fruit crops, banana has a prominent place in Kerala. Though 80 per cent of this crop is grown under rainfed conditions, only very few nutritional studies have been reported on rainfed banana, especially with respect to the different phosphatic fertilisers. The literature pertinent to the subject of interest viz., "comparative efficiency of different phosphatic fertilisers in rainfed Nendran banana" is briefly reviewed as under.

2.1. Effect of phosphorus on growth

2.1.1. Height and girth

Jagirdar and Ansari (1966) observed an increase in stem girth on Basrai variety of banana due to phosphorus application @ 48 lbs $acre^{-1}$. According to Ramaswamy (1976) there was an increase in pseudostem height with P_2O_5 upto 60 g $plant^{-1}$.

On the nutritional investigation in Nendran banana Bhavani Sankar (1980) reported that phosphorus, within limits could increase the height and girth of the plant. The increase was noticed upto 30 g of phosphorus but further increase led to reduction in plant height.

Chattopadhyay and Bose (1986) in their studies with the Cv. Giant Governor found a significant increase in plant height and girth for phosphorus applied singly or in various combinations @ 45 and 90 g $plant^{-1}$.

2.1.2. Number of leaves and leaf area

Chattopadhyay and Bose (1986) observed significant increase in leaf number when phosphorus was tried at 45 and 90 g $plant^{-1}$ over control, in the variety Giant Governor. According to Beena Natesh (1987), the morphological characters such as number of functional leaves and total leaf area were not significantly influenced by various treatments with NPK.

2.2. Effect of phosphorus on yield and yield parameters

Lin et al. (1962) studied the optimum nitrogen, phosphorus and potassium ratio for bananas and observed comparatively less effect for phosphorus application than nitrogen or potassium on the yield of banana. But, Jagirdar and Ansari (1966) in their studies on the effect of N, P and K on the growth and production of Cavendish banana reported that plants receiving phosphorus produced heavier fruit bunches than the control. According to Bhan (1967), phosphorus did not produce any appreciable response in yield under Indian conditions. But, P application increased the yield in Maharashtra. Turner and Bull (1970) reported comparatively better yield for an annual dose of

55-110 kg P ha^{-1} in New South Wales. Tsaotia *et al.* (1972) revealed that growth and yield were the highest when plants were supplied with 600 g superphosphate. Koen *et al.* (1976) in Levebu area observed that an annual application of 110 to 230 g superphosphate $plant^{-1}$ was adequate for optimum yields and good quality fruits. In the studies on the effect of spacing and nutrition on growth and fruit yield of Robusta banana, Kohli *et al.* (1976) reported that 155 g P_2O_5 $plant^{-1}$ $year^{-1}$ was the optimum fertilizer dose for giving maximum fruit yield. Singh *et al.* (1977) studied the effect of NPK fertilisation on growth, yield and quality of Basrai banana in UP and they found that 90 g P_2O_5 $plant^{-1}$ gave the highest yield. Pillai *et al.* (1977) studied the response of Nendran banana to different levels of N, P, and K with 0-228 g N and P and 0-456 g K_2O $plant^{-1}$. According to them, there was little or no response to P.

In a trial with Giant Cavendish and Dwarf Cavendish Cvs., the effects were compared of potassium dihydrogen phosphate (2 per cent solution) applied either as a spray to the bunch alone or to the whole plant or as a soil drench. A marked increase in fruit volume and weight were recorded by Venkatarayappa *et al.* (1978) in all the treatments. According to Bhavani Sankar (1980), the bunch weight was influenced significantly by N and P treatments.

The highest bunch weight was recorded with 100 g N and 30 g P plant^{-1}, which was on par with 15 g P plant^{-1}. Therefore, 15 g P plant^{-1} appears to be optimum for 'Nendran' banana grown under garden land conditions.

In a 4 year trial by Shaikh et al. (1985) with Basrai banana which received 225 and 450 kg P_2O_5 ha^{-1}, the optimum P with regard to plant growth and yield was reported as 393 kg P_2O_5 ha^{-1}. Beena Natesh (1987) studied the effect of split application of fertilizers in banana Cv. Nendran and reported a maximum bunch weight of 11.13 kg by plants treated with 140 g P_2O_5 plant^{-1} year^{-1} in two splits.

Yield parameters

Bhangoo et al. (1962) reported that 160 lbs of P plant^{-1} increased the yield and average number of hands bunch^{-1}. Sundar Singh (1972) studied the effect of nitrogen and potash on Robusta banana and according to him, the length of fruit was more under N P treatments than K P treatments. In a 4 year NPKCa trial with Nendran banana in Kerala. Veeraraghavan (1972) reported significant increase in the number of fruits with the application of 228 g P_2O_5 plant^{-1} year^{-1}. In another experiment with 'Robusta' as test variety, the number of hands bunch^{-1} was found to increase with 60 g P_2O_5 plant^{-1} (Ramaswamy, 1976). Manica et al. (1978) studied the response of banana

Cv. Nanicao to fertilization with 3 levels of nitrogen, phosphorus and potassium. The best result with regard to number of hands and fingers bunch^{-1} was obtained for a treatment receiving 300 g P_2O_5 plant^{-1}.

2.3. Effect of phosphorus on total drymatter production

Drymatter production in banana is influenced by the variety, climate, soil and plant nutrients.

Bhavani Sankar (1980) found that the total drymatter production in banana var. Nendran did not show much variation between the NP treatments at various levels. Total drymatter production was in the range of 6.68 to 7.06 kg plant^{-1}. The drymatter production due to increased doses of N and P was not perceptible since the lowest levels of N and P produced drymatter as that of the one by highest levels. A dose of 15 g P plant^{-1} was found to be optimum in the production of maximum drymatter. Dave et al. (1990) studied the influence of plant nutrients on the growth of banana Cv. 'Basrai' in deep black soils of South Gujarat and recommended 180 g each of NPK plant^{-1}. They further reported that there was gradual increase in drymatter in all the plant parts throughout the growth period but the rate of increase was proportionately very low.

2.4. Uptake of P

Jauhari *et al.* (1974) reported that the uptake of phosphorus was very rapid during the first few months of plant growth and thereafter decreased. This indicates that the nutrient requirement for banana is maximum during the initial growth phase.

Pillai (1975) observed that the uptake of P was comparatively higher in plants with more number of functional leaves. In the studies by Veerannah *et al.* (1976) on the nutrient uptake in Robusta and Poovan, they noticed that the P requirement of Robusta differs from that of Poovan, Robusta requiring 75 kg P_2O_5 ha^{-1} while Poovan 35 kg ha^{-1}.

Valsamma Mathew (1980) observed that the uptake of phosphorus by banana plant was high both at shooting and harvest stages. In general, uptake of phosphorus increased with the advancement of growth of plants. As in the case of nitrogen, phosphorus uptake was more in the vegetative phase of the crop and prominent in the laminae.

Bhavani Sankar (1980) revealed that phosphorus requirement of Nendran banana was lower at least when grown under garden land conditions; 'Nendran' banana requires less P than the others. However, the uptake of P was found to increase significantly with the increase in P levels and no significant difference was observed by increasing P from 15 to 45 g plant^{-1}.

Sheela (1982) studied potassium nutrition in rainfed banana var. 'Palayankodan' and reported that the total uptake of phosphorus continued to increase throughout the crop growth. Due to the synergestic relationship that existed between potassium and phosphorus, the increased doses of potassium significantly increased the uptake of phosphorus. The phosphorus uptake by banana was very low compared to that of nitrogen and potassium. The maximum uptake of phosphorus was recorded during the period between late vegetative phase and shooting. A decrease in the content of phosphorus was observed after shooting stage indicating a possibility for mobilisation of the nutrient to the reproductive parts of the plant. Uptake of P compared to N and K was reported to be little, and little or no response to P in banana was pointed out by several workers (Norris and Ayyar, 1942; Turner, 1969; Rajeevan, 1985). Based on the investigations on the P uptake at the Banana Research Station, Yaval (India), Dagade (1986) recommended 40 g P_2O_5 plant^{-1}. Du Plessis (1987) reported that nitrogen applications increased the uptake of phosphorus.

2.5. Foliar nutrient status in banana

Analysis of the leaf tissue or any other specific plant part is usually being done to determine the nutritional status of the plant. On the basis of these analyses, we can improve the final yield by taking remedial measures against nutrient deficiencies or toxicities or nutrient imbalances. Results of leaf analysis may be applied with great precision for establishing interrelationship between the amount of fertilizer added to soil in which the crop is grown, the concentration of major elements in leaf tissue of the crop after the fertilizer addition and fruit yield of the crop. The relationship will help in predicting fertilizer rates for desired optimum level of nutrient concentration in leaf tissue and subsequent fruit yield (Randhawa et al., 1973).

Ashok Kumar (1977) studied the growth and development of banana var. 'Robusta' and he observed that the leaf concentration of nutrients at shooting ranged from 0.96 to 2.66, 0.11 to 0.37, 3.60 to 5.00 per cent N, P_2O_5 and K_2O respectively.

Samuels et al. (1978) reported that the leaf samples from unfertilized plots contained 0.28 per cent P at 10 months after planting. Ramirez et al. (1978) analysed the first and third leaf of Dwarf Cavendish banana at various stages of plant growth viz., before flowering and at the time of formation of fruit and found that the concentration of phosphorus was lower in the third leaf than in the first leaf and occasionally was below 0.19 per cent.

Balakrishnan (1980) reported that the distribution pattern of phosphorus in different organs of the plant was similar over different sites in 'Robusta' banana. At all stages of growth, leaves and pseudostem contained substantial amounts of phosphorus, while in vegetative phase, corm contained the maximum. Valsamma Mathew (1980) observed that the phosphorus content in the third leaf at shooting stage ranged from 0.14 to 0.17 per cent in 'Palayankodan' banana. In banana plants, the nitrogen and potassium concentration in the third leaf during and after flowering decreased, while leaf Ca increased and phosphorus and Mg remained constant (Garcia et al., 1980). Turner (1980) suggested that the flowering stage of the plant was physiologically best for sampling in leaf analysis.

Valsamma Mathew (1980) observed that the nutrient status of the third leaf at shooting stage ranged from 1.33 to 2.08, 0.14 to 0.17 and 2.05 to 2.76 per cent for N, P and K respectively. Krishnan and Shanmugavelu (1980) in a study on water requirement of banana, analysed leaf nutrient concentration and total uptake of nutrients and observed that the critical leaf concentration of nitrogen, phosphorus, and potassium at shooting stage ranged from 2.32-2.44, 0.22 to 0.25 and 3.97 to 4.19 per cent respectively.

Beena Nateah (1987) reported that compared to nitrogen and potassium, phosphorus concentration was low (0.66-0.69 per cent). Dave et al. (1990) in their studies on the nutrition and growth of banana Cv. 'Basrai' in deep black soils of South Gujarat found that P content in the leaf ranged from 0.25 to 0.13 per cent. The concentration of phosphorus was marginally increased with the increase in fertilizer level but decreased with the age of the plant. The critical concentration suggested was 0.2 per cent in the third leaf.

2.6. Phosphorus availability as influenced by organic matter addition

Most of the phosphorus present in soils is not readily available to plants. When phosphatic fertilizers are added to soils, phosphorus is often fixed or rendered insoluble and unavailable to plants even under ideal soil conditions. Hence large quantities of phosphatic fertilizers need to be applied to the soil, eventhough crop removal of phosphorus is comparatively less. Thus, increasing the availability of native soil phosphorus and reducing fixation are the major fields of scientific importance with respect to phosphorus nutrition of the crops.

From various findings it is quite evident that organic matter and microorganisms strikingly affect phosphorus availability. Products of organic matter decay such as organic acids and humus are thought to be effective in forming complexes with iron and aluminium compounds, which reduces phosphorus fixation to a remarkable degree. Some of the salient works in this regard are reviewed as under:

According to Vyas and Motiramani (1971) addition of organic matter to the soil increased the availability of native as well as applied phosphorus. Mandal and Khan (1972) studied the effect of organic matter on the release of phosphorus from insoluble phosphatic materials such as rockphosphate, bonemeal and basic slag under the laboratory conditions and showed that more than 86 per cent of phosphorus added as superphosphate was converted to unavailable form within 15 days of application. Basic slag and rockphosphate always maintained a higher amount of available phosphorus in the soil than superphosphate. According to them, application organic matter did not bring about any additional increase in the release of phosphorus. Mandal and Mandal (1973) in their studies on the influence of organic matter on the transformation of applied phosphate in acidic low land rice soils reported that the application of organic matter significantly reduced the fixation of P. They attributed this to the chelating properties of the compounds formed during the decomposition of organic matter to produce insoluble compounds with aluminium. They also attributed the decrease in Fe-P to the production of chelating compounds and the highly reduced conditions created during decomposition of organic matter. Dashrath Singh and Datta (1974) found that the efficiency of utilisation of applied phosphorus increased by 14 to 28 per cent with phosphate-farm-yard manure combinations over phosphate alone in Coorg and Kangra soils.

Singh and Singh (1976) reported that organic matter can influence pH by intensifying reduction through the liberation of CO_2 and organic acids. They observed an increased concentration of Al-P, consequent to the decreased content of Ca-P and an increased concentration of Fe^{++} ions after the addition of organic matter.

Dashrath Singh et al. (1976) in their incubation study with rockphosphates from Udaipur, Mussoorie and

Laccadive phosphate deposits reported that, although the application of rockphosphate without farmyard manure appeared to be slightly superior to rockphosphate plus farmyard manure combination, the superiority, however was not statistically significant. Due to addition of phosphorus to soil there may be some sort of triggering action on native soil phosphorus resulting in increased availability. In some cases, this being more than the quantity applied through fertilizers. Phosphorus availability from these phosphate carriers in soil increased with the incubation period upto 75 days and thereafter showed declining trend. Such a behaviour may be expected as the maximum availability limit might perhaps have reached. In view of the absence of uptake of P by plants in incubated soil, process of phosphorus fixation might have become preponderant over solubilising ones at the maximum availability limit.

Talashilkar and Patel (1979) studied the effect of organic matter on the availability of phosphorus from superphosphate and rockphosphate in submerged soil. The addition of organic matter in the soil treated with superphosphate increased the available P upto 28 days of submergence followed by a gradual decrease. The rock-phosphate-compost combination maintained a higher amount of added phosphorus in the available form over the one receiving rockphosphate alone till 35 days of submergence. The reason for the increased duration of availability of P from the rockphosphate may be due to the solubilising effect of certain organic acids formed during decomposition of organic matter by anion replacement.

Singh et al. (1980) reported that continuous application of farmyard manure in Sierozem soil in the semi-arid region of Haryana resulted in the build up of available phosphorus in the soil. Mathur et al. (1980) worked on the release of nitrogen and phosphorus from compost treated with rockphosphate. Compost with varying levels of Mussoorie rockphosphate with and without pyrite at different time intervals showed that the release of phosphorus was greater from the compost treated with rockphosphate alone, than that with rockphosphate and pyrite in the earlier stages of incubation. Application of organic manure significantly reduced fixation of added as well as native phosphorus making the phosphorus more available to plants (Ghosh et al., 1981).

