EFFECTS OF GRADED DOSES OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE GROWTH AND LEAF NUTRIENT STATUS IN COCOA (*Theobroma cacao* L.)

BY

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THESIS

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D E C L A R A T I O N

I hereby declare that this thesis entitled "Effects of graded doses of nitrogen, phosphorus and potassium on the growth and leaf nutrient status in cocoa (Theobroma cacao L.)" is a bonafide record of research work done by me during the course of research work and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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C E R T I F I C A T E

Certified that this thesis entitled "Effects of graded doses of nitrogen, phosphorus and potassium on the growth and leaf nutrient status in cocoa (Theobroma cacao L.)" is a record of research work done independently by Kum. Salikutty Joseph under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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C E R T I F I C A T E

We, the undersigned members of the Advisory Committee of Kum. Salikutty Joseph a candidate for the degree of Master of Science in Horticulture with major in Horticulture agree that the thesis entitled "Effects of graded doses of nitrogen, phosphorus and potassium on the growth and leaf nutrient status in cocoa (Theobroma cacao L.)" may be submitted by Kum. Salikutty Joseph in partial fulfilment of the requirements for the degree.

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Introduction

I N T R O D U C T I O N

Cocoa is one of the most important beverage crops of the world and it is next only to tea and coffee. Though cocoa has been introduced to India about fifty years back, its commercial importance has been felt only during the last six years because of its heavy demand in the world market and consequent increase in prices. The cocoa of commerce is the fermented and dried beans. Though cocoa deserves national importance in terms of foreign exchange earnings, research efforts on this crop remains very much limited in India.

Cocoa is a fast growing and quick yielding crop. The nursery life of cocoa is four to six months. Such a crop, which has a short nursery life and a comparatively short juvenile period (1½ to 2 years) has to be nourished properly in the nursery. However, no attempt has been made in India to assess the nutritional requirement of cocoa in the nursery.

There is also scope for standardising tissue analysis technique for this crop as a guide to nutrient deficiency diagnosis. Though soil tests would throw light on the available nutrient status of the soil, foliar diagnosis technique has often proved better in as much as it represents the amount of nutrient absorbed by the plant. Standardisation of a representative leaf suitable for this purpose thus becomes a prerequisite.

The present investigations were therefore undertaken with the following objectives:

i) To study the effect of graded doses of nitrogen, phosphorus and potassium on the growth and uptake of these nutrients by cocoa in the nursery.

ii) To standardise the diagnostic leaf for cocoa seedlings.

iii) To study the relationships among the available soil nutrients, foliar nutrient levels and plant growth.

Review of Literature

2. REVIEW OF LITERATURE

Literature relating to the nutrition of cocoa is not voluminous. Much of the work done in this aspect has been in major cocoa producing countries like Ghana, Nigeria and Trinidad. The available literature on cocoa nutrition and other aspects related to the present study has been reviewed in this section.

2.1. Growth and yield vis a vis NPK fertilisation.

De Amorim *et al.* (1964) found that the dry weight of leaf and stem in cocoa seedlings increased with increasing levels of applied nitrogen, while the dry weight of roots decreased with increasing phosphorus and potassium levels. Thus dry matter production was found to be directly related to leaf nitrogen content. In another experiment with cocoa seedlings involving five nitrogen levels and five calcium levels in all combinations, Lockard and Asomaning (1964) observed that the total dry weight of the plant was not appreciably influenced by nitrogen application, until four months after sowing. After eight months of growth, dry weight was found to rise rapidly with increasing levels of nitrogen. According to Saenz and Romer (1966), nitrogen had a more significant effect than potassium on the growth of cocoa plants. Phosphorus did not have any effect on the fresh weight of the plant.

None of the nitrogen, phosphorus and potassium interactions was found to be statistically significant. From the results of a pot trial, Asomaning and Kwaka (1968) suggested that the potassium requirements of two cocoa varieties namely, Amelonado, Nanay (Amazon) were quite different. Total dry weights of Nanay plants were found to be higher than those of the Amelonado plants from the sixth week onwards. Okali and Owusu (1975) reported that cocoa seedlings under sand culture with medium shade and highest nutrient level had maximum relative growth rate.

In the Ivory Coast, Verliere (1965) obtained highly significant correlations between the cocoa yield on the one hand and calcium content, N/P and Ca/K ratios in the leaf on the other. He also reported that application of phosphorus and potassium had a significant positive effect on yield of cocoa and there was a synergistic interaction between them. Phosphorus in combination with potassium increased the yield considerably and profits of over 800% of fertiliser costs were recorded. However, Benac (1965) observed no difference in yield between fertiliser treatments in a similar study. Ahenkorah and Akrofi (1968) reported that the K and PK fertiliser effects were highly significant. Fertiliser brought about a 10% increase in yield. The unshaded cocoa recorded almost double the yield of those under heavy shade. Plants receiving no shade with PK treatment produced the highest yield, followed by plants receiving medium shade with PK treatment. The effect of potassium alone was also pronounced in the absence of shade. According to Benac and De Jardin (1970), low yielding cocoa trees were benefited from the application of nitrogen and phosphorus, whereas potassium had a depressing effect. On the contrary, high yielders benefitted from potassium in combination with phosphorus. In Bahia, Rosand et al. (1978) found a highly significant increase in productivity due to phosphorus. The beneficial effect of nitrogen was noted in only two out of four years. There was no response to potassium application. In another study conducted at Bahia, Morais et al. (1978) reported a significant response of young cocoa trees to phosphorus and nitrogen which reflected in an appreciable increase in yield. However, in this study also potassium had no effect on yield. Poeloengam (1978) found that nitrogen and magnesium had little effect on yield of young cocoa trees; but phosphorus increased dry bean weight per tree.

2.2. Uptake of nutrients.

Hardy et al. (1935) reported the effects of manurial treatments on foliar composition in cocoa. Potash manuring increased the total ash, while the total nitrogen and phosphate contents were decreased. The nitrogen/potash ratio decreased while the potash/phosphate ratio increased. Nitrogen or phosphate manuring alone had no significant effect on leaf composition. However, nitrogen with potash, and phosphorus with potash significantly increased the potash content of leaves. They concluded that nitrogen and phosphorus manuring changed the nutrient ratios in the leaf and apparently produced nutrient imbalance. Burridge <u>et al</u>. (1963) remarked that fertilising with NP would increase the cocoa's need for potassium. Lockard and Asomaning (1964) reported that raising the nitrogen concentrations in nutrient solutions applied to cocoa seedlings, resulted in increased leaf nitrogen and decreased leaf potassium. De Amorim <u>et al</u>. (1964) observed that the nitrogen, phosphorus and potassium contents of leaves of cocoa responded positively to the concentration of these elements in the nutrient solution. Leaf N also increased with increasing P levels. The leaf nutrient ratios such as N/P and K/P decreased when K and N respectively, were absent or in excess in the solution. The N/K ratio increased with increasing phosphorus in the solution. The nitrogen levels in both upper and lower leaves were nearly equal. The upper leaves were richer in phosphorus and potassium than the lower ones. According to Wessel (1965), nitrogen fertilisation increased the nitrogen level of cocoa leaves; but both nitrogen and potassium fertilizers decreased the phosphorus content. He further reported that wider spacing lowered the levels of potassium and phosphorus. Verliere (1965) reported a highly significant negative interaction between nitrogen, phosphorus and potassium in cocoa. Verliere (1969) observed that the mean annual values of foliar nitrogen throughout the period of four years were remarkably constant and reached a maximum at the onset of rainy season. Foliar nitrogen increased in response to nitrogen fertiliser applications; but phosphorus application had a gradually increasing depressive effect on foliar nitrogen. Correlations between nitrogen and phosphorus were generally positive; but rarely significant. Foliar phosphorus was greater in leaves taken from plots which were fertilized with phosphorus. Santana and Igue (1979) reported that nitrogen and potassium levels in the plant tended to increase with fertilisation.

2.3. Foliar diagnosis and soil testing.

2.3.1. Trunk girth as a calibrating variate for field experiments:

The variability in trees derived from seeds is so much that it is almost impossible to conduct a field experiment without previously calibrating the trees. It is possible to reduce the variability of yield by eliminating the effects of initial variation. The usual calibrating variates are yield over an approximate period or some measure of size, most frequently trunk girth, where this could be easily recorded.

Glendinning (1960) reported that correlations existed between the rate of growth of cocoa before bearing and the total yield upto five years age. The faster growing varieties reached bearing size earlier and did not give a relationship between growth rate and long term yield. With the commencement of bearing, vegetative growth slowed down when a high correlation existed between reduction in growth rate and total yield. He found that under West African conditions a cocoa plant attained a diameter of atleast six cm. before flowering and in Atlantic Costa Rica conditions, production began with 5 cm diameter. Enriques et al. (1962) analysed several characteristics in a cocoa hybrid trial and concluded that there was no correlation between precocity measured by the total production of beans per plot and vigour expressed as trunk diameter and height of two year old plants. Longworth and Freeman (1963) reported that in cocoa, correlations between trunk girth and yield tended to decrease with age, while it was not so for correlations between yields in successive periods. Several other studies (Glendinning, 1960; Soria, 1964; Mariano, 1966) had clearly indicated the high positive relationship between quick growth and yield. Glendinning (1966) reported that once the varieties were well into bearing, differences in their trunk diameter had little effect. The relationship between yield and diameter increment while bearing, generally appeared to be negative indicating that yield was being obtained at the expense of current growth. Trials with older trees proved that the trunk diameter growth finally slowed down and came almost to a standstill. Yield was then very closely associated with pre-bearing growth rate, which in effect was the same as the degree of reduction in growth rate. In his attempt to determine a numerical relationship between stem diameter and yield he found that the relationship between these two parameters was not consistent under varying conditions. Nya-Nyatchou and Lotode (1967) found highly significant correlation between trunk diameter at 20 cm from the ground level and precocity. The highest correlations were found at 22 months of age.

2.3.2. Leaf sampling and foliar diagnosis:

Foliar analysis is now widely accepted as a useful technique for diagnosing the fertilizer requirements of many plants. The term 'Diagnostic Foliaire' was first used in France by Lagatu and Maume (1926). The concept of tissue analysis as a diagnostic technique for mineral deficiencies in plants was given a rational and scientific footing by these Scientists.

In Trinidad, Hardy *et al.* (1935) used cocoa leaves from terminal shoots 'which had just hardened and were turning green' for chemical analysis. Using the analytical values obtained for the different fertilizer plots, they found a close relationship between leaf nutrient composition and yield. They expressed the results as ratios and gave the optimum ratios as (1) $N/P_2O_5 = 4.66$ (2) $N/K_2O = 0.89$ and (3) $K_2O/P_2O_5 = 5.21$. They reported that high yields were associated with these values of the ratios and that departures from these values resulted in lower yields. Later, Murray (1953) while showing the effect of shade on levels of nutrients, found that Hardy's 'ideal' values for the ratios did not apply on other sites. Machicado and Havord (1958) applied the leaf analysis technique in Costa Rica; but ran into problems of non-uniformity in samples and seasonal variation. In a fertilizer trial conducted at River Estate, Maliphant (1959) demonstrated the difference in leaf analysis values, due to season and shade. Loue (1962) carried out leaf analysis of cocoa in the Ivory Coast and showed widespread deficiencies of phosphorus and potassium in the field. Chapman (1964) suggested to use 2nd or 3rd fully green leaf below the apex of shoot in cocoa for sampling. Acquaye (1964) reported that the age, size and position of leaf with respect to light and sampling time affected the concentrations of N, P, K, Ca and Mg in the cocoa leaves. In Ghana, Burridge _et al_. (1964), sampling every four weeks, have recorded the changes in nutrients with season. They drew attention to the fall in N and P in the leaves when the crop was developing. The lowest concentrations of nitrogen, phosphorus and potassium were found in the leaves collected during the peak of the main season harvest. The highest levels of these elements were found in leaves collected near the end or a few weeks after the end of the main harvest. Shade increased the levels of nitrogen, phosphorus and potassium. Fertiliser increased the levels of nitrogen and phosphorus; but decreased the levels of potassium in the leaves. The effect of irrigation was small; but it decreased the levels of nitrogen and potassium in the leaves. In Ivory Coast, Verliere (1965) reported that the level of nutrients in cocoa leaves were influenced by the period of sampling; the most suitable period being August-October, when the trees were bearing the most fruits. Murray (1966) opined that it would seem unlikely that with any other crop, the results of fertiliser experiments would be so unsatisfactory or so unpredictable as with cocoa. He gave the following as the normal levels in the leaf, low levels where growth was affected but visual symptoms did not appear and deficient levels where visual symptoms were seen.

