

Comparision of the Efficacy of the Soil Application
vs
Soil-cum-Foilar Application of NPK Nutrients on Proliferation
of
Suckers in Cardamom (*Elettaria Cardamomum* Maton.)

J. VENKATESHA, *B.Sc. (Hort)*

Division of Horticulture
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE
1980

Comparision of the Efficacy of the Soil Application
VS
Soil-cum-Foilar Application of NPK Nutrients on Proliferation
of
Suckers in Cardamom (*Elettaria Cardamomum* Maton.)

J. VENKATESHA, *B.Sc. (Hort)*

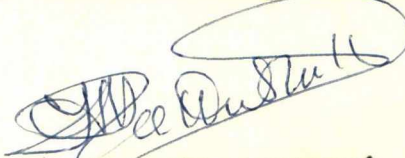
Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements for
the degree
of
MASTER OF SCIENCE (HORTICULTURE)
in
PLANTATION CROPS

Division of Horticulture
University of Agricultural Sciences
Bangalore

CERTIFICATE

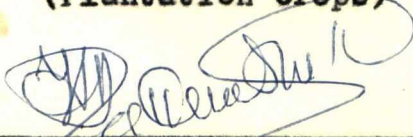
This is to certify that the thesis entitled "COMPARISON OF THE EFFICACY OF THE SOIL APPLICATION vs. SOIL-CUM-FOLIAR APPLICATION OF NPK NUTRIENTS ON PROLIFERATION OF SUCKERS IN CARDAMOM (Elettaria cardamomum Maton.)" submitted by Mr. J. VENKATESHA for the degree of MASTER OF SCIENCE (HORTICULTURE) in PLANTATION CROPS of the University of Agricultural Sciences, Bangalore, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

Bangalore
January , 1980


(H.V.PATTANSHETTI)
Associate Professor of Horticulture
(Plantation Crops)


APPROVED BY:

Chairman :



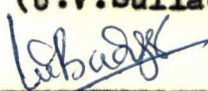
(H.V.Pattanshetti)

Members : 1.



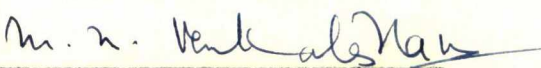
(U.V.Sulladmata)

2.



(M.K. Badiger)

3.



(M.N.Venkataram)

ACKNOWLEDGEMENT

I take this opportunity to express my deep sense of gratitude to my Associate Professor and Chairman of the Advisory Committee, Mr.H.V.Pattanshetti, University of Agricultural Sciences, Bangalore, for his valuable guidance, constant encouragement and keen interest in the progress of work during the field experimentation and also for his thought provoking discussion and useful suggestions during the preparation of thesis. To me it was indeed a great source of inspiration to be associated with him.

I am deeply indebted to Dr.U.V.Sulladmath, Professor and Head, Division of Horticulture, University of Agricultural Sciences, Bangalore, for his valuable comments and useful suggestions for the improvement of this thesis as a Member of my Advisory Committee.

My grateful thanks are due to Dr.M.K.Badiger, Associate Professor of Chemistry and Soils, and Mr.M.N.Venkataram, Statistician for their encouragement and helpful suggestions as Members of my Advisory Committee.

I am extremely thankful to Dr.R.C.Yaraguntiah, Chief Scientific Officer, Regional Research Station, Mudigere, for providing necessary facilities to conduct the experiment at the Research Station, Mudigere.

My thanks are also due to Mr.N.S.Parameshwar, Breeder, and Mr.G.S.Sulikeri, Agronomist, Regional Research Station, Mudigere for their valuable advice during the course of investigation.

The help rendered by Mr.K.G.Raghothama during the period of experiment, analysis and preparation of this thesis is invaluable and

memorable one.

ii

My thanks are due to Mr.L.V.Satyamadhava and other friends for their useful help and suggestions in the preparation of this manuscript.

I am equally thankful to Mr.P.Damodara Rao, Artist, Mr.H. Ravindra Kamath and Mr.V.Ramachandra Upadya, Research Assistants and all the staff members of the Regional Research Station, Mudigere, who helped me in various ways during the experimental period.

I am grateful to the University of Agricultural Sciences for providing hostel facilities at the Regional Research Station, Mudigere.

My reverential thanks are due to my parents, brother-in-law and brothers for their unfailing support, encouragement and cooperation throughout the course of my research.

I am sincerely thankful to Mr.T.Venkatesh, Superintendent, Registrar Office, University of Agricultural Sciences, Bangalore, for his timely help and cooperation.

Finally, my sincere thanks are also due to the Indian Council of Agricultural Research, New Delhi, for awarding me the Junior Fellowship, during the course of this study.

Bangalore
January , 1980


(J.VENKATESHA)

CONTENTS

<u>Chapter</u>	<u>Title</u>	<u>Page</u>
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
III	MATERIAL AND METHODS	34
IV	EXPERIMENTAL RESULTS	46
	1. Sucker production	46
	2. Leaf production	50
	3. Total length of suckers per clump	55
	4. Average height of the sucker.. ..	59
	5. Leaf length and breadth	61
	6. Panicle production	63
	7. Total fresh weight and dry weight of the cardamom clump	66
	8. Percentage contribution of weights of different parts of the plant to the total fresh and dry weight of the whole clump	68
	9. Chemical composition of different parts of cardamom plant	72
	10. Uptake of nutrients by different parts of the plants as influenced by NPK and their mode of application	81
	11. Uptake of nutrients by plants as influen- ced by NPK and their mode of application.. ..	91
	12. Chemical analysis of the soil at the end of the experiment.	95
V	DISCUSSION	98
VI	SUMMARY	116
VII	REFERENCES	122
	APPENDICES	131

LIST OF TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
I	Soil analysis of the experimental plot ..	36
IIa	Effects of NPK and their mode of application on the number of suckers produced in cardamom..	47
IIb	Main effects of NPK, NP, NK and PK on the number of suckers produced per clump of cardamom ..	48
IIc	Effects of sub X main interactions on the number of suckers produced in cardamom ..	49
IIIa	Effects of NPK and their mode of application on the number of leaves produced in cardamom ..	51
IIIb	Main effects of N, P, K, NP, NK and PK on the number of leaves produced per clump of cardamom ..	52
IIIc	Effects of sub x main interactions on the number of leaves produced in cardamom clump ..	53
IVa	Effects of NPK and their mode of application on total length (cm) of suckers in a cardamom clump ..	56
IVb	Main effects of N, P, K, NP, NK and PK on total length (cm) of suckers in a cardamom clump ..	57
IVc	Effects of sub x main interactions on total length (cm) of suckers in a cardamom clump ..	58
V	Effects of NPK and their mode of application on average height (cm) of suckers in cardamom..	60
VI	Effects of NPK and their mode of application on average length of leaf (cm) of cardamom ..	62
VII	Effects of NPK and their mode of application on average leaf breadth (cm) of cardamom ..	64
VIII	Effects of NPK and their mode of application on the number of panicles produced per treatment, 11 months after planting ..	65

<u>Table</u>	<u>Title</u>	<u>Page</u>
IX	Total fresh weight (g) and dry weight (g) of cardamom clumps as influenced by NPK and their mode of application ..	67
X	Effects of NPK and their mode of application on percentage composition of fresh weight (g) in different parts of the cardamom clump ..	69
XI	Effects of NPK and their mode of application on percentage composition of dry matter in different parts of the cardamom clump ..	71
XIIa	Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application (Nitrogen) ..	73
XIIb	Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application (Phosphorus) ..	75
XIIc	Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application (Potassium) ..	77
XIId	Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application (Calcium) ..	78
XIIe	Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application (Magnesium) ..	80
XIIIa	Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application (Nitrogen) ..	82
XIIIb	Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application (Phosphorus) ..	84
XIIIc	Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application (Potassium) ..	86

<u>Table</u>	<u>Title</u>	<u>Page</u>
XIIIId	Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application (Calcium) ..	88
XIIIe	Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application (Magnesium) ..	90
XIV	Effects of NPK and their mode of application on uptake of different nutrients (kg/ha) in cardamom ..	92
XV	Chemical analysis of the soil at the end of the experiment ..	96

LIST OF FIGURES

<u>Table</u>	<u>Title</u>	<u>Between pages</u>
I	Number of suckers produced per clump as influenced by NPK during different months ..	49-50
IIa	Number of leaves produced per clump as influenced by soil and soil-cum-foliar application of NPK ..	53-54
IIb	Number of leaves produced per clump as influenced by NPK during different months ..	53-54
IIIa	Total length of the suckers in a clump as influenced by soil and soil-cum-foliar application of NPK ..	58-59
IIIb	Total length of the suckers in a clump as influenced by NPK ..	58-59
IV	Average height of the suckers in a clump as influenced by NPK at the end of 11 months after planting ..	60-61
Va	Total fresh weight of the cardamom clump as influenced by NPK at the end of 11 months after planting ..	67-68
Vb	Total dry weight of the cardamom clump as influenced by NPK at the end of 11 months after planting ..	67-68
VIa	Percentage contribution of fresh weight by different parts of the clump to the whole clump as influenced by NPK and their mode of application at the end of 11 months ..	69-70
VIb	Percentage contribution of dry weight by different parts of the clump to the whole clump as influenced by NPK and their mode of application at the end of 11 months ..	69-70
VII	Uptake of nutrients by the plants as influenced by NPK at the end of 11 months after planting ..	92-93

LIST OF PLATES

<u>Plate</u>	<u>Title</u>
1	A view of the experimental plot
2	Interior view of the experimental plot
3	A vegetative unit of clonal planting material
4	Cardamom clumps in different treatments at the end of 11 months after planting
5	Cardamom clumps in different treatments at the end of 11 months after planting
6 (a-g)	Comparison of cardamom clumps within a pair consisting of two main treatments at fixed level of sub-treatments
7a	Comparing of sub-treatments at fixed level of main treatments
7b	Comparing of sub-treatments at fixed level of main treatments

INTRODUCTION

CHAPTER I.

INTRODUCTION

Cardamom is one of the most valuable and important spices all over the world. It is represented by the monotypic genus, Elettaria cardamomum M. It belongs to the family Zingiberaceae, under the order Scitaminae. Cardamom originated in the mountains of the southern parts of the Indian Peninsula and nearby island of Ceylon (Abraham, 1965). Among spices of India, it occupies a unique position as the second largest foreign exchange earner ranking next to black pepper.

Cardamom admired as "Queen of spices," is one of the most valued spices of the world (Shanmugavelu and Madhav Rao, 1977). India produces nearly 70 per cent of the world output of cardamom. The annual production during 1978-79 was about 4,000 metric tonnes as against 1,000 metric tonnes in Guatemala, 450 metric tonnes in Sri Lanka and 200 metric tonnes in Tanzania. In India, it is estimated that nearly 86,000 hectares are under cardamom cultivation at present. Of these, 49,826 hectares in Kerala, 28,600 hectares in Karnataka and 7,574 hectares in Tamil Nadu, accounting for the production of 2,900, 800 and 300 metric tonnes respectively.

India is the predominant supplier of cardamom to the world market with an export potential of 2,600 metric tonnes bringing home nearly 60 crores of rupees as foreign exchange per annum. Indian cardamom is considered to be superior to that of other producing countries because of its higher oil content and pleasing

aroma. It is exported to about 60 countries, the main importers being Kuwait, Saudi Arabia, U.S.S.R., Japan, Qatar EI Trucial Omen and Bahrain Islands.

Cardamom is a perennial plant and has a tall pseudostem formed by the encircling of leaf sheaths, wrapped one over the other. Depending on the variety, a normal fully grown plant would be about 2 to 4 metres in height. The real stem is a rhizome, which is sub-terranean in habit. Plants are shallow rooted and are mostly confined to the top 15 to 20 cm layer. The variety minor, comprising three important cultivars viz., Mysore, Malabar and Vazhukka, can be distinguished on the basis of certain specific morphological characters.

In India, cardamom grows under natural conditions in the ever green forests of Western Ghats. The optimum growth and development is observed in the warm and humid conditions with temperature ranging from 10°C to 35°C. It requires well distributed annual rainfall of over 150 cm. It can thrive well in areas where the altitude ranges between 600 and 1200 metres. Well drained sloping lands having pH 5.5 to 6.5, high organic matter and deeply penetrated humus layer are highly suitable for the growth.

Cardamom is grown in India from times immemorial. But scientific cultivation practices to improve growth and yield have not been fully developed. Cardamom produces suckers throughout the year with a reproductive growth in one stage or

the other, being present in the clump over the entire period of a year. As such, depletion of plant nutrients occurs all over the year. Judicious application of fertilizers is of paramount importance for cardamom.

It is reported that cardamom is responsive to both organic and inorganic manures. Response to nitrogen, potassium and to trace elements like magnesium, have been indicated (Anonymous, 1977). But there are no experimental data giving the growth or yield response of the crop to various ingredients and their levels or proportions. Although reports of fertilizer trials being conducted and continued, are made in annual reports of Cardamom Stations, there are no conclusive results about the response of the plant. But there is some useful information on the uptake of nutrients by mature cardamom plants. The tissue composition and the total uptake figures clearly indicate the need for higher supply of potassium (Kulkarni et al., 1971).

Studies on deficiency symptoms by Despande and Kulkarni (1971) have shown that plants in the solution culture with minus K, was the first to manifest the K deficiency. These reports suggested that with an improved methodology in this nutritional trial, fertilizer response of cardamom could be determined. In order to minimise the leaching and also to study the quick response of the plant to the foliar nutrients so that it could be later on tried on the cardamom grown under natural conditions, the experiment is planned. In view of this, present investigation

was undertaken with the following objectives:

1. To study the efficacy of the mode of application of soil application vs soil-cum-foliar application of NPK on proliferation of suckers in cardamom.
2. To study the effects of different nutrients on the production of suckers.
3. To assess the uptake of nutrients based on dry matter production under the influence of N, P and K and their combinations.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE,

The information on the effects of manuring and different methods of application of manures to cardamom is very meagre. Hence, in addition to cardamom, the literature available on other crops which are grown in similar ecological conditions (coffee, tea and cocoa) or on those which have structural similarity (paddy, sugarcane and banana) has also been reviewed. The chapter has been presented under the following heads.

1. Soil and plant analysis in cardamom
2. Fertilizer recommendations to cardamom
3. Shade and nutrition
4. Soil application of nitrogen, phosphorus and potassium
5. Foliar application of nitrogen, phosphorus and potassium.

II.1. Soil and plant analysis

Proper understanding of the chemical composition of the soil and plant, and uptake of nutrients by the plant considerably helps in improving the fertilization practice. Ratnaval et al. (1968) analysed soil samples collected from different cardamom plantations for pH, organic carbon, total P_2O_5 , exchangeable calcium and exchangeable magnesium, and reported ranges of these following values: pH 4.82-5.8; organic carbon 3.23 to 6.03 per

cent, total P_2O_5 0.088-0.126 per cent; exchangeable calcium 4.12-11.42 me/100 g soil and exchangeable magnesium 1.13-2.06 me/100 g soil. They also analysed different healthy leaves of cardamom for their chemical composition. Analysis of second leaf from top revealed the tissue composition as follows:

P_2O_5 0.423 per cent, K_2O 2.76 per cent, CaO 0.297 per cent and MgO 0.174 per cent. Fifth leaf from the tip P_2O_5 0.314 per cent, K_2O 2.62 per cent, CaO 0.711 per cent and MgO 0.228 per cent. Analysis of healthy shoots indicated the presence of following quantities of K_2O 5.38 per cent, P_2O_5 0.302 per cent, CaO 0.93 per cent and MgO 0.109 per cent. Based on these data, the following inferences were drawn.

1) Potassium requirement of cardamom grown under shade is high.

2) Forest soils being rich in nitrogen bring about a greater demand for potassium, so that nitrate may be reduced in plant metabolism.

3) If K is low and its content in the plant tissue is diminished as a result, the total base content of the sap decreases, even though the contents of Ca and Mg may increase to substitute to some extent, the decreased uptake of K. Decrease of total base concentration of sap upsets balance in the nutrition. For these reasons, it was considered essential to maintain the level of potassium in sap solution at a higher level.

4) Low crop yield is due to lack of phosphorus than to any other nutrient. Phosphorus is concentrated not only in the tissue of the growing tips of roots, but also in the developing kernels and seeds. Beneficial effects of phosphorus is more in seeds than in the leaves.

5) Phosphorus aids the uptake of K and tends to counteract the effects of excess N. For these reasons, it was considered beneficial to increase and maintain a high level of phosphorus in the sap solution.

6) Though calcium promotes greater soil activity and improves the soil, sap content of plant tissues should have proper balance of K and Mg. Deficiency of K may lead to excess of Ca. The sap content may, to the best advantage of the plants growing under shade, be maintained at $K > Ca > Mg$.