Izza and Indiati (1981) suggested that incorporation of various organic materials like maize stalk, compost, and poultry manure, ranging in phosphorus content from

0.03 to 1.37 per cent, to a soil of low phosphorus fixing capacity increased the soil available phosphorus content. Broadbent (1983) pointed out that organic matter influences phosphorus availability indirectly by influencing the growth of microorganisms which produce organic acids capable of solubilising inorganic phosphates in addition to influencing the release of P from the organic form such as inositol phosphates. Krishnaswamy and Ramaswamy (1984) reported that organic manure at 15 t and P_2O_5 at 80 kg ha^{-1} had significant effect in increasing the available phosphorus from the native and applied sources. Compost or farmyard manure had also increased significantly the phosphorus availability. Hesse (1984) conducted an incubation study with sandy loam soil to assess the transformation of native and applied phosphorus as affected by different moisture regimes and farmyard manure. Application of farmyard manure resulted in marked increase in all the four forms of inorganic phosphorus in soil viz. saloid-P, Fe-P, Al-P and Ca-P. The farmyard manure increased saloid-P, Al-P, and Fe-P more under field capacity. Increased availability of phosphorus from the addition of organic matter under aerobic and anaerobic conditions may be due to the production of CO_2 and organic acids, as well as mineralisation of phosphorus in farmyard manure.

Chakravarty *et al.* (1985) incubated alluvial soil with compost, paddy straw, and water hyacinth and observed that organic matter addition exerted a favourable effect on the release of plant nutrients and the maximum amount of available phosphorus was produced by compost followed by water hyacinth. More and Ghonsikar (1983) studied the effect of some organic manure on the availability of phosphorus to wheat. They found that the availability of phosphorus increased with the application of a mixture of superphosphate and organic manure than superphosphate alone. This might be due to the fact that organic anions compete with phosphate ions for the binding sites on the soil particles and the complex organic anions chelate Al^{3+}, Fe^{3+} and Ca^{2+} and thus decreasing the phosphate precipitating power of these cations. Sood and Minhas (1989) observed that increased mineralisation of organic phosphorus was brought about at moist conditions thereby accelerating the rate of decomposition. Nageeb (1989) observed that organic matter as farmyard manure was more efficient than green leaves and composted salvinia in increasing the content of available P in the soil. The concentration of available P in the soil was not significantly affected by the variations in sources of applied P, as superphosphate or Mussoorie rockphosphate. Awasthi

(1990) reported that the use of organic manure helped to increase the efficiency of rockphosphate in the acid soils of Himachal Pradesh and Tamil Nadu. The organic materials increase the availability of soil and fertilizer phosphorus because the CO_2 evolved during decomposition of organic residues produce weak carbonic acid which dissolves phosphate and increase solubility by

(i) the formation of phospho humic complexes which are more easily assimilable by plants

(ii) anion replacement of the phosphate ions by humate ions

(iii) coating of sesquioxide particles by humus to form a protective cover and thus reduce the phosphate fixing capacity of the soil.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation consists of two experiments viz., a field experiment and a laboratory incubation experiment. The field experiment was carried out with banana var. Nendran as test crop at two locations viz., the Instructional Farm of the College of Agriculture, Vellayani and in a selected cultivator's field at Kattakada.

3.1. Field experiment

The main objective of the field study was to compare the efficiency of different sources of phosphatic fertilizers under upland soil conditions in rainfed banana crop.

3.1.1. Weather data

Vellayani is situated at a latitude of 8.5°N, longitude of 76.9°E and at an altitude of 29 metres above mean sea level. During the period of investigation, there was an average rainfall of 9.18 cm $month^{-1}$. The average relative humidity maintained during the period was 74.27 per cent. The daily maximum temperature during the cropping period ranged from 29.82 to 33.42°C and the minimum from 18.46 to 26.66°C. At Kattakada, during the period of investigation, there was an average rainfall of 14.60 cm $month^{-1}$. The daily maximum temperature during

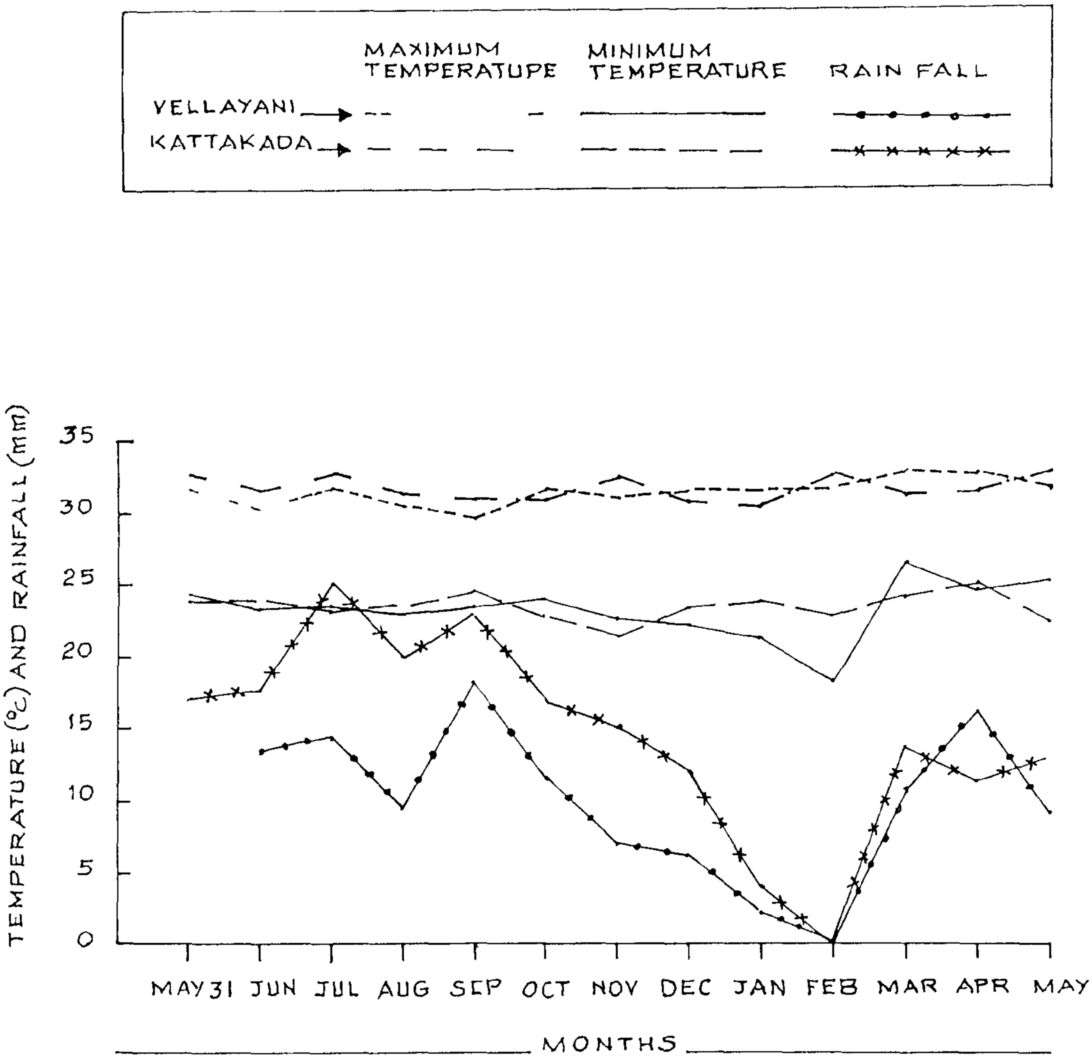

FIG 1 WEATHER CONDITION DURING THE CROPPING PERIOD

the cropping period ranged from 30.50 to 38.80°C and the minimum from 21.2 to 25.0°C (Fig. 1). The details of the meteorological observations for the croppin season at Vellayani and Kattakada are given in appendix.

3.1.2. Preliminary analysis

The soils collected from the plots before planting suckers were analysed for physico-chemical properties adopting standard analytical procedures (Table 1). The results are given in Table 2.

3.1.3. Field preparation

Pits of size 50 cm^3 were dug at a spacing of 2 m x 2 m after thorough ploughing and levelling for planting the suckers of uniform size and age. All the agronomical operations including the application of manures and fertilizers were done as per the package of practice recommendation of the Kerala Agricultural University.

3.1.4. Experimental design and layout

The experiment was laid out in randomised block design with four treatments and five replications. The layout of the experiment is shown in Figure 2. Selected banana suckers with uniform size and age of 'Nendran' variety were planted with a spacing of 2 m x 2 m, in such

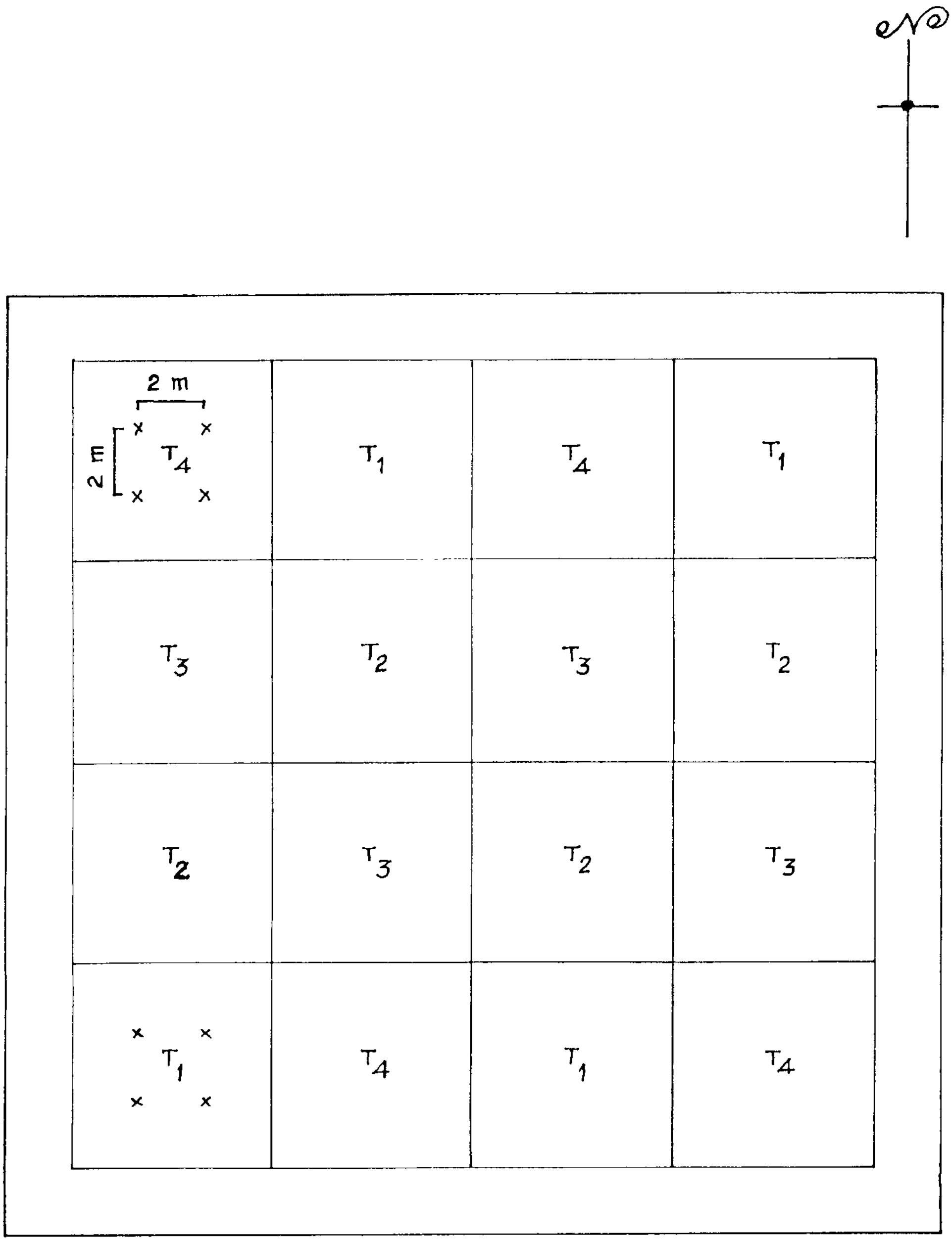

FIG 2 LAY OUT PLAN - RANDOMISED BLOCK DESIGN

a way that there were four banana plants for observation with required number of border plants. Thus there were sixteen plants in each plot.

3.1.5. Treatments

Three different phosphatic fertilizers were applied at the recommended level of P viz., 115 g plant^{-1} along with a control to compare the efficiency of the different phosphatic fertilizers on rainfed banana. The treatments are as follows:

T_1 Control (No phosphorus)

T_2 Mussoorie rockphosphate

T_3 Rajasthan rockphosphate

T_4 Superphosphate

3.1.6. Observations

Observations on various morphological characters were recorded at 45 days interval from planting to shooting.

3.1.6.1. Plant characters

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

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

Table 1. Analytical methods used for the determination of various physico-chemical properties of soil

Parameter	Method
Mechanical analysis of soil	Bouyoucos hydrometer method (Black, 1965)
Soil reaction	1:2.5 soil water suspension using pH meter (Jackson, 1973)
Waterholding capacity	Troelle's method using Keen Raczkowskibox (Wright and Harold, 1939)
Organic carbon	Walkley and Black's rapid titration method (Piper, 1950)
Total nitrogen	Modified Microkjeldahl method (Jackson, 1973)
Total phosphorus	Vanado molybdo phosphoric yellow colour method (Piper, 1966)
Available nitrogen	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available phosphorus	Dickman and Brays Molybdenum blue method (Jackson, 1973)
Exchangeable potassium	Atomic Absorption Spectro photometer using neutral normal ammonium acetate extract (Jackson, 1973)
Phosphorus fixing capacity of soil	Methods by Petel and Viswanath (1946)

Table 2. Physico-chemical properties of soil at Vellayani and Kattakada

Parameter	Locations	
	Vellayani	Kattakada
Coarse sand	13.80 per cent	26.00 per cent
Fine sand	28.50 "	8.00 "
Silt	26.00 "	20.60 "
Clay	20.00 "	24.10 "
Texture	Sandy loam	Loam
Moisture	8.7 per cent	5.40 per cent
pH	5.2	4.8
Water holding capacity	34.40 per cent	28.00 per cent
Organic carbon	0.46 "	0.70 "
Total nitrogen	0.014 "	0.043 "
Total phosphorus	0.049 "	0.040 "
Total potassium	0.315 "	0.497 "
Available nitrogen	180.32 kg ha^{-1}	191.00 kg ha^{-1}
Available phosphorus (P_2O_5)	36.20 "	28.06 "
Exchangeable potassium	80.40 "	120.00 "
Phosphorus fixing capacity of soil	45.00 per cent	48.00 per cent

3.1.6.1.3. Total number of leaves: Number of fully opened photosynthetically active leaves were noted.

3.1.6.1.4. Length of the leaf: taken from the base of the lamina to its tip.

3.1.6.1.5. Width of lamina: was measured at the broadest point in the middle region.

3.1.6.1.6. Leaf area: was determined at the time of emergence of the bunch, using the formula given by Murray (1960).

(Leaf area = Length x breadth x 0.8)

3.1.6.1.7. Number of days taken for flowering: The date of emergence of bunch was noted.

3.1.6.2. Bunch characters: The bunches were harvested when they were fully matured as indicated by the disappearance of angles to round full (Simmonds, 1959).

The following observations were made on the bunches.

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

3.1.6.2.2. Number of hands and fingers: The number of hands $bunch^{-1}$ and the total number of fingers in each bunch were recorded.