Nutrient	% in leaves classified as		
	Deficient	Low	Normal
N	1.80	1.80-2.00	2.00
P	0.13	0.13-0.20	0.20
K	1.20	1.20-2.00	2.00
Ca	0.30	0.30-0.40	0.40
Mg	0.20	0.20-0.45	0.45

Smyth (1966) pointed out that there is no satisfactory substitute for field experimentation to determine the fertiliser requirements of cocoa. Murray (1967) in his work entitled 'leaf analysis applied to cocoa' summarised the problems involved in leaf analysis. There was difficulty in getting leaves of the same age trees growing under similar light intensities. With the habit of leaf production by flushing, the choice of leaves of same age was not easy. In the young fully expanded leaf, the levels of N, P and K were normally high and they decreased with increasing age. Trees growing under otherwise comparable conditions showed higher levels of nutrients in their leaves under heavy shade as compared with trees growing under light shade or no shade. He further stated that despite the work that has been done, the technique is still of only limited value in planning fertiliser usage in cocoa. If a marked deficiency existed, the low levels in the leaf would override problems of sampling and indicate the type of fertiliser required to correct the deficiency. In the more normal range, however, the technique lacked precision. He concluded that, as with soil analysis, leaf analysis is not the final answer in determining the nutrient requirement of cocoa.

Verliere (1969) stated that the mean annual values of foliar nitrogen throughout the period of four year study were remarkably constant and reached a maximum at the onset of rainy season. Large seasonal variations were recorded for foliar K. Morais <u>et al</u>. (1978) remarked that foliar analysis in cocoa leads to variable results depending on leaf age, position and method of sampling. Santara and Igue (1979) pointed out that leaf nitrogen and potassium tended to decrease with leaf age. Leaf nitrogen was found to increase with shading. Little seasonal variation was observed for the macro nutrients except potassium which decreased at the flushing period.

2.3.3. <u>Soil-plant nutrient relationship</u>:

Hardy <u>et al</u>. (1935) stated that the relationships that existed between the plant and its environment were not simple and factors other than nutrient supply may affect the growth and composition of the plant. Thus a nutrient supply adequate for one level of water supply might be quite inadequate for another and the same may hold true for other growth conditions also. Schroo (1960) made an attempt to compare the results of soil analysis with those obtained from leaf analysis as a guide to the nutritional demands of young cocoa. The closest agreement was found for phosphorus and magnesium. Agreement for nitrogen, potassium and calcium was less satisfactory. Hence, leaf analysis has been recommended as a complementary method. While experimenting with four-year old cocoa plants, Acquaye et al. (1965) observed positive correlation between soil exchangeable K and leaf K. Wessel (1970) reported that the nitrogen content of soils was of no indication as to the nitrogen availability to cocoa and that the leaf data for nitrogen can only be used in detecting the deficiency of this element in the soil. But a positive relationship existed between soil and leaf phosphorus. He concluded that soil and leaf analyses are of limited value for assessing the nitrogen requirements of cocoa; but can fairly accurately determine the phosphorus requirements of the crop.

Materials and Methods

3. MATERIALS AND METHODS

The studies reported herein were conducted at the College of Horticulture (Department of Plantation Crops and Spices), Vellanikkara, Trichur during 1979-80. A pot culture experiment was conducted to study the effects of graded doses of nitrogen, phosphorus and potassium on the growth of cocoa seedlings in the nursery. The same experimental material was used for developing a leaf sampling technique for cocoa seedlings. In another experiment, field grown young cocoa plants were used for examining the relationships of available soil nutrients with plant growth and foliar nutrient levels.

3.1. Pot culture experiment.

3.1.1. Potting mixture:

The seedlings were grown in polythene bags (30 x 20 cm size and 150 gauge thickness) using potting mixture as the growth medium. Potting mixture consisted of dried powdered cowdung, sand and soil mixed in equal proportions. The chemical analysis of this mixture showed N-0.252%, P-0.0025% and K-0.07%. Three kilograms of this potting mixture were weighed into each polythene bag and kept ready for sowing the cocoa beans.

3.1.2. Seeds and sowing:

Uniformly sized, well ripe pods were collected from five-year old plants bearing 50-60 pods per year. Pods were broken on the same day of harvest and the beans from the middle portion alone were selected for sowing. One seed each was sown flat 1.0 cm below the soil surface in polythene bags on 17th May, 1979. After sowing, pots were kept under a thatched bamboo shed to avoid direct sunlight.

3.1.3. Experimental design and layout:

Fertilizer treatments were given when the seedlings were 120 days old. The treatments consisted of factorial combinations of nitrogen (N_0 - 75 kg N/ha, N_1- 100 kg N/ha, N_2- 125 kg N/ha)*, Phosphorus (P_0- 30 kg P_2O_5/ha, P_1- 40 kg P_2O_5/ha, P_2- 50 kg P_2O_5/ha)*, potassium (K_0- 105 kg K_2O/ha, K_1- 140 kg K_2O/ha, K_2- 175 kg K_2O/ha)*. An absolute control with no fertilizer was also included in the experiment for comparison. Thus, there were 28 (27+1) treatments. The experiment was laid out in completely randomised design with two replications. There were 27 plants receiving each treatment in each replication.

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* Only one-third of the adult doses were given to the seedlings. The actual quantity was calculated at the above rate for three kilogram of potting mixture.

Urea (46% N), superphosphate (18% P_2O_5) and muriate of potash (60% K_2O) were used as sources of nitrogen, phosphorus and potassium respectively. The fertilizers were dissolved in water prior to application.

3.1.4. Growth measurements:

The following observations on various growth characteristics of the seedlings were recorded at monthly intervals starting from the day of fertilizer application (120 days after sowing) to 240th day of growth.

Height: Height of the plant was measured from the base of the stem to the tip of the growing bud.

Girth: Girth of the plant at the collar region was measured.

Number of leaves: The total number of fully opened, functional leaves present at the time of observation was recorded.

3.1.5. Dry matter production and nutrient uptake:

To assess the dry matter production and nutrient uptake, plants were removed at monthly intervals from the fourth month after sowing (i.e. one month after fertilizer application) upto the eighth month. From each replication, three plants per treatment were uprooted. The leaves and stems were cleaned off the dust with a damp cloth. The roots were cleaned first under the tap and then with distilled water to remove all the adhering soil particles. Care was taken to avoid any loss of root material. Leaf, stem and root were then separated. Each portion was pooled and dried separately in an air oven at 70-75°C for 48 hours and weighed. The total dry matter content of the plant was then worked out.

The dried leaf, stem and root were then ground in a Wiley mill separately and stored in polythene bottles. Samples from these powdered materials were taken for the determination of nitrogen, phosphorus and potassium. The total quantity of a nutrient in a plant organ was calculated from the values of dry matter and concentration of that nutrient in that organ. Total uptake of a nutrient was arrived at by adding up the quantities of that nutrient in the leaf, stem and root.

3.1.6. <u>Standardisation of leaf sampling technique</u>:

For this purpose, leaves were collected from three plants per treatment per replication at 180 and 210 days of growth. The leaves were numbered downwards starting from the first fully opened one. The leaf ranks 1, 2, 3, 4 and 5 were collected from the three plants and pooled separately. The leaves were dried at 70-75°C and powdered prior to chemical analysis.

3.2. Studies with field-grown cocoa.

This study was conducted to evaluate the relationships between soil test values and leaf nutrient concentration and plant growth. Plants from an existing field trial started in 1976 to study the optimum spacing and fertilizer requirement of cocoa were utilised for this study.

3.2.1. Selection of plants:

Thirtyfive plants receiving varying levels of nitrogen, phosphorus and potassium were selected in order to obtain good variation in soil and plant nutrient contents. The girth of the trunk of these plants at 20 cm above the ground level was then measured. This measurement was taken as an index of plant growth.

3.2.2. Leaf sampling:

Second and third mature leaves were collected from fans and chupons of these plants. Ten leaves each from fans and chupons were collected from each plant and comp sited separately. The leaves were dried at 70-75°C in an air oven for 48 hours, powdered and stored in polythene bottles awaiting analysis.

3.2.3. Soil sampling:

Soil sampling was done at three points at 45 cm radius from the base of each plant. At these points, samples were collected from 0-15, 15-30 and 30-45 cm depths. The samples for each depth were then composited. Soil and leaf samples were collected on 17th May, 1980 before the application of fertilisers.

3.3. Analytical methods.

3.3.1. Plant analysis:

Nitrogen: Nitrogen content was estimated by microKjeldahl digestion distillation method (A.O.A.C.,1960). Plant sample weighing 0.1 g was digested with 15 ml of concentrated sulphuric acid and about one gram digestion accelerators (1:10 $CuSO_4$ and K_2SO_4). The digest was made upto 100 ml with distilled water. An aliquot of this solution was steam distilled and the ammonia evolved was absorbed in 4% boric acid (pH 4.2) containing bromocresol green (0.5%)-methyl red (0.1%) indicator. When distillation was complete after 10 minutes, the absorbed ammonia was neutralised by titration with standard sulphuric acid.

Phosphorus and potassium: For the determination of phosphorus and potassium, 1.0 g of the ground sample was digested in 15 ml of an acid mixture containing perchlorio (60%), sulphuric (concentrated) and nitric (concentrated) acids in the ratio of 1:2:9. The volume of the digest was made upto 100 ml with distilled water.

Phosphorus was determined in an aliquot of this extract by vanadomolybdo-phosphoric yellow colour method (Jackson, 1973). To 5.0 ml of the digest, 5.0 ml of vanadomolybdate reagent was added for the development of yellow colour. The solution was then diluted to 25 ml and the concentration of phosphorus was measured directly at 470 nm using a "Perkin Elmer uv-vis microprocessor controlled recording spectrophotometer".

Potassium in the triple acid digest of the sample was determined flame photometrically (Jackson, 1973) using an EEL flame photometer.

3.3.2. Soil analysis:

Total nitrogen was determined by Kjeldahl digestion-distillation method (Jackson, 1973).

Available phosphorus was extracted using Bray No.1 reagent (0.03 N NH_4F in 0.025 N HCl) and phosphorus in the extract was estimated by the chlorostannous reduced molybdo phosphoric blue colour method (Jackson, 1973).

Available potassium extracted by 1 N neutral ammonium acetate was determined flame photometrically (Jackson, 1973).

3.3.3. Statistical analysis:

The data from these studies were subjected to statistical analysis by standard methods.

Results and Discussion

4. RESULTS AND DISCUSSION

The effects of graded doses of nitrogen, phosphorus and potassium on the growth of cocoa seedlings in the nursery were investigated in a pot culture experiment. The levels of nitrogen were N_0-75 kg N/ha, N_1-100 kg N/ha and N_2-125 kg N/ha while those of phosphorus were P_0- 30 kg P_2O_5/ha, P_1- 40 kg P_2O_5/ha and P_2- 50 kg P_2O_5/ha. In the case of potassium the levels were K_0- 105 kg K_2O/ha, K_1- 140 kg K_2O/ha and K_2- 175 kg K_2O/ha. The results obtained from the experiment are discussed hereunder.

4.1. Effects of NPK fertilisation on the growth characters and dry matter production.

The data relating to the height of plants as influenced by NPK levels at various stages of growth are presented in Table 1 and the analysis of variance in Appendix I. As could be observed from the Table, there was no significant difference in the height of plants receiving various treatments. However, NP interaction and NK interaction were found to be significant during the first and the second months respectively. There was a progressive increase in the height of the plants with increasing period of crop growth.

Table 1. Effect of NPK treatments on height of cocoa seedlings

Treatments	Height (cm)				
	Stage of growth (months)				
	1	2	3	4	5
Control	26.41	32.71	39.04	43.19	46.98
N_0	28.64	34.01	39.70	43.12	48.47
N_1	28.71	33.77	38.90	43.03	48.44
N_2	28.67	33.16	39.32	43.21	47.61
CD	-	-	-	-	-
P_0	29.44	35.71	41.65	45.63	50.84
P_1	27.81	32.40	38.53	42.79	47.87
P_2	28.76	32.37	37.75	40.96	45.83
CD	-	-	-	-	-
K_0	29.79	34.51	40.03	43.81	48.73
K_1	28.97	33.95	39.66	43.41	48.61
K_2	27.27	32.47	38.25	42.17	47.19
CD	-	-	-	-	-

Table 2 presents mean girth of plants as influenced by NPK treatments. The analysis of variance is given in Appendix II. As in the case of height, no significant differences were observed in girth of the plants due to graded levels of N, P and K. However, during the first month of growth, P_1 and P_2 treatments tended to dácrease the girth of the plants as compared to P_0 level. The control plants seemed to be better in girth than those receiving fertilisers.

Table 3 presents the mean values of number of leaves of plants as influenced by NPK treatments. The analysis of variance is given in Appendix III. It can be seen that the leaf production was not influenced by the treatments. Plants kept as control were found to be more healthy and vigorous and possessed more number of leaves.

The data relating to total dry matter production as influenced by graded doses of nitrogen, phosphorus and potassium at various stages of growth are presented in Table 4 and the analysis of variance in Appendix IV. The statistical analysis showed that dry matter production was not influenced by the treatments. However, during the third sampling, the effects of P_2 and P_0 were on par; but both were significantly superior to P_1.