7) Nitrogen is usually available in forest soil in abundant quantities. For every 18°F decline in temperature, the average N content of soil increases two to three times. Need for N is less under conditions of low intensity of light. In relatively high elevations in the mountains, most of the available N appears to be in the form of ammonia. For these reasons, addition of N fertilizers in cardamom may not be essential.

Srivastava et al. (1968) collected the leaf samples of healthy and infected plants from two important cardamom growing areas in Karnataka viz.; Coorg and Sakaleshpur. Leaf samples

were analysed for macro and micro nutrients. Nitrogen in the various leaf samples ranged from 1.62 to 2.46 ppm. There was no consistent trend in the N composition of leaves in relation to the healthy and infected conditions of the plant. The N, P_2O_5 , K_2O , Ca and Mg contents of the Katte infected plants from Appangala area were 1.62 ppm, 0.22 ppm, 0.96 ppm, 3.032 ppm and 0.63 ppm respectively, while these values for the Katte infected plants of Sakaleshpur area were 2.45 ppm, 0.29 ppm, 3.01 ppm, 1.65 ppm and 0.70 ppm respectively. The healthy plants from Appangala area had 1.96 ppm, 0.29 ppm, 1.38 ppm, 3.26 ppm and 0.73 ppm and from Sakaleshpur area had 2.46 ppm, 0.28 ppm, 2.50 ppm, 1.54 ppm and 0.54 ppm of N, P_2O_5 , K_2O , Ca and Mg respectively.

Kulkarni et al. (1971) have studied the uptake of nutrients by cardamom, by analysing the plants collected from 10 year old plantation (Malabar prostrate) at Regional Research Station, Mudi-gere. The plants were fertilized with 34 -45 -45 kg of NPK per ha. The soil type was clay loam, distinctly acidic (5.8 pH), rich in organic matter (5.92%), low in available P (14.71 kg/ha) and K (156.2 kg/ha). Analysis of the different parts of the plant revealed that nitrogen (2.452-2.52%), P (0.23-0.37%) and Ca (0.45-0.50%) contents of leaves increased from young to mature stage; a general decrease in K (2.46-2.10%) and Mg (0.09-0.05%) contents were seen. However, at bearing stage, N (1.85-1.33%), P (0.10-0.03%) and K (2.04-0.48%) decreased in the leaf tissues, but a definite increase was observed in case of Ca (1.03-1.64%) and Mg (0.12-0.22%).

In case of pseudostem, there was a general reduction in the N (0.68-0.63%), P (0.46-0.10%), K (3.96-1.20%) and increase in the Ca (0.18-0.58%) and Mg (0.06-0.13%) contents which increased with age of the plants.

Considering the total uptake of nutrients by suckers at different stages, rhizome and roots, it was seen that uptake of K was maximum (52.11 kg/ha), followed by N (25.97 kg/ha) and Ca (13.96 kg/ha), P and Mg uptake^{being} comparatively in lesser quantity (4.35 and 3.48 kg/ha). The ratio of N, P, K, Ca and Mg in cardamom clone was 6 : 1 : 12 : 3 : 0.8 respectively. It was also seen that production of 1 kg of cardamom capsules removed 0.122 kg N, 0.014 kg P and 0.20 kg K.

II.2. Some fertilizer recommendations to cardamom

Most of the cardamom growing areas are situated in high rainfall regions on hill slopes of high altitudes. A substantial amount of plant nutrients leach out from soil in such conditions. While fertilizing, one has to take care of nutrient removal by plants as well as its loss due to leaching and fixation. Considering the nutrients removal by the plants, giving allowances for leaching and fixation losses, Abdul Khadher and Mohamed Sayed (1977) recommended a fertilizer dose of 75 kg N, 75 kg P₂O₅ and 150 kg K₂O per ha.

Kelolgi (1977) suggested application of 75 kg N, 75 kg P₂O₅ and 150 kg K₂O per ha to a cardamom crop yielding a normal crop

of 100 kg of dry capsules. An additional doze of 0.65 kg N, 0.65 kg P_2O_5 and 1.3 kg K_2O per ha for every increase in yield of 2.5 kg of capsules over the normal yield was recommended. In another report based on a normal crop of 40 kg of capsules per acre per year, application of 32.5 g N, 25.0 g P_2O_5 and 50 g K_2O per clump per year is recommended (Anon., 1977).

According to Shanmugavelu and Madhava Rao (1977) well rotten cattle manure and sheep manure greatly enhanced yields in cardamom. Manuring twice a year viz., in June-July and September-October is better. They also recommended application of 30 kg N, 30 kg P_2O_5 and 40 kg K_2O per acre per year.

II.3. Shade and nutrition

Shade serves as an insurance against drought and scorching effect of sun. An optimum combination of shade and nutrients will result in better plant growth and increased yields.

Wight (1951) found that an application of 80-100 lb (36 to 45%) per acre of sulphate of ammonia to tea plants under 50 per cent light intensity, was most effective. N became less effective as shade increased and for some kinds of tea there was no benefit in combining higher levels of N and shade. But tea grown in full sun with N would cause the exhaustion of soil. Murray (1954) found that as the cocoa plants grew in size, the effect of the fertilizer application became increasingly evident depending, however, on the light intensity under which plants were growing.

Under heavy shade there was little difference between the treatments, but in the absence of shade, the plants receiving the full NPK treatments were larger and greener than the control receiving no fertilizer. Bearing plants under 15 and 25 per cent light intensity (heavy shade) gave low yield, irrespective of fertilizer application. With increasing light, yield increased upto 50 per cent light but at light levels above this, the yield was markedly affected by the presence or absence of fertilizer. In the absence of fertilizer, yields fell at light intensity greater than 50 per cent. With fertilizers, yield increased to its maximum at 75 per cent light. This showed that shade requirement for cocoa and the response to fertilizers cannot be considered separately (i.e., inter-related).

A trial on tea was conducted with four forms of N at two levels under 50, 70 and 100 per cent light intensities. It was found that there were no significant differences in yield due to light intensities, though yields from treatments receiving 100 and 70 per cent light tended to be higher than those receiving 50 per cent light intensity (Anon., 1955). Gokhale (1958) found that application of N as ammonium sulphate to tea plants growing under acid soil resulted in increased absorption of N, and yield responses to N were greater under unshaded conditions, compared to shaded conditions. Tea plants growing under low fertility soil with 50 per cent light intensity yielded 65 to 135 per cent higher than the full sun light.

In another experiment, Barua (1960) reported greater plucking and pruning weights of tea in plants grown in richer soil and full sun light compared to those under 35 per cent illumination. The results of number of experiments showed that response to fertilizer rates are generally less marked under shade than full day light (Visser, 1961).

Montoya et al. (1961) conducted a trial on coffee consisting of 3 levels of light intensity (100, 75 and 50% of full sun light) and of urea (0, 100 and 200 g/plant/year) with a common dose of 100 g P_2O_5 and 200 g K_2O . They found that increasing the shade reduced the number of nodes per branch. Production of nodes was correlated with yield, the correlation being higher in plants under conditions of 75 per cent light. Suarez Decastro et al. (1962) found that coffee seedlings grown under 36 to 52 per cent shade produced a longer root system and had a better aerial development with thicker stems and more primary branches than either those under full sun or under 81 per cent shade.

In an experiment with cacao plants grown under light condition with combinations of 2 or more of the elements N, P and Mg with N at two levels, plant height and dry weight responded positively to N, P and Mg and outstandingly to N, whereas K tended to have adverse effect. Further, the responses of plant height to weekly urea spray was significant, but dry weight of cacao did not differ significantly (Dorez Zamora et al., 1965).

Based on a long term shade and fertilizer experiment, Thung Tjiang Pek (1966) found that shade is beneficial to tea grown without fertilizers. It increased the number of shoots per bush and influence their formation and weight. Shade removal caused a temporary yield increase followed by a gradual decrease^{due} to lack of fertilizer. Tea in poor condition responded more quickly to fertilizer when shaded. Unshaded plants were sickly in appearance and yielded only 80 per cent as much as shaded tea.

Denys (1966) conducted a study providing 36, 52 or 81 per cent of shade with 10, 5, 10 (N, P, K) fertilizer mixture on coffee. He found that 52 per cent shade with NPK mixture, had significantly high yields of cherry per plant than 36 and 81 per cent shade.

Sen (1967) summarized the series of NPK experiments conducted since 1937 on mature shaded and unshaded tea. He reported that with N levels of 35-65 kg per ha response to P and K under shade, were inconsistent on the various soil types. The overall effects were non-significant but P alone and in combination with K generally tended to depress yields. But at N levels of 90-135 kg per ha the response to P, K and P plus K under shade were positive to all soil types. The overall responses to P and K being highly significant. The addition of P at 35 kg per ha to tea under shade, increased the yield of processed tea by 90 kg per ha. The response to K was highly variable on different soil types, but the overall response to P plus K was highly significant.

Hadfield (1968) conducted a manurial trial comprising either normal N (100 kg/ha), high N (200 kg/ha) or high N in a 5 : 1 : 2 NPK mixture with shaded and unshaded tea bushes. In the first, he found an increase in yield amounting to 10, 13 and 7 per cent respectively over shaded tea bushes. In the following year the corresponding yields of unshaded bushes were 11, 6 and 5 per cent respectively, less than those of the shaded bushes. There was no evidence between shade and N, but there was marked response to P plus K in terms of average increase in yield for the shaded and unshaded tea amounting to 14 per cent compared to N alone. He also reported that the beneficial effects of no shade were associated with temperatures below 30°C and concluded that shade was an **insurance** against adverse climatic conditions, particularly in case of heavy leafed types of tea bushes.

Ahenkorihand Akrot (1968) studied the effects of shade and no shade combined with high, low and no NPK fertilizer on four year old cacao trees. The fertilizers were urea, providing 0, 67 or 112 kg N per ha, triple superphosphate at 0, 12 or 23 kg per ha and muriate of potash at 0, 50 or 111 kg K per ha. K and PK effects were highly significant. The unshaded cacao yielded almost double that of cacao under heavy shade. No shade plus PK treatment had uniformly highest yield followed by PK plus medium shade. K effect was very much pronounced in the absence of shade.

Wargadipura et al. (1974) conducted a trial involving four levels of shade and 5 levels of NP fertilization on tea. The

highest yield of tea was recorded from bushes receiving the highest level of NP viz., 1200 kg sulphate of ammonia, 400 kg double superphosphate per ha per year. The next highest yields were from unshaded tea receiving the next highest NP levels and the yield for any given NP level decreased with increase in shade.

Lee (1975) observed that in an irrigated NPK fertilizer trial on young upper Amazon cacao grown under light shade, there was no significant response to the main effect of N (2236 kg/ha), P (2179 kg/ha) and K (2180 kg/ha) in terms of wet beans. N and K in combination significantly increased the yield above that of N or K alone. There was significant response to P in the absence of K and to K in the absence of P. The effect of N alone reduced yields (13.91 kg/ha) wet beans significantly over the control (2222 kg/ha). The combination of NK resulted in an increase of wet beans of 436 kg per ha over the control.

II.4. Soil application of nitrogen, phosphorus and potassium

Effect of nitrogen

In a nutritional trial with different formulation of N- P_2O_5 - K_2O on banana Bangeo et al. (1962) reported that application of 200 lb (90 kg) and 550 lb (157.7 kg) of nitrogen decreased the soil pH (5.57 to 5.53). The use of 650 lb (292.5 kg) of N alone lowered the pH and increased the NO_3^- and NH_3^- contents of soil. The N content of leaf tissue increased with increasing application of N viz., 17.2, 17.6 and 21.1 per cent from 200 lb (90 kg), 250 lb

(157.50 kg) and 650 lb (292.5 kg) of N respectively over the control. The Ca and Mg content of leaf tissue were increased over the control by all treatments except 200 lb (90 kg) of N.

Faizullah et al. (1966) have stated that application of 40 lb (18 kg) and 80 lb (36 kg) N per acre resulted in tea yields significantly higher than control upto 4 years of age. However, in the first year, 80 lb (36 kg) N per acre gave a lower yield as compared to 40 lb (18 kg) N per acre. In the fifth year the yield increase due to 80 lb N was significantly greater than that due to 40 lb N.

In various manurial trials conducted at Uganda with Robusta and Arabica coffee, Stephens (1967) confirmed that N fertilizers increased coffee yields. Application of urea particularly in split doses tended to have greater effects on yields than ammonium sulphate.

According to Gusejnov and Mirzojan (1967), the application of high doses of nitrogen (360 kg/ha) to 20 year old tea plantations increased yields significantly. However, for plantations less than 10 years old, the most effective nitrogen rate was 180-200 kg per ha.

Lin (1967) conducted a fertilizer trial on tea involving treatments N_0PK , $N_{40}PK$, $N_{80}PK$, $N_{120}PK$, $N_{80}K$ and $N_{30}P$. He found that tea yield increased with increasing application of nitrogen. The application of higher levels of N increased leaf N but reduced the leaf K.

Krishnamurthy (1967) at Dharwad, under rainfed condition with H₂₂ finger millet variety reported that the number of tillers produced per plant were linearly related to levels of nitrogen application. As a mean of all N levels in all, 7.92 shoots were produced.

In a ten year fertilizer trials on Arabica coffee, Subramanian et al. (1969) have found that application of N at 90 kg per ha as calcium, ammonium nitrate or urea raised yields by 700-900 kg per ha over the control (2200 kg/ha).

Talybly (1969) reported that application of 300 kg N per ha as ammonium sulphate to tea, increased yield to 2622 kg per ha during the first six years and in the following seven years the yield increased to 5491 kg per ha. Dey and Sharma (1970) found in their seven years fertilizers trial on tea that application of 110 and 163 kg N per ha was superior in increasing tea yield. Dale (1971) stated that application of 40 to 120 lb (54.00 kg) of N per acre, resulted in a response of 11.2 lb (5.04 kg) of made tea per acre for each additional pound (0.45 kg) of N applied. At the highest N level (200 lb/acre) the corresponding response amounted to 7.4 lb of made tea per acre. There was a little difference among the responses to ammonium sulphate, urea and calcium ammonium nitrate.

According to Ishigaki (1971), application of 25, 50 or 100 ppm N as ammonium nitrate per plant resulted in higher growth rate

and higher N content in coffee plants. In general, N content of plant was increased with increasing N application.

Rao and Iyengar (1975) have studied the different nitrogen levels (0, 45, 90, 135, 180, 225 kg/ha) on coffee. They found that there were no significant differences in average yields of coffee in different treatments. However, the highest yield was recorded in 135 kg N per ha (9273 kg/ha), followed by 180 kg N per ha (8996 kg/ha) and lowest yield was recorded in 45 kg N per ha (8647 kg/ha). The content of N in leaf rose significantly with the levels of N application viz., 3.0, 3.25, 3.3, 3.34, 3.52 and 3.59 per cent respectively.

Shawky et al. (1974) conducted an experiment with foliar application of nitrogen and soil application of N on banana. They observed no obvious variation between two methods of application with regard to the bunch shooting, bunch maturation and in the yield of two seasons. This indicates that each method of application was almost similar in its effect.

Ramkhub (1974) studied relative efficiency of soil and soil-cum-foliar application of nitrogen in different doses (0, 40, 80, 120, 160 and 200 kg/ha) on wheat. He found that plant receiving half soil plus half foliar application of N resulted in significantly shorter growth and had less tiller density per unit area than those of soil and three-fourth soil plus one-fourth foliar application of N.

Effect of phosphorus

Unlike nitrogen, the effects of phosphorus are not striking. Phosphorus generally gives little response. Experimental data are still lacking with regard to the efficient use of phosphorus. However, lack of response should not be taken as deciding factor regarding its value.

Fernando (1967) reported that annual application of P at 30 and 60 lb per acre resulted in increased coffee yields compared to no P application.

In a fertilizer trial on tea, Lin (1967) observed that the increase in tea yield was associated with P content (less than 0.26%) in the leaf.

Lin (1967) conducted field trials with NPK fertilizers on coffee. He found that application of 20 kg P_2O_5 per ha was sufficient in increasing the yield. The leaf analysis indicated that P content of 0.25 per cent or lower would make the application of P fertilization worthwhile in case of coffee.

According to Daraselia (1968), deep placement of P increased the total root mass and encouraged the root development in deep layers, so that there was better use of sub-soil water and P. This resulted in 18 per cent increase in yield.

Wilson and Choudhury (1969) conducted NPK trial involving five forms of phosphorus. Application of these forms, either singly or in mixture, resulted in marked improvement in yield

and quality of tea. Ranganathan (1971) stated that placement of tea at 5-10 or 15-25 cm depth of soil would give better response to tea than broadcasting it with or without dibbling in. Rock phosphate was effective compared to other phosphorus sources.