3.1.6.2.3. Weight of the bunch

Weight of the bunch was recorded at maturity in kilograms.

3.1.6.2.4. Girth and length of finger

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

3.1.6.2.4. Phosphorus uptake and drymatter production

To assess the uptake of phosphorus, plant samples were collected at the harvest stage. Sampling was done adopting the method outlined by Twyford and Walmsley (1973). One plant was uprooted from each treatment replication wise and separated into different plant parts.

The fresh weight of the different plant parts were recorded. Samples were weighed fresh and dried in the oven at 70°C until consecutive weights agreed.

The total dry weight of the whole plant was calculated from the fresh weight of the sample. All plant parts were analysed separately for the phosphorus content. Total uptake of P was computed from the values of the concentration of element and the dry weight of the individual organs sampled.

3.1.6.3. Chemical analysis

Soil

Chemical analysis for nitrogen and potassium was done for initial soil samples collected from the field before the planting of the crop and for the soil samples collected at the time of harvest of the crop. But chemical analysis for phosphorus was done for all the soil samples collected at 45 days interval after the planting of the crop.

3.1.6.4. Incubation study

A laboratory incubation study was carried out with the soil collected from the Instructional Farm, College of Agriculture, Vellayani. This study was aimed to find out the influence of organic matter on the release of phosphorus from different phosphatic fertilizers under moist conditions (30 per cent moisture). This study included five treatments and five replications. The treatments were as follows:

T_1 Soil without organic matter

T_2 Soil + organic matter

T_3 Soil + organic matter + Mussoorie rockphosphate

T_4 Soil + organic matter + Rajasthan rockphosphate

T_5 Soil + organic matter + superphosphate

Soil collected from the field was air dried, sieved and kept in thick polythene containers for incubation under moist condition after adding calculated quantities of organic matter and different phosphatic fertilizers viz., Mussoorie rockphosphate, Rajasthan rockphosphate and superphosphate as per package of practice recommendation for banana. Available P was estimated in each treatment by Dickman and Bray's Molybdenum blue method (Jackson, 1973) at 45 days interval till 225th day of incubation.

RESULTS

4. RESULTS

The results of the studies are presented as follows with suitable tables and illustrations.

4.1. Effect of different sources of phosphorus on growth parameters

4.1.1. Height of pseudostem

The data on the mean height at 45 days intervals upto shooting period of the plant at two places viz., Vellayani and Kattakada are presented in Table 3. At Vellayani, the height of banana plant did not vary with the different phosphatic fertilizers tried. But, phosphorus application significantly increased the plant height over control. The plants receiving superphosphate recorded the maximum height (234 cm) at 225 days after planting, when the no phosphorus treatment recorded the minimum height (221 cm). Similar variation was also noticed in the mean plant height at all intervals except at the 45th day after planting when plants receiving Mussoorie rock-phosphate recorded the maximum height of 81.6 cm which was on par with superphosphate (80.4 cm).

At Kattakada also, similar variations were recorded on the height of plant due to different P fertilizers applied. Maximum height of 238.0 cm was noticed by plants

Table 3. Effect of different phosphatic fertilizers on the plant height (cm) at 45 days intervals at two places, Vellayani and Kattakada

Vellayani

Treatments	Period in days					Mean (Treatments)
	45	90	135	180	225	
T_1	70.40	112.60	146.00	180.00	221.00	146.00
T_2	81.60	123.20	151.00	190.00	232.00	155.56
T_3	79.80	120.00	150.00	187.95	230.00	153.55
T_4	80.40	125.00	153.00	193.00	234.00	157.08
CD (Treatments) (0.05)	1.790	14.024 (NS)	4.864	8.398	4.806	-
Kattakada						
T_1	69.80	107.40	141.00	185.00	225.20	145.68
T_2	82.00	125.20	150.00	190.80	236.40	156.8[illegible]
T_3	80.40	122.40	146.40	187.00	232.00	153.64
T_4	82.40	125.00	152.80	191.00	238.00	157.84
CD (0.05) (Treatments)	1.467	1.942	2.227	3.713	3.683	-

receiving superphosphate and the minimum height of 225.2 cm by the one with no P treatment at 225 days after planting. The difference between the heights of plants due to the application of Mussoorie rockphosphate and superphosphate was not significant while they were found to be superior to Rajastan rockphosphate and control.

4.1.2. Girth of pseudostem

Phosphorus application influenced the girth of pseudostem over control. However, no significant difference could be noticed due to the application of different P sources on this character (Table 4). At 45 days after planting, a slight increase in girth was recorded by the plants treated with Mussoorie rockphosphate at Vellayani, but was on par with superphosphate and found to be superior to Rajasthan rockphosphate and control. In later stages of observation, the plants supplied with superphosphate recorded slightly higher girths but on par with the other sources.

At Kattakada also the effect due to the different sources of P on the girth of pseudostem was found to be the same. However, a comparatively slight increase was recorded by the plants supplied with superphosphate at all stages of observation.

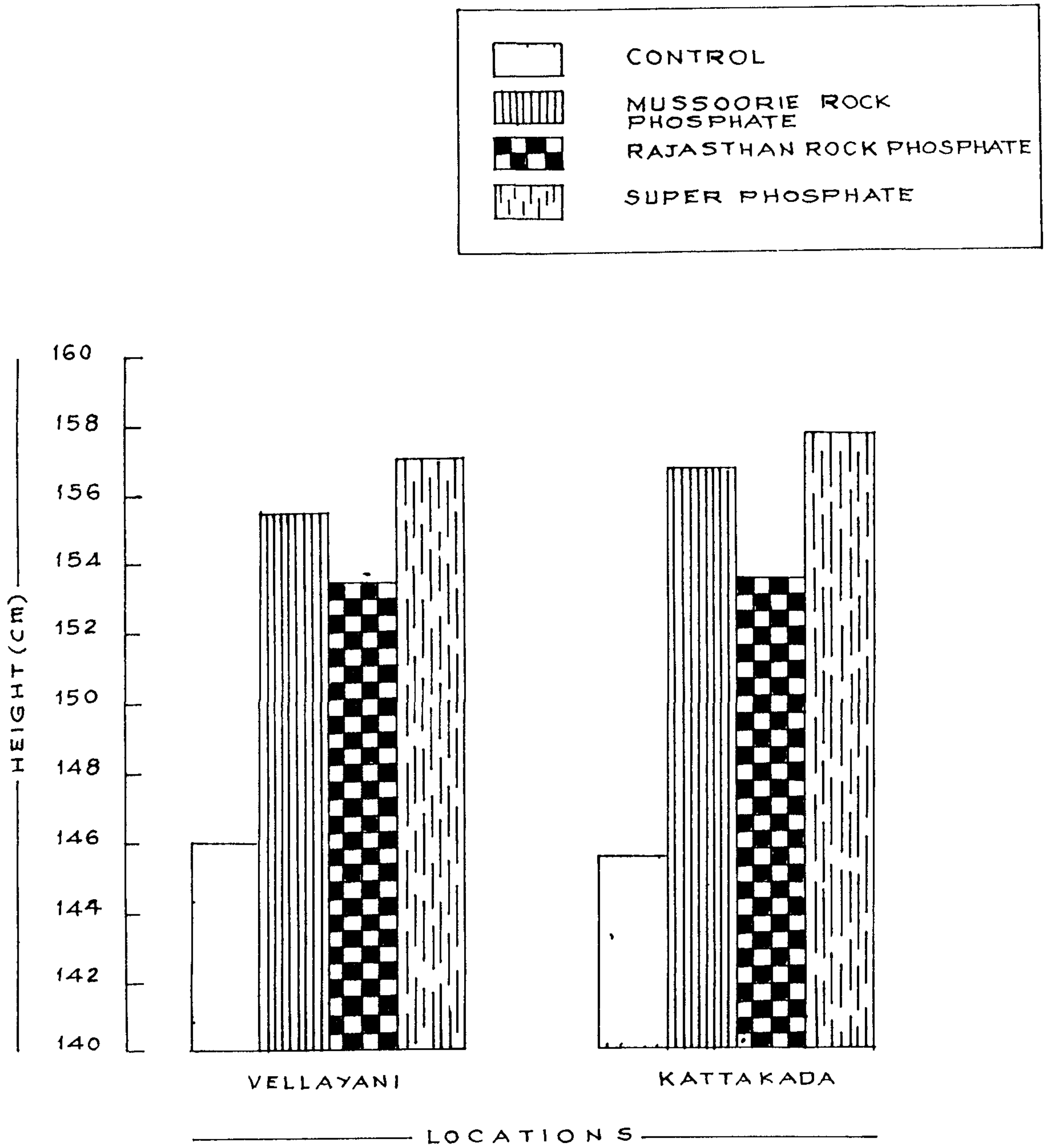

FIG 3 HEIGHT OF PLANT AS INFLUENCED BY DIFFERENT PHOSPHATIC FERTILIZERS APPLICATION IN BANANA

Table 4. Effect of different phosphatic fertilizers on girth of plant (cms)

Treatments	Period in days 45	90	135	180	225	Mean
T_1	17.35	24.15	29.30	32.00	34.25	27.41
T_2	19.40	25.40	31.00	33.00	35.05	28.77
T_3	17.90	25.30	30.25	33.40	35.80	28.59
T_4	18.00	26.00	32.40	33.80	37.15	29.47
CD (0.05)	1.407	1.837	2.947	3.564 (NS)	2.819	-
Kattakada						
T_1	16.60	22.00	30.00	33.35	35.00	27.39
T_2	18.00	24.00	32.10	35.50	37.35	29.39
T_3	17.60	25.40	31.80	36.25	37.20	29.65
T_4	18.20	25.20	32.60	37.55	38.00	30.31
CD (0.05)	1.422	4.279 (NS)	2.192	4.831 (NS)	1.974	-

At 225 days after planting, plants treated with superphosphate recorded comparatively higher girths of 37.50 cm and 38.00 cm, and control plots recorded the minimum girths of 34.25 cm and 35.00 cm at Vellayani and Kattakada respectively.

4.1.3. Number of green leaves

Table 5 indicates the total number of functional leaves recorded at 45 days intervals upto shooting period. Different P sources were on par, but were found to be superior to control plots. At 225 days after planting, a maximum of 10.95 and a minimum of 9.77 number of leaves were produced by plants receiving Mussoorie rockphosphate and the plants with no P treatment respectively at Vellayani. The difference between the P sources was not significant at Kattakada also. At 225 days after planting, plots receiving Rajasthan rockphosphate recorded the maximum number of leaves (10.60) and the minimum (9.52) by the plots with no P. There was no definite pattern of the influence of the treatments at different intervals in both locations.

4.1.4. Leaf area

The mean values recorded on the leaf area at Vellayani and Kattakada at shooting stage of the crop

Table 5. Effect of different phosphatic fertilizers on the number of green leaves

Vellayani

Treatments	Period in days					Mean
	45	90	135	180	225	
T_1	3.25	6.70	8.72	10.22	9.77	7.73
T_2	4.25	8.00	11.55	11.25	10.95	9.20
T_3	4.70	8.35	11.55	11.85	10.40	9.37
T_4	4.65	8.60	12.05	10.95	10.25	9.30
CD (treatments (0.05)	0.292	2.054 (NS)	2.530	1.951 (NS)	2.851 (NS)	-
Kattakada						
T_1	4.05	8.06	8.82	9.77	9.52	8.05
T_2	4.20	8.30	10.85	11.60	9.95	8.97
T_3	4.40	8.30	11.50	12.05	10.60	9.37
T_4	4.80	8.60	11.75	12.00	10.00	9.43
CD (treatments 0.05)	1.252 (NS)	2.529 (NS)	2.264	1.994	2.833 (NS)	-

(7th month) are as shown in Table 6. Significant difference in leaf area between the plants, as influenced by the treatment was observed at both locations. At Vellayani, the maximum leaf area of 5771.84 cm^2 was recorded by the plants receiving superphosphate and was on par with Rajasthan rockphosphate and Mussoorie rockphosphate but, statistically it was found to be superior to control plots. Similar results were recorded at Kattakada also, wherein maximum value for leaf area (5451.60 cm^2) recorded by plants receiving superphosphate was found to be on par with Rajasthan rockphosphate, but superior to Mussoorie rockphosphate and control plots. The minimum leaf area was recorded by control plots as 4934.72 cm^2 and 4958.80 cm^2 at Vellayani and Kattakada respectively.

4.1.5. Number of days taken for flowering

Table 6 represents the data on the number of days taken for shooting from planting. It was found that the plants of the control plot required more days for flowering compared to the treated plots. Plants without P took the maximum number of days for flowering at both places (227 and 219) and minimum days of 191 and 204 were recorded by plants receiving superphosphate both at Vellayani and Kattakada respectively. At Vellayani, T_4 and T_3 were on par and superior to T_2 and T_1. At Kattakada,

Table 6. Effect of different phosphatic fertilizers on the total leaf area (cm^2) and the number of days taken for flowering at Vellayani and Kattakada

Treatments	Leaf area (cm^2)		Number of days for flowering	
	Locations		Locations	
	Vellayani	Kattakada	Vellayani	Kattakada
	(Mean values)		(Mean values)	
T_1	4934.72	4958.80	227	219
T_2	5365.84	5226.40	216	216
T_3	5424.8[illegible]	5418.00	19[illegible]	210
T_4	5771.84	5451.80	191	204
CD (0.05)	560.930	200.177	1[illegible].036	10.547