Table 2. Effect of NPK treatments on girth of cocoa seedlings

	Girth (cm)				
Treatments	Stage of growth (months)				
	1	2	3	4	5
Control	2.16	2.38	2.69	2.80	2.84
N_0	2.22	2.39	2.66	2.79	2.87
N_1	2.19	2.35	2.67	2.82	2.89
N_2	2.22	2.30	2.67	2.80	2.90
CD	-	-	-	-	-
P_0	2.30	2.43	2.75	2.58	2.96
P_1	2.13	2.34	2.63	2.79	2.88
P_2	2.20	2.36	2.62	2.74	2.82
CD	0.128	-	-	-	-
K_0	2.26	2.42	2.72	2.86	2.94
K_1	2.20	2.36	2.63	2.79	2.88
K_2	2.18	2.36	2.65	2.76	2.84
CD	-	-	-	-	-

Table 3. Effect of NPK treatments on leaf production in cocoa seedlings

Treatments	Number of leaves: Stage of growth (months) 1	2	3	4	5
Control	13.50	17.00	22.50	25.50	28.50
N_0	13.16	15.50	18.00	20.00	22.78
N_1	13.11	15.67	18.00	20.50	23.17
N_2	12.77	15.33	18.17	20.27	23.11
CD	-	-	-	-	-
P_0	13.83	16.17	19.06	21.28	23.94
P_1	12.66	15.00	17.39	19.89	22.72
P_2	13.06	15.33	17.72	19.61	22.38
CD	-	-	-	-	-
K_0	13.56	15.94	18.50	20.72	23.44
K_1	13.33	16.00	18.39	20.50	23.11
K_2	12.17	14.56	17.28	19.56	22.50
CD	-	-	-	-	-

Table 4. Effect of NPK treatments on dry matter production in cocoa seedlings

Treatments	Total dry matter (g/plant)				
	Stage of growth (months)				
	1	2	3	4	5
Control	3.88	6.11	9.40	11.80	15.24
N_0	3.51	5.61	8.21	10.72	14.61
N_1	3.32	4.90	7.99	10.58	14.93
N_2	2.99	5.17	8.11	10.66	13.94
CD	-	-	-	-	-
P_0	3.34	5.76	8.42	11.26	15.70
P_1	3.27	4.79	7.34	10.18	14.29
P_2	3.21	5.13	8.54	10.53	13.48
CD	-	-	1.02	-	-
K_0	2.94	5.42	8.34	10.75	14.73
K_1	3.09	4.80	7.82	10.82	14.89
K_2	3.79	5.46	8.15	10.40	13.85
CD	-	-	-	-	-

From the foregoing, it is apparent that fertilisation during the seedling stage has no effect on the growth of cocoa plants. No regular trends in the effects of various levels of nitrogen, phosphorus and potassium on growth parameters such as height, girth of the plants, number of leaves and dry matter production were observed. The fact that with regard to growth, control plants were either at par or better than those receiving NPK fertilisers implies that addition of fertilisers to the seedlings is not necessary.

4.2. Effect of NPK treatments and period of growth on the nitrogen content of cocoa seedlings.

The data on the concentration of nitrogen in the leaves are furnished in Table 5. The analysis of variance is given in Appendix V.

The results show that the application of nitrogen had no effect on the nitrogen content of leaves, while the effect of phosphorus on the leaf nitrogen content during third month was significant. The nitrogen content of the leaves of plants receiving phosphorus at P_1 and P_2 levels were on par. The P_1 plants contained 2.97% of nitrogen in their leaves while P_2 plants had 2.92% of nitrogen. These values were found to be significantly higher than the

Table 5. Effect of NPK treatments on foliar nitrogen content of cocoa seedlings

Treatments	Nitrogen in leaf (%) Stage of growth (months)				
	1	2	3	4	5
Control	3.03	2.66	2.87	3.15	3.01
N_0	3.10	2.85	2.85	2.88	2.89
N_1	3.20	2.83	2.85	2.87	2.75
N_2	3.30	2.86	2.96	2.92	2.88
CD	-	-	-	-	-
P_0	3.17	2.89	2.77	2.86	2.78
P_1	3.22	2.79	2.97	2.90	2.92
P_2	3.20	2.87	2.92	2.91	2.82
CD	-	-	0.122	-	-
K_0	3.17	2.88	2.84	2.80	2.81
K_1	3.22	2.80	2.89	2.92	2.87
K_2	3.20	2.87	2.93	2.95	2.84
CD	-	-	-	0.119	-

nitrogen concentration in the leaves of P_0 plants which was 2.77%. A similar observation was made for leaf nitrogen content of plants receiving potassium at varying levels during the fourth month. The nitrogen content of leaves of plants receiving potassium at K_1 and K_2 levels were on par. However, nitrogen content of K_0 plants was significantly lower. For K_2 and K_1 treatments, the concentration of nitrogen in leaf was 2.95% and 2.92% respectively and for K_0 it was 2.80%. During the fourth month, the control plants were found to have a significantl higher nitrogen content in their leaves than plants of all the other treatment combinations. With age, the nitrogen content of leaves decreased from 3.20% at the first month to 2.85% at the 2nd month. Thereafter it remained more or less steady (Fig.1).

The data on the concentration of nitrogen in stem are furnished in Table 6 and the analysis of variance in Appendix VI.

The results show that nitrogen as well as NK and PK interactions significantly influenced the nitrogen content of stem during the first month only. The effect of N_2 was on par with that of N_1; but significantly superior to N_0. In general, the control plants were found to have a lower concentration of nitrogen in their

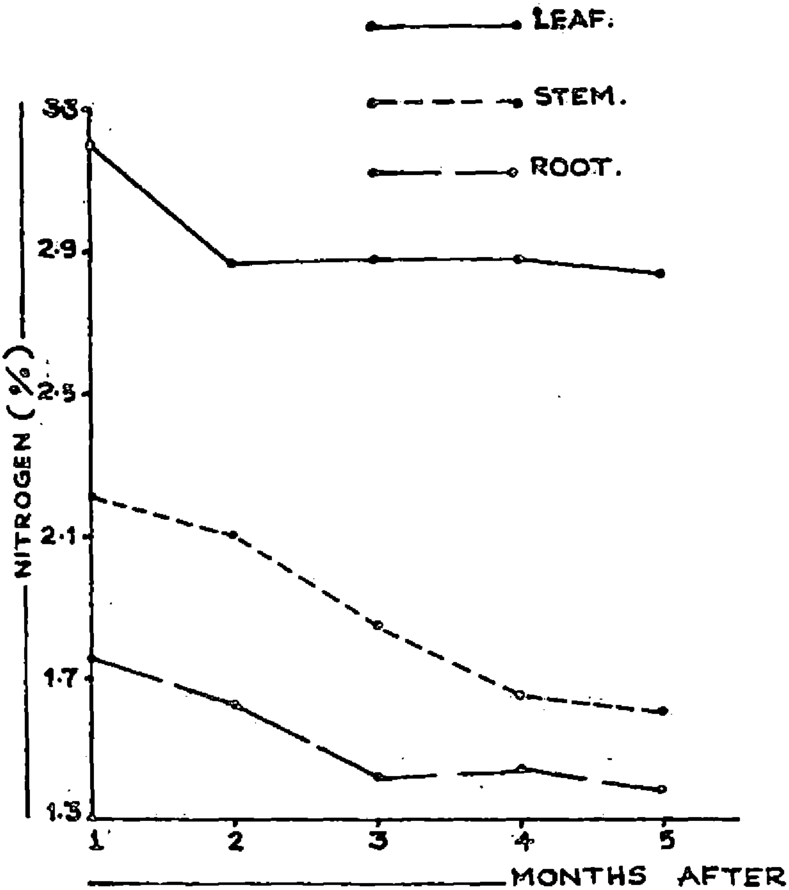


FIG. 1. NITROGEN CONTENT OF LEAF, STEM AND ROOT Vs AGE OF THE SEEDLINGS.

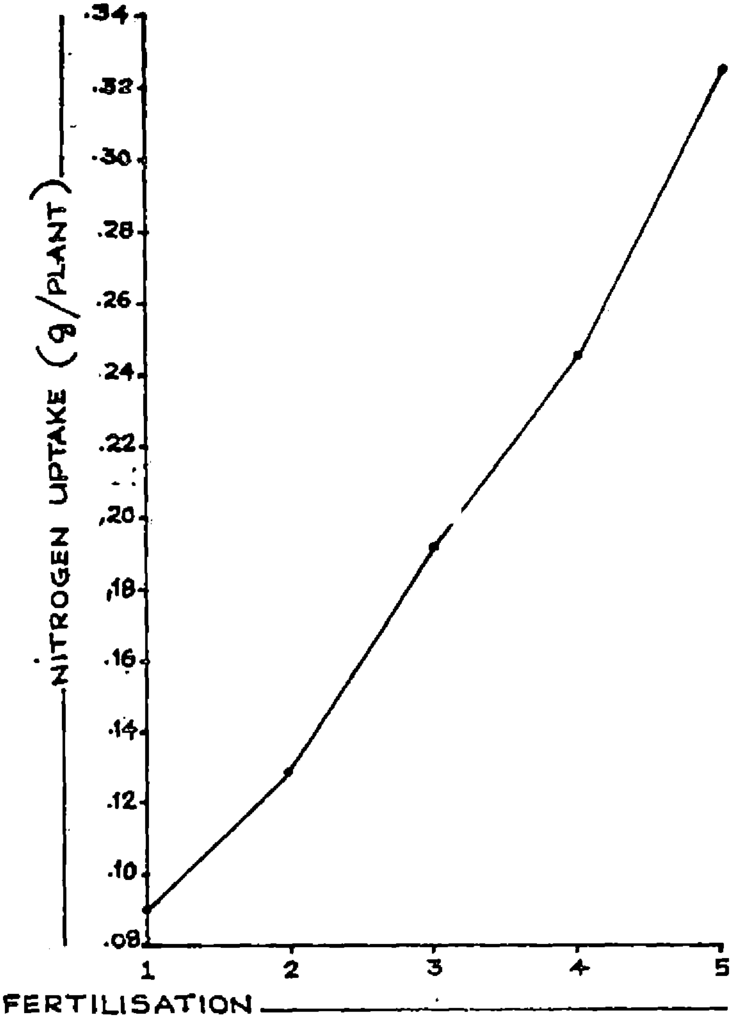


FIG. 2.-UPTAKE OF NITROGEN Vs AGE OF THE SEEDLINGS.

Table 6. Effect of NPK treatments on nitrogen content of stem of cocoa seedlings

Treatments	Nitrogen in stem (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	1.82	1.61	1.68	1.82	1.54
N_0	2.07	2.01	1.76	1.63	1.66
N_1	2.25	2.08	1.92	1.71	1.60
N_2	2.31	2.22	1.87	1.63	1.58
CD	0.116	-	-	-	-
P_0	2.16	2.06	1.88	1.62	1.62
P_1	2.19	2.12	1.86	1.67	1.63
P_2	2.28	2.13	1.81	1.67	1.59
CD	-	-	-	-	-
K_0	2.17	2.10	1.86	1.62	1.65
K_1	2.26	2.02	1.86	1.67	1.62
K_2	2.19	2.19	1.84	1.67	1.57
CD	-	-	-	-	-

stems (1.82%). The NK and NP interactions were foundto be significant during the fourth and fifth months respectively. Regarding the effect of age of plant on nitrogen content of stem, it was found that there was a steady decrease. The nitrogen concentration decreased from 2.20% at first month to 1.60% at fifth month (Fig.1).

The data on nitrogen content of root are furnished in Table 7. The analysis of variance is given in Appendix VII.

The data reveal that the fertiliser treatments had no significant effect on the nitrogen content of roots, except during the first month. Effect of N_2 was superior to that of N_0. N_2 was on par with N_1. The concentration of nitrogen in roots of plants under treatment N_2 was 1.89% as against 1.67% for N_0 and 1.74% for N_1. As in the case of stem, the nitrogen content of roots also decreased with age of plants. The mean value of 1.77% at first month decreased to 1.42% at third month and thereafter it remained steady (Fig.1).

The data on total nitrogen uptake are given in Table 8. The analysis of variance is given in Appendix VIII.