In the NPK trial, Parra (1972) reported that there would be better correlation with dry weight of coffee and soil phosphorus. If soil is deficient in P dry matter production of coffee fell markedly. According to Aduayi (1972), application of varying levels of P (50-800 ppm) to two and a half year old coffee plant in green house, under sand culture resulted in greater fresh and dry weight. But, 100 ppm was found better compared to other levels of phosphorus. Phosphorus content of leaf was increased with increasing levels of P application.

Ramaswamy (1976) reported that application of 60 g of P_2O_5 per banana plant resulted in an increase in pseudostem height, hand number per bunch, bunch weight and volume, as well as earlier flowering compared to N (170 g/plant) and K (170 g/plant).

A study was conducted at Banana Research Station with different levels of P_2O_5 (0, 40 and 80 g) per plant on Basrai banana, revealed that application of 40 and 80 g P_2O_5 per plant resulted in better plant growth (153 and 154 cm respectively) and girth (61 cm each) compared to control (151 cm height and 59.5% cm girth) (Anon., 1978).

Effect of potassium

According to Lin (1967), increase in potassium content of tea leaf was significantly related to yield. However, yield responses to K occurred at leaf K level below 1.1 per cent.

In the NPK trial on banana, Jagirdar and Ansari (1966) have found that the plants receiving 96 lb (43.2 kg) potassium sulphate per acre resulted in highest yield in terms of bunch weight of fingers per unit area and highest monetary returns per pound of fertilizer applied compared to other treatment combinations.

Rahman and Roy (1970) have reported mean annual increase in the yield of made tea per kg of K_2O applied, assessed over a five year period. They found that the lowest K_2O application of 22.5 kg per ha would increase the amount between 4 and 6.5 kg made tea per kg of K_2O .

Jambulingam and Ramaswamy (1975) observed that application of 360 g K_2O per banana plant through soil application resulted in higher K content in the leaf associated with increase in pseudo-stem height, girth, leaf area and sucker production. It also resulted in earlier flowering and maturity with good graded bunches. The results suggested that K content above 4.3 per cent was optimum.

Ranganathan et al. (1975) reported that application of 120 kg K_2O per ha in four split doses enhanced the tea yield

irrespective of N level. However, application of K_2O in two split doses resulted in slight increase in tea yields over single application of K_2O .

Lahav (1977) in a nutritional trial on banana reported that no antagonism between N and K existed with regard to uptake by the plants. But there was antagonism between K and Ca. Decrease in the level of Ca was expected to follow an increase in K level. He also found that an increase in the level of K fertilizer was followed by a decrease in the Mg level in the sucker. Antagonism between K and Mg (Blade, $r = -0.272$, petiole $r = -0.377$) was more compared to Ca.

Ramaswamy and Ranganathan (1977) conducted an experiment on dwarf cavandish banana with five levels of K (0, 250, 350, 450 and 550 g K_2O /plant). They found that application of 350 g and 450 g per plant increased the pseudostem height (107.55 cm and 99.2 cm respectively), girth (40.8 cm and 39.8 cm) and number of sucker production (3.6 and 5.1 respectively) compared to rest of the treatments. Also earliness in emergence of bunch was noticed at the levels of 250 and 350 g per plant.

A study was conducted at Banana Research Station, Yawal, Maharashtra, with different levels of K_2O per plant (0, 200 and 400 g) on Basrai banana, revealed that application of 400 g K_2O per plant resulted in highest plant height (156.5 cm) and girth (62.0 cm) compared to control (151 cm height and 59 cm girth).

Tissue analysis indicated that increase in K content increased K_2O levels significantly. Uptake of N decreased with increased levels of K application (Anon., 1978).

Effect of nitrogen and phosphorus

Kuratti (1963) reported that the maximum number of tillers were produced by giving N_2 level (45 lb or 20.25 kg) plus P_2 level (30 lb or 13.5 kg) P in two doses (33 tillers) compared to no fertilizers (14 tillers).

Depante et al. (1965) conducted NPK fertilizer trial in a coffee plantation established in red soil and found that there was a positive response to P in the presence of high N. Gaspar (1966) conducted series of experiments on nutrition of coffee. He found that high phosphorus levels, especially in conjunction with moderate N proved very beneficial in increasing yield. Study- ing on NPK nutrition of Arabica coffee, Raju et al. (1969), high N and P content in the leaf showed good correlation with yield. Ramos (1969) conducted a fertilizer trial to compare the yield of coffee with two levels of N, either alone or combined with P and K. He found that treatment receiving two levels of N alone, one level of NP (N_1P_1) and two levels of N and one level of (N_2P_1) gave 6 to 8 fold increase in yield.

In an NPK fertilizer trial, Wilson and Choudhury (1969) reported that balanced application of nitrogen in the form of ammonium nitrate rather than sulphate of ammonia and phosphorus

was the best compromise between yield and quality of tea. According to Wargadipura et al. (1973), yield of tea was enhanced by NP fertilization in terms of 600 kg per ha ammonium sulphate and 100 kg per ha phosphate fertilizer.

Effect of nitrogen and potassium

According to Willson (1969) the response of tea plant was greatly increased when N and P levels were optimum. Martin-Prevel (1969) studied the combinations of N, P, K, S, Ca and Mg on Dwarf Cavendish banana, during three production cycles. Data on growth and fruit yield revealed that earliness of the crop was found to be influenced by N supply and yield, by an N : K equilibrium.

Lahav (1973-74) conducted a sand culture study with different nutrients on banana. He observed no antagonism between nitrogen and with regard to uptake by the plants. Lahav (1977) reported that application of nitrogen as CaNH_4NO_3 (800 kg/ha) and K as KCl (500 kg/ha) on banana resulted in taller suckers (+10 cm) and earlier flowering (by 9-10 days) compared to K or N alone.

Effect of phosphorus and potassium

In a trial conducted by Jagirdhar and Ansar (1966) application of P and K at the rate of 48 (21.60 kg) and 96 (43.40 kg) pounds per acre in the form of superphosphate and potassium sulphate on banana cv. Basrai resulted in increased stem girth and height, compared to control.

Majorova (1969) reported that application of PK +250 kg N per ha to 4-5 year old tea plantations resulted in an yield of 1000 kg of green leaf per ha compared to P and K in combination (675 kg/ha).

Experiments were conducted by Beridze et al. (1969) on tea in different soils of humid sub-tropical districts of Georgia. Analysis of yield data indicated that tea plants grown on brown earth soil required 50 mg P_2O_5 and 20 mg K_2O per 100 g soil whereas tea cultivar grown on a podzol required only 30 mg of P_2O_5 with 200 μ g K_2O per 100 g soil.

Lahav (1973) found that combined application of P and K fertilizers (1000 kg/ha) as superphosphate and KCl resulted in increase in banana plant height (125 cm) and its yield (mean 48% over control).

In NPK nutritional trial on tea, Scarborough (1975) reported that application of 150 kg K_2O and 150 kg P_2O_5 per ha resulted in highest yield compared to no P and K.

Effect of nitrogen, phosphorus and potassium

Bangoo et al. (1962) conducted nutritional trial on banana with different formulations of N- P_2O_5 - K_2O and reported the nutrient content of banana leaf (III leaf) at shooting stage increased in direct proportion to the amount of NPK fertilizer applied. The leaf compositions were 2.8 per cent N, 0.95 per cent P_2O_5 , 3.45 per cent K_2O , 9.73 per cent CaO and 0.77 per cent MgO.

Godoy and Graner (1967) studied the fertilizer trial on irrigated and non-irrigated coffee by giving treatments no manure or fertilizer (control), only FYM, FYM with NPK and NPK alone. The quantities of NPK applied were 75 g N, 50 g P₂O₅ and 100 g K₂O and 10 kg FYM per plant. They observed that in non-irrigated coffee, the average annual yields due to NPK treatments and NPK plus FYM treatment were superior to those of FYM and control treatments. In irrigated plots, the treatments FYM and NPK were superior to control.

According to Majorova (1969), in tea, application of PK+200 kg N per ha and PK+250 kg N per ha to two year old and three year old plants respectively, resulted in increased yield (1000 kg/ha) compared to PK alone (675 kg/ha). Zurbeikij et al. (1969) observed the best growth and development of tea treated with NPK whereas absence of K considerably reduced the number of flushes. They also reported that fertilizer had a significant influence on the respiration rate, photosynthetic intensity and pigment content.

Canukvadze (1970) conducted pot trials on tea with NPK application at 0.15, 0.10 and 0.10 g per kg of soil. The growth of young plants was increased by 64 per cent. The addition of P to the above doses increased shoot growth by 104 per cent and root weight by 100 per cent compared to the control (unfertilized). Similar results were also noted in field trials.

According to Gamkrelidze (1970), plants applied with NPK

(0-700 kg/ha) to tea plants, generally increased yield by about three to four times. Cesareguerra (1972) conducted a fertilizer trial on tea in Peru over a period of 4 years. He found that the most profitable of application of NPK was 180 + 60 + 90 kg per ha per year which raised the yield by 100 per cent to 2600 kg.

In a 13 year trial with different levels of N (90, 180 or 360 kg/ha), P (90, 180 or 540 kg/ha) and K (100, 200 or 300 kg/ha) on tea, Guseino (1973) found that the best growth and yield of tea was more with NPK at 360 : 180 : 200 kg per ha respectively. But leaf quality was better with lower N rates. Mahalkal and Guptha (1973) stated that application of N with P and K induced vigorous growth in banana and high yields. According to Maheran and Hakamara (1974), 18 months old rooted cuttings of tea cv. Yabukita were planted out in the autumn and NPK was applied in 10 split applications. One year after planting the dry weight of roots, stems and leaves was increased by 17-7 and 34 fold respectively, compared to control.

Kimeu (1974) compared the treatments N, NP and NPK at 20 sites in the Meru and Machakos districts of Kenya. At Meru, a single dressing of NPK (15:15:15) combined with two dressings of N doubled the coffee yields. At Machakos fertilizer treatment had no significant effect on the yields from plots with higher soil P (more than 200 ppm). In general, the use of compound fertilizers were recommended for small holdings producing on an average

2.5 tonnes of clean coffee per ha (about 11 kg of fresh cherry per tree).

In a 5 year trial, banana spaced at 2.4 x 1.8 m or 2.4 x 2.4 m were fertilized with annual application of N at 90 to 270 g per plant in five split applications, P at 15.5 to 46 g per plant in three split applications and K at 75 to 460.25 g per plant in five split application, Kohli et al. (1976), found that the highest pseudostem length was obtained due to 180 g N and 273.5 g K per plant per year. However, the highest yields were obtained with a spacing of 2.4 x 1.8 m and 180 g N, 15.5 g P and 186.75 g K per plant per year.

Alice Abraham and Kosny (1978) conducted a comparative study of foliar and soil application of complex fertilizers Vijay (17-17-17) on paddy. The required amount of Vijay complex fertilizer (0.4 g/pot) was dissolved in 10 ml water and sprayed on the foliage for foliar application. The same amount of fertilizer applied around the plants in the pots for soil application. They found that there was no significant difference in the yield of grain and straw due to foliar application of complex fertilizers, partially or fully, at any growth stage. However, complete soil application of complex fertilizer was found superior to foliar application.

II.5. Foliar application of nitrogen, phosphorus and potassium

One of the significant developments in the field of plant

nutrition is the use of foliar nutrition. Application of nutrition through foliage results in rapid absorption and utilization of nutrients, reduction in wastage as leaching, fixation and utilization by other weeds as compared to application of nutrients through soil. Foliar sprays may be employed profitably in relieving the stress symptoms of the plants. This may be at best a supplement to soil application but not a substitute to it (Ananth et al., 1965).

II.5.1. Absorption

Nitrogen: Croome (1959) found that about 95 per cent of the nitrogen applied in the form ^{15}N urea as foliar spray was absorbed within nine hours after application in coffee. Cain (1957) in trials using semi-microtechnique reported complete absorption of sprayed urea solution in less than 24 hours in coffee and cocoa.

Malavolta and Cowry (1957) found an increase in nitrogen content in foliage of coffee from 2.38 per cent to 3.42 per cent and recovery of the N deficient plants by applying 2.5 per cent urea at 2 lit per bush. They also reported that absorption was better in younger leaves. Ananth (1961) also obtained similar results.

Ananth and Iyengar (1965) observed maximum absorption of nitrogen between 4 and 8 hours after application of urea at 2 per cent. In those treated with urea at 1 per cent maximum absorption took place between 8 and 24 hours after treatment. The leaf

nitrogen was increased from 3.33 per cent to 4.0 per cent.

Krishnamurthy Rao et al. (1976) sprayed 1, 2, 5 or 10 per cent urea on 10 year old Arabica coffee plants and found that maximum absorption occurred within 48 hours of spray. They recorded significant increase in N content of leaf at 2 per cent (3.16%N), 5 per cent (3.26% N) and 10 per cent (3.5% N). They further indicated that sprays of urea upto 5 per cent were safe as they did not cause any injury to coffee plants.

Phosphorus: Ananth (1961) reported that the absorption of foliage applied P was slowest than that of nitrogen in case of coffee and leaf age made no difference. The application of higher concentration of P lead to the highest leaf P content.

According to the work of Ananth and Iyengar (1965), higher percentage of P (0.42 %) in plants as a result of application of NPK combination mixture compared to that of only NP (0.33%) combination indicates that K has certain influence on the higher uptake of P in plant tissue.

According to Krishnamurthy Rao et al. (1976), superphosphate was found to be suitable for foliar sprays on coffee at concentrations of 0.5 and 1.0 per cent. The P content in the leaf was significantly increased after 48 hours of spray. There was not much difference in P content between 48 hours (0.18% P_2O_5) and 98 hours (0.20% P_2O_5) after treatment at 5 per cent concentration and 0.19 and 0.20 per cent P_2O_5 respectively at 1 per cent concentration.

Potassium: In the preliminary experiment on coffee, Ananth (1961) reported that K absorption was slower than that of nitrogen and phosphorus. Ananth and Iyengar (1965) have studied the absorption of potassium by giving muriate of potash at 0.5 and 1 per cent on coffee. They observed that maximum absorption of potassium took place in young leaves between 24 and 48 hours after the treatment. The maximum K content in young leaves was 3.90-4.35 per cent compared to 2.96 to 3.54 per cent in old leaves.

II.5.2. Effect of NPK

Anonymous (1956) recorded an increase in yield of sugarcane by 13.69 and 17.29 metric tonnes per acre respectively by spraying N and P (10 lb or 4.5 kg/acre each), as sulphate of ammonia and superphosphate (2% each) after cessation of grain period.

Godoy (1958) sprayed coffee seedlings fortnightly with 50 g superphosphate, 25 g sodium nitrate and 10 g potassium chloride per 10 lit water and 5 g per lit water of a mixture of ammonium phosphate, 42 g potassium nitrate and 21 g urea, after four months plants with treatments were markedly taller, greener and uniform than control (water spray only). Final analysis showed that the control was significantly inferior in height, fresh weight, number of leaves and number of branches compared to the plants sprayed with 37 g ammonium phosphate, 42 g potassium nitrate and 21 g of urea.

Chiang (1960) reported an increase in yield from tea bush

by spraying urea at a concentration of 1.2 per cent. However, application of both urea (1.2%) and manganese (0.2%) increased yield considerably by 28.2 per cent. But foliar application had no effect on the quality of either black or green tea.

It was reported that foliar application of urea at doses higher than 25 kg N per ha was not effective on sugarcane in increasing yield (Anon., 1966). To verify this, Panje et al. (1966-67) conducted trial with application of 50 kg nitrogen as urea to soil and 50 kg N as urea (4%) through foliar application. They found that the differences in yield and juice quality due to graded doses of fertilizer and mode of its application were non-significant. Another experiment was conducted by Panje et al. (1967-68) by employing doses of 0, 25, 50 and 100 kg nitrogen per ha as urea. This fertilizer was applied (i) all at planting, (ii) half at planting in soil and half subsequently as foliar sprays, and (iii) all as foliar sprays. For foliar sprays 4 per cent aqueous solution of urea was used at 25 kg N per ha at a time. Statistical analysis of the yield and juice quality due to graded doses of fertilizer and mode of its application were found non-significant.