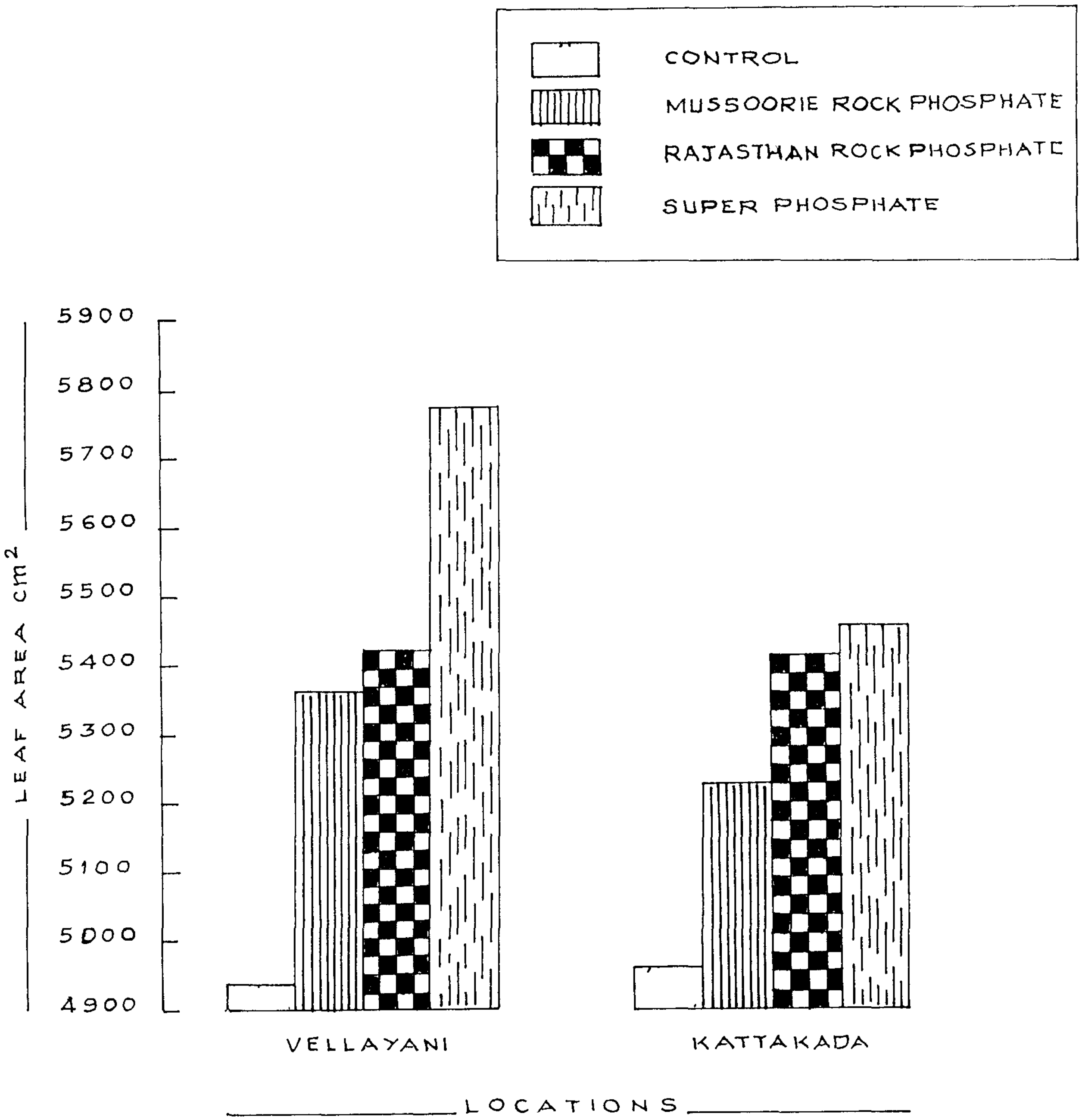

FIG 4 EFFECT OF DIFFERENT PHOSPHATIC FERTILIZERS ON THE LEAF AREA

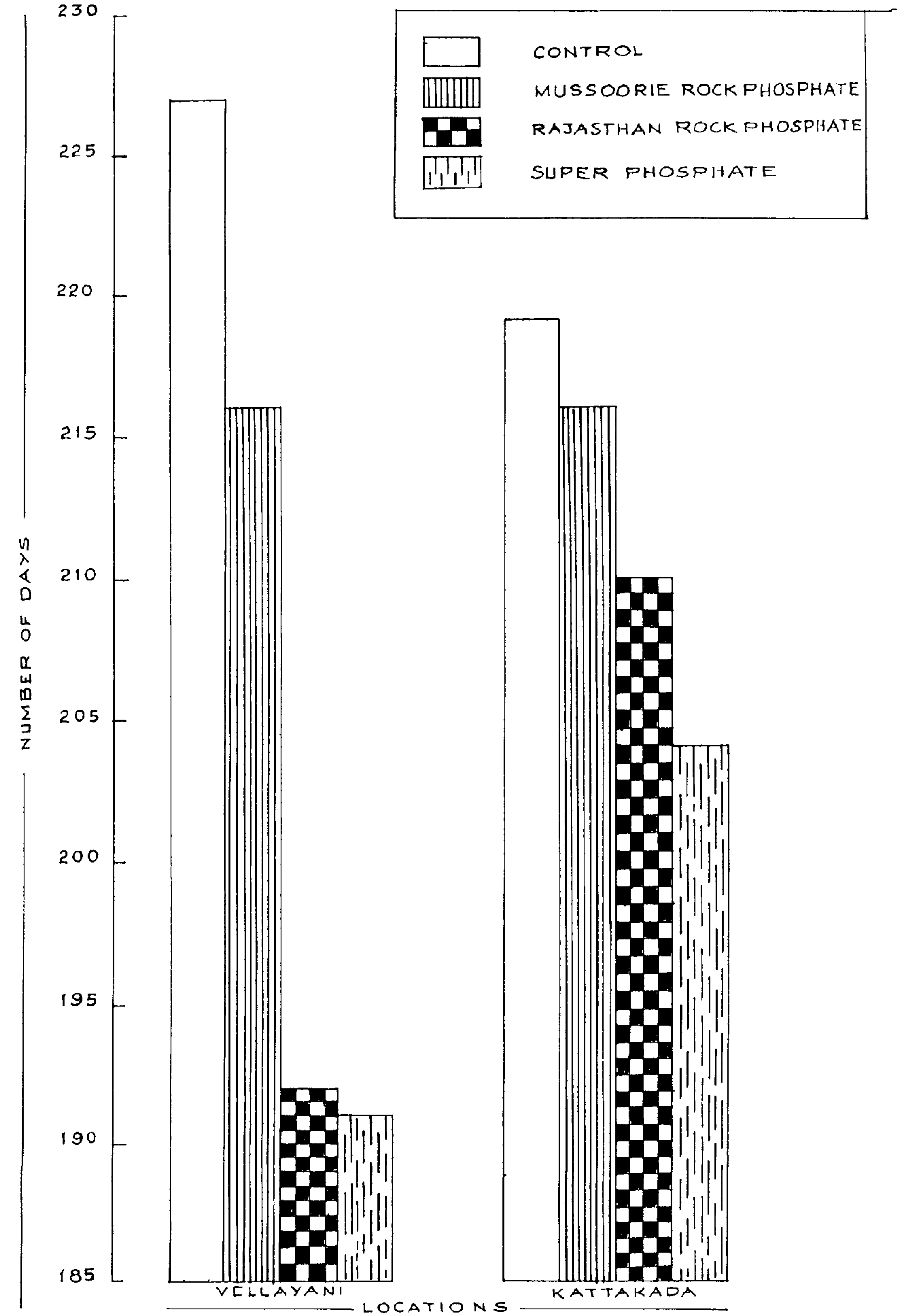

FIG 5 INFLUENCE OF DIFFERENT PHOSPHATIC FERTILIZERS ON THE PERIOD TAKEN FOR FLOWERING IN BANANA

T_4 was on par with T_3 which inturn was on par with T_1 and T_2.

4.2. Bunch characters

The data relating to various bunch characters as influenced by different phosphatic fertilizers is presented in Table 7.

4.2.1. Weight of bunch

Significant difference on the yield of banana due to different treatments was noticed at both places. However, phosphorus application increased the yield significantly over control. The effect of different phosphatic fertilizers applied was found to be the same on the yield of banana at Vellayani ie., T_4, T_2 and T_3 were on par. While at Kattakada, T_4 was on par with T_2 but superior to T_3 and T_1; T_2 inturn was on par with T_3 and T_1. Thus, relatively higher yields (9.23 and 10.79 kg plant^{-1}) were recorded by plants treated with superphosphate and lower yields (8.29 and 9.85 kg plant^{-1}) by control plots at Vellayani and Kattakada respectively.

4.2.2. Length of bunch

The treatments recorded significant influence on length of bunch at Vellayani but at Kattakada, no significant

Table 7. Effect of different phosphatic fertilizers on bunch characters

Vellayani

Treatments	Weight of bunch (kg plant^{-1})	Length of bunch (cm)	Number of hands per bunch	Number of fingers per bunch	Length of finger (cm)	Girth of finger (cm)
T_1	8.29	40.90	4.90	36.00	17.65	15.20
T_2	9.17	44.65	5.90	39.00	17.95	16.30
T_3	8.90	51.25	6.20	37.00	18.90	15.80
T_4	9.23	46.75	5.75	40.00	17.80	15.50
CD (0.05)	0.437	4.743	0.658	2.854	1.011	1.178 (NS)
Kattakada						
T_1	9.85	46.90	5.05	41.00	18.00	15.60
T_2	10.22	49.00	5.25	46.00	19.00	16.62
T_3	9.92	50.95	5.15	44.00	19.20	16.40
T_4	10.79	49.60	5.45	47.00	19.80	17.20
CD (0.05)	0.580	5.356 (NS)	0.400 (NS)	4.348	1.684 (NS)	1.811 (NS)

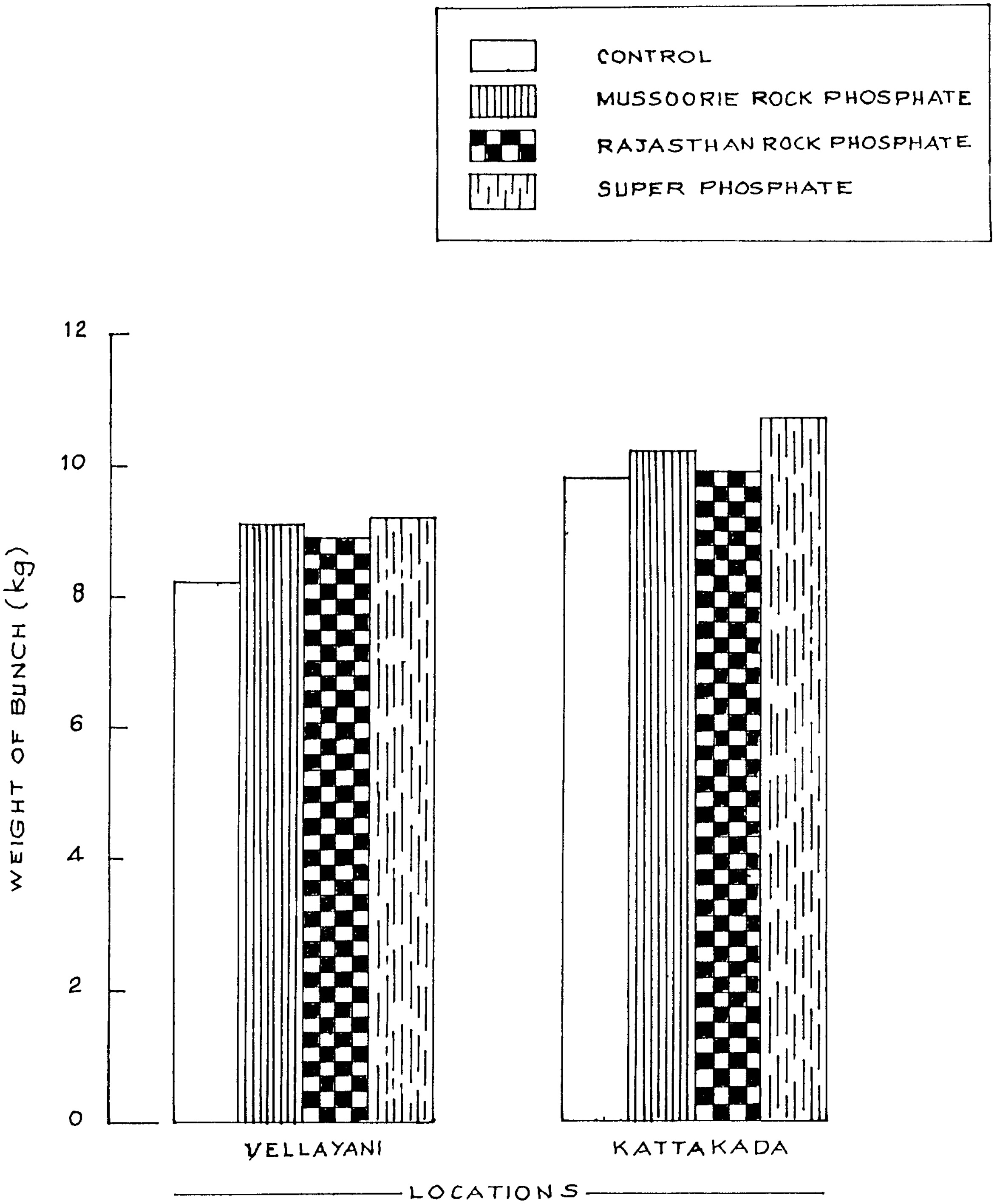

FIG 6 EFFECT OF DIFFERENT PHOSPHATIC FERTILIZERS ON THE YIELD OF BANANA

difference between the treatments was observed on this character. Relatively greater length of bunch was produced by plants supplied with Rajasthan rockphosphate (51.25 and 50.95 cm) both at Vellayani and at Kattakada respectively. The control plots recorded the minimum lengths, 40.90 and 46.90 cm respectively for the two locations. At Vellayani, T_3 was found to be on par with T_4 and superior to T_2 and T_1.

4.2.3. Number of hands bunch^{-1}

There was significant effect due to treatments on the number of hands bunch^{-1} at Vellayani soil, unlike Kattakada. At Vellayani, it was observed that the sources of P had no significant influence on this character. Plants treated with Rajasthan rockphosphate produced maximum number of hands per bunch (6.20), while the control plots produced a minimum of 4.90 hands bunch^{-1}.

At Kattakada, plots treated with superphosphate recorded relatively greater number of hands bunch^{-1} (5.45) and control plots recorded the minimum (5.05).

4.2.4. Number of fingers per bunch

At Vellayani, a maximum of 40 fingers bunch^{-1} was produced by superphosphate which was on par with Mussoorie rockphosphate which inturn was on par with Rajasthan rockphosphate. The control plots recorded the minimum number of 36 fingers $bunch^{-1}$. At Kattakada, T_4, T_2 and T_3 were found to be on par but T_4 and T_2 were superior to T_1. Maximum number of fingers $bunch^{-1}$ (47) was produced by plants treated with superphosphate and minimum (41) by control plots.

4.2.5. Length of finger

At Vellayani, the greatest length of 18.90 cm was recorded by plants treated with Rajasthan rockphosphate which was on par with Mussoorie rockphosphate and lowest length of 17.65 cm by plants with no phosphorus. At Kattakada, no significant difference between treatments could be noticed. However, slightly greater length of finger (19.80 cm) was recorded by plants treated with superphosphate and lowest length (18.00 cm) by control plots.

4.2.6. Girth of finger

No significant influence for the different treatments was observed on the girth of finger at both places. However, comparatively higher value for girth of 16.30 cm and 17.20 cm was recorded at Vellayani and Kattakada by Mussoorie rockphosphate and superphosphate respectively.