The results reveal that the total uptake of nitrogen was not influenced by the levels of nitrogen applied. None

Table 7. Effect of NPK treatments on nitrogen content of roots of cocoa seedlings

Treatments	Nitrogen in root (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	1.82	1.61	1.47	1.47	1.47
N_0	1.67	1.65	1.45	1.45	1.37
N_1	1.74	1.60	1.36	1.49	1.42
N_2	1.89	1.63	1.44	1.39	1.35
CD	0.166	-	-	-	-
P_0	1.79	1.65	1.42	1.46	1.36
P_1	1.73	1.56	1.40	1.41	1.40
P_2	1.78	1.66	1.43	1.45	1.38
CD	-	-	-	-	-
K_0	1.80	1.59	1.42	1.49	1.39
K_1	1.71	1.58	1.36	1.40	1.36
K_2	1.80	1.70	1.47	1.45	1.38
CD	-	-	-	-	-

Table 8. Effect of NPK treatments on uptake of nitrogen by cocoa seedlings

Treatments	Uptake of nitrogen (g/plant)				
	Stage of growth (months)				
	1	2	3	4	5
Control	0.100	0.139	0.221	0.296	0.345
N_0	0.091	0.136	0.193	0.248	0.335
N_1	0.093	0.120	0.187	0.243	0.328
N_2	0.087	0.130	0.197	0.248	0.312
CD	-	-	-	-	-
P_0	0.091	0.143	0.194	0.256	0.347
P_1	0.091	0.117	0.178	0.237	0.326
P_2	0.090	0.127	0.204	0.246	0.302
CD	-	-	-	-	-
K_0	0.085	0.134	0.195	0.243	0.330
K_1	0.084	0.116	0.186	0.252	0.336
K_2	0.102	0.136	0.196	0.243	0.310
CD	-	-	-	-	-

of the levels of phosphorus or potassium was found to influence the total uptake of nitrogen by the crop. The nitrogen uptake progressively increased from 0.090 g/plant at first month to 0.325 g/plant at fifth month (Fig.2).

In the present study, added nitrogen failed to bring about any significant increase in its concentration in cocoa seedlings. Robinson (1961) and Raja and Subramaniam (1969) reported that added nitrogen could bring about an increase in the nitrogen content of coffee leaves, only during some particular periods in an year. In African oil palm, nitrogen content in leaves was not affected by any of the treatments (Ferwerda, 1961). Increasing the levels of applied phosphorus and potassium was found to better the nitrogen content of leaf during the third and the fourth months, respectively. In direct contrast to this observation, Verliere (1965) reported a negative interaction between nitrogen and potassium. He also reported a depressing effect on foliar nitrogen by the application of phosphorus.

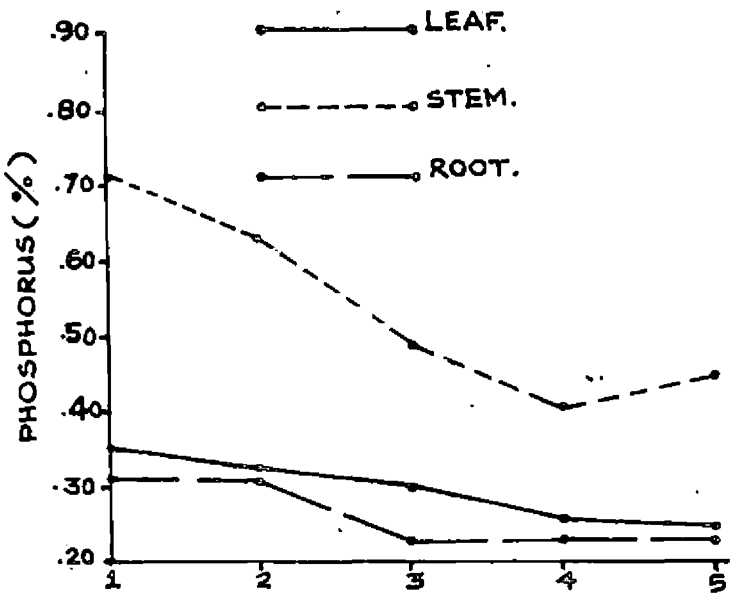
4.3. Effect of NPK treatments and period of growth on phosphorus content of cocoa.

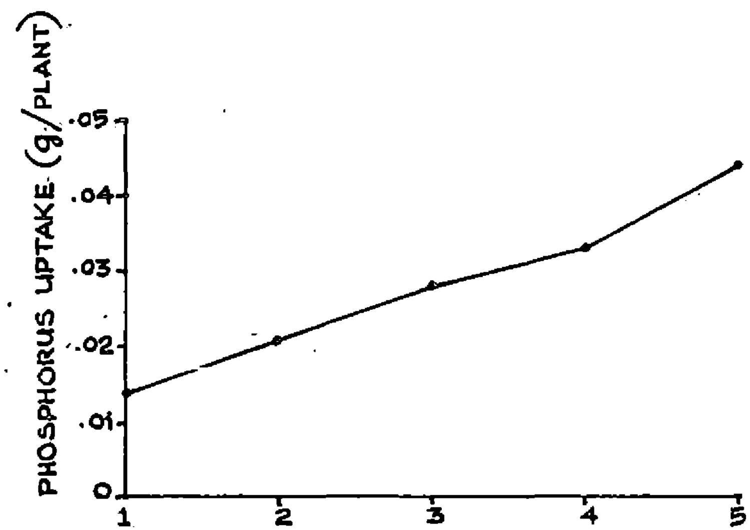
The data on phosphorus content of leaf as influenced by NPK treatments and period of growth are presented in Table 9. The analysis of variance is given in Appendix IX.

Table 9. Effect of NPK treatments on foliar content of cocoa seedlings

Phosphorus in leaf (%)

Treatments	Stage of growth (months)				
	1	2	3	4	5
Control	0.264	0.268	0.304	0.246	0.221
N_0	0.342	0.313	0.301	0.264	0.240
N_1	0.354	0.313	0.287	0.242	0.240
N_2	0.354	0.321	0.318	0.277	0.282
CD	-	-	-	-	0.030
P_0	0.351	0.318	0.292	0.276	0.250
P_1	0.336	0.310	0.304	0.244	0.261
P_2	0.364	0.318	0.311	0.263	0.251
CD	-	-	-	-	-
K_0	0.356	0.318	0.306	0.272	0.266
K_1	0.332	0.317	0.301	0.281	0.244
K_2	0.363	0.311	0.300	0.230	0.252
CD	-	-	-	)38	-





MONTHS AFTER FERTILISATION

FIG. 3. PHOSPHORUS CONTENT OF LEAF, STEM AND ROOT Vs AGE OF THE SEEDLINGS.

FIG. 4. UPTAKE OF PHOSPHORUS Vs AGE OF THE SEEDLINGS.

The application of phosphorus was not found to exert any significant effect on the phosphorus content of leaf. The levels of applied nitrogen also had no marked influence on the concentration of phosphorus, except during the fifth month. Phosphorus content of plants receiving N_2 level was 0.282% whereas it was 0.240% in plants receiving N_0 and N_1. The application of potassium also showed no effect on phosphorus content of leaf, except during the fourth month. At this stage, higher levels of applied potassium depressed the phosphorus level in leaf. Phosphorus content of leaf at K_2 level was 0.230% as compared to 0.281 and 0.272% at K_1 and K_0 levels, respectively. PK and NP interactions were found to be significant during the first and the third months, respectively. Mean values for phosphorus content in leaves decreased steadily throughout the period, from 0.35% at thefirst month to 0.25% at the fifth month (Fig.3).

The data on phosphorus content of stem as influenced by period of gr‥th and NPK treatments are presented in Table 10. The analysis of variance is given in Appendix X.

The data reveal that the varying levels of nutrients had no effect on the percentage content of phosphorus in stem, except those of nitrogen, during the fifth month.

Table 10. Effect of NPK treatments on phosphorus content of stem of cocoa seedlings

Treatments	Phosphorus in stem (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	0.551	0.631	0.542	0.364	0.374
N_0	0.668	0.690	0.497	0.420	0.454
N_1	0.742	0.567	0.479	0.429	0.400
N_2	0.725	0.626	0.493	0.390	0.498
CD	-	-		-	0.064
P_0	0.708	0.601	0.481	0.416	0.442
P_1	0.667	0.682	0.496	0.406	0.459
P_2	0.760	0.601	0.492	0.418	0.450
CD	-	-	-	-	-
K_0	0.740	0.620	0.479	0.396	0.463
K_1	0.654	0.632	0.508	0.416	0.440
K_2	0.741	0.631	0.483	0.428	0.450
CD	-	-	-	-	-

Significantly higher content of phosphorus (0.498%) was found in the stem of plants receiving the highest level of nitrogen. The effects of N_0 and N_1 levels were similar, 0.454 and 0.400% phosphorus, respectively. The phosphorus content of stem was higher than that of leaf and root. It decreased continuously from 0.71% at the first month to 0.41% at the fourth month. Then it increased slightly to 0.45% during the fifth month (Fig.3).

Table 11 presents the mean values of phosphorus in root as influenced by NPK treatments and period of growth. The analysis of variance is given in Appendix XI.

It is clear from the Table that the concentration of phosphorus in root was unaffected by the application of nitrogen, phosphorus and potassium. The mean values for phosphorus content of root showed a slight decrease after two months of growth and thereafter it remained constant at 0.23% (Fig.3).

Table 12 presents the mean values of total uptake of phosphorus as influenced by NPK treatments and period of growth. The analysis of variance is given in Appendix XII.

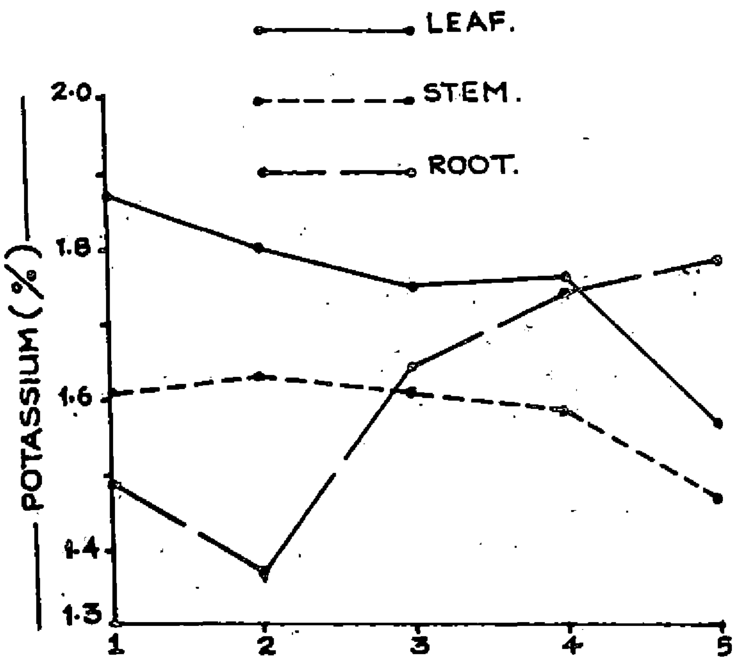
The data show that the total uptake of phosphorus was not influenced by levels of nitrogen, phosphorus and potassium tried. However, total uptake was influenced by

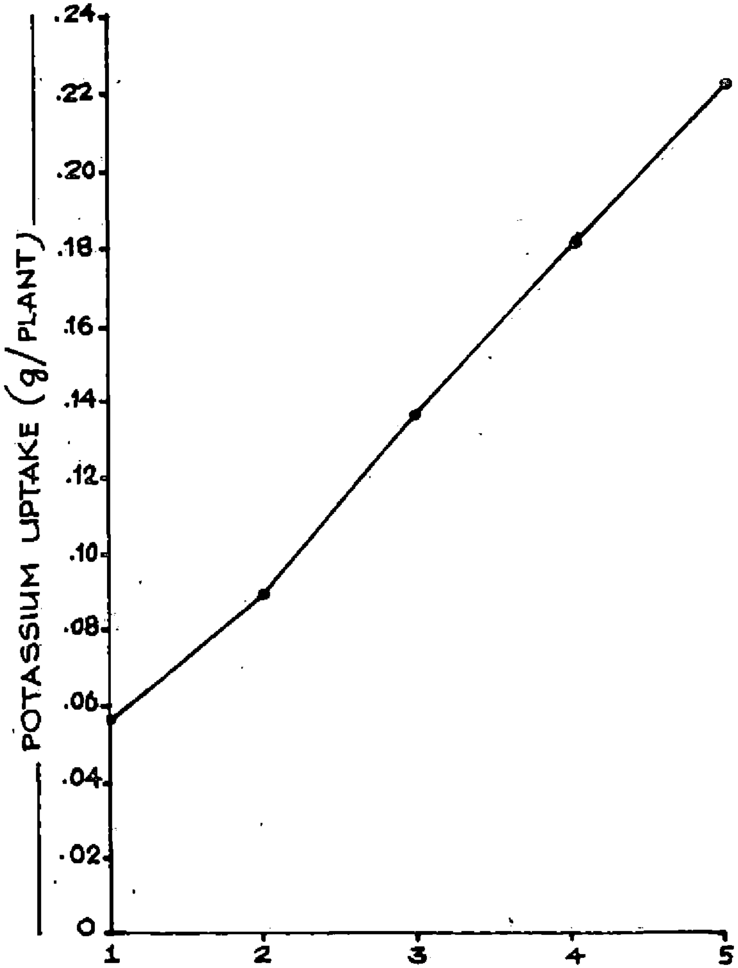
Table 11. Effect of NPK treatments on phosphorus content of root of cocoa seedlings

Treatments	Phosphorus in root (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	0.304	0.300	0.242	0.225	0.219
N_0	0.294	0.327	0.239	0.232	0.232
N_1	0.309	0.288	0.227	0.234	0.209
N_2	0.330	0.315	0.234	0.231	0.242
CD	-	-	-	-	-
P_0	0.301	0.298	0.222	0.220	0.216
P_1	0.289	0.311	0.246	0.241	0.241
P_2	0.343	0.321	0.231	0.236	0.225
CD	-	-	-	-	-
K_0	0.326	0.292	0.234	0.225	0.229
K_1	0.295	0.310	0.238	0.235	0.219
K_2	0.313	0.327	0.228	0.238	0.235
CD	-	-	-	-	-

Table 12. Effect of NPK treatments on uptake of phosphorus by cocoa seedlings

Treatments	Uptake of phosphorus (g/plant)				
	Stage of growth (months)				
	1	2	3	4	5
Control	0.013	0.021	0.034	0.033	0.041
N_0	0.016	0.023	0.029	0.033	0.044
N_1	0.014	0.018	0.026	0.032	0.041
N_2	0.013	0.021	0.029	0.033	0.047
CD	-	-	-	-	-
P_0	0.015	0.022	0.028	0.035	0.047
P_1	0.013	0.020	0.026	0.030	0.045
P_2	0.014	0.021	0.030	0.032	0.042
CD	-	-	-	-	-
K_0	0.014	0.022	0.029	0.033	0.045
K_1	0.012	0.019	0.027	0.034	0.045
K_2	0.016	0.022	0.028	0.030	0.043
CD	-	-	-	-	-





MONTHS AFTER FERTILISATION

FIG. 5. POTASSIUM CONTENT OF LEAF, STEM AND ROOT Vs AGE OF THE SEEDLINGS.