A comparative study on efficacy of soil versus foliar application on coffee, revealed that application of N (112 kg/ha) in 3 doses and P_2O_5 (51 kg/ha) in one dose as soil application increased the mean yield of 7 years (7347 kg/ha) over other treatments viz., 30 kg N + 51 kg P_2O_5 as soil application + 40 kg N per

ha as foliar application (6950 kg/ha), 38 kg N per ha as soil application and 40 kg N + 50 kg P_2O_5 kg per ha as foliar application (6570 kg/ha), 72 kg N + 51 kg P_2O_5 per ha as soil application + 40 kg N per ha as foliar application (6522 kg/ha), 72 kg N per ha as soil application and 40 kg N + 51 kg P_2O_5 as foliar application (6492 kg/ha) and 112 kg N per ha in three doses as soil application + 51 kg P_2O_5 per ha as foliar application (6348 kg/ha). However, statistical analysis of the data of one year (1973-74) indicated no significant differences in yield between soil and foliar application (Anon., 1967).

Kimeu (1970) studied the effect of NPK on total dry matter production in coffee. The treatment involved two compound fertilizers (15 : 15 : 15 + 6% Mg and trace elements) viz., Delta foliar feed and Wchsal liquid NPK fertilizer (9 : 9 : 7 + trace elements). It was found that Delta alone (0.5% foliar spray) and Delta (0.5%) + Wchsal spray (0.5%) increased the dry matter 40.4 g and 49.9 g per plant respectively. Wchsal alone gave an increase of about 3.3 g per plant over the control. However, he found that Delta spraying at 1 per cent concentration had a scorching effect on the leaves. The Wchsal or delta combination treatment produced significant increase in the total N (796 mg), P (92 mg) and K (12 to 6 mg) contents of the seedlings compared to control (N- 383 mg, P- 53 mg and K 639 mg).

MATERIAL AND METHODS

CHAPTER III

MATERIAL AND METHODS

The experiment was conducted at the Regional Research Station, Mudigere, Chikmagalore district, during the period between June 1978 and May 1979. Mudigere is situated at 13°25' N latitude and 75°25' E longitude and has an elevation of 975.6 m above mean sea level.

III.1. Weather condition:

The weather data recorded at the meteorological observatory situated at the Regional Research Station, Mudigere, is presented in Appendix I. The total rainfall during the period of study was 2552.20 mm. The mean maximum and minimum temperatures were 30.70°C and 12.88°C respectively. The average annual rainfall for a period of 15 years (2359 mm) was spread over a period of 7 months from the month of May to November. An excess rainfall of 192.47 mm over and above the average for 15 years was recorded during the period.

III.2. Soil and its characteristics

The experiment was located on a gently sloping uniform sandy loam soil. From the experimental site, composite soil samples were drawn from the 0-30 cm depth and analysed for physical and chemical properties. At the end of the experiment, treatment-wise soil samples were drawn from 0-30 cm depth and for chemical analysis.

Both the results are presented in Table I and Table XIV respectively.

III.3. Experimental details

The treatments comprise of two methods of application and two levels of NPK in different combinations. The details are as follows:

i) Main treatments:

M_1 = Complete soil application of N, P and K

M_2 = Soil-cum-foliar application of N, P and K

ii) Sub-treatments

<u>Nutrients</u>	<u>Two levels</u>	
	<u>I</u>	<u>II</u>
N	0	32.5 g N per plant
P	0	25.0 g P_2O_5 per plant
K	0	50.0 g K_2O per plant

III.4. Design and layout of experiment

The experiment was laid out in the form of split plot design ($2 \times 2^3 \times 3$).

- i) Replications .. Three
- ii) Plot size ..
 - a) Gross plot size 1.82 m X 3.6 m
 - b) Net plot size 1.82 m X 2.44 m
- iii) Spacing .. 1.82 m X 0.6 m
- iv) Number of plants per plot .. Four plants in each plot with a common guard row between treatments. All the four plants were used for observation.

Table I. Soil analysis of the experimental plot

	<u>Per cent</u>
<u>Mechanical analysis</u>	
Coarse sand (per cent)	35.12
Fine sand (per cent)	32.48
Silt (per cent)	8.56
Clay (per cent)	19.36
Texture	Sandy loam
<u>Chemical analysis</u>	
pH	5.10
E.C.(mmhos/cm)	200
Organic carbon (per cent)	1.60
Total nitrogen (per cent)	0.1
CEC (me/100 g)	6.5
Available phosphorus (kg/ha)	6.5
Available potassium (kg/ha)	169.5
Exchangeable calcium (me/100 g)	2.74
Exchangeable magnesium (me/100 g)	0.85

III.5.1. Preparation of the experimental field

After clearing the land free of scrub growth, trenches measuring 6.71 m in length, 0.61 m in width and 0.46 m in depth were opened to accommodate 11 plants. The trenches were left for weathering for about one month, then they were filled with same soil after thoroughly mixing, leaving a gap of 7-8 cm from the top.

III.5.2. Lime application

Agricultural lime with an assay of 72 per cent calcium carbonate was applied before planting, at the rate of 3 kg per trench.

III.5.3. Erection of pandal

An overhead pandal raised to a height of 1.75 m on stone pillars was erected and a coir mat with a mesh was spread horizontally over the support of galvanized iron wire network.

III.5.4. Preparation of planting material

Monoclonal plant material obtained by dividing the clumps of P₅ clone was used in the experiment. Each vegetative planting unit consisted of a section of a rhizome with grown up shoot having one or two growing shoots. The cut portions of rhizome and roots were dipped in a solution of 0.2 per cent Captan for 10 minutes before planting.

Plate 1. A view of the experimental plot

Plate 2. Interior view of the experimental plot

Plate 3. A vegetative unit of clonal planting material

Plate 1



Plate 2

Plate 3



III.5.5. Planting of suckers

The trenches were filled with the soil leaving a head space of 7-8 cm. The suckers were planted to an appropriate depth which consisted of retaining the swollen base of the stem at the soil level in the trench. The newly planted suckers were staked and irrigated. A thick polythene sheet measuring 1.5 m long and 0.9 m wide was retained as a screen at the centre of the long trench to separate it into two sections for confining the effects of main treatments to the main plot only.

III.5.6. Basin preparation and mulching

Small basins were prepared around each plant to minimise transportation of surface soil during irrigation. A strip of polythene sheet of natural colour and of 0.6 m width was spread at the base of clumps to prevent soil erosion during monsoon.

III.5.7. Fertilizers

a) Soil application of NPK: In this study, 32.5 g of N, 25.0 g of P_2O_5 and 50 g of K_2O per plant per year were applied as recommended by University of Agricultural Sciences, Bangalore (Anon., 1977). To supply the above quantities of nutrients, 73.68 g urea (44%), 156.2 g of superphosphate (16%) and 85 g of muriate of potash (60%) were applied. Out of the total quantity of fertilizers, 1/8th of urea, 1/4th of superphosphate and 1/4th of muriate of potash were applied one month after planting. The remaining quantities were applied in 3 split doses at monthly

interval after planting. The fertilizers were applied in a ring drawn 15 to 20 cm away from the clump and they were incorporated into the soil by stirring.

b) Soil-sum-foliar application of NPK: In these treatments 50 per cent of the total quantity of NPK was applied through soil and the remaining 50 per cent was given as foliar spray.

i) 50 per cent soil application: To supply 16.25 g of N, 12.5 g of P_2O_5 and 25.0 g of K_2O per plant, 36.93 g of urea, 78.1 g of superphosphate and 42.5 g of muriate of potash were applied. Out of these quantities $1/8$ th of urea, $1/4$ th of superphosphate and $1/4$ th of muriate of potash were applied one month after planting, and the remaining quantities were applied in eight split doses at monthly interval. The same method of application was followed as described in soil application of NPK.

ii) 50 per cent foliar application: Urea (44%), orthophosphoric acid (88.93%) and muriate of potash (60%) were used as source of nitrogen, phosphorus and potassium respectively.

iii) Concentration of solution: A concentration of 1 per cent fertilizer solution in each of urea, orthophosphoric acid and muriate of potash, was selected for applying separately. The individual ingredients N, P and K, a more dilute form of fertilizer solution of 0.5 per cent for each of the ingredients was selected in cases where more than one ingredients (viz., NP, NK, PK and NPK) were to be applied in combination. Before using orthophosphoric

acid the pH of the solution was adjusted to 6.5-7.0 by using sodium hydroxide.

iv) Quantity of solution: In the early period, the canopy of the cardamom clump was very much limited and the entire spray material could not be applied at a stretch. Therefore, sprays were repeated till the entire quantity was applied. The quantum of spray solution that could be applied at a time increased gradually and a spray solution of 25, 30, 50, 80 and 90 ml was required for the plants of the age of 4, 5, 7, 9 and 10 months after planting.

III.6. Other cultural operations

III.6.1. Weeding:

The plots were kept free from weeds by weeding periodically.

III.6.2. Irrigation

No irrigation was required upto the end of October as there were regular showers. Regular irrigation was given from November, at a rate of 20 litres per plant at weekly intervals.

III.6.3. Plant protection

Regular plant protection measures were taken. During the period of establishment of suckers, Dimethoate (Rogor) 30E at the rate of 32 ml in 18 lit of water and Blitox 40 g in 10 lit of water were sprayed once in 15 days. Later, the sprays were restricted to 30-45 days interval.

III.7. Biometrical observations

Observations recorded on all the four clumps in each treatment were worked out as average per clump and presented in Table concerned.

III.7.1. Sucker production

The number of suckers produced were recorded once in every month (November to May) starting from the date of imposition of the main and sub-treatments. Suckers which measured 5 cm and more in length were included in the count.

III.7.2. Leaf production

The total number of leaves produced by the plant were counted once in a month (November to April), treatment-wise averages per clump were worked out.

III.7.3. Total height of the plant

For recording the total height of the clump, cumulative effect of the linear length of the individual suckers, measured from the base of the pseudostem to the base of the freshly opened leaf, was taken into consideration. This was recorded at monthly intervals from November to April.

III.7.4. Average height of the sucker:

This was expressed by dividing the total height of the clump by the number of suckers.

III.7.5. Length and breadth of leaf

Third leaf from the top of the sucker was selected for measuring length and breadth of leaf. For recording length of the leaf, length of the leaf blade measured from the base to the tip was taken. For noting the breadth of the leaf maximum width was taken. This was recorded from November to April.

III.7.6. Panicle production

The number of panicles produced in the plants were counted at the end of experiment (11 months after planting) and it was recorded as the number of panicles produced per treatment.

III.8. Production of fresh weight and dry weight

Production of fresh weight and dry matter was estimated at the end of the experiment. From each treatment one representative plant was uprooted and its rhizome was washed free of soil. Then the clump was separated into leaves, shoot, rhizome and roots and their weights were recorded. The samples were thoroughly washed with clean water and air dried. The samples were dried in an oven at 60°C to a constant weight. From these determinations total dry matter production and its distribution into leaves, shoot, rhizome and roots were worked out. Besides, percentage distribution was also worked out from these figures. The same dried samples were used for chemical analysis.

III.9. Soil analysis

III.9.1. Physical properties

III.9.1.1. Mechanical analysis of soil: It was carried out by the International Pipette Method described by Piper (1950). Soil texture was then computed as detailed in U.S.D.A. Survey Manual (1956).

III.9.1.2. Chemical analysis of soil

III.9.2.1. Soil pH: It was measured in 1 : 2.5 soil and water suspension on pH meter fitted with combination electrode (Jackson, 1958).

III.9.2.2. Electrical conductivity: It was measured in the filtrate of 1 : 2.5 soil : water by using multiple range conductivity bridge (Jackson, 1958).

III.9.2.3. Organic carbon: It was determined by following the Wet Oxidation method using potassium dichromate and sulphuric acid as described by Jackson (1958).

III.9.2.4. Total nitrogen: Total nitrogen was determined by Macro Kjeldahl method. Copper-potassium sulphate and Selenium catalyst mixture was used during the digestion process.

III.9.2.5. Available phosphorus: Available P_2O_5 was estimated colorimetrically on "Spectrocal" at 420 nm. Bray's No.1 (0.03N NH_4F in 0.025 N HCl) extracted was used for extracting the soils and molybdenum blue colour was developed by using ammonium molybdate

reagent and stannous chloride reductant as described by Jackson (1958).

III.9.2.6. Available potassium: Available potassium was determined on a suitable aliquot obtained by 1.0N neutral ammonium acetate flame - photometrically by using "AIMIL" model flame photometer using K filter (Jackson, 1958).

III.9.2.7. Exchangeable calcium and magnesium: Soil sample was leached with 1.0N neutral ammonium acetate and in the leachate exchangeable calcium and magnesium were estimated by Versenate titration using appropriate indicators (Jackson, 1958).

III.10. Analysis of plant samples

Plant samples were analysed for total nitrogen, phosphorus, potash, calcium and magnesium.

III.10.1. Total nitrogen:

It was determined on one gram of dry sample after digesting with sulphuric acid and digestion mixture. Ammonia was distilled by Micro Kjeldahl method as described by Jackson (1958).

III.10.2. Wet ashing

Samples weighing 1 gram were pre-digested with 15 ml nitric acid on water and sand baths, and digested with tri-acid mixture of sulphuric acid, perchloric acid and nitric acid (1 : 4 : 10). The clean digested material was made upto 100 ml volume and filter paper to remove silica. This solution was used for estimating P_2O_5 , K_2O , CA and Mg.

III.10.3. Phosphorus

A characteristic yellow colour was developed on a suitable aliquot by mixing Vanado-molybdate. The resultant yellow colour intensity was measured at 660 nm wavelength on "Spectronic-20" spectrometer as described by Jackson (1958).

III.10.4. Potassium

This was determined flame photometrically by using "AIMIL" model with K-filter (Jackson, 1958).

III.10.5. Calcium and magnesium

The procedure followed for soil samples was adopted for plant samples also.

EXPERIMENTAL RESULTS

CHAPTER IV

EXPERIMENTAL RESULTS

The results obtained from the present investigation have been presented.

IV.1. Sucker production

Data on number of suckers produced per clump during different months as influenced by NPK and their mode of application are presented in Table IIa, IIb and IIc, and Fig.1.

The production of suckers under the influence of main treatments was found to be non-significant while it was found to be significant under the influence of sub-treatments, during all the months from November to May.

The plants fertilized with $N_1P_1K_1$ recorded significantly more number of suckers in all the monthly observations made compared to rest of the treatments. The number of suckers in this treatment showed an increase from 4.33 to 31.84 from November 1978 to May 1979 respectively. The plants in control produced lowest number of suckers throughout the period of observation (November to May). The following groups of treatments namely, N_1P_1 , P_1K_1 and N_1K_1 , which followed $N_1P_1K_1$ consistently throughout the period of observation, did not differ amongst themselves.

The main effects of N, P and K showed significant influence on the number of suckers produced from December to May compared to that of control. None of the interactions was significant.