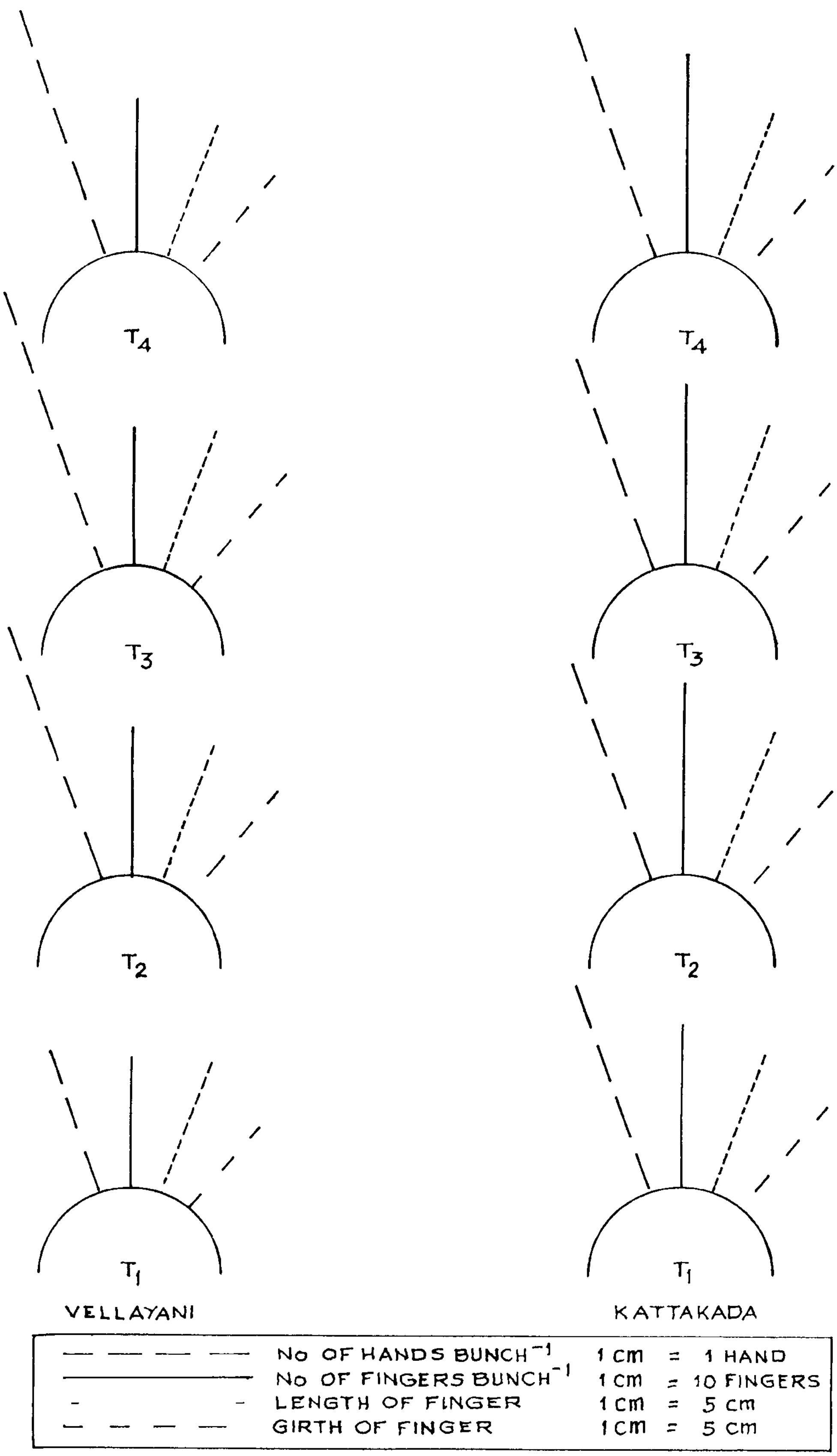

FIG 7 BUNCH CHARACTERS OF BANANA AS INFLUENCED BY PHOSPHATIC FERTILIZERS

4.3. Total drymatter production

The fresh weight of the different plant parts were recorded and their samples were weighed fresh and oven dried at 70°C. The total dry weight of the whole plant was calculated and recorded from the fresh weight of the sample (Table 8). At both locations, treatments showed significant influence on this character. The total drymatter produced by plants supplied with superphosphate was the highest at Vellayani (6.90 kg $plant^{-1}$) and at Kattakada (7.07 kg $plant^{-1}$). At both places, minimum quantities were produced by control plots as 6.47 kg and 6.76 kg $plant^{-1}$ respectively at Vellayani and Kattakada.

4.4. Uptake of phosphorus by banana

The mean values of the P uptake at harvest are shown in Table 9. At both places, the treatments produced significant effect on the P uptake by the plant, but the sources of phosphorus did not show marked difference on this character. At Vellayani, maximum uptake (14.47 g $plant^{-1}$) was found to be for Mussoorie rockphosphate, and minimum of 11.31 g P_2O_5 $plant^{-1}$ was recorded by plants treated with zero phosphorus. Maximum uptake was recorded by plants receiving superphosphate (15.05 g P_2O_5 $plant^{-1}$) and minimum uptake (12.12 g P_2O_5 $plant^{-1}$) by control plots at Kattakada.

Table 8. Effect of different phosphatic fertilizers on the total drymatter production

Vellayani

Treatments	Different organs (g $plant^{-1}$)					Total
	Corm	Pseudostem	Leaf	Bunch	Malebud	
T_1	885.0	2520.0	616.2	2393.4	60.0	6474.6
T_2	954.8	2523.8	632.6	2529.8	62.6	6703.0
T_3	981.0	2519.0	634.6	2168.0	62.0	6664.3
T_4	895.0	2520.0	636.0	2592.7	60.4	6904.0
CD (0.05)	-	-	-	-	-	101.24
Kattakada						
T_1	944.00	2552.80	625.60	2581.80	60.20	6764.30
T_2	962.00	2568.80	636.00	2779.64	62.40	7008.84
T_3	970.00	2544.00	636.00	2740.25	62.20	6952.45
T_4	965.00	2553.00	675.00	2817.00	61.40	7071.80
CD (0.05)	-	-	-	-	-	61.877

Table 9. Effect of different phosphatic fertilizers on the uptake of phosphorus at harvest

Vellayani

Treatments	Different organs (g P_2O_5 plant^{-1})					Total uptake
	Corm	Pseudostem	Leaf	Bunch	Malebud	
T_1	0.52	4.50	1.23	4.87	0.184	11.31
T_2	0.76	4.85	1.67	6.99	0.197	14.47
T_3	0.85	4.88	1.39	6.89	0.199	14.21
T_4	0.54	4.81	1.46	7.35	0.188	14.34
CD (0.05)	-	-	-	-	-	0.346
Kattakada						
T_1	0.90	4.38	1.32	5.32	0.18	12.12
T_2	0.53	4.95	1.52	6.95	0.19	14.17
T_3	0.53	4.92	1.39	7.58	0.19	14.61
T_4	0.66	4.83	1.51	7.80	0.19	15.05
CD (0.05)	-	-	-	-	-	0.470

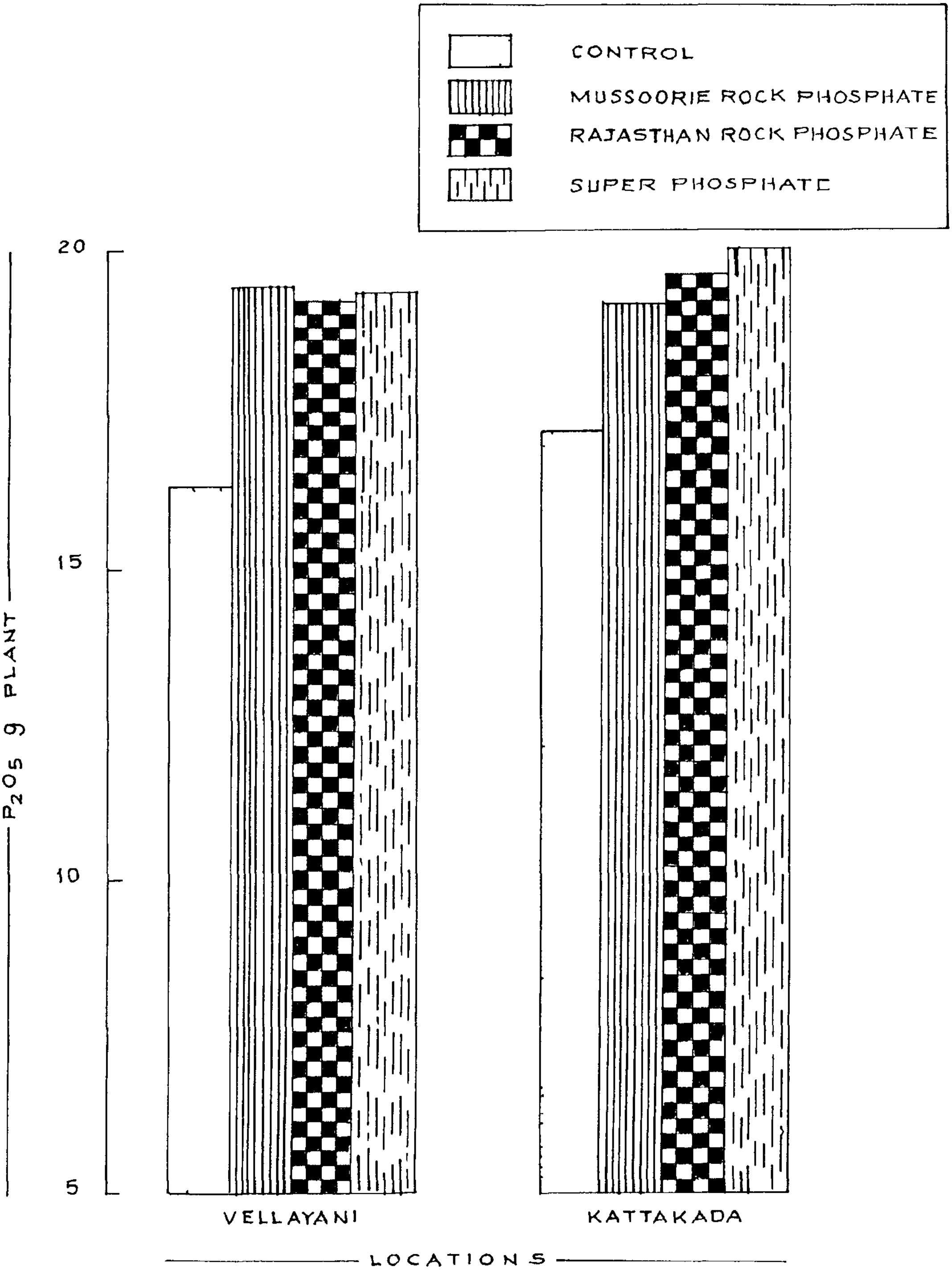

FIG 8 EFFECT OF DIFFERENT PHOSPHATIC FERTILIZERS ON THE P UPTAKE IN BANANA

4.5. Phosphorus content in the leaf

Phosphorus content in the leaf recorded at 45 days interval upto shooting is presented in Table 10. At both locations, there was significant difference between the treatments on the leaf P content. At 45th day of leaf sampling, a maximum concentration of 0.15 and 0.11 per cent P_2O_5 was noticed for the plants treated with superphosphate both at Vellayani and Kattakada respectively. In general, it was found that the leaf P content increased (0.26 per cent) till 180 days after planting ie., the late vegetative phase of the crop, and decreased thereafter, especially at the harvest stage of the crop.

4.6. Available P content in the soil

The mean values of the available P content in the soil are given in Table 11. Eventhough P fertilization increased the P content in the soil, the variation due to different sources of P on the P availability in the soil remains the same, or without significant difference between them. At Vellayani, the P content in the soil at 45 days after planting was maximum in plots treated with superphosphate (47.92 kg P_2O_5 ha^{-1}) which was on par with Mussoorie rockphosphate and Rajasthan rockphosphate.

Table 10. Effect of different phosphatic fertilizers on the phosphorus content in the leaf (percentage) at 45 days interval

Vellayani

Treatments	Period in days						Mean
	45	90	135	180	225	Harvest	
T_1	0.09	0.13	0.19	0.23	0.21	0.20	0.18
T_2	0.14	0.18	0.21	0.26	0.25	0.23	0.22
T_3	0.15	0.18	0.22	0.25	0.25	0.22	0.21
T_4	0.15	0.17	0.22	0.25	0.25	0.23	0.22
CD (0.05)	0.004	0.003	0.003	0.004	0.015	-	-
Kattakada							
T_1	0.07	0.12	0.19	0.24	0.22	0.21	0.18
T_2	0.13	0.18	0.21	0.25	0.25	0.24	0.21
T_3	0.13	0.17	0.20	0.26	0.25	0.22	0.21
T_4	0.14	0.17	0.22	0.25	0.25	0.23	0.21
CD (0.05)	0.006	0.004	0.006	0.005	0.005	-	-

Table 11. Effect of different phosphatic fertilizers on the available P_2O_5 content in soil (kg ha^{-1})

Treatments	Period in days					Mean
	45	90	135	180	225	
Vellayani						
T_1	37.44	36.20	35.80	34.55	33.00	35.39
T_2	47.76	42.20	37.60	36.40	35.95	39.98
T_3	45.00	40.50	38.60	38.00	37.50	39.92
T_4	47.92	40.60	39.65	35.45	36.20	39.96
CD (0.05)	3.062	4.657	2.404	3.249	6.354	-
Kattakada						
T_1	29.30	27.80	26.30	25.70	26.40	27.10
T_2	36.40	34.65	33.75	32.33	30.10	33.84
T_3	3[illegible].50	35.00	31.44	30.40	2[illegible].52	32.77
T_4	37.10	32.24	30.25	2[illegible].63	2[illegible].62	31.30
CD (0.05)	2.79[illegible]	3.598	5.244	3.071	5.[illegible]33	-

At Kattakada also, the variation due to the different P sources on the available phosphorus content in the soil was not significant. In the final stages of sampling, the maximum available P content was recorded with Mussoorie rockphosphate (30.1 kg P_2O_5 ha^{-1}) and minimum for control plot (26.4 kg P_2O_5 ha^{-1}).

4.7. Total phosphorus content in soil

The mean values obtained at 45 days intervals on the total phosphorus content of the soil are presented in Table 12. At Vellayani, in all the stages of sampling, different P sources produced no significant difference on the total phosphorus content in the soil but were superior to control plots. Eventhough the different P sources were on par, the maximum content of total phosphorus in soil was accounted by plots treated with Mussoorie rockphosphate (0.06 per cent) and the minimum by control plot (0.05 per cent). At Kattakada also a similar trend in variation was noticed. The plots treated with superphosphate recorded the maximum (0.048 per cent) and the one with no phosphorus, minimum (0.046 per cent) P_2O_5 content in soil.

4.8. Influence of organic matter on the phosphorus availability from different P sources

Available P content (Bray I) was estimated in soils

Table 12. Effect of different phosphatic fertilizers on the total P_2O_5 content in soil (percentage)

Treatments	Period in days					Mean
	45	90	135	180	225	
Vellayani						
T_1	0.05	0.05	0.05	0.05	0.05	0.047
T_2	0.06	0.06	0.06	0.06	0.06	0.059
T_3	0.06	0.06	0.06	0.05	0.06	0.056
T_4	0.06	0.06	0.06	0.06	0.06	0.058
CD (0.05)	0.004	0.005	0.004	0.004	0.006	-
Kattakada						
T_1	0.05	0.05	0.05	0.05	0.05	0.046
T_2	0.05	0.05	0.05	0.05	0.05	0.048
T_3	0.05	0.05	0.05	0.05	0.05	0.047
T_4	0.05	0.05	0.05	0.05	0.05	0.048
CD (0.05)	0.004	0.004	0.004	0.005	0.003	-

incubated under moist conditions (30 per cent moisture) at an interval of 45 days. The data on this incubation experiment are presented in Table 13. In the 45th day after incubation, a drastic increase in the available P content in the soil was recorded and this trend continued upto 90 days and at this period, the P availability was found to be maximum under moist conditions. There after, a gradual decline was recorded in the availability of phosphorus. When the mean values of available P over all the periods were compared, maximum availability was recorded by T_5 (130.71 ppm), while T_3 (128.53 ppm) and T_4 (126.95 ppm) were on par but superior to T_2 (111.40 ppm) and T_1 (100.10 ppm).

When the periods of incubation were compared with respect to the mean values of available P, though the highest value (125.96 ppm) was recorded at 135 days after incubation, the value obtained at 90th day (125.36 ppm) was on par with the one at 135 days.