FIG. 6. UPTAKE OF POTASSIUM Vs AGE OF THE SEEDLINGS.

NP, NK and PK interactions during the third month. PK interaction was significant during the fourth and the fifth months also. The uptake of phosphorus progressively increased from 0.014 g/plant at the first month to 0.044 g/plant at the fourth month (Fig.4).

4.4. Effect of NPK treatments and period of growth on potassium content of cocoa.

Table 13 presents the mean values of potassium content of leaf as influenced by NPK treatments and period of growth. The analysis of variance is given in Appendix XIII.

The data reveal that varying levels of applied nutrients could not bring about any significant difference in potassium content of leaves, except during the fourth month. During this month, the effect of K_1 was superior to that of K_0 and K_2. NK interaction was significant during the fifth month. Control plants were having significantly lesser potassium content in leaves when compared to plants under different treatments, during the third month. There was a decrease in the potassium content of leaf from 1.87% at the first month to 1.76% at the fourth month. Then it decreased to 1.56% during the fifth month (Fig.5).

Table 13. Effect of NPK treatments on foliar potassium content of cocoa seedlings

Treatments	Potassium in leaf (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	1.91	1.83	0.96	1.99	1.54
N_0	1.88	1.84	1.81	1.84	1.55
N_1	1.92	1.64	1.71	1.72	1.55
N_2	1.81	1.91	1.72	1.73	1.58
CD	-	-	-	-	-
P_0	1.88	1.77	1.73	1.81	1.58
P_1	1.96	1.79	1.74	1.78	1.57
P_2	1.77	1.83	1.77	1.70	1.53
CD	-	-	-	-	-
K_0	1.91	1.75	1.72	1.72	1.52
K_1	1.33	1.80	1.67	1.88	1.59
K_2	1.87	1.85	1.85	1.70	1.58
CD	-	-	-	0.148	-

The data relating to the potassium content of stem as influenced by NPK fertilisation at various stages of growth are presented in Table 14 and the analysis of variance in Appendix XIV.

The data show that the content of potassium in stem was not influenced by the levels of nitrogen, phosphorus and potassium applied. However, the effect of PK interaction was found to be significant during the third month. The potassium content of stem remained more or less constant during the first four months. A decrease was noted during the fifth month (Fig. 5).

Table 15 presents the mean values of potassium content of root as influenced by NPK treatments and Appendix XV presents the analysis of variance.

The analysis of roots indicate that the potassium content was influenced by the levels of nitrogen during the first month and by the levels of nitrogen, phosphorus and potassium during the second month. During the first month, plants under N_0 treatment was found to have a concentration of 1.56% potassium in their roots whereas plants under N_2 and N_1 contained 1.50 and 1.41% potassium respectively. During the second month also N_0 was superior to N_2 and N_1. Effects of P_1 and P_0 were on par and P_2 was

Table 14. Effect of NPK treatments on potassium content of stem of cocoa seedlings

Treatments	Potassium in stem (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	1.59	1.73	1.61	1.65	1.51
N_0	1.69	1.66	1.66	1.63	1.52
N_1	1.51	1.56	1.59	1.59	1.44
N_2	1.64	1.67	1.59	1.56	1.42
CD	-	-	-	-	-
P_0	1.64	1.51	1.63	1.52	1.46
P_1	1.57	1.70	1.57	1.61	1.49
P_2	1.63	1.69	1.64	1.64	1.42
CD	-	-	-	-	-
K_0	1.63	1.62	1.61	1.58	1.43
K_1	1.61	1.72	1.58	1.59	1.50
K_2	1.61	1.56	1.64	1.60	1.44
CD	-	-	-	-	-

Table 15. Effect of NPK treatments on potassium content of root of cocoa seedlings

Treatments	Potassium in root (%)				
	Stage of growth (months)				
	1	2	3	4	5
Control	1.60	1.28	1.53	2.05	1.99
N_0	1.56	1.48	1.68	1.79	1.83
N_1	1.41	1.22	1.60	1.79	1.77
N_2	1.50	1.42	1.65	1.65	1.73
CD	0.113	0.130	-	-	-
P_0	1.44	1.30	1.66	1.76	1.75
P_1	1.55	1.34	1.55	1.77	1.82
P_2	1.48	1.48	1.71	1.69	1.76
CD	-	0.130	-	-	-
K_0	1.51	1.44	1.69	1.77	1.70
K_1	1.47	1.40	1.67	1.79	1.78
K_2	1.49	1.28	1.57	1.67	1.85
CD	-	0.130	-	-	-

superior to both. K_0 was superior to K_1 and K_2 treatments which were on par. NK interaction was significant during the second month. Average potassium content in roots was 1.49% during the first month, which decreased to 1.37% during the second month. Thereafter, it increased steadily to 1.78% at the fifth month (Fig.5).

The data relating to the total uptake of potassium are presented in Table 16 and the analysis of variance in Appendix XVI.

The data show that the fertilizer treatments had no effect on the total uptake of potassium by the crop. However, NK interaction was found to influence the potassium uptake during the first, third and fourth months and the combination N_0K_2 was found to be superior during these three months. PK interaction was found to influence total K uptake during the fourth month. Potassium uptake increased with the age of the crop from 0.057 g/plant at the first month to 0.222 g/plant at the fifth month (Fig. 6).

By and large, there was no consistent pattern of uptake of NPK by the plants following fertilizer application.

Table 16. Effect of NPK treatments on uptake of potassium by cocoa seedlings

Treatments	Uptake of potassium (g/plant)				
	Stage of growth (months)				
	1	2	3	4	5
Control	0.070	0.108	0.118	0.222	0.243
N_0	0.063	0.097	0.146	0.190	0.229
N_1	0.058	0.078	0.131	0.178,	0.224
N_2	0.051	0.092	0.135	0.176	0.213
CD	-	-	-	-	-
P_0	0.060	0.095	0.142	0.192	0.243
P_1	0.059	0.083	0.122	0.175	0.220
P_2	0.054	0.088	0.148	0.178	0.202
CD	-	-	-	-	-
K_0	0.053	0.091	0.141	0.179	0.221
K_1	0.053	0.083	0.128	0.192	0.232
K_2	0.066	0.092	0.143	0.173	0.213
CD	-	-	-	-	-

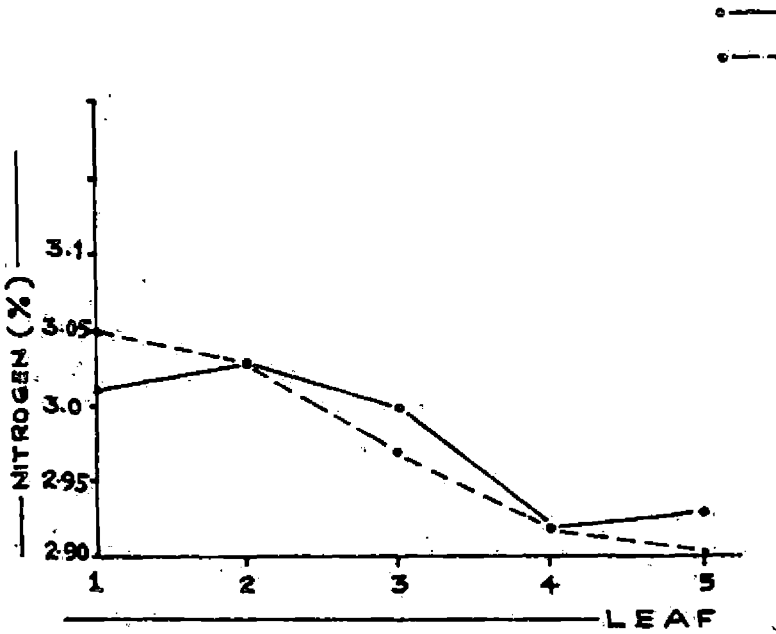


FIG. 7.–NITROGEN CONTENT OF LEAF IN RELATION TO LEAF POSITIONS.

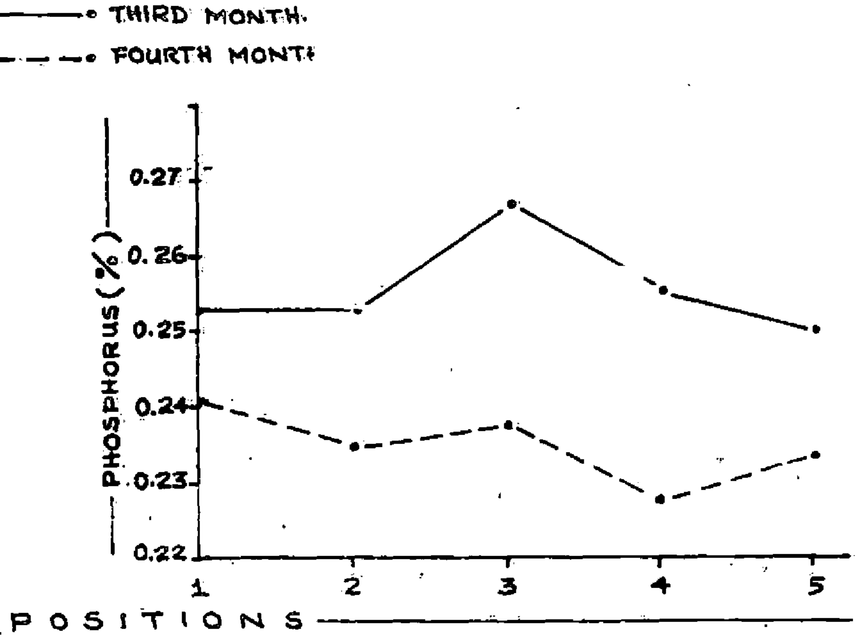


FIG. 8. PHOSPHORUS CONTENT OF LEAF IN-RELATION TO LEAF POSITION.

The results indicate that the uptake of major nutrients was not enhanced by the application of NPK fertilisers. Such a situation can arise if the supply of nutrients in the growth medium (pot mixture) is adequate to meet the nutritional requirement of the plants during the nursery stage. This probably will explain the absence of response to added fertilisers in terms of leaf and dry matter production, height of the plant etc. discussed in section 4.1.

4.5. Standardisation of leaf sampling technique in cocoa seedlings.

For the purpose of standardisation of leaf sampling techniques, samples were taken from various leaf positions starting from the first fully opened leaf through lower older leaves upto the fifth leaf.

The data on nitrogen content of leaf in relation to its position are furnished in Table 17 and Fig. 7. The leaves were sampled only at the third and fourth months of growth. The nitrogen content of leaf varied depending on its position on the plant. Young leaves contained more nitrogen than older ones. The trend was similar at both stages of growth. The results also showed that the leaf position x treatment interaction was not significant (Appendix XVII).