Table IIa. Effects of NPK and their mode of application on the number of suckers produced in cardamom

Treatments	Months						
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
	<u>Main treatment means</u>						
M ₁ (S)	3.05	3.91	7.21	9.99	13.04	17.27	21.28
M ₂ (S + F)	2.89	3.52	6.52	9.21	11.80	16.21	19.52
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.D. at 1%	NS	NS	NS	NS	NS	NS	NS
	<u>Sub-treatment means</u>						
N ₀ P ₀ K ₀	2.38	2.79	4.92	6.79	7.79	10.41	12.31
N ₀ P ₀ K ₁	2.55	3.25	5.21	7.75	10.16	14.62	18.09
N ₀ P ₁ K ₀	3.20	3.58	7.13	9.66	11.58	15.62	18.12
N ₀ P ₁ K ₁	3.08	3.70	6.92	10.20	13.58	17.91	22.31
N ₁ P ₀ K ₀	2.44	3.08	4.92	7.26	9.83	12.87	17.51
N ₁ P ₀ K ₁	2.83	3.37	6.33	8.29	10.91	16.54	19.22
N ₁ P ₁ K ₀	2.95	3.75	7.56	10.33	13.97	19.66	23.74
N ₁ P ₁ K ₁	4.33	6.16	11.93	16.54	21.54	27.29	31.84
C.D. at 5%	0.83	1.03	2.25	3.03	3.48	4.05	4.95
C.D. at 1%	1.13	1.39	3.03	4.08	4.69	5.47	6.67

NS=Non-significant

Table IIb. Main effects of N, P, K, NP, NK and PK on the number of suckers produced per cardamom clump

Effects	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
N ₀	2.77	3.33	6.04	8.46	10.80	14.39	17.71
N ₁	3.16	4.09	7.68	10.71	14.06	19.09	23.08
C.D. at 5%	0.43	0.52	1.12	1.50	1.74	2.03	2.48
P ₀	2.55	3.12	5.34	7.50	9.70	13.61	16.79
P ₁	3.39	4.29	8.38	11.67	15.16	19.87	24.01
C.D. at 5%	0.43	0.52	1.12	1.50	1.74	2.03	2.48
K ₀	2.76	3.29	6.13	8.61	10.79	14.39	17.92
K ₁	3.17	4.12	7.59	10.57	14.04	19.09	22.87
C.D. at 5%	0.43	0.52	1.12	1.50	1.74	2.03	2.48
N ₀ P ₀	2.41	3.02	5.06	7.02	9.03	12.51	15.20
N ₀ P ₁	3.14	3.64	7.02	9.90	12.58	16.26	20.22
N ₁ P ₀	2.68	3.22	5.62	7.99	10.37	14.70	18.37
N ₁ P ₁	3.64	4.95	9.74	13.43	17.75	23.47	27.79
C.D. at 5%	0.61	0.73	1.59	2.13	2.46	2.89	3.50
N ₀ K ₀	2.79	3.18	6.02	8.22	9.68	12.51	15.22
N ₀ K ₁	2.76	3.47	6.06	8.72	11.87	16.26	20.20
N ₁ K ₀	2.74	3.41	6.24	9.01	11.90	16.26	20.63
N ₁ K ₁	3.58	4.76	9.13	12.41	16.22	21.91	25.53
C.D. at 5%	0.61	0.73	1.59	2.13	2.46	2.89	3.50
P ₀ K ₀	2.46	2.93	4.92	7.24	8.81	11.64	14.92
P ₀ K ₁	2.64	3.41	5.77	7.77	10.54	15.58	18.64
P ₁ K ₀	3.07	3.66	7.34	9.99	12.77	17.14	20.93
P ₁ K ₁	3.70	4.93	9.42	13.37	17.56	22.60	27.08
C.D. at 5%	0.61	0.73	1.59	2.13	2.46	2.89	3.50

Table IIc. Effects of sub x main interactions on the number of suckers in cardamom

Interaction	Sub x Main interaction means						
	Months						
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
N ₀ P ₀ K ₀ M ₁	2.58	3.25	6.08	7.83	9.25	12.41	14.50
N ₀ P ₀ K ₀ M ₂	2.19	2.33	3.75	5.75	6.33	8.41	10.13
N ₀ P ₀ K ₁ M ₁	2.50	3.16	5.25	7.33	10.83	14.91	18.79
N ₀ P ₀ K ₁ M ₂	2.41	3.33	5.16	7.16	9.50	9.50	17.41
N ₀ P ₁ K ₀ M ₁	3.58	4.16	9.00	12.00	13.91	15.91	20.69
N ₀ P ₁ K ₀ M ₂	2.83	3.00	5.25	7.33	9.24	13.33	15.55
N ₀ P ₁ K ₁ M ₁	2.83	3.86	6.91	9.66	13.41	17.50	23.00
N ₀ P ₁ K ₁ M ₂	3.33	3.58	6.91	10.75	13.75	18.33	21.63
N ₁ P ₀ K ₀ M ₁	2.66	3.41	5.75	9.08	12.00	15.41	20.63
N ₁ P ₀ K ₀ M ₂	2.41	2.75	4.08	6.33	7.33	10.33	14.38
N ₁ P ₀ K ₁ M ₁	2.91	3.41	6.25	7.91	10.00	16.91	19.25
N ₁ P ₀ K ₁ M ₂	2.75	3.33	6.41	8.66	11.50	16.16	19.16
N ₁ P ₁ K ₀ M ₁	2.83	3.75	6.75	9.91	13.13	17.83	21.61
N ₁ P ₁ K ₀ M ₂	3.83	3.75	8.39	10.75	14.75	21.50	25.85
N ₁ P ₁ K ₁ M ₁	4.50	6.25	11.66	16.16	21.75	27.25	31.74
N ₁ P ₁ K ₁ M ₂	4.16	6.08	12.16	16.91	21.33	27.33	31.91
* C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.D. at 1%	NS	-	-	-	-	-	-
**C.D. at 5%	NS	NS	NS	NS	NS	NS	NS
C.D. at 1%	-	-	-	-	-	-	-

*C.D. is for comparing two sub-treatment means at fixed level of main treatment means

**C.D. is for comparing two main treatment means at fixed or different levels of sub-treatment means

NS=Non-significant

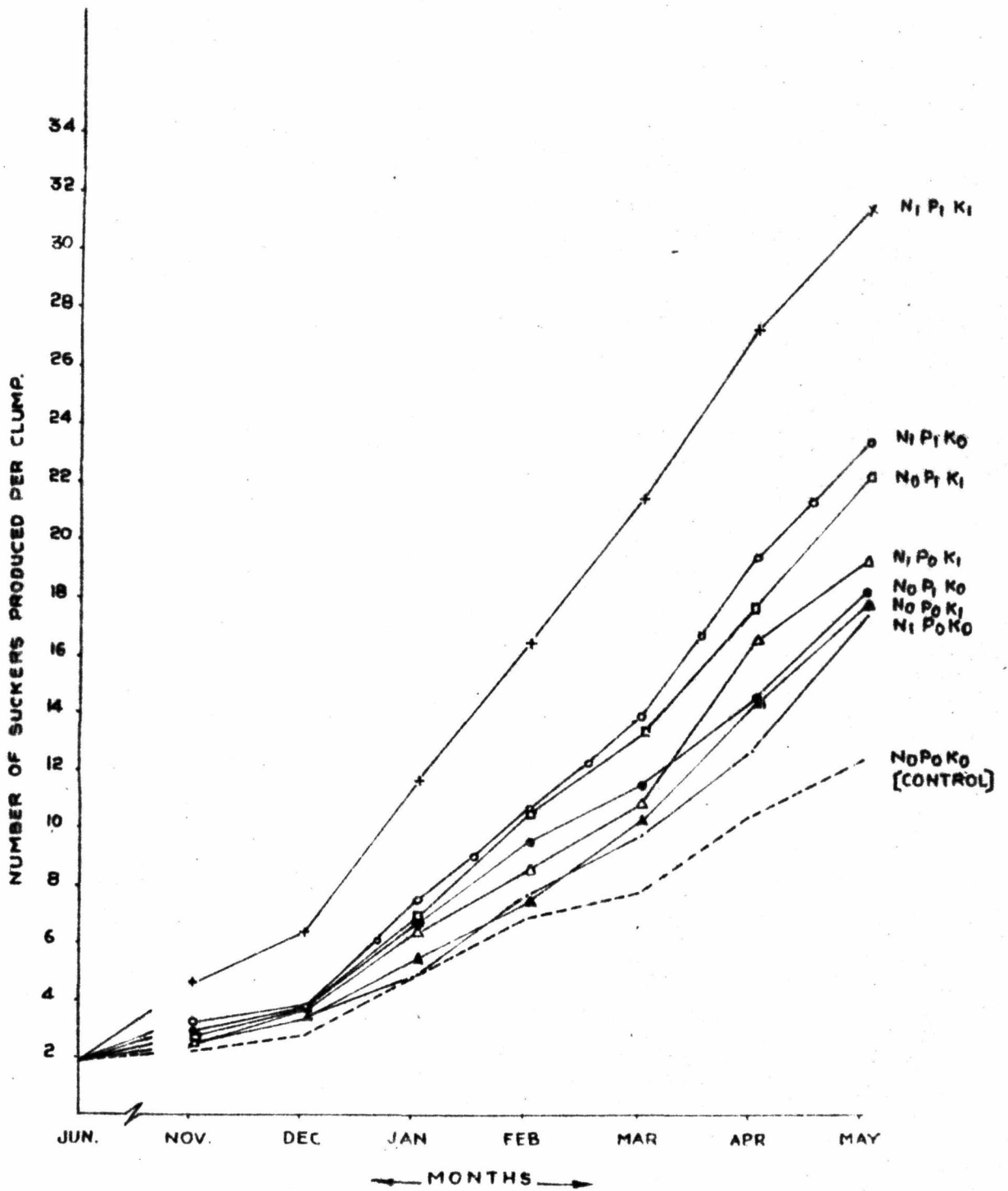


Fig. I: NUMBER OF SUCKERS PRODUCED PER CLUMP AS INFLUENCED BY N P K DURING DIFFERENT MONTHS.

Plate 4. Cardamom clumps in different treatments at the end of 11 months after planting

S = Soil application of NPK

(Left to right : $N_0P_0K_0$, $N_1P_0K_0$, $N_0P_0K_1$, $N_1P_0K_1$,
 $N_0P_1K_0$, $N_0P_1K_1$, $N_1P_1K_0$, $N_1P_1K_1$)

Plate 5. Cardamom clumps in different treatments at the end of 11 months after planting

S = Soil-cum-foliar application of NPK

(Left to right: $N_0P_0K_0$, $N_0P_0K_0$, $N_0P_0K_1$, $N_1P_0K_1$,
 $N_0P_1K_0$, $N_0P_1K_1$, $N_1P_1K_0$, $N_1P_1K_1$)



Plate 4



Plate 5

IV.2. Leaf production

Data on number of leaves produced per cardamom clump during different months influenced by the treatment effects of NPK and their mode of application are presented in Table IIIa, IIIb and IIIc, and Fig.IIa and IIb.

Monthly observations as regards the number of leaves produced were taken from November 1978 onwards. The main treatment effects significantly differed only during the months of March and April. During the month of March, the number of leaves produced by the main treatment (69.75) consisting of soil application of NPK was significantly higher than that of soil-cum-foliar application of NPK (59.95). Similar trend continued during the following months and it was observed that as against 110.62 leaves produced by soil application of NPK, only 91.76 leaves were produced per clump under soil-cum-foliar application of NPK. The differences persisted during April when last observation was made before lifting the clumps for the study of dry matter and nutrient uptake. The number of leaves produced under sub-treatments differed significantly in all the monthly observations made. The treatment $N_1P_1K_1$ produced significantly higher number of leaves compared to that of other treatments, throughout the observation period. The number of leaves in this treatment in November and April were 22.75 and 171.20 respectively. The effects of P_1K_1 , N_1P_1 and P_1 ranked next to that of $N_1P_1K_1$ with respect to number of leaves produced. The lowest number of leaves were recorded in the plants grown under control, throughout the period of observation.

Table IIIa. Effects of NPK and their mode of application on the number of leaves produced in cardamom

Treatments	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<u>Main treatment means</u>						
M ₁ (S)	17.06	19.97	29.69	52.36	69.75	110.62
M ₂ (S + F)	16.21	17.93	26.51	45.31	59.95	91.76
C.D. at 5%	NS	NS	NS	NS	5.03	10.02
C.D. at 1%	-	-	-	-	NS	NS
<u>Sub-treatment means</u>						
N ₀ P ₀ K ₀	14.22	15.41	20.24	33.45	43.54	62.00
N ₀ P ₀ K ₁	14.33	15.46	22.58	38.38	52.33	89.08
N ₀ P ₁ K ₀	17.63	18.00	30.96	52.12	61.62	94.83
N ₀ P ₁ K ₁	18.34	20.79	29.79	52.45	73.36	116.66
N ₁ P ₀ K ₀	14.02	14.29	20.33	36.79	51.12	72.96
N ₁ P ₀ K ₁	15.58	17.08	24.33	45.29	54.37	92.16
N ₁ P ₁ K ₀	17.92	20.25	31.23	52.58	71.33	110.62
N ₁ P ₁ K ₁	22.75	30.29	45.08	82.67	111.16	171.20
C.D. at 5%	4.32	6.59	9.46	17.61	21.24	29.90
C.D. at 1%	5.82	8.89	12.76	23.76	28.65	40.33

NS = Non-significant

Table IIIb. Main effects of N, P, K, NP, NK and PK on the number of leaves produced per cardamom clump

Effects	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
N ₀	15.79	17.41	25.96	40.17	57.71	90.64
N ₁	17.48	20.47	30.22	54.33	71.99	111.74
C.D. at 5%	2.17	3.30	4.73	8.01	10.63	14.95
P ₀	14.06	15.55	21.92	38.47	50.33	79.05
P ₁	19.20	22.33	34.26	56.02	79.35	123.33
C.D. at 5%	2.17	3.30	4.73	8.91	10.63	14.95
K ₀	15.52	16.98	25.74	43.73	56.90	85.10
K ₁	17.74	20.90	30.44	50.77	72.80	117.28
C.D. at 5%	2.17	3.30	4.73	8.91	10.63	14.95
N ₀ P ₀	13.50	15.43	21.56	35.91	47.93	75.54
N ₀ P ₁	18.08	19.39	30.37	44.43	67.49	105.74
N ₁ P ₀	14.62	15.68	22.29	41.04	52.74	82.56
N ₁ P ₁	20.33	25.27	38.15	67.62	91.24	140.91
C.D. at 5%	3.05	4.67	6.70	12.59	15.03	21.14
N ₀ K ₀	15.25	16.70	25.75	42.78	52.58	78.42
N ₀ K ₁	16.33	18.12	26.18	37.56	62.84	102.87
N ₁ K ₀	15.79	17.27	25.74	44.68	61.22	91.79
N ₁ K ₁	19.16	23.68	34.70	63.98	82.76	131.68
C.D. at 5%	3.05	4.67	6.70	12.59	15.03	21.14
P ₀ K ₀	13.27	14.85	20.39	35.12	47.33	67.48
P ₀ K ₁	14.85	16.26	23.45	41.83	53.35	90.62
P ₁ K ₀	17.77	19.12	31.09	52.35	66.47	102.72
P ₁ K ₁	20.64	25.54	37.43	59.71	92.26	143.93
C.D. at 5%	3.05	4.67	6.70	12.59	15.03	21.14

Table IIIc. Effects of sub x main interactions on the number of leaves produced in cardamom clump

Interaction	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
N ₀ P ₀ K ₀ M ₁	13.33	14.00	23.50	38.00	50.00	74.83
N ₀ P ₀ K ₀ M ₂	12.44	13.50	17.58	28.91	37.08	49.16
N ₀ P ₀ K ₁ M ₁	13.08	15.66	23.33	38.58	55.33	98.16
N ₀ P ₀ K ₁ M ₂	15.13	15.25	21.83	38.16	49.33	80.00
N ₀ P ₁ K ₀ M ₁	24.00	20.01	38.83	68.91	76.00	121.33
N ₀ P ₁ K ₀ M ₂	14.58	16.00	23.08	35.33	43.91	68.33
N ₀ P ₁ K ₁ M ₁	14.08	20.58	29.75	54.00	71.15	116.90
N ₀ P ₁ K ₁ M ₂	19.66	21.00	29.84	50.91	75.58	116.91
N ₁ P ₀ K ₀ M ₁	14.41	15.83	23.66	43.08	61.75	90.08
N ₁ P ₀ K ₀ M ₂	12.92	12.41	16.83	30.41	40.50	55.83
N ₁ P ₀ K ₁ M ₁	15.75	18.00	22.58	38.50	50.58	92.58
N ₁ P ₀ K ₁ M ₂	15.41	16.16	26.08	46.08	58.16	91.75
N ₁ P ₁ K ₀ M ₁	17.75	19.08	29.83	53.41	69.83	110.66
N ₁ P ₁ K ₀ M ₂	15.08	21.41	32.63	51.75	72.83	110.66
N ₁ P ₁ K ₁ M ₁	13.33	33.25	46.00	84.41	120.08	181.00
N ₁ P ₁ K ₁ M ₂	21.08	27.33	44.13	80.91	102.25	161.41
* C.D. at 5%	NS	NS	NS	NS	NS	42.95
C.D. at 1%	-	-	-	-	-	59.18
**C.D. at 5%	NS	NS	NS	NS	NS	42.18
C.D. at 1%	-	-	-	-	-	58.20

* C.D. for comparing two sub-treatment means at a fixed level of main treatment means.