At 45th day, no significant difference on the available P content could be noticed between the various phosphorus sources though organic matter addition increased the availability of phosphorus in the soil. At 135 days after incubation, the influence of organic matter on the release of phosphorus from superphosphate treated and

Table 13. Changes in available-P (ppm) as influenced by different sources and organic matter under moist conditions

Treatments	Period in days					Mean
	45	90	135	180	225	
T_1	86.20	101.28	112.29	100.30	98.44	100.10
T_2	92.40	119.40	117.65	116.38	111.20	111.41
T_3	112.60	135.10	133.10	131.00	130.80	128.53
T_4	111.80	132.75	130.61	130.00	129.60	126.95
T_5	114.28	138.20	136.17	133.40	131.50	130.71
CD (0.05) (treatments)	4.549	4.405	5.181	5.731	5.044	1.695

17C2C2

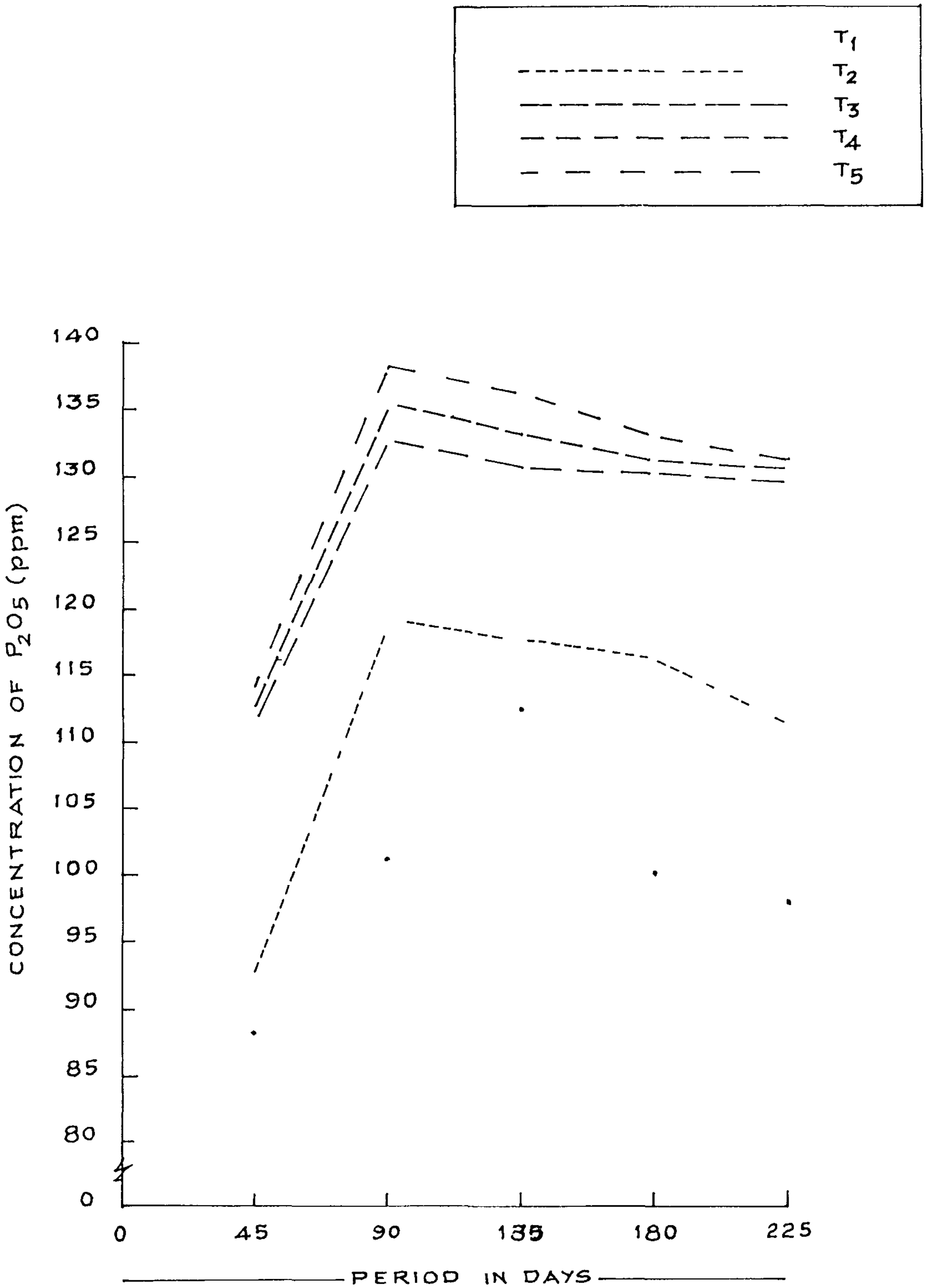

FIG 9 PHOSPHORUS AVAILABILITY AS INFLUENCED BY ORGANIC-MATTER ADDITION FROM DIFFERENT P SOURCES

Mussoorie rockphosphate treated soil was not significant. During the final stages of estimation (180 and 225 days) it has been noticed that the P released by organic matter incubation from all the phosphatic fertilizers added soil was almost uniform. The total P_2O_5 content estimated was 0.049 and 0.050 per cent for T_1 and T_2 respectively and 0.056 per cent for T_3, T_4 and T_5.

DISCUSSION

5. DISCUSSION

Kerala ranks first in the country with respect to the area under banana cultivation and rainfed banana occupies about 80 per cent of the total area. Some of the earlier workers (Valsamma Mathew, 1980; Sheela, 1982) have emphasized the need for further nutritional studies on rainfed banana. Though there are a number of studies in banana with nitrogen and potassium fertilizers either individually or in combination, only very few studies have been reported on phosphorus nutrition of the crop. Several workers are of the opinion that banana requires less of phosphorus than nitrogen and potassium. Or phosphorus had less effect than nitrogen or potassium (Norris and Ayyar, 1942). According to Lin et al. (1962), N or K alone produced insignificant influence on growth and yield of banana when compared to their combined application.

The present study lays stress on the assessment of the efficiency of different P sources on rainfed banana and the salient results obtained are discussed as under.

5.1. Effect of phosphorus on growth characters

The various growth characters studied in this experiment include the height and girth of pseudostem, number of green leaves and total leaf area.

In this study, the height of the plant was not significantly influenced by the different phosphatic fertilizers applied (Fig.3). However, the control plots recorded the lowest height over the P treated ones indicating the significant influence of phosphorus on plant height. Chu (1960) had also observed that P fertilization greatly increased pseudostem growth in banana. The pronounced role of P in cell division, and growth can be the explanation for this result.

5.1.2. Girth of pseudostem

The present study revealed that phosphorus influenced the girth of pseudostem significantly. Jagirdar and Ansari (1966) also indicated that in Basrai variety of banana, stem girth was increased when P was applied alone or with K at the rate of 48 and 96 lbs per acre respectively.

5.1.3. Number of green leaves

The total number of leaves produced by a banana plant varies with the variety or the environment under which the crop is grown (Oppenheimer, 1960). The present study indicated significant influence of phosphorus on the total number of leaves produced, though the various sources of P were on par. Similarly, positive significant influence of P on this character was also observed by Chattopadhyay and Bose (1986).

5.1.4. Total leaf area

Since it has been reported that the banana plants produce maximum leaf area at shooting stage ie., 7th month after planting, observations on this character were recorded at this particular growth phase. The increase in leaf area at shooting stage may possibly be due to the increased uptake of nutrients as reported by Valsamma Mathew (1980).

Leaf area was worked out using a coefficient 0.8 from the length x width measurements (Obiefuna and Ndubizu, 1979). In the present study, relatively higher value for leaf area was recorded by plants treated with superphosphate (Fig. 4). The better growth in P applied plots as evidenced by increased height and girth (Table 3 and 4) could have helped to increase the leaf area. More over, the ultimate yield was also the maximum for this treatment, indicating the possible positive correlation between leaf area and yield, as observed by Sheela (1982).

5.1.5. Number of days taken for flowering

From this study, it was found that when no P was supplied to plants, flowering was delayed compared to the plants supplied with P (Fig. 5). Phosphorus alone had no appreciable effect on flowering but a combination of N and K in the correct proportion is necessary for manipulating crop growth which was established by many earlier workers (Croucher and Mitchel, 1940; Summerville, 1944; Bhangoo *et al.*, 1966). According to Singh *et al.* (1977) phosphorus @ 90 g $plant^{-1}$ along with N and K at 150 and 170 g $plant^{-1}$ gave best growth and induced earliness in flowering. In the present study, there was not much variation between the sources of phosphorus with respect to the number of days taken for flowering. This could be easily explained by the observations on their growth characters, which also did not differ significantly between different sources of P (Table 3, 4 and 6).

5.2. Bunch characters

Amount of rainfall received during the crop growth is one of the main factors governing the growth of banana especially grown under the upland soil situations. Comparatively low yield recorded in this study, may possibly be due to the poor rainfall obtained during the shooting and prior to the shooting periods of the crop. From this study, it was observed that phosphorus application could influence the yield of banana significantly over control but the effect of different sources of P was on par (Fig.6&7). Thus, it indicates the possibility of utilizing cheaper rockphosphates rather than using costly water soluble forms in banana. The influence of phosphorus on the yield of banana is low when compared to potassium application. Significant increase in yield due to potassium application has been reported by various researchers (Hewitt and Osborne, 1963; Sheela, 1982). Pillai et al. (1977) studied the response of Nendran banana to different levels of NPK. According to them, yields were greater with N and K_2O at 191 and 501 g plant^{-1}, there was however little or no response to phosphorus. But, in Honduras, Bhangoo et al. (1962) indicated significant response to the application of phosphorus and potassium in conjunction with nitrogen, improving the average bunch weight of "Giant Cavendish" banana. Little or no response was obtained from the use of nitrogen alone. Similarly P alone could not influence the yield of banana, but when supplied with appreciable amount of N and K could enhance the yield. Bhavani Sankar (1980) tried different levels of N and P on Nendran banana under gardenland conditions, and found that at 100 g N plant^{-1} application of P had no significant influence on number of fingers bunch^{-1} and length and girth of finger. While Sundar Singh (1972) reported that length of fruit of 'Robusta' banana was more under NP treatment and in presence of P and K, nitrogen significantly influenced the number of hands, fruits, and inturn the weight of bunch. In the present study, yield showed a significant positive association with total uptake of P (r = +0.5149) indicating the positive response of banana to phosphorus application.

Vijayaraghavakumar _et al_. (1984) observed maximum direct effect for number of fingers on the bunch weight. According to Krishnan and Shanmugavelu (1983), bunch weight is a complex character and is influenced by the component morphological characters of the plant and bunch. Maximum efficiency was shown by plants treated with superphosphate in most of the plant characters under observation here and hence it reflected in the yield also. But at the same time, the efficiency of rockphosphates was comparable with that of superphosphate. Thus indicating the possibility of utilizing the cheaper rockphosphates as an economic source of P for banana especially grown under upland acid soil conditions, rather than the more costly superphosphate.

5.3. Total drymatter production

In the present investigation, total drymatter production in banana was in the range of 5.38 kg to 7.07 kg plant^{-1}. This finding is in agreement with that of Bhavani Sankar (1980) in 'Nendran' banana. Earlier workers have reported 4.5 to 10.5 kg in Lactan bananas (Bolano, 1960), 19 kg plant^{-1} in Dwarf Cavendish banana under French Guinea conditions (Baillon et al., 1933). Twyford and Walmsley (1973) recorded 5.15 kg drymatter in 'Robusta' banana. From these findings, it has been inferred that the drymatter production in banana varies with variety and locations. Total drymatter production showed a significant positive correlation with P uptake (r = +0.8358) at Vellayani and (r = +0.8847) at Kattakada showing the significant effect of phosphorus on the drymatter production in banana. With respect to the effect due to sources of P on total drymatter, though superphosphate, the easily available P source produced the maximum quantity in both places, all sources of P were on par.

5.4. Uptake of phosphorus

Comparatively low uptake of phosphorus was observed in both locations viz., Vellayani and Kattakada. This finding was in general agreement with that of Sheela (1982). The P uptake was high by plants in the P fertilized plot compared to the control plots (Fig. 8). But the variation due to different sources of P was negligible or not significant on this character. Perhaps, in the acidic soil conditions, the availability of P from the rockphosphates could have easily met the requirement by the crop. Increased availability of P from slowly soluble forms in acid soils has been reported by many Scientists (Mistry and Yadav, 1981; Yadav and Mistry, 1984).

The uptake of phosphorus by banana is low compared to that of nitrogen and potassium (Norris and Ayyar, 1942; Martin-Prevel, 1964; Turner, 1969; Vadivel, 1976). Varietal variation as well as location influence on the uptake of phosphorus was reported by Martin-Prevel (1964). In banana, P uptake ranged from 12.5 kg ha^{-1} to 90 kg ha^{-1} (Martin-Prevel *et al.*, 1968). According to Chattopadhyay and Malik (1978), P uptake increased with frequent high irrigation and high level of P application. The low uptake of phosphorus by banana in the present study may possibly be due to the fact that the crop was grown as a rainfed one.

5.5. Phosphorus content in the leaf

The concentration of P was significantly influenced by the treatments though the sources of phosphorus did not show much variation. This could be easily explained by the fact that the uptake of P also did not vary significantly with the different sources of P applied (Table 9). According to Beena Natesh (1987) compared to N and K the concentration of phosphorus in the leaf was very little.

In the present study, maximum P content was recorded at the late vegetative phase of the crop. This result was confirmed with the findings of the earlier workers (Mathew, 1980; Sheela, 1982). After shooting period, a decrease in the content of phosphorus in the vegetative organs was observed and this might be due to the mobilisation of P to the reproductive parts (Sheela, 1982). Martin-Prevel (1964) had claimed that total uptake of phosphorus ceased at shooting as it was mobilised from the vegetative organs for fruit development.

In this study, the concentration of P was maximum for plants which received superphosphate especially in the initial periods and as the crop attained maturity, the concentration was found to increase for other sources of P as well. This might be due to the easy availability of P from water soluble P sources at the initial periods and as days went by, the availability of P from rockphosphates also increased and became comparable to that of water soluble sources.

5.6. Available and total phosphorus content in the soil

It was found that the P availability was highest in the soil at the 45th day after planting. The reason might be that, in banana, within one month after planting, the full dose of phosphorus was supplied and 15 days after the fertilization, the sampling was done and estimated for available P content. At this period, the root system of the plant may not have established well and hence the plants would not have started exploiting the nutrient fully. Moreover, within this period, the added phosphatic fertilizer may not have been subjected to appreciable loss and thus the availability becomes maximum. But as the plant attained maturity, due to the crop removal and other reasons such as ageing of applied P the availability in the soil tended to decrease.

A slight decrease in the total P_2O_5 concentration was also recorded in the soil towards the maturity of the crop. Both at Vellayani and Kattakada, availability of P in the Mussoorie rockphosphate treated soil was found to be maximum compared to the other sources. Various findings showed that rockphosphate is particularly suited for soils below pH 5.5, while single superphosphate is a proven fertilizer for a wide range of soils (Tandon, 1987). Mishra (1980) reported that in deciding the efficiency of rockphosphate to crops, the crop x environment interaction is important. Scientists differ in their opinion about the availability of P from superphosphate and rockphosphate in acid soils. Eventhough maximum values for P availability was recorded by Mussoorie rockphosphate treated soils, difference between water soluble P sources and acid soluble rockphosphates in the P availability was statistically not significant in this study. This result is in conformation with the earlier findings by many workers (Chang and Chiang, 1953; Rastogi et al., 1976; Motsara and Datta, 1976; Nair and Aiyer, 1980; Kabeerthumma and Mohankumar, 1986).