Table 17. NPK content (%) of leaves in relation to their positions

Leaf rank*	Stage of growth					
	3rd month			4th month		
	N	P	K	N	P	K
1**	3.01	0.253	1.65	3.05	0.241	1.65
2	3.03	0.253	1.58	3.03	0.235	1.59
3	3.00	0.267	1.63	2.97	0.238	1.56
4	2.92	0.256	1.52	2.92	0.228	1.48
5	2.93	0.251	1.45	2.90	0.234	1.50
CD (0.05)	0.09	-	0.11	0.04	-	0.07

* From the top downwards

** First fully opened one

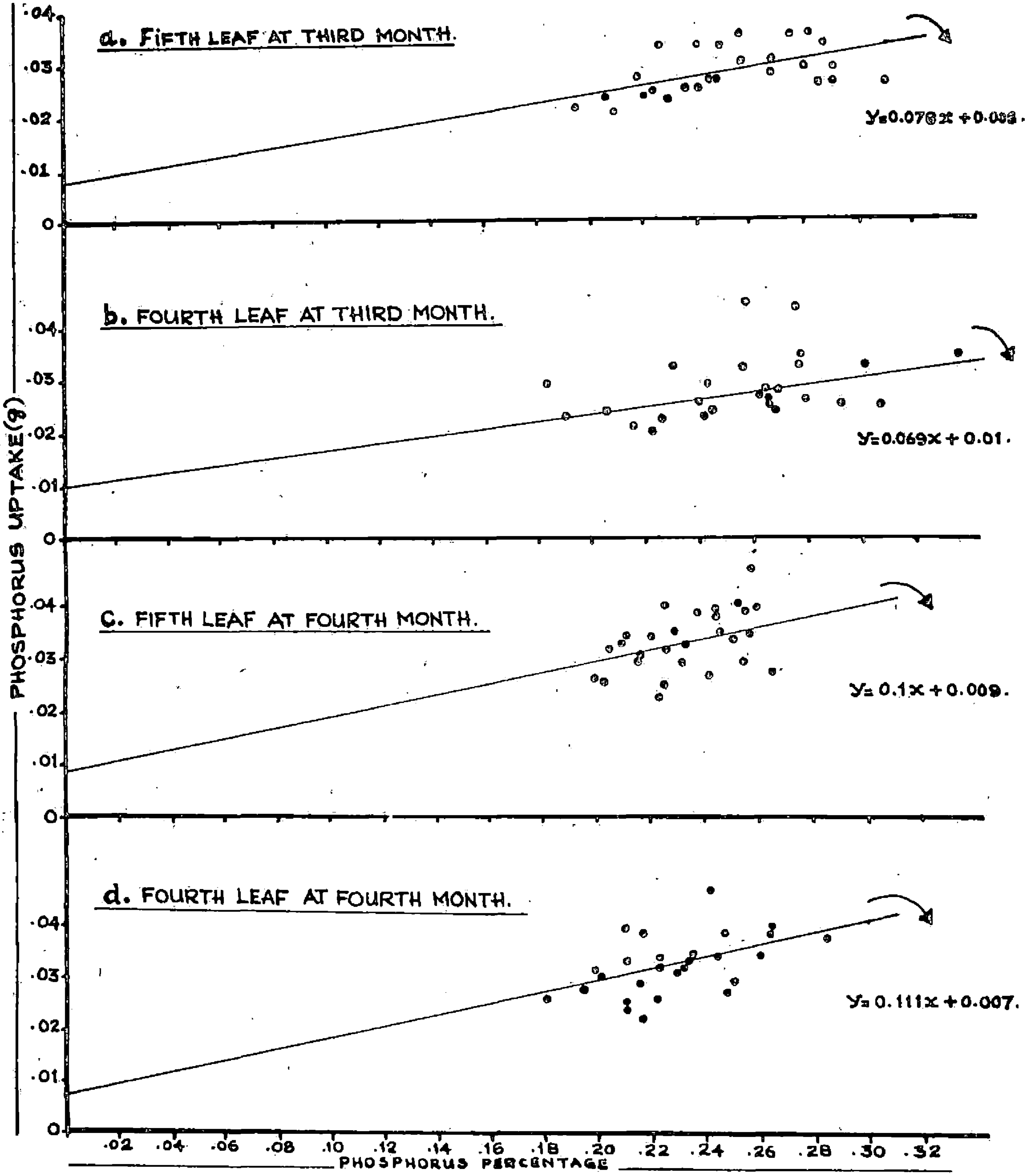


FIG. 9 [a – d] – RELATIONSHIP BETWEEN PHOSPHORUS UPTAKE AND PHOSPHORUS IN LEAF RANKS.

The data on phosphorus content of leaf in relation to leaf position are furnished in Table 17 and Fig. 8. The results indicate that the phosphorus content of the leaf was not influenced by its position on the plant. The differences in phosphorus content of leaves were not found to be significant. As in the case of nitrogen, leaf position x treatment iteraction was also not significant (Appendix XVII).

Unlike phosphorus, potassium content varied significantly among the leaf ranks (Table 17 and Fig. 10). The younger leaves accumulated more potassium than the older leaves. The pattern was almost similar to that of nitrogen. In this case also, leaf position x treatment interaction was not significant (Appendix XVII).

NPK content of different leaves was subjected to correlation analysis with the uptake of corresponding nutrients. The correlation coefficients (r values) are presented in Table 18. The results indicate that nitrogen content of leaves at any position was not related to the uptake of nitrogen by the cocoa seedlings. Of the three nutrients studied, phosphorus content of lower leaves, namely, the fourth and the fifth leaves was correlated signifioantly with phosphorus uptake (Table 18 and Figs. 9.a,b,c,d). The relationships between phosphorus

Table 18. Correlation coefficients between total nutrient uptake by the plant and nutrient contents in leaf ranks

Leaf positions (Ranks)	Nitrogen		Phosphorus		Potassium	
	3rd month	4th month	3rd month	4th month	3rd month	4th month
1	-0.194	-0.033	0.276	0.239	0.091	-0.013
2	0.055	-0.178	0.346	0.290	0.252	0.127
3	0.189	-0.159	0.367	0.300	0.164	0.230
4	-0.097	-0.137	0.389*	0.531**	0.138	0.226
5	-0.200	-0.098	0.376*	0.478**	0.364	0.124

* Significant at 5% level

** Significant at 1% level

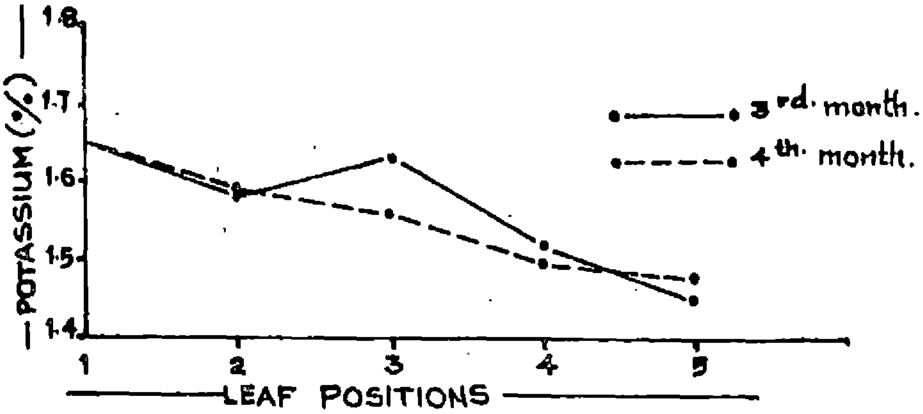


FIG. 10. POTASSIUM CONTENT OF LEAF IN RELATION TO LEAF POSITION.

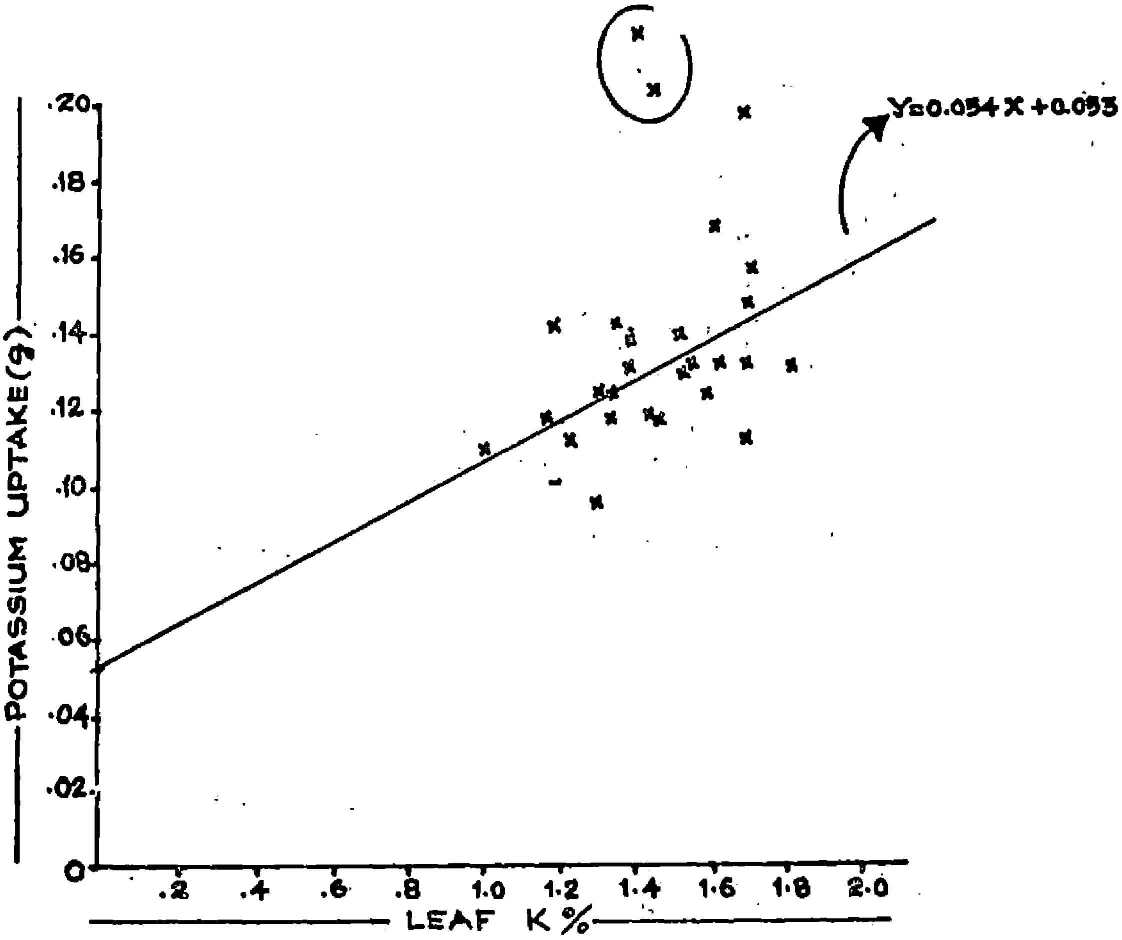


FIG. 11. RELATIONSHIP BETWEEN POTASSIUM UPTAKE AND POTASSIUM CONTENT OF FIFTH LEAF AT THIRD MONTH OF GROWTH.

content of the fourth leaf at the third and fourth months of growth and phosphorus uptake by the plant could be expressed by the equations $y = 0.069x + 0.01$ and $y = 0.111x + 0.007$, respectively. The corresponding equations for the fifth leaf were $y = 0.078x + 0.008$ and $y = 0.1x + 0.009$.

The relationship between potassium content of the fifth leaf and the uptake of potassium is presented in Fig.11. The correlation coefficient was only 0.364. Significant correlation was obtained ($r = 0.526$) when two points were removed and analysis conducted again. These points are shown encircled in Fig. 11.

From these considerations, it is apparent that leaf numbered fifth from the apex is more suitable for sampling than leaf numbered fourth. Eventhough fourth leaf gave slightly higher correlation coefficients at the third and the fourth months between leaf phosphorus levels and total phosphorus uptake as compared to fifth leaf, correlations between potassium levels in the fourth leaf and potassium uptake were not significant. Therefore, leaf ranked fifth from the apex is suggested as the standard leaf for leaf analysis in cocoa seedlings.

4.6. Relationships between soil and leaf nutrients in adult cocoa plants.

In order to examine the relationships between soil and leaf nutrient levels, a study was undertaken with field grown adult cocoa plants receiving varying levels of nitrogen, phosphorus and potassium. Samples were taken from three depths, namely, 0-15, 15-30 and 30-45 cm from the soil basins at a radial distance of 45 cm from the plant. Available phosphorus and potassium in the soil were estimated and correlated with leaf phosphorus and potassium. Second and third fully green leaves from chupons and fans were sampled separately for this purpose.

Available phosphorus in soil decreased with depth. In the topmost layer (0-15 cm), available phosphorus ranged from 3 to 91 ppm and in more than 50% of the cases it was higher than 25 ppm. In the second layer (15-30 cm), it varied from traces to 69 ppm. Only traces of phosphorus were present in the third layer (30-45 cm).

As the soil depth increased, the available potassium also decreased. Available potassium in the soil varied from 210 to 860 ppm in 0-15 cm layer, 200 to 700 ppm in 15-30 cm layer and 110 to 400 ppm in 30-45 cm layer. These variations were expected in view of the varying levels of phosphorus and potassium the plants were receiving.

Statistical analysis showed that the relationship between phosphorus levels in soil and leaf was not significant. The correlation coefficients were found to be positive; though not significant. Phosphorus in chupon leaves was found to be better related with soil available phosphorus than phosphorus in fan leaves.