**C.D. for comparing two main treatment means at a fixed or different levels of sub-treatment means

NS = Non-significant

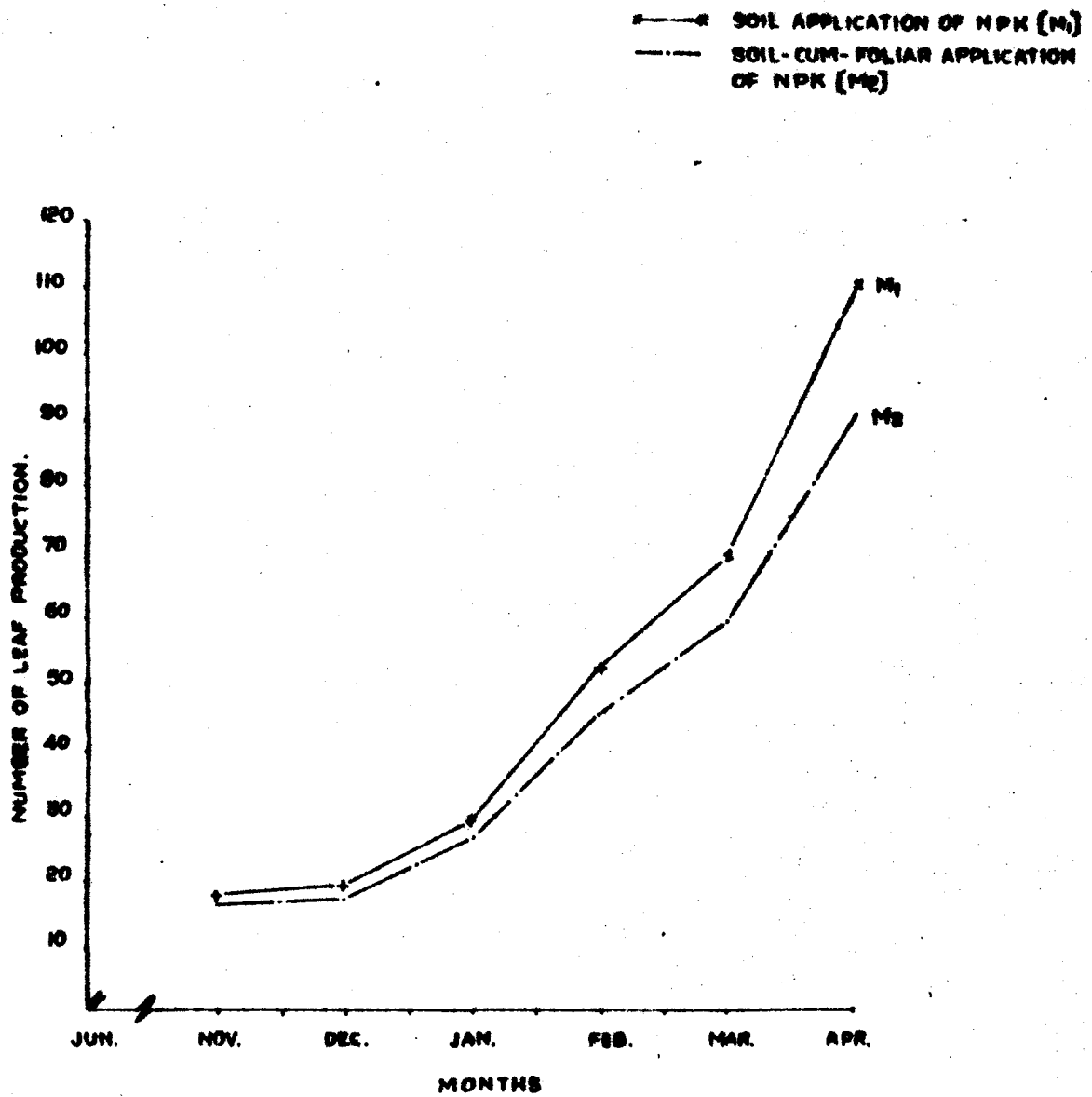


Fig. II a. NUMBER OF LEAVES PRODUCED PER CLUMP AS INFLUENCED BY SOIL AND SOIL-CUM-FOLIAR APPLICATION OF NPK.

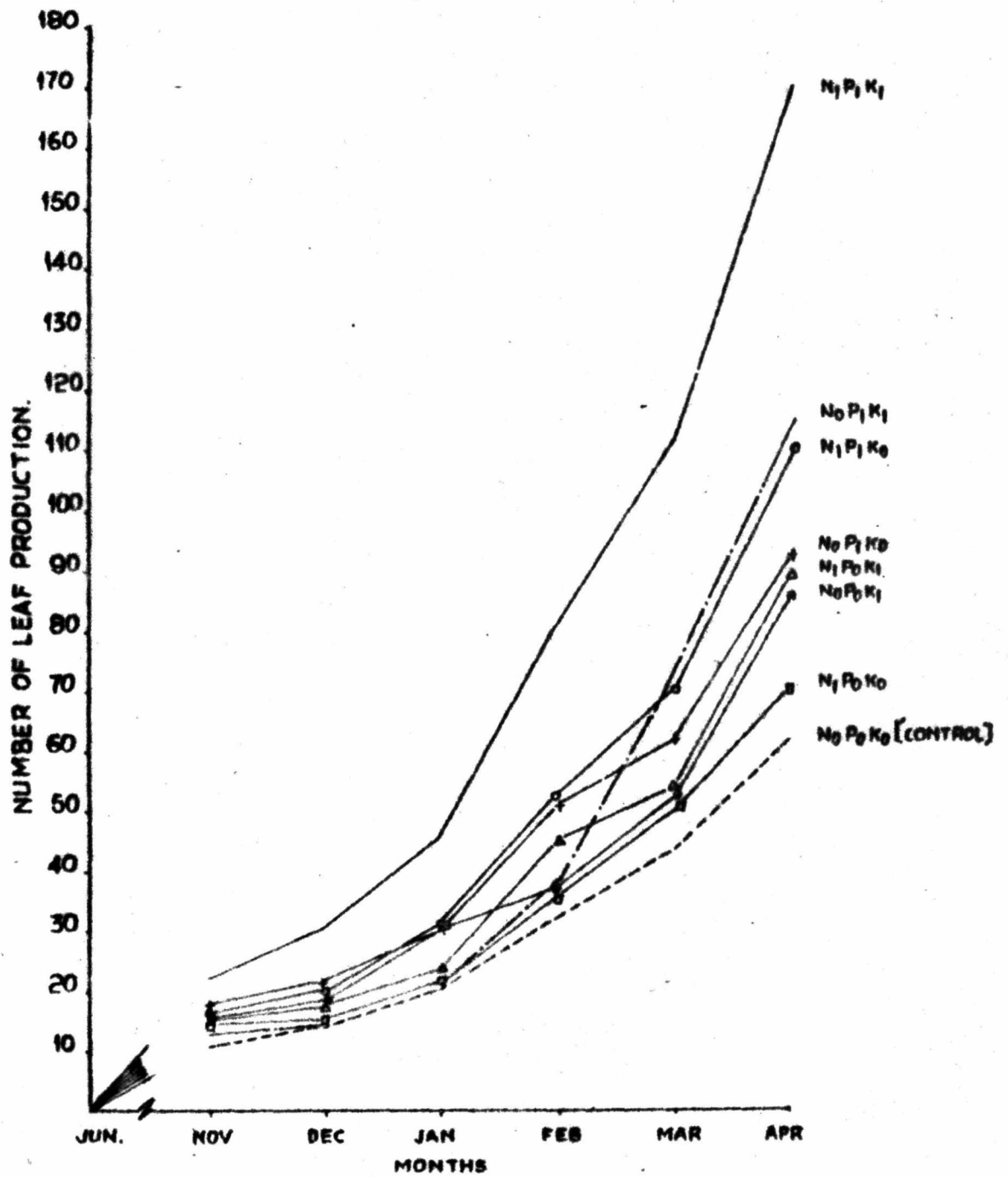


Fig. II b. NUMBER OF LEAVES PRODUCED PER CLUMP AS INFLUENCED BY NPK DURING DIFFERENT MONTHS.

The main effects of N, P and K treatments produced significantly more number of leaves during the period of observation from December to April than control.

Interaction effects between main and sub-treatments with respect to number of leaves produced was noticed only during the month of April (Table IIIc). The plants provided with $N_1P_1K_1$ (181.00) through soil application recorded significantly more number of leaves compared to rest of the treatments. The number of leaves produced by the plants grown under P_1 - soil application (121.33) was significantly higher than that by control (74.83). Treatments P_1K_1 , $N_1P_1K_1$, N_1K_1 , N_1 and control (soil application) did not differ in respect of leaf production.

The plants provided with $N_1P_1K_1$ through soil-cum-foliar application produced significantly more leaves (161.41) compared to other treatments. At fixed level of M_2 soil-cum-foliar application of P_1K_1 (116.91) and N_1P_1 (110.66) produced significantly higher number of leaves than that of N_1K_1 (91.75), K_1 (80.00), P_1 (68.33), N_1 (55.83) and control (49.16).

The plants provided with $N_1P_1K_1$ through soil as well as soil-cum-foliar application (181.00 and 161.41 respectively) recorded significantly more number of leaves compared to that of other treatments, irrespective of mode of application. It was followed by soil application of P_1 (121.33). However, the lowest number of leaves (49.16) was recorded in the control (soil-cum-foliar application).

IV.3. Total length of the suckers per clump

Data on total length of suckers as influenced by NPK and their modes of application are presented in Table IVa, IVb and IVc, and Fig.IIIa and IIIb.

The total length of suckers significantly differed between main treatments during the months of February, March and April. The main treatment values of M_1 (soil application of NPK) for total length of suckers during the months of February (462.72 cm), March (718.18 cm) and April 1045.32 cm) significantly differed from the corresponding values of M_2 (soil-cum-foliar application of NPK) during February (410.84 cm), March (604.12 cm) and April (935.46 cm) respectively.

The total length of suckers grown under different sub-treatments differed significantly from December to April. The total length of suckers in $N_1P_1K_1$ was significantly higher for December to April as compared to that of other treatments. The total length of suckers in this treatment in December and April were 209.08 cm and 1791.70 cm respectively. The following group of sub-treatments viz., P_1K_1 , N_1P_1 , P_1 , N_1K_1 and K_1 , which followed $N_1P_1K_1$ consistently during the period of observation (December to April) did not differ amongst themselves. The lowest total length of suckers was recorded in the clumps grown under control (549.75) and N_1 (637.95 cm).

The main effects of N and K was significantly influenced on

Table IVa. Effects of NPK and their mode of application on total length (cm) of suckers in a cardamom clump

Treatments	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<u>Main treatment means</u>						
M ₁ (S)	136.03	149.34	235.94	462.72	718.18	1045.32
M ₂ (S+F)	127.47	138.04	213.56	410.84	604.12	935.46
C.D. at 5%	NS	NS	NS	28.09	76.07	87.09
C.D. at 1%	-	-	-	NS	NS	NS
<u>Sub-treatment means</u>						
N ₀ P ₀ K ₀	100.17	102.87	154.91	279.25	402.58	549.75
N ₀ P ₀ K ₁	115.29	118.97	185.87	349.00	549.60	902.58
N ₀ P ₁ K ₀	158.00	164.12	248.12	464.62	657.41	903.16
N ₀ P ₁ K ₁	120.75	146.75	250.45	485.91	775.04	1184.37
N ₁ P ₀ K ₀	102.83	112.66	155.54	330.12	483.91	637.95
N ₁ P ₀ K ₁	123.50	136.08	204.16	360.75	549.60	868.62
N ₁ P ₁ K ₀	137.92	141.00	240.66	442.95	686.60	1084.96
N ₁ P ₁ K ₁	137.88	209.08	358.25	442.95	1216.00	1791.70
C.D. at 5%	NS	44.48	79.38	167.83	255.44	338.00
C.D. at 1%	-	60.01	107.09	226.43	344.63	456.00

NS = Non-significant

Table IVb. Main effects of N, P, K, NP, NK and PK on total length (cm) of suckers in a cardamom clump

Effects	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
N ₀	125.55	137.67	209.83	394.69	592.20	884.96
N ₁	125.53	149.70	239.65	394.19	730.10	1045.70
C.D. at 5%	20.03	22.24	39.69	83.91	125.59	169.00
P ₀	118.44	117.64	175.12	329.77	488.13	739.72
P ₁	138.63	169.73	277.36	459.10	833.76	1241.04
C.D. at 5%	20.03	22.24	39.69	83.91	125.59	169.00
K ₀	124.72	130.16	199.80	379.23	557.62	793.95
K ₁	124.35	157.22	249.68	409.65	764.68	1186.81
C.D. at 5%	20.03	22.24	39.69	83.91	125.59	169.81
N ₀ P ₀	139.38	110.92	170.39	314.12	468.18	726.16
N ₀ P ₁	139.38	164.43	249.28	475.26	716.22	1043.76
N ₁ P ₀	113.16	124.37	179.85	345.43	508.91	753.25
N ₁ P ₁	137.90	175.04	299.45	442.95	951.30	1438.33
C.D. at 5%	28.26	31.46	56.14	118.66	180.61	229.00
N ₀ K ₀	129.08	133.49	201.51	371.93	528.99	726.45
N ₀ K ₁	118.02	141.86	218.16	417.45	654.41	1043.47
N ₁ K ₀	120.37	126.83	198.10	386.53	585.25	861.45
N ₁ K ₁	130.69	172.58	281.20	401.85	874.95	1330.16
C.D. at 5%	28.26	31.46	56.14	118.66	180.61	229.00
P ₀ K ₀	101.50	107.76	155.22	304.68	433.24	593.85
P ₀ K ₁	119.39	127.52	195.01	354.87	533.85	855.60
P ₁ K ₀	147.96	152.56	244.39	453.78	672.00	994.06
P ₁ K ₁	129.31	186.91	304.35	464.43	995.52	1488.03
C.D. at 5%	28.26	31.46	56.14	118.66	180.61	229.00

Table IVc. Effects of sub x main interactions on total length (cm) of suckers in a cardamom clump

Interaction	Sub x Main interaction means					
	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
N ₀ P ₀ K ₀ M ₁	94.66	107.41	166.33	301.66	459.91	635.25
N ₀ P ₀ K ₀ M ₂	89.66	98.00	143.50	256.83	348.58	464.25
N ₀ P ₀ K ₁ M ₁	99.75	115.41	183.58	351.41	574.16	979.25
N ₀ P ₀ K ₁ M ₂	108.83	122.13	188.16	346.58	493.41	825.91
N ₀ P ₁ K ₀ M ₁	165.53	191.91	310.41	602.58	863.41	1131.66
N ₀ P ₁ K ₀ M ₂	113.50	136.33	185.83	326.66	451.41	674.66
N ₀ P ₁ K ₁ M ₁	132.50	168.83	256.41	474.66	772.30	1168.75
N ₀ P ₁ K ₁ M ₂	109.00	160.33	244.50	493.83	777.58	1200.00
N ₁ P ₀ K ₀ M ₁	98.91	114.25	173.75	386.00	573.08	711.41
N ₁ P ₀ K ₀ M ₂	97.14	111.08	137.33	274.25	394.75	564.50
N ₁ P ₀ K ₁ M ₁	102.33	120.75	173.08	312.91	521.00	790.16
N ₁ P ₀ K ₁ M ₂	134.66	151.41	235.25	408.58	546.83	947.08
N ₁ P ₁ K ₀ M ₁	132.91	148.75	234.08	460.16	701.33	1079.33
N ₁ P ₁ K ₀ M ₂	112.91	133.25	247.25	425.75	671.50	1090.58
N ₁ P ₁ K ₁ M ₁	169.66	226.75	389.83	809.08	1283.08	1866.75
N ₁ P ₁ K ₁ M ₂	151.41	191.41	326.66	754.25	1148.91	1716.66
* C.D. at 5%	NS	NS	NS	NS	365.85	NS
C.D. at 1%	-	-	-	NS	500.97	-
**C.D. at 5%	NS	NS	NS	NS	342.54	NS
C.D. at 1%	-	-	-	-	469.96	-

* C.D. for comparing two sub-treatment means at fixed level of main treatment.