5.7. Influence of organic matter on the release of phosphorus

In the incubation study, it was observed that the addition of organic matter to a soil treated with different phosphatic fertilizers significantly increased the available P content of soil under moist conditions (Fig. 9). The influence of farmyard manure on the increased availability of P from different phosphatic fertilizers in acid soil had been reported by many earlier workers (Mukhthopadhyay and Mandal, 1979; Nageeb, 1989). The increased availability might be due to the decomposition of organic matter under anaerobic condition which lowers the redox potential in the soil to a great extent. The resulting reduced condition favours the solubilisation of more ferric phosphates in the form of ferrous phosphates. Under favourable reduced condition, organic acids released from the decomposition of organic matter may solubilise ferrous ions by complex formations (Savant and Ellis, 1964; Purnachandra Rao, 1966) and thereby reducing possibility for phosphorus fixation. Compared to aerobic condition, anaerobic situation increases the availability of phosphorus due to reduction and enhanced solubility of Fe-P caused by the reducing conditions as well as increased pH (Ponnamperuma, 1965).

In addition to the above factors, mineralisation of organic P would have also contributed to the pool of available P (Kanwar, 1976). Mandal and Mandal (1973) reported that organic matter application, reduced fixation of P due to the chelating properties of the compounds formed during organic matter decomposition. The availability of P from rockphosphates increased considerably during the incubation of soil with farmyard manure under moist conditions. This is due to the conversion of insoluble tricalcium phosphate to more soluble mono and dicalcium phosphate by the large quantity of CO_2 formed during the decomposition of organic matter (Khan and Mandal, 1973).

In this study, the maximum availability of phosphorus was recorded upto 90th day of incubation from the

P sources and thereafter a gradual decrease was noticed in the P availability. A similar trend in the P availability was reported by Najeeb (1989). This might be due to the reoxidation of ferrous to ferric and the reformation of Ca-P, thus reducing the P availability (Singh and Ram, 1977).

From this study, the favourable effect of phosphorus on banana is confirmed. Since large quantities of native as well as added P were subjected to loss through fixation by soil, it would be worth while if the residual effect of different forms of P on banana is investigated.

This study also revealed the significant influence of organic matter on the release of P from different sources. Hence studies may be conducted under field conditions to evaluate the positive role of organic matter on P availability.

SUMMARY

SUMMARY

ockphosphate is an indigenous, cheaper source of fertilizer P, since the cost of which is about 40 per cent less than that of processed phosphates. The information available on the utilization of this cheap source of P under upland soil conditions is very meagre. Hence a study was conducted to compare the efficiency of different P sources under upland soil situations with rainfed Nendran banana as the test crop. A laboratory study was also conducted to investigate the influence of organic matter on the P releasing capacity of soil from various phosphatic fertilizers.

The field experiment was conducted in two locations viz., at the Instructional Farm of College of Agriculture, Vellayani and in the cultivator's field at Kattakada. The experiment was laid out in randomised block design with four treatments and five replications. Biometric characters of the plant like height and girth of the pseudostem, and number of green leaves were recorded upto shooting period at 45 days interval. The leaf area at shooting period alone was recorded since the plant acquires maximum leaf area at this stage. Period taken for flowering, bunch characters like length of bunch, number of fingers and hands $bunch^{-1}$ and length and girth of finger were also

recorded. The data were analysed statistically and interpreted. A laboratory study was conducted by incubating the soil collected from Vellayani under moist conditions (30 per cent moisture) with organic matter and three different P sources, viz., superphosphate, Mussoorie rockphosphate and Rajasthan rockphosphate and soils with and without organic matter. At 45 days interval, soil samples were drawn and analysed for the total and available phosphorus contents. The data obtained were analysed statistically and the results are summarised as follows:

1. The height of banana plant was found to be influenced by phosphorus application. But there was no significant difference between P sources on the height of the plant. The plants treated with superphosphate recorded relatively greater height at both locations tried, viz., Vellayani and Kattakada.

2. The effect due to different phosphatic fertilisers on the girth of pseudostem was statistically on par and the maximum girth was recorded by plants supplied with superphosphate and minimum by the control plots, at both locations.

3. The number of functional leaves produced was found to be influenced by phosphorus application eventhough the

difference between the ~ sources on this character was not significant. At Vellayani, plants treated with Mussoorie rockphosphate produced maximum number of leaves while at Kattakada those with Rajasthan rock-phosphate produced the maximum number of leaves and the control plots, the minimum number at both places.

4. The leaf area was found to be significantly influenced by phosphorus application. At both locations, plants receiving superphosphate recorded the maximum leaf area, and those with no P treatment recorded the minimum.

5. Phosphorus application had significant influence on the flowering of the banana plant, since the plants without P took more days for flowering compared to the treated ones. Plants supplied with superphosphate flowered earlier than the others at both sites.

6. From this study, the growth characters of banana plant were found to be influenced by phosphorus application. However different sources were on par in their influence in most of the growth characters.

7. Phosphorus application significantly influenced the yield of banana plant over control. A significant positive correlation with yield and upta[illegible] of [illegible]es

observed. No significant difference could be noticed due to different P sources on the yield of banana. The greatest yield was recorded by plants treated with superphosphate.

8. Length of bunch was significantly influenced by the treatments while not much significant effect was observed on the number of fingers bunch^{-1}. Superphosphate was found to be on par with Mussoorie rockphosphate which inturn was on par with other treatments. With respect to number of hands bunch^{-1}, at Vellayani, the treatments produced significant influence unlike at Kattakada. Similarly, the different treatments produced significant influence on the length of finger at Vellayani unlike at Kattakada. While no significant influence could be observed on the girth of finger at both locations.

9. The treatments produced significant effect on the total drymatter production. The quantity of drymatter produced varied with locations and treatments. At both locations, superphosphate treated plants recorded the maximum drymatter content. A significant positive correlation between the total drymatter production and P uptake was observed.

10. At both locations, application of phosphatic fertilizers produced significant effect on the P uptake by plants but the variations due to different P sources were not significant.

11. In general, the phosphorus content in the leaf was found to increase from late vegetative phase to shooting period. As the period increased, concentration of P in the leaf tended to increase upto shooting and then decreased at harvest stage. At 45 days after planting, superphosphate treated plants recorded the maximum concentration of P in the leaf but later, the concentration of P from rockphosphate was also found to increase and thus at shooting stage, all the three forms of P were on par with respect to leaf P content.

12. Application of phosphatic fertilizers influenced significantly the available P content in the soil but the effects of the different P sources were statistically on par in this character. At the initial period of sampling, P availability was the greatest for the soils treated with superphosphate and at later stages, no significant difference was noted between the treatments on the P availability.

13. P fertilization increased total P_2O_5 content in the soil while variation between the sources were not significant.

14. In this study, in most of the growth and yield characters, maximum efficiency was shown by plants treated with superphosphate but at the sametime the efficiency of rockphosphates was comparable with that of superphosphate in these characters. Thus, it indicates the possibility of utilizing the cheaper rockphosphates as an economic source of P for banana especially under upland soil conditions in Kerala.

15. In the laboratory incubation study to assess the influence of organic matter on the release of P from different P sources, an initial drastic increase in the P availability was observed upto 90 days of incubation which gradually decreased later. This study indicates the significant influence of organic matter on the increased P availability from the soils treated with different P sources. Maximum P availability was recorded in superphosphate treated soils incubated with organic matter. Various sources of P behaved similarly and were on par with respect to the release of phosphorus due to organic matter incubation.

1C. Phosphorus being fixed in soil, it's residual effect is considerable especially in the case of the slowly soluble forms. In the light of this fact, it would be worth while, to study the residual effect of these forms of nutrient P on banana, with and without organic matter additions.

REFERENCE

REFERENCES

Anonymous (1989). Farm Guide. Farm Information Bureau. Government of Kerala, India.

Ashok Kumar, A.K. (1977). Studies on the growth and development of banana Musa (AAA group, Cavendish subgroup) 'Robusta' in relation to foliar and soil application of nitrogen and Azotobacter. M.Sc.(Ag.) thesis, TNAU, Coimbatore.

Awasthi, P.K. (1990). Marketing of Rockphosphate as direct phosphatic fertilizer. Fert. News. 35(4): 91-97.

Baillon, A.F., Holmes, E. and Lewis, A.H. (1933). The composition of and nutrient uptake by banana plant with special reference to the Cannaries. Trop. Agric. Trin. 10: 139-144.

Balakrishnan, R. (1980). Studies on growth, development, sucker production and nutrient uptake at different ploidy levels in banana (Musa sp). Ph.D. thesis in Horticulture, Tamil Nadu Agricultural University, Coimbatore.

Beena Natesh (1987). Effect of split application of fertilizers in banana cv. 'Nendran'. M.Sc.(Hort.) thesis submitted to Kerala Agricultural University, Trichur.

Bhan, K.C. (1967). Banana - a fruit of masses. Indian Hort., 11: 16-20.

Bhangoo, M.S., Altman, F.G. and Karon, M.L. (1962). Investigations on the Giant Cavendish banana. I. Effect of nitrogen, phosphorus and potassium on fruit yield in relation to nutrient content of soil and leaf tissue in Honduras. Trop. Agric. Trin. 39: 189-201.

Bhavani Sankar, K. (1980). Nutritional investigation in Nendran Banana. (French Plantain AAB). M.Sc.(Ag.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Black, C.A. (1965). Methods of soil analysis. American Society of Agronomy, Wisconsin, U.S.A.

Boland, D. (1960). Leaf analysis in banana. Rep. Banana Board Res. Dept. Jamaica.

*Broadbent, F.E. (1983). Effects of organic matter on nitrogen and phosphorus supply to plants. In proceedings of the second international symposium. Peat in Agriculture and Horticulture. 141-144. Abstracted in Soils and Fert. 48: 1142.

Chakravarty, A., Mukherjee, D. and Mukhopadhyay, P.K. (1985). Influence of organic matter on the changes in organic carbon and availability of nitrogen and phosphorus in soil. Indian Agric. 29(1): 25-29.

Chang, S.C. and Chiang, C.T. (1953). The availability of various phosphatic fertilizers for rice on main soil groups of Taiwan. Soils and Fert. 90-91.

Chattopadhyay, P.K. and Bose, T.K. (1986). Effect of NPK nutrition on growth, yield and quality of Dwarf Cavendish banana. (Musa cavendishii Lamb). Indian Agric. 30(3): 213-222.

Chattopadhyay, T.K. and Mallik, P.C. (1978). Uptake of nutrients by banana at the 8th and 19th leaf stage. Scientia Horticulturae 1: 55-65.

Chu, C.C. (1960). The effect of K fertilizer on the production of banana. Soils and Fert. 24: 1701.

*Croucher, H.H. and Mitchel , W.K. (1940). Fertilizer investigation with Grosmichel banana. Trop. Agric., Trin. 37: 31-50.

Dagade, V.G. (1986). Effects of graded levels of nitrogen, phosphorus and potassium fertilization on growth, yield and nutrient status of 'Basrai' banana. Indian J. Agric. Chem. 19(1): 1-7.

Dashrath Singh and Datta, N.P. (1974). Saturation of soil with respect to phosphorus in relation to the efficiency of utilization of applied phosphorus form indigenous phosphate rocks. J. Indian Soc. Soil Sci. 22(2): 125-129.

Dashrath Singh, N.D., Mannikar and Srivas, N.C. (1976a). Fertilizer value of indigenous rockphosphates compared with single superphosphate. Laboratory incubation studies with FYM. J. Indian Soc. Soil Sci. 24(1): 78-80.

Dave, S.K., Katrodia, J.S. and Patel, M.L. (1990). Nutrition and growth of Banana Cv. Basrai in deep black soils of South Gujarath. Fert. News 35(2): 19-21.

Du Plessis, S.F. (1987). The effect of different NP levels on growth and nutrient uptake of Dwarf Cavendish bananas. Fruits. 42(1): 53-58.

*Garcia, R., Guijarro, R. and Diaz, B. (1980). Changes in the nutritional status of banana due to the effects of potassium on red soils of Cuba, their relations with yield and with the control of fertilizing. Potash Rev. Sub. 95: 7-10.

Ghosh, S.C., Omanwar, P.K., Sachen, R.S. and Sharma, R.B. (1981). Reserves of organic and total phosphorus in the cultivated and forested moth soils. J. Indian Soc. Soil Sci. 29: 322-336.

Hesse, P.R. (1984). In organic matter and rice. International Rice Research Institute, Manila, Philippines.

Hewitt, C.W. and Osborne, R.E. (1963). The effects of frequency of application of N, P and K fertilizer on Laetan banana in Jamaica. Trop. Agric. 40: 1-8.

Izza, C. and Indiati, R. (1981). Effect of farm organic residues added to the soil on phosphorus sorption.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Jagirdar, S.A.P. and Ansari, A.R. (1966). Effect of nitrogen, phosphorus and potassium on the growth and production of Cavendish banana (Musa cavendishii Lamb.). Proc. Agric. Symp. Atomic Energy Centre Daca. 71-80.

Jauhari, O.S., Mishra, R.A. and Tiwari, C.B. (1974). Nutrient uptake of banana variety 'Basrai' Dwarf. Indian J. Agric. Chem. 7(1): 73-79.

Kabeerthumma, S. and Mohan Kumar, B. (1986). Efficiency of rockphosphate as a source of phosphorus to sweet potato. J. Indian Soc. Soil Sci. 34: 806-809.

Kanwar, J.S. (1976). Soil fertility - Theory and practice in rice soils. Soil Sci., 94: 256-262.

Khan, S.K. and Mandal, L.N. (1973). Distribution of different forms of P in rice soils of West Ben al. J. Indian Soc. Soil Sci. 21: 395-402.

Koen, T.J., Smart, C. and Korungu, J.J. (1976). Manurial trials with bananas. (Dwarf Cavendish) in the Levebu area. Citrus and subtropical Fruit Journal. 515: 5-7.

Kohli, R.R., Chacko, E.K., Randhawa, G.S. (1976). Effect of spacing and nutrition on growth and fruit yield of Robusta banana. Indian J. agric. Sci. 46(8): 382-385.

Krishnaswamy, V. and Ramaswamy, K.P. (1984). Effect of nitrogen phosphorus and potassium on CSH-5 Seeds. Madras agric. J. 71(11): 709-11.

*Krishnan, B.H. and Shanmugavelu, K.G. (1980). Studies on water requirement of banana cv Robusta III leaf nutrient concentration and total uptake of nutrients. Mysore J. Agric. Sci. 14(2): 215-223.

Krishnan, B.M. and Shanmugavelu, K.G. (1983). Correlation studies in banana cv 'Robusta'. South Indian Horticulture 31: 110-111.

Lin, K.C., Li, K.T. and Lin, C.T. (1962). The optimum nitrogen phosphorus potassium ratio for bananas. Agric. Res. Taiwan. 11(3): 36-44.

Mandal, L.N. and Khan, S.K. (1972). Release of phosphorus from insoluble phosphatic materials in acidic low land rice soils. J. Indian Soc. Soil Sci. 20(1): 19-25.

Mandal, L.N. and Khan, S.K. (1975). Influence of moisture regimes on transformation of inorganic phosphorus in rice soils. J. Indian Soc. Soil Sci. 23: 31-37.