Correlations between soil potassium and potassium content of fan leaves and chupon leaves were also not significant. The correlations between available potassium in 0-15 cm and 15-30 cm soil depths and chupon potassium were found to be negative (Table 19).

Apart from these correlations, Bray I phosphorus and exchangeable potassium were also correlated with tree girth. Tree girth was considered as an index of growth in cocoa (Glendinning, 1960). However, no significant correlations were obtained between either available phosphorus or exchangeable potassium and tree girth.

These results indicate the unsuitability of two conventional extractants, namely, Bray I and ammonium acetate for assessing the available phosphorus and potassium, respectively for cocoa in laterite soils. Perhaps, other extractants may give better correlations with plant uptake of the two nutrients. It is also possible that absolute concentration of these nutrients in the soil

Table 19. Coefficients of correlation between soil nutrients, plant nutrients and tree girth

Soil depth (cm)	Plant P (%)		Plant K (%)	
	Chupon	Fan	Chupon	Fan
0-15	0.299	0.107	-0.080	0.060
15-30	-	-	0.270	-0.023
30-45	-	-	0.230	0.220
Tree girth	0.135	0.054	0.025	0.071

may not correspond to plant uptake. Wahid et al. (1974) observed that ammonium acetate extractable potassium was poorly correlated with plant uptake of potassium, in coconut. They found a better relationship between the ratio of the available potassium and sodium in soil with plant potassium uptake. Such relationships will be more meaningful as the absorption of a nutrient is governed by the presence of other nutrients in the soil, especially in the case of mono-and divalent cations where antagonism exists. In the case of phosphorus also, Bray I phosphorus was not found to correlate with leaf phosphorus (Wahid et al., 1977). They found that the correlation between Bray I phosphorus and leaf phosphorus in coconuts growing in laterite soil was very low.

Chapman (1964) suggested second or third fully green leaf below the apex of shoot for sampling in cocoa for nutrient deficiency diagnosis. However, no mention was made of the suitability or otherwise of chupon and fan leaves. In the present study, an attempt was made to examine the variation in phosphorus and potassium concentrations in these two types of leaves. Significant positive correlations were obtained between phosphorus content of chupons and fans, and between potassium content of these leaves (Figs. 12 and 13). When the data were subjected to 't' test, it was found, however, that potassium content of fan leaves was significantly different from that of chupon leaves. These results indicate that indiscriminate sampling of chupon and fan leaves would vitiate the chemical analysis. The results also point to the necessity of specifying the type of leaf used for analysis when the data are reported.

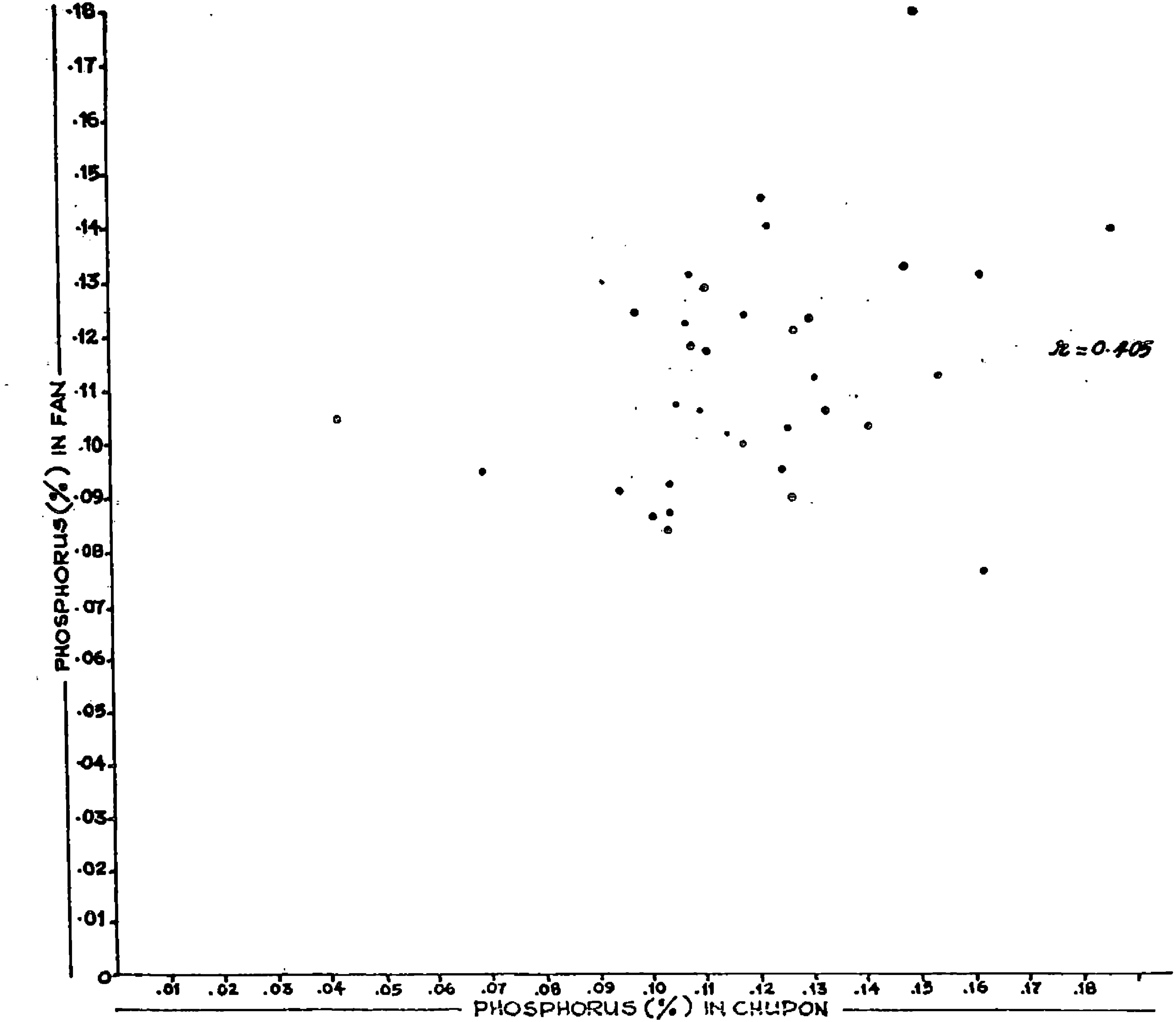


FIG. 12.–RELATIONSHIP BETWEEN PHOSPHORUS CONTENT IN CHUPON AND FAN LEAVES OF COCOA.

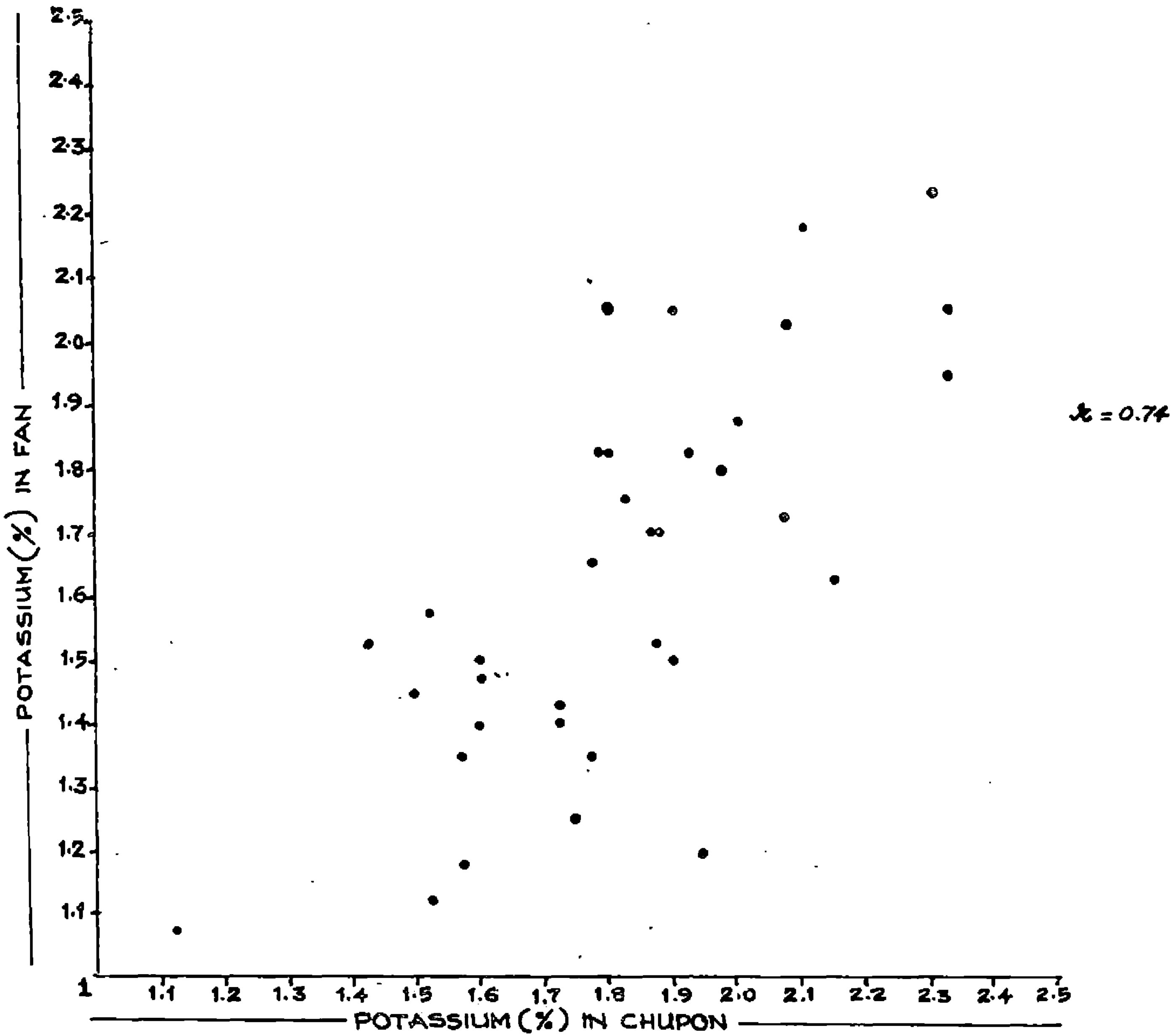


FIG. 13.—RELATIONSHIP BETWEEN POTASSIUM CONTENT IN CHU
AND FAN LEAVES OF COCOA.

Summary

S U M M A R Y

An experiment was conducted at the College of Horticulture, Vellanikkara during 1979-80 to study the effect of graded doses of nitrogen, phosphorus and potassium on the growth of cocoa seedlings and to standardise leaf sampling technique as a preliminary step towards the nutrient deficiency diagnosis in the nursery stage. The treatments consisted of three levels each of nitrogen (75, 100 and 125 kg N/ha), phosphorus (30, 40 and 50 kg P_2O_5/ha) and potassium (105, 140 and 175 kg K_2O/ha). The experiment was laid out as a 3^3 factorial in completely randomised design with an absolute control. The second part of the study related to evaluating the relationships among soil test values, leaf nutrient concentration and plant growth, in the field. The important findings are summarised below.

1. Application of N, P and K to seedlings grown in potmixture did not improve their growth in terms of height, girth, leaf production and dry matter content suggesting thereby, fertilisation of seedlings in the nursery may not be necessary.

2. Application of nitrogen failed to bring about any significant increase in its concentration in leaf,

stem and root of the cocoa seedlings.

3. Phosphorus uptake by the plant was not influenced significantly by the addition of this element.

4. The uptake of potassium by the crop was not enhanced following the application of this element.

5. The nitrogen content of leaves at various positions was not related to the nitrogen uptake by cocoa seedlings.

6. Leaf ranked fifth from the apex is suggested as standard leaf for leaf analysis in cocoa seedlings.

7. The correlations between soil and leaf phosphorus and potassium contents were not significant.

8. No significant correlations existed between either available phosphorus or exchangeable potassium and tree girth.

9. Two conventional extractants namely, Bray I solution and ammonium acetate were found to be unsuitable for assessing the soil available phosphorus and potassium respectively, to cocoa plants growing on laterite soil.

10. Either fan or chupon leaves may be used for foliar nutrient analysis in cocoa. However, indiscriminate sampling between the two types of leaves would lead to erroneous analysis.