**C.D. for comparing two main treatment means at fixed or different levels of sub-treatments.

NS = Non-significant

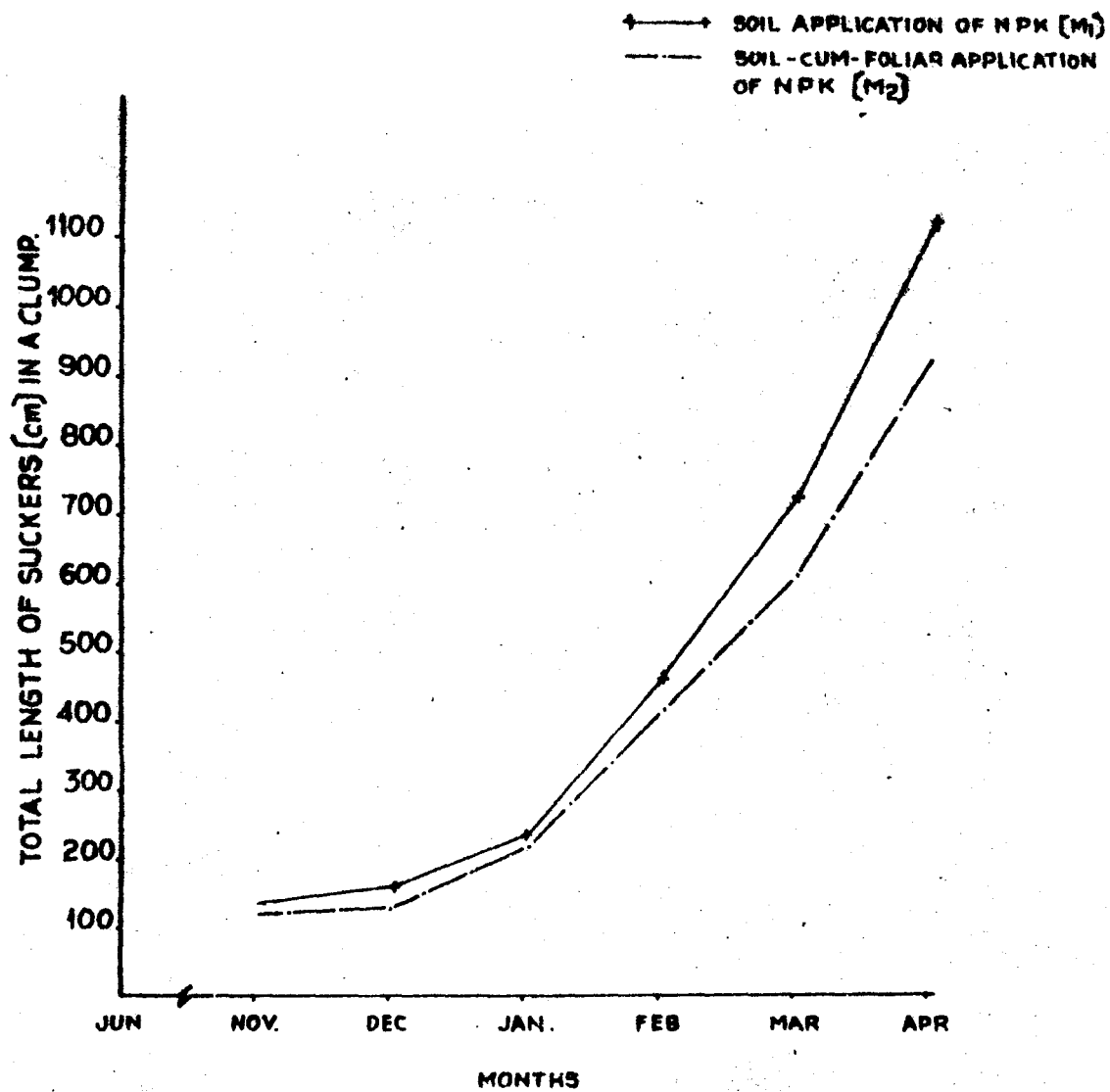


Fig. III a. TOTAL LENGTH OF THE SUCKERS IN A CLUMP AS INFLUENCED BY SOIL AND SOIL-CUM-FOLIAR APPLICATION OF NPK.

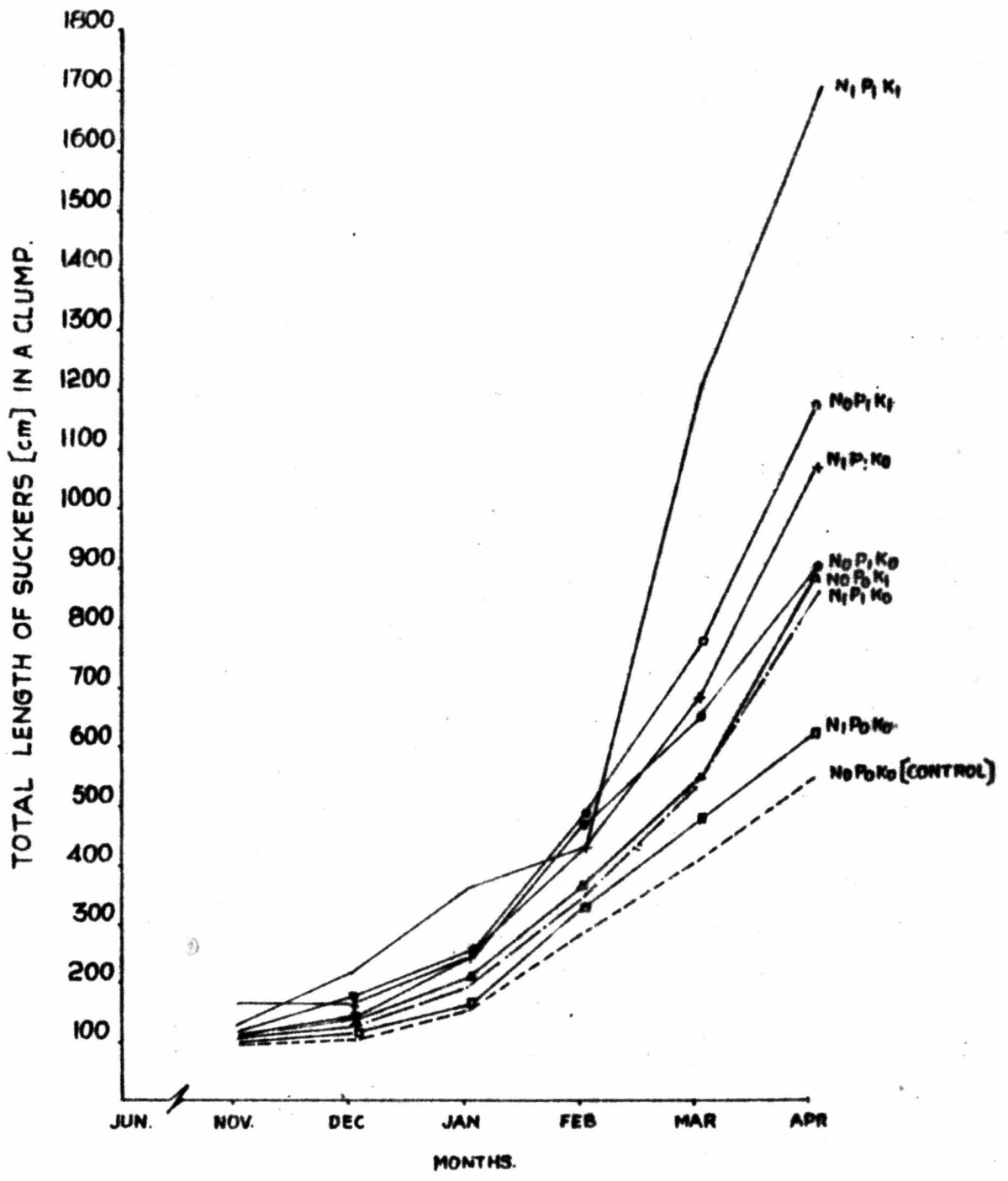


Fig. III b. TOTAL LENGTH OF THE SUCKERS IN A CLUMP AS INFLUENCED BY N P K.

Plate 6. Comparison of cardamom clumps within a pair consisting of two main treatments at fixed level of sub-treatments

a) Clumps provided with N through soil-cum-foliar application (S+F) and soil application (S)

b) Clumps provided with P through soil-cum-foliar application (S+F) and soil application (S)

c) Clumps provided with K through soil-cum-foliar application (S+F) and soil application (S)

Plate 6a



Plate 6b



Plate 6c

Plate 6. Comparison of cardamom clumps within a pair consisting of two main treatments at fixed level of sub-treatments

d) Clumps provided with NP through soil-cum-foliar (S+F) and soil application (S)

e) Clumps provided with NK through soil-cum-foliar (S+F) and soil application (S)

f) Clumps provided with PK through soil-cum-foliar (S+F) and soil application (S)

Plate 6d



Plate 6e

Plate 6f



Plate 6. Comparison of cardamom clumps within a pair consisting of two main treatments at fixed level of sub-treatments

g) Clumps provided with NPK through soil-cum-foliar (S+F) and soil application (S)

Plate 7a. Comparing of sub-treatments at fixed level of main treatments.

A pair showing $N_0P_0K_0$ and $N_1P_1K_1$

(S = Soil application)

Plate 7b. Comparing of sub-treatments at fixed level of main treatments.

A pair showing $N_0P_0K_0$ and $N_1P_1K_1$

(S+F = Soil-cum-foliar application)

Plate 6g

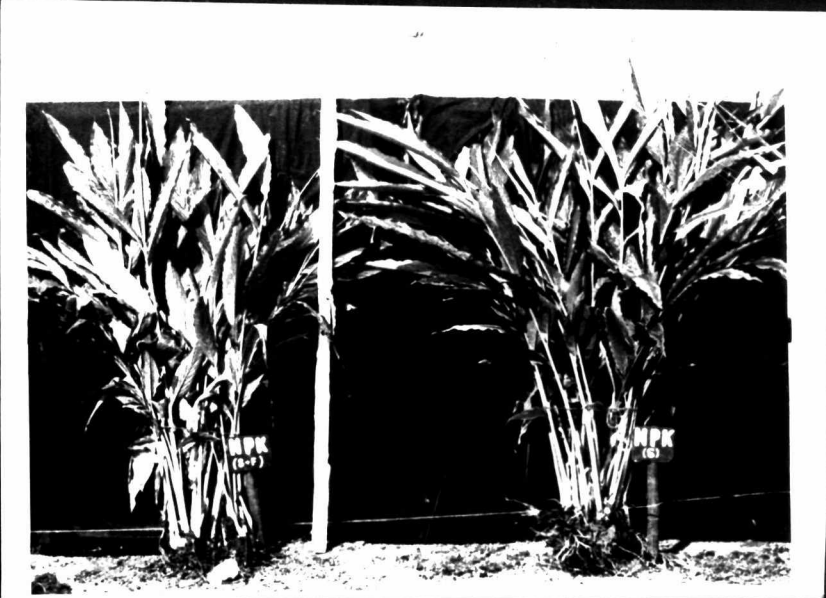


Plate 7a



Plate 7b



total length of suckers during the months of March and April compared to that of control, whereas the main effect of P was found to be significantly superior in total length of suckers than that of control, throughout the period of observation.

Interaction effects of main x sub-treatments were found to be significant during March only. Application of fertilizer mixture $N_1P_1K_1$ through soil (1283.08 cm) produced significantly highest value for the total length of suckers compared to that of other treatments namely, P_1K_1 (772.30 cm), N_1P_1 (701.33 cm), K_1 (574.16), N_1 (573.08 cm) and N_1K_1 (521.00 cm). supplied with $N_1P_1K_1$ through a combined mode of application, produced maximum total length of suckers (1148.91 cm) compared to that of other treatments. The total length of suckers produced in P_1K_1 (777.58 cm) was significantly higher compared to that of N_1 (394.75 cm) and control (348.58 cm) which however did not significantly differ from that of N_1K_1 (546.83) and P_1 (451.41 cm).

The soil application of $N_1P_1K_1$ (1283.08 cm) as well as soil-cum-foliar application of $N_1P_1K_1$ (1148.91 cm) produced significantly higher total length of suckers compared to the rest of the treatments, irrespective of the mode of application. The minimum total length (348.58 cm) of suckers was recorded in the clumps grown under control (soil-cum-foliar application).

IV.4. Average height of the sucker

Data on the average height of suckers are presented in Table V and Fig.IV.

Table V. Effects of NPK and their mode of application on average height (cm) of sucker in cardamom

Treatment	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	<u>Main treatment means</u>					
M ₁ (S)	42.91	39.14	33.03	45.28	52.86	60.38
M ₂ (S + F)	43.50	40.55	35.31	44.22	51.49	55.46
C.D. at 5%	NS	NS	NS	NS	NS	NS
C.D. at 1%	-	-	-	-	-	-
	<u>Sub-treatment means</u>					
N ₀ P ₀ K ₀	41.54	37.02	32.63	40.63	50.44	50.51
N ₀ P ₀ K ₁	42.01	39.42	35.82	47.90	50.82	60.30
N ₀ P ₁ K ₀	48.50	45.26	35.73	47.72	55.14	61.77
N ₀ P ₁ K ₁	44.72	44.84	36.16	47.48	58.49	65.53
N ₁ P ₀ K ₀	42.63	37.90	35.44	42.19	49.07	53.75
N ₁ P ₀ K ₁	44.99	41.99	32.09	42.93	49.34	52.08
N ₁ P ₁ K ₀	41.45	37.46	34.42	42.97	50.08	54.08
N ₁ P ₁ K ₁	36.98	34.84	31.04	46.16	55.52	64.46
C.D. at 5%	NS	NS	NS	NS	NS	9.76
C.D. at 1%	-	-	-	-	-	NS

NS = Non-significant

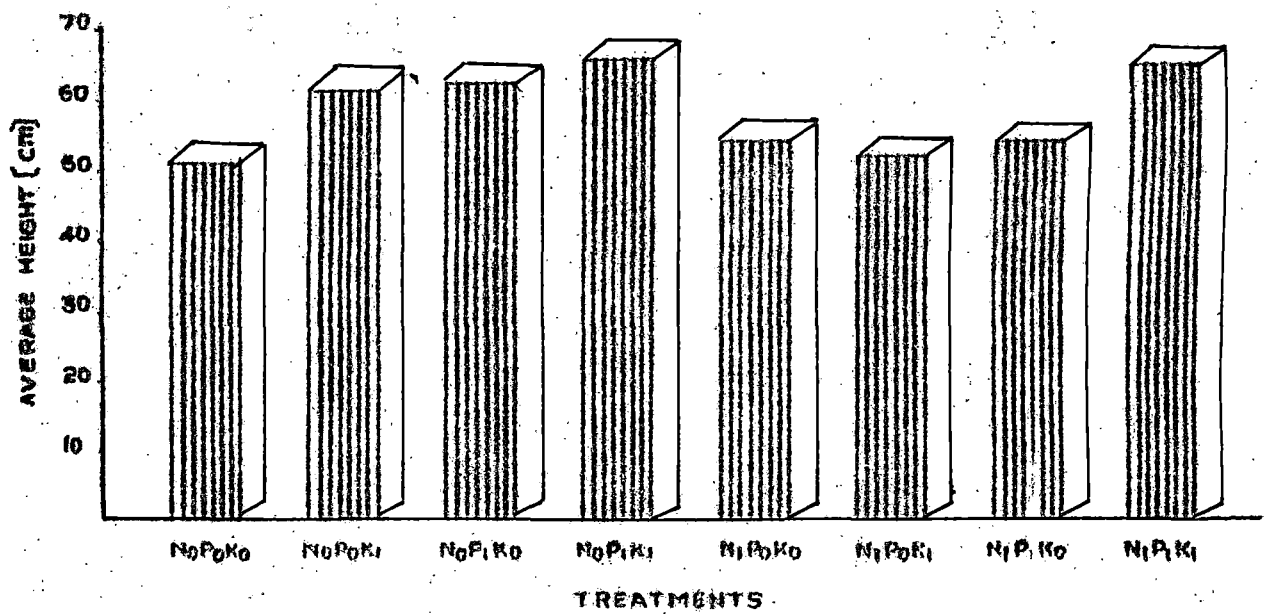


Fig. IV AVERAGE HEIGHT OF THE SUCKERS IN A CLUMP AS INFLUENCED BY NPK AT THE END OF 11 MONTHS AFTER PLANTING.

Significant differences were recorded amongst the sub-treatments, 10 months after planting. P_1K_1 and $N_1P_1K_1$ (65.53 cm and 64.46 cm, respectively) recorded significantly higher average height of suckers compared to that of N_1P_1 (54.08 cm), N_1 (53.75 cm), N_1K_1 (52.08 cm) and control (50.51 cm), but these treatments did not differ among themselves. The average height of suckers in the plants receiving P_1 (61.77 cm) and K_1 (60.30 cm) was on par with P_1 , K_1 and $N_1P_1K_1$. Interactions of treatments had no effect on height of suckers.

IV.5. Leaf length and breadth

The data on leaf length and breadth are presented in Table VI and VIII

IV.5.1. Leaf length

The leaf length did not differ significantly between main treatments except for the 10th month (April). At the 10th month, the length of leaf was 31.38 cm in soil application of N, P and K as against 29.99 cm in soil-cum-foliar application of N, P and K.

Significant differences were recorded amongst different sub-treatments only during 8th month (February) after planting. The length of the leaves in treatments N_1 (25.83 cm), P_1 (25.72 cm), K_1 (25.47 cm) and P_1K_1 (25.44 cm) recorded significantly higher values compared to that of plants under treatments N_1K_1 (22.71 cm) and control (22.34 cm). However, there were no significant differences among the treatments $N_1P_1K_1$, N_1P_1 , N_1K_1 and control.

Table VI. Effects of NPK and their mode of application on average length of leaf (cm) of cardamom

Treatments	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
<u>Main treatment means</u>						
M ₁ (S)	27.60	26.71	24.73	26.58	28.72	31.38
M ₂ (S + F)	27.10	26.70	24.36	26.59	29.17	29.99
C.D. at 5%	NS	NS	NS	NS	NS	1.27
C.D. at 1%	-	-	-	-	-	NS
<u>Sub-treatment means</u>						
N ₀ P ₀ K ₀	27.60	21.65	22.34	24.41	26.37	27.77
N ₀ P ₀ K ₁	28.70	27.60	25.47	26.80	30.13	31.20
N ₀ P ₁ K ₀	30.00	28.99	25.72	27.50	30.62	31.27
N ₀ P ₁ K ₁	30.00	28.61	25.44	28.49	30.81	32.12
N ₁ P ₀ K ₀	27.00	26.51	25.83	25.02	27.93	29.38
N ₁ P ₀ K ₁	29.00	27.64	22.71	25.96	26.51	30.25
N ₁ P ₁ K ₀	26.70	25.22	24.08	26.44	30.29	30.68
N ₁ P ₁ K ₁	29.00	27.32	24.68	28.06	31.23	32.82
C.D. at 5%	NS	NS	2.64	NS	NS	NS
C.D. at 1%	-	-	NS	-	-	-

NS = Non-significant

None of the interactions was found significant.