Mandal, L.N. and Mandal, K.C. (1973). Effect of organic matter and lime on the transformation of applied phosphate in acidic low land rice soils. J. Indian Soc. Soil Sci. 21: 57-62.

*Manica, I., Defelipo, B.V., Conde, A.R., Lino, J. an Passos, L.C.C. (1978). The response of banana cultivar Manico to fertilization with three levels of nitrogen phosphorus and potassium. 25 Revista Ceres. Hort. Abstr. 1979. 49(10).

Martin-Prevel, P. (1964). Nutrient elements in the banana plant and fruit. Fertilite 22: 3-14.

Martin-Prevel, P., Lacoeuilhe, J.J. and Marchal, J. (1968). Mineral elements in the Gros Michael banana plant in Cameroon. Fruits, 23: 259-269.

Marwaha, B.C. and Kanwar, B.S. (1981). Utilization of ground rockphosphate as a direct phosphatic fertilizer - A Review Fert. News. 26.

Marwaha, B.C., Kanwar, B.S. and Tripathi, B.R. (1981). Direct and residual effect of Mussoorie rockphosphate related to the crop species in acid soil. J. Indian Soc. Soil Sci. 29(3): 349-355.

Mathew (1980). Nitrogen nutrition in rainfed banana cv 'Palayankodan'. M.Sc.(Hort.) thesis submitted to Kerala Agricultural University, Trichur.

Mathur, B.S., Sarhar, A.K. and Mishra (1980). Release of N and P from compost charged with rockphosphate. J. Indian Soc. Soil Sci. 28(2): 206-212.

Mishra, B. (1980). Direct and residual effect of MRP applied in conjunction with pyrites or SSP in maize-wheat rotation in submontane soils. Indian J. agric. Sci. 50: 691-697.

Mistry, K.B. and Yadav, N.B. (1981). Evaluation of ammonium polyphosphate fertilizers in Indian soils B*C (Memographed). In. Phosphorus in Indian Agriculture. Tech. Bull. ENSP.

More, S.D. and Ghonsikar, C.P. (1982). Effect of some organic manures on the availability of phosphorus to wheat. J. Indian Soc. Soil Sci. 30: 372-374.

Motsara, M.R. and Datta, N.P. (1976). Management of acid soils by the use of basic slag and rockphosphate. Bull. Indian Soc. Soil Sci. 11: 277-282.

Mukhthopadhyay, A.K. and Mandal, S.K. (1979). Influence of moisture regime and application of fertilizer phosphorus and farmyard manure prior to floodin on the availability of phosphorus in soils. Bull. Indian Soc. Soil Sci. 12: 300-303.

Murray, D.B. (1960). The effect of the major nutrients on growth and leaf analysis of the banana. Trop. Agric. 37: 97-106.

Nageeb, P.H. (1989). Influence of form of organic matter on the mineralisation of applied phosphorus in submerged rice soils. M.Sc.(Ag.) thesis submitted to Kerala Agricultural University, Vellayani.

Nair, C.S. and Aiyer, R.S. (1980). Studies on the use of Mussoorie rockphosphate in acid soils of Kerala. The first twenty five year silver jubilee publication. Kerala Agricultural University 1955-1980.

Norris, R.V. and Ayyar, C.V.R. (1942). The nitrogen and mineral requirement of the plantain. Agric. J. India. 20: 463-467.

Obiefuna, J.C. and Ndubizu, T.O.C. (1979). Estimation of leaf area of plantain. Sci. Hort. 11: 31-36.

Oppenheimer, C.H. (1960). The influence of climatic factors on banana growing in Israel. Publn. Nat. and Univ. Inst. Agric. Rehovot Series No. 350.

Patel, D.K. and Vishwanath, D. (1946). Comparative studies on Indian soils. 1. Phosphate fixation capacities of soils. Indian J. Agric. Sci. 16: 428-434.

Pillai, G.R., Balakrishnan, S., Veeraraghavan, P.G., Santhakumari, G. and Gopalakrishnan, R. (1977). Response of Nendran banana to different levels of N, P and K. Agric. Res. J. Kerala 15(1): 37-40.

Pillai, O.A. (1975). Studies on the effect of number of functional leaves maintained on the growth and development of 'Poovan' banana. M.Sc.(Ag.) thesis, Tamil Nadu Agricultural University.

Piper, C.S. (1950). Soil and plant analysis. Inter Science Publishers, Inc. New York.

Ponnamperuma, F.N. (1955). The chemistry of submerged soils in relation to growth and yield of rice. Ph.D. thesis. Cornell Univ., USA.

Purnachandra Rao (1966). Water regime of rice soil and redox potential. M.Sc.(Ag.) thesis, Tamil Nadu Agricultural University, Coimbatore.

Rajeevan, P.K. (1985). Interclonal variations and nutritional studies in banana cv. 'Palayankodan'. Ph.D. thesis submitted to Kerala Agricultural University, Trichur.

Ramaswamy, N. (1976). Studies on the effect of different levels of phosphoric acid on the yield and quality of Robusta banana. Annamalai University Agricultural Research Annual. 6: 30-37.

*Ramirez, F., Haddad, O., Laboren, G. and Albarran, S.J. (1978). Accumulation of N, P and K in banana leaf tissue in Aragua State. Agronomia Tropical 28(5): 421-433. Hort. Abstr. 52: (7).

Randhawa, G.S., Sharma, C.B., Kohli, R.R. and Chacko, E.K. (1973). Studies on nutrient concentration in leaf tissues and fruit yield with varying planting distance and nutritional levels in Robusta banana. Indian J. Hort. 30: 467-474.

Rastogi, P.C., Mishra, B. and Ghildyal, B.P. (1976). Effect of pyrites and organic matter on the release of P from rockphosphate. J. Indian Soc. Soil Sci. 24: 175-181.

* Samules, G., Beak, A. and Torres, S. (1978). Nutrient content of the plantain (Musa AAB group) during growth and fruit production. J. Agric. Univ. Puerto Rico 62(2): 175-185.

Savant, N.K. and Ellis, Jr., R. (1964). Changes in redox potential and phosphorus availability in submerged soil. Soil Sci. 98: 388-393.

Shaikh, M.K., Rana, M.A., Rizvi, S.I.A. and Jagirdar, S.A.P. (1985). Effect of various NPK doses on the growth and production of Basrai banana. Pakistan J. Agric. Res. 6(3): 183-186.

Sheela, V.L. (1982). Potassium nutrition in rainfed banana. Musa (AAB group) 'Palayankodan'. M. Sc.(Hort.) thesis. Kerala Agricultural University, Trichur.

Simmonds, N. . (1959). Bananas. Longman London I Edn. pp. 232-266.

Singh, U.R., Khan, A. and Singh, G. (1977). Effect of NPK fertilization on growth yield and quality of banana Cv. Basrai Dwarf. Punjab Hort. J. 27 (1 and 2): 64-69.

Singh, S. and Ram, P. (1977). Changes in solubility of phosphorus and it's availability to rice plant in the waterlogged soils. J. Indian Soc. Soil Sci. 25: 129-133.

Singh, S. and Singh, S.B. (1976). Effect of waterlogging and organic matter on inorganic phosphorus fractions of soils. J. Indian Soc. Soil Sci. 24: 88-90.

Singh, L., Verma, R.N. and Lohja, S. . (1980). Effect of continuous application of farmyard manure and chemical fertilizer on some soil properties. J. Indian Soc. Soil Sci. 28: 170-172.

Sood, K.D. and Minhas, R.S. (1989). Studies on the mineralisation of organic phosphorus in some soils of Himachal Pradesh. J. Indian Soc. Soil Sci. 37: 29-34.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for estimation of available nitrogen in soils. Curr. Sci. 25: 259-260.

* Summerville, W.A.T. (1944). Studies on nutrition as qualified by development in Musa Cavendishii Lambert. Qd. J. agric. Sci. 1: 1-27.

Sundar Singh, S. (1972). Studies on the effect of nitrogen potash on Robusta banana (Musa cavendishii). M.Sc. (Ag.) Diss. Annamalai University, Annamalainagar.

Talashilkar, S.C. and Patil, M.D. (1979). Effect of organic matter on the availability of phosphorus from single superphosphate and rockphosphate in a submerged soil. J. Indian Soc. Soil Sci. 27(2): 201-202.

Tandon, H.L.S. (1976). Phosphorus in Indian Agriculture. Tech. Bull. RNSP. pp. 62.

Tandon, H.L.S. (1987). Phosphorus Research and Agricultural Production in India. Fertilizer development and consultation organization, New Delhi.

Teaotia, S.S., Tripathi, R.S. and Gangwar, B.M. (1972). Effect of irrigation and fertilizer levels on growth yield and quality of banana (Musa cavendishii). Progve. Hort. 3: 57-63.

Tomar, N.K., Sharma, A.K. and Gupta, A.P. (1987). Effect of pyrites on the transformation of Rockphosphate and Triple superphosphate during decomposition of cattle dung. J. Indian Soc. Soil Sci. 35(2): 244-246.

* Turner, D.W. (1969). Research into fertilizer for banana. Agric. Gaz. N.S.W. 33(7): 19-20.

Turner, D.W. (1980). Some factors related to yield components of bananas in relation to sampling to assess nutrient status. Fruits 35(1): 19-23.

Turner, D.W. and Bull, J.H. (1970). Some fertilizer problems with banana. Agric. Gaz. 81: 365-367.

Twyford, I.T. and Walmsley, D. (1973). The mineral composition of the Robusta banana plant. 1. Methods and plant growth studies. Plant and Soil: 227-243.

Vadivel, E. (1976). Studies on the growth and development of Musa (AAA group, Cavendish subgroup) 'Robusta' in relation to potassium nutrition. M.Sc.(Ag.) thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Valsamma Mathew (1980). Nitrogen nutrition in rainfed banana cv 'Palayankodan'. M.Sc.(Hort.) thesis submitted to Kerala Agricultural University, Trichur.

Veerannah, L., Selvaraj, P. and Alagiamanavalan, R.S. (1976). Studies of nutrient uptake in Robusta and Poovan. Indian J. Hort. 33(3 & 4).

Veeraraghavan, P.G. (1972). Manurial cum liming experiments on Nendran banana. Agric. Res. J. Kerala 10(2): 116-118.

Venkatarayappa, T., Narasimhan, B. and Venkatesan, C. (1978). Banana fruit development and composition as influenced by potassium dihydrogen phosphate. Progve. Hort. 10(3): 5-13.

Vijayaraghavakumar, George, K.C. and Nair, N.K. (1984). Statistical analysis of the influence of biometric characters on yield in some culinary varieties of banana. Agric. Res. J. Kerala, 22(1): 67-72.

Vyas, M.K. and Motiramani, D.P. (1971). Effect of organic matter silicates and moisture levels on availability of phosphate. J. Indian Soc. Soil Sci. 19: 39-43.

Wright, C. and Harold (1939). Soil Analysis. Thomas Murby and Co., 1 Fleet Lane, E.C.-4, London.

Yadav, V.B. and Mistry, K.B. (1984). Reaction products of triammonium pyrophosphates in different Indian soils. Fertilizer Research 5: 423-434.

* Original not seen

APPENDICES

Appendix

Weather data during the cropping period from May 1988 - May 1989

Month	Temperature				Rainfall (cm)	
	Maximum		Minimum			
	Locations		Locations		Locations	
	Vellayani	Kattakada	Vellayani	Kattakada	Vellayani	Kattakada
May	31.67	32.30	24.39	24.00	-	17.00
June	30.06	31.57	23.81	24.05	13.3	17.78
July	31.70	32.59	23.53	23.40	14.62	25.1
August	30.57	31.50	23.49	23.60	9.2	20.0
September	29.82	31.00	23.59	24.50	18.86	23.0
October	31.69	31.00	24.09	23.00	11.6	17.1
November	31.04	32.50	22.96	21.20	7.16	15.5
December	31.77	31.00	22.28	23.50	6.4	12.1
January	31.71	30.50	21.83	24.04	2.2	4.0
February	31.8	32.75	18.46	23.00	-	-
March	33.42	31.33	26.66	24.38	10.83	13.75
April	33.21	31.51	24.84	25.00	16.15	11.2
May	31.6	32.27	23.44	22.50	9.03	13.3

COMPARATIVE EFFICIENCY OF DIFFERENT PHOSPHATIC FERTILIZERS IN RAINFED NENDRAN BANANA

BY

SHEEJA V. G.

ABSTRACT OF A THESIS
SUBMITTED TO PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE
MASTER OF SCIENCE IN AGRICULTURE
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
VELLAYANI THIRUVANANTHAPURAM

1990

ABSTRACT

Though phosphorus is one of the key nutrients for plant growth, the consumption rate of phosphatic fertilizers in India is found to be comparatively low. The escalating cost of the imported raw material used for the manufacture of P fertilizers may be one of the possible reasons for the low intake. In this regard, the direct application of cheap native ground rockphosphate as a P source is a fruitful attempt especially in acid soils. The present investigation was conducted to compare the efficiency of different phosphatic fertilizers including rockphosphates in upland soils with 'Nendran' variety of banana as the test crop. The present study comprises of two aspects, field experiment and laboratory incubation study. The field experiment was conducted at two locations, viz. at the Instructional Farm attached to College of Agriculture, Vellayani and at Kattakada, in the cultivator's field. The experiment was laid out in randomised block design with four treatments and five replications. The laboratory study was carried out in the soil, treated with different phosphatic fertilizers after incubation with organic matter under moist conditions to assess the influence of organic matter on the release of P from different P sources.

The growth characters of banana plant such as height and girth of pseudostem, number of photosynthetically active leaves, leaf area and period taken for flowering were recorded and analysed upto shooting stage of the crop. The bunch characters like weight of bunch, length of bunch, number of fingers and hands bunch^{-1}, and length and girth of finger were also recorded and analysed. Phosphorus application significantly influenced biometric characters of the crop while the differences between the various P sources were not statistically significant. In most of the growth and yield characters, comparatively higher efficiency was shown by plants treated with superphosphate, eventhough, it was statistically on par with the other sources in both locations. Thus, it indicates the possibility of using cheaper rockphosphates for meeting the phosphorus requirement of banana in upland soils of Kerala, rather than going in for the costly superphosphate.

The effect of treatments on the drymatter production was significant at both locations. Phosphorus application significantly increased the P uptake. However the different P sources could not produce significant variation in the uptake of phosphorus in both locations. The phosphorus content in the leaf was found to be maximum from the late vegetative phase to shooting period of the plant growth.

With respect to available and total P_2O_5 content in the soil, the differences between the various sources were not statistically significant though, addition of phosphorus increased the available as well as total P_2O_5 content of soil significantly over no P treatment. A significant positive correlation existed between the leaf P content and total P uptake. Similarly a significant positive correlation between yield as well as total drymatter content with P uptake was observed.

The incubation study revealed that organic matter produced significant effect on the release of phosphorus from different P sources added to the soil under moist conditions. Upto 90 days of incubation, increased availability of phosphorus was recorded in all treatments, and the trend continued till 135 days. A gradual decline in the concentration of available P was noticed thereafter. However, a favourable influence of organic matter on the release of P from different sources has been brought out from this study. When the mean values of available P over all the periods were compared, maximum availability was recorded by soils incubated with organic matter and superphosphate. In general, various sources of P behaved similarly and were on par with respect to the release of phosphorus due to organic matter incubation.