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* Original not seen

Appendices

Appendix I. Analysis of variance for effect of NPK treatments on height of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.025	3.51	2.82	0.148	4.28
P	2	12.04	58.03	76.43	99.57	114.26
N x P	4	45.39*	59.48	41.12	35.65	22.86
K	2	29.58	20.10	16.11	13.31	13.23
N x K	4	29.77	73.10*	65.71	65.39	47.63
P x K	4	13.28	36.08	44.87	64.70	57.10
N x P x K	8	11.89	33.63	39.88	51.25	40.36
Treatment x Control	1	9.93	1.69	14.07	0.008	2.78
Error	28	16.01	25.86	31.71	44.21	40.90

* Significant at 5% level

Appendix II. Analysis of variance for effect of NPK treatments on girth of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.004	0.010	0.0004	0.004	0.006
P	2	0.122*	0.040	0.085	0.092	0.084
N x P	4	0.038	0.037	0.026	0.010	0.011
K	2	0.030	0.020	0.040	0.052	0.049
N x K	4	0.028	0.020	0.025	0.066	0.068
P x K	4	0.081	0.090	0.071	0.064	0.071
N x P x K	8	0.096	0.050	0.047	0.041	0.039
Treatment x Control	1	0.005	0.000005	0.001	0.0001	0.005
Error	28	0.038	0.030	0.035	0.034	0.032

* Significant at 5% level

Appendix III. Analysis of variance for effect of NPK treatments on leaf production in cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.79	5.0	0.166	1.12	0.79
P	2	2.01	6.50	14.00	14.35	12.07
N x P	4	7.29	11.66	8.50	8.51	8.26
K	2	10.01	12.05	8.22	6.90	4.12
N x K	4	5.20	13.55*	10.22	11.90	11.32
P x K	4	4.26	7.47	8.30	8.71	11.43
N x P x K	8	2.67	5.76	6.80	8.75	8.67
Treatment x Control	1	0.447	4.33	38.09*	52.96*	57.94*
Error	28	3.17	3.80	5.71	8.13	8.07

* Significant at 5% level

Appendix IV. Analysis of variance for effect of NPK treatments on dry matter production of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	1.21	2.28	0.215	0.089	4.62
P	2	0.086	4.31	7.83*	5.52	2.27
N x P	4	1.57	1.65	2.83	0.719	8.16
K	2	3.67	2.51	1.23	0.929	5.68
N x K	4	4.47	4.64	8.40	6.32	20.56
P x K	4	2.02	0.523	2.92	5.62	30.61
N x P x K	8	1.05	2.20	3.34	1.85	23.05
Treatment x Control	1	0.714	1.50	3.23	2.52	1.07
Error	28	1.66	2.85	2.22	2.35	15.29

* Significant at 5% level

Appendix V. Analysis of variance for effect of NPK treatments on foliar nitrogen content of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.184	0.005	0.077	0.016	0.029
P	2	0.010	0.045	0.202*	0.011	0.005
N x P	4	0.453	0.007	0.053	0.025	0.056
K	2	0.464	0.033	0.040	0.114*	0.028
N x K	4	0.428	0.024	0.043	0.093*	0.033
P x K	4	0.305	0.114	0.026	0.017	0.006
N x P x K	8	0.124	0.036	0.045	0.071*	0.012
Treatment x Control	1	0.026	0.069	0.006	0.129*	0.010
Error	28	0.177	0.057	0.032	0.031	0.012

Significant at 5% level

Appendix VI. Analysis of variance for effect of NPK treatments on nitrogen content of stem of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.281*	0.209	0.126	0.044	0.029
P	2	0.072	0.026	0.024	0.018	0.004
N x P	4	0.039	0.068	0.125	0.017	0.056*
K	2	0.042	0.132	0.003	0.019	0.028
N x K	4	0.123*	0.033	0.155	0.084*	0.033
P x K	4	0.130*	0.101	0.052	0.012	0.005
N x P x K	8	0.113	0.144	0.084	0.022	0.012
Treatment x Control	1	0.291*	0.472	0.056	0.053	0.010
Error	28	0.029	0.120	0.060	0.017	0.012

* Significant at 5% level

Appendix VII. Analysis of variance for effect of NPK treatments on nitrogen content of roots of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.222*	0.011	0.045	0.041	0.028
P	2	0.016	0.058	0.005	0.011	0.007
N x P	4	0.095	0.020	0.012	0.025	0.022
K	2	0.044	0.070	0.054	0.033	0.005
N x K	4	0.072	0.046	0.017	0.029	0.012
P x K	4	0.150	0.015	0.014	0.017	0.008
N x P x K	8	0.142	0.023	0.015	0.014	0.015
Treatment x Control	1	0.005	0.0004	0.005	0.001	0.016
Error	28	0.059	0.046	0.024	0.014	0.008

* Significant at 5% level

Appendix VIII. Analysis of variance for effect of NPK treatments on uptake of nitrogen by cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.0002	0.0011	0.0005	0.0002	0.0025
P	2	0.00001	0.0032	0.0031	0.0017	0.0089
N x P	4	0.0016	0.0008	0.0017	0.0005	0.0065
K	2	0.0020	0.0022	0.0005	0.0005	0.0034
N x K	4	0.0028	0.0029	0.0035	0.0014	0.0102
P x K	4	0.0017	0.0002	0.0017	0.0020	0.0170
N x P x K	8	0.0011	0.0012	0.0017	0.0007	0.0130
Treatment x Control	1	0.0002	0.0002	0.0015	0.0048	0.0007
Error	28	0.0013	0.0014	0.0011	0.0011	0.0082

Appendix IX. Analysis of variance for effect of NPK treatments on foliar phosphorus content of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.0009	0.0003	0.0042	0.0056	0.0104*
P	2	0.0035	0.0003	0.0017	0.0046	0.0005
N x P	4	0.0002	0.0012	0.0053*	0.0066	0.0031
K	2	0.0049	0.0002	0.0002	0.0132*	0.0021
N x K	4	0.0059	0.0035	0.0008	0.0043	0.0042
P x K	4	0.0230*	0.0051	0.0019	0.0041	0.0048
N x P x K	8	0.0029	0.0004	0.0021	0.0021	0.0027
Treatment x Control	1	0.0140	0.0043	0.000003	0.0004	0.0021
Error	28	0.0047	0.0027	0.0017	0.0030	0.0018

* Significant at 5% level

Appendix X. Analysis of variance for effect of NPK treatments on phosphorus content of stem of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.026	0.067	0.002	0.007	0.043*
P	2	0.039	0.039	0.001	0.001	0.001
N x P	4	0.040	0.009	0.015	0.011	0.008
K	2	0.044	0.001	0.004	0.004	0.002
N x K	4	0.079	0.021	0.004	0.003	0.011
P x K	4	0.042	0.009	0.021	0.009	0.011
N x P x K	8	0.032	0.012	0.004	0.007	0.013
Treatment x Control	1	0.049	0.00002	0.005	0.004	0.011
Error	28	0.030	0.027	0.008	0.007	0.008

* Significant at 5% level

Appendix XI. Analysis of variance for effect of NPK treatments on phosphorus content in roots of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.0054	0.0072	0.0006	0.00005	0.0050
P	2	0.0025	0.0023	0.0026	0.0023	0.0029
N x P	4	0.0008	0.0063	0.0007	0.0031	0.0016
K	2	0.0042	0.0055	0.0005	0.0008	0.0012
N x K	4	0.0008	0.0010	0.0016	0.0052	0.0059
P x K	4	0.0061	0.0054	0.0041	0.0006	0.0007
N x P x K	8	0.0044	0.0050	0.0020	0.0008	0.0030
Treatment x Control	1	0.0002	0.0002	0.0001	0.0001	0.0001
Error	28	0.0054	0.0078	0.0018	0.0019	0.0024

Appendix XII. Analysis of variance for effect of NPK treatments on uptake of phosphorus by cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.00004	0.00011	0.00004	0.00003	0.00016
P	2	0.00002	0.00004	0.00007	0.00011	0.00011
N x P	4	0.00001	0.00002	0.00009*	0.00006	0.00006
K	2	0.00008	0.00006	0.00001	0.00008	0.00002
N x K	4	0.00009	0.00009	0.00009*	0.00006	0.00007
P x K	4	0.00005	0.00001	0.00012*	0.00012*	0.00034*
N x P x K	8	0.00001	0.00005	0.00003	0.00002	0.00016
Treatment x Control	1	0.000001	0.000004	0.00007	0.00005	0.00002
Error	28	0.00004	0.00004	0.00003	0.00003	0.00009

* Significant at 5% level

Appendix XIII. Analysis of variance for effect of NPK treatments on foliar potassium content of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.061	0.340	0.056	0.082	0.006
P	2	0.166	0.013	0.006	0.052	0.014
N x P	4	0.050	0.096	0.057	0.092	0.013
K	2	0.034	0.045	0.145	0.172*	0.027
N x K	4	0.153	0.033	0.097	0.078	0.075*
P x K	4	0.108	0.165	0.005	0.076	0.019
N x P x K	8	0.094	0.190	0.097	0.067	0.016
Treatment x Control	1	0.004	0.002	1.180*	0.095	0.001
Error	28	0.120	0.125	0.073	0.046	0.022

* Significant at 5% level

Appendix XIV. Analysis of variance for effect of NPK treatments on potassium content of stem of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.145	0.066	0.025	0.023	0.050
P	2	0.025	0.206	0.028	0.065	0.023
N x P	4	0.041	0.111	0.067	0.031	0.029
K	2	0.002	0.112	0.013	0.001	0.026
N x K	4	0.105	0.030	0.049	0.030	0.037
P x K	4	0.065	0.267	0.086*	0.093	0.034
N x P x K	8	0.149	0.046	0.017	0.052	0.006
Treatment x Control	1	0.001	0.017	0.000004	0.007	0.006
Error	28	0.131	0.127	0.020	0.041	0.028

* Significant at 5% level

Appendix XV. Analysis of variance for effect of NPK treatments on potassium content of root of cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.093*	0.328*	0.032	0.124	0.052
P	2	0.056	0.166*	0.113	0.035	0.025
N x P	4	0.080	0.098	0.063	0.115	0.062
K	2	0.007	0.131*	0.078	0.066	0.107
N x K	4	0.003	0.233*	0.092	0.087	0.100
P x K	4	0.081	0.095	0.045	0.050	0.069
N x P x K	8	0.026	0.056	0.033	0.034	0.107
Treatment x Control	1	0.023	0.019	0.026	0.183	0.085
Error	28	0.027	0.036	0.069	0.046	0.037

* Significant at 5% level

Appendix XVI. Analysis of variance for effect of NPK treatments on uptake of potassium by cocoa seedlings

Source	df	Mean square				
		Stage of growth (months)				
		1	2	3	4	5
Total	55					
N	2	0.0007	0.0017	0.0012	0.0010	0.0011
P	2	0.0002	0.0006	0.0032	0.0014	0.0074
N x P	4	0.0004	0.00004	0.0012	0.0002	0.0014
K	2	0.0011	0.0004	0.0011	0.0016	0.0016
N x K	4	0.0012*	0.0011	0.0043*	0.0033*	0.0052
P x K	4	0.0006	0.0006	0.0011	0.0032*	0.0090
N x P x K	8	0.0005	0.0011	0.0009	0.0009	0.0048
Treatment x Control	1	0.0003	0.0007	0.0007	0.0032	0.0008
Error	28	0.0004	0.0008	0.0011	0.0011	0.0030

* Significant at 5% level

Appendix XVII. Analysis of variance for the NPK contents (%) of leaves in relation to their positions and NPK treatments

Source	df	Mean square					
		Stage of growth					
		Nitrogen		Phosphorus		Potassium	
		3rd month	4th month	3rd month	4th month	3rd month	4th month
Total	279						
Leaf positions	4	0.142*	0.236*	0.002	0.0012	0.374*	0.279*
Treatments	27	0.112	0.048	0.0090	0.0040	0.328	0.144
Leaf position x Treatment	108	0.053	0.006	0.0008	0.0004	0.050	0.020
Error	140	0.053	0.013	0.0030	0.0009	0.088	0.032

* Significant at 5% level

EFFECTS OF GRADED DOSES OF NITROGEN, PHOSPHORUS AND POTASSIUM ON THE GROWTH AND LEAF NUTRIENT STATUS IN COCOA (*Theobroma cacao* L.)

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ABSTRACT OF A THESIS
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ABSTRACT

Investigations were carried out at the College of Horticulture, Vellanikkara during 1979-80 to study the effect of graded doses of nitrogen, phosphorus and potassium on the growth and leaf nutrient status of cocoa. The results of a pot culture experiment in Completely Randomised Design revealed that the growth parameters (height, girth and number of leaves) as well as dry matter production remained unaffected following the application of nitrogen, phosphorus and potassium. The studies indicated that addition of fertilisers to seedlings grown in potmixture may not be necessary. It has also been observed that the uptake of nitrogen, phosphorus and potassium by cocoa seedlings was not affected by varying levels of these nutrients. Leaf ranked fifth from the apex was found to be suitable for leaf analysis in cocoa seedlings.

Field grown young cocoa trees were utilised for evaluating the relationships between soil test values and leaf nutrient concentration _vis a vis_ plant growth. The studies indicated the suitability of either fan or chupon leaves for foliar nutrient analysis in cocoa. However, indiscriminate sampling between the two types

is to be avoided. No significant correlations existed between phosphorus and potassium contents in soil and leaf, and tree growth.