IV.5.2. Leaf breadth

The average leaf breadth of cardamom as influenced by NPK and their mode of application is presented in Table VII.

There were no significant differences in the breadth of leaves between main treatments.

The breadth of leaves of the plants which was receiving sub-treatments differed significantly at only 8th month (February) after planting. The maximum breadth of the leaves of the plants receiving P_1K_1 (6.13 cm) and N_1P_1 (5.79 cm) as against the plants under treatments control (5.01 cm) and N_1 (4.79 cm). There were no significant differences among $N_1P_1K_1$, K_1 , P_1 and N_1K_1 in the breadth of leaves. The breadth of leaves of the plants under treatments N_1K_1 , control and N_1 were on par. None of the interaction effects were found to be significant.

IV.6. Panicle production

The data on the influence of NPK and their mode of application on panicles produced per treatment are presented in Table VIII.

The maximum number of panicles per treatment (20.50) was recorded in the plants fertilized with $N_1P_1K_1$ at the rate of 32.5 g of N + 25.0 g of P_2O_5 + 50 g of K_2O per plant through soil. It was followed by soil application of N_1P_1 (16.50) and lowest number of panicles (1.00) was found in control (soil application).

Table VII. Effects of NPK and their mode of application on average leaf breadth (cm) of cardamom

Treatments	Months					
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
	<u>Main treatment means</u>					
M ₁ (S)	4.98	4.67	4.60	5.48	5.54	5.47
M ₂ (S + F)	4.67	4.66	4.89	5.55	5.52	5.40
C.D. at 5%	NS	NS	NS	NS	NS	NS
C.D. at 1%	-	-	-	-	-	-
	<u>Sub-treatment means</u>					
N ₀ P ₀ K ₀	4.01	4.00	4.09	5.01	5.60	4.86
N ₀ P ₀ K ₁	5.00	4.95	4.99	5.71	5.75	5.54
N ₀ P ₁ K ₀	5.00	5.00	5.20	5.54	5.53	5.44
N ₀ P ₁ K ₁	5.90	5.00	5.31	6.13	5.96	5.72
N ₁ P ₀ K ₀	4.20	4.09	4.24	4.79	5.03	5.41
N ₁ P ₀ K ₁	4.90	4.67	4.99	5.43	5.59	5.25
N ₁ P ₁ K ₀	5.00	4.62	5.17	5.79	5.65	5.52
N ₁ P ₁ K ₁	4.85	4.60	5.31	5.71	5.66	5.72
C.D. at 5%	NS	NS	NS	0.737	NS	NS
C.D. at 1%	-	-	-	NS	NS	-

NS = Non-significant

Table VIII. Effects of NPK and their mode of application on the number of panicles produced per treatment (11 months after planting)

Sub-treatments	Number of panicles/treatment	
	Main treatments	
	M ₁ (S)	M ₂ (S+F)
N ₀ P ₀ K ₀	1.00	2.50
N ₀ P ₀ K ₁	-	-
N ₀ P ₁ K ₀	7.00	-
N ₀ P ₁ K ₁	1.00	1.00
N ₁ P ₀ K ₀	1.00	2.00
N ₁ P ₀ K ₁	4.00	1.50
N ₁ P ₁ K ₀	16.50	13.50
N ₁ P ₁ K ₁	20.50	14.00

IV.7. Total fresh weight and dry weight of the cardamom clump

The data on the influence of NPK and their mode of application on the fresh weight and dry weight production of cardamom plant are presented in Table IX and Fig.Va and Vb.

IV.7.1. Fresh weight

There were no significant differences in the fresh weight of plants between the main treatments.

Significant differences were found in the fresh weight of the plants grown under sub-treatments. The plants fertilized with $N_1P_1K_1$ recorded significantly higher fresh weight (2999.88 g) compared to that of other treatments except P_1K_1 (2065.47 g). The fresh weight of the plants with P_1K_1 , N_1P_1 , K_1 , P_1 , N_1 and N_1K_1 did not differ significantly. The lowest fresh weight was found in control (481.70 g), but it was on par with K_1 , P_1 , N_1 and N_1K_1 treatments. Interaction effects did not show any significant influence on the fresh weight of the plants.

IV.7.2. Dry weight

The effects of main treatments did not show any significant difference in the dry matter production. Significant differences were recorded in the dry weight of plants grown under sub-treatments. The dry weight of the plants fertilized with $N_1P_1K_1$ (473.58 g) was significantly higher compared to rest of the treatments. The dry weight of the plants with N_1P_1 (241.56 g) was on

Table IX. Total fresh weight (g) and dry weight (g) of cardamom clumps as influenced by NPK and their mode of application

Sub-treatment	Fresh weight (g)			Dry weight (g)			Per cent dry weight		
	M ₁	M ₂	Average	M ₁	M ₂	Average	M ₁	M ₂	Average
N ₀ P ₀ K ₀	512.32	451.08	481.70	72.50	58.24	65.39	14.150	12.913	13.532
N ₀ P ₀ K ₁	1769.69	1298.12	1533.90	206.54	152.10	179.32	14.821	11.765	13.293
N ₀ P ₁ K ₀	1523.91	1159.83	1341.87	235.31	164.41	199.86	15.441	14.170	14.806
N ₀ P ₁ K ₁	2185.00	1945.94	2065.47	221.35	217.71	219.53	10.135	11.185	10.660
N ₁ P ₀ K ₀	1224.93	1224.17	1224.55	194.08	154.32	174.20	15.844	12.065	13.955
N ₁ P ₀ K ₁	1185.07	1141.57	1163.32	145.57	127.95	136.76	12.285	11.204	11.745
N ₁ P ₁ K ₀	1684.44	1886.99	1785.71	235.25	243.87	241.56	14.205	12.925	13.565
N ₁ P ₁ K ₁	3244.29	2755.47	2999.88	505.34	441.82	473.58	15.475	18.220	16.848
Average	1666.21	1452.90	1574.55	224.97	195.03	211.27	14.050	13.060	13.551

F-test C.D.at 5% C.D.at 1% F-test C.D.at 5% C.D.at 1%

Main treatment	NS	-	-	NS	-	-
Sub-treatments	*	1129.50	1523.49	*	55.09	74.32
Interaction	NS	-	-	NS	-	-

NS = Non-significant

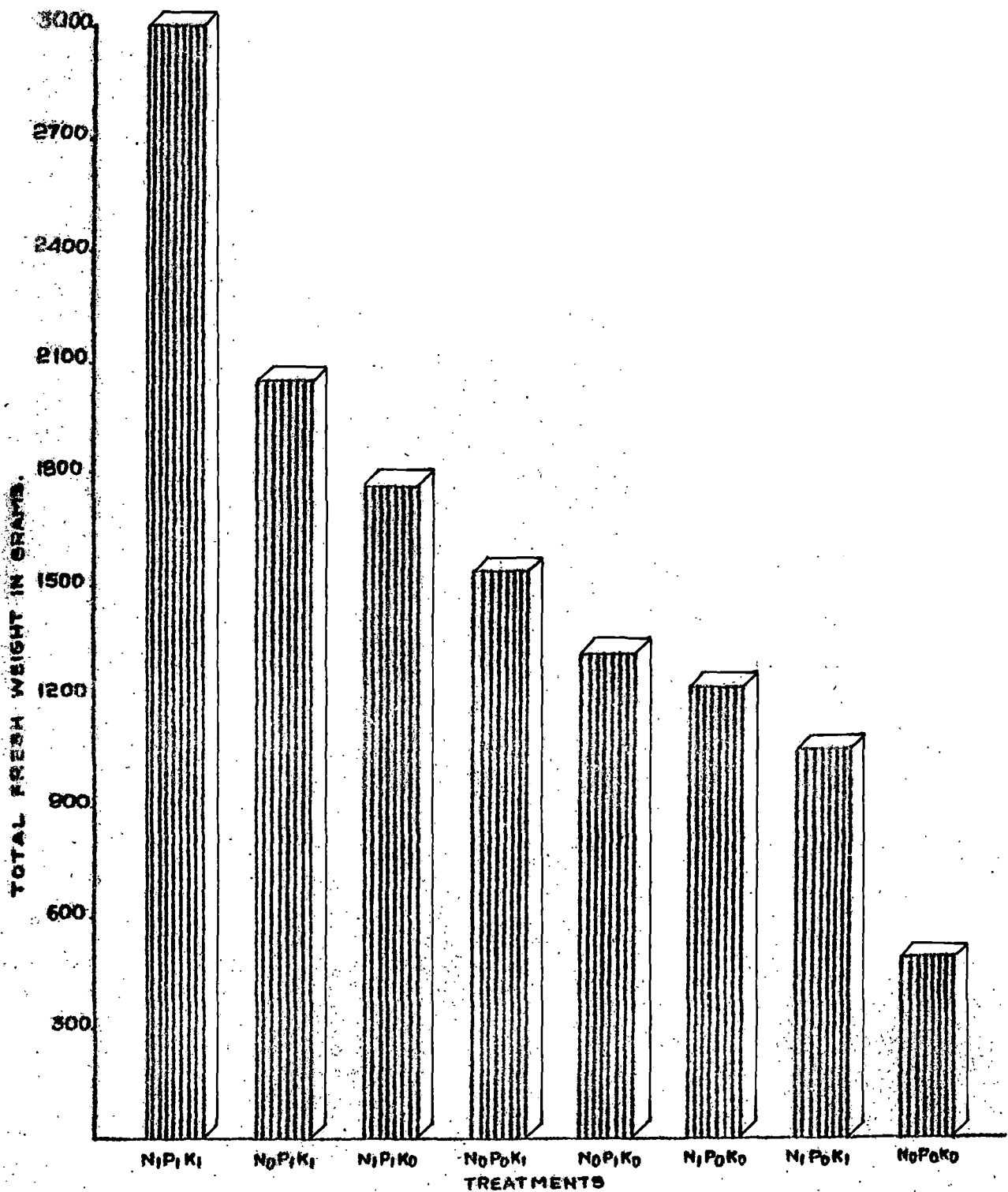


Fig. 1 a. TOTAL FRESH WEIGHT OF THE CARDAMOM CLUMP AS INFLUENCED BY NPK AT THE END OF 11 MONTHS AFTER PLANTING.

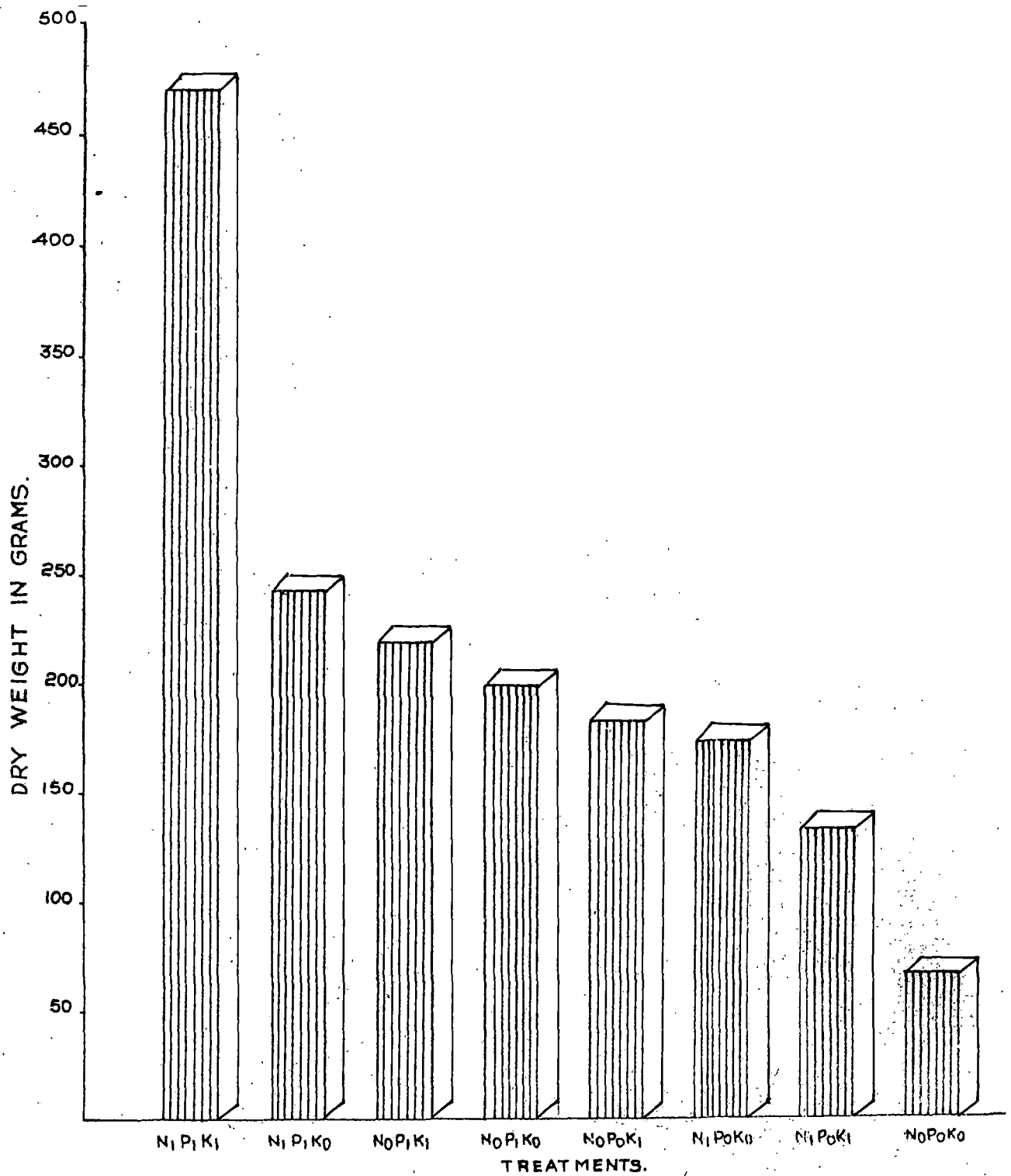


Fig. 5 b. TOTAL DRY WEIGHT OF THE CARDAMOM CLUMP AS INFLUENCED BY N P K AT THE END OF 11 MONTHS AFTER PLANTING.

par with that of P_1K_1 (219.53 g) and P_1 (199.86 g), but differed significantly with the dry weight of the plants receiving K_1 (179.32 g), N_1 (174.20 g), N_1K_1 (136.76 g) and control (65.37 g). However, there were no significant differences amongst P_1K_1 , P_1 , K_1 and N_1 in the dry matter production. The plants grown in control recorded significantly lower dry weight (65.39 g) compared to that of other treatments.

None of the interactions was found to be significant.

IV.8. Percentage contribution of weights of different parts of the plant to the total fresh and dry weight of the whole clump

The data on the percentage contribution of different parts of the plant viz., leaf, shoot, rhizome and roots to the total fresh weight and dry weight of the cardamom clump are presented in Table X and XI and Fig.VIa and VIb.

IV.8.1. Fresh weight

In general, the average contributions of different parts of the cardamom clump to the total fresh weight of the clump were as follows: leaves 23.10 per cent, shoot 45.94 per cent, rhizome 21.00 per cent and roots 9.96 per cent (Table X).

Fresh weight of leaves of control constituted 26.25 per cent of the total fresh weight of the clump. This percentage was found to be the highest compared to that of other treatments for the leaf section. Fresh weight of leaves of the treatment N_1P_1 constituted a lowest value of 19.37 per cent to the total fresh weight.

Table X. Effect of NPK and their mode of application on percentage composition of fresh weight (g) in different parts of the cardamom clump

Part of the clump	Main treatments	Sub-treatments												Average
		N ₀ P ₀ K ₀	N ₀ P ₀ K ₁	N ₀ P ₁ K ₀	N ₀ P ₁ K ₁	N ₁ P ₀ K ₀	N ₁ P ₀ K ₁	N ₁ P ₁ K ₀	N ₁ P ₁ K ₁	N ₁ P ₀ K ₀	N ₁ P ₀ K ₁	N ₁ P ₁ K ₀	N ₁ P ₁ K ₁	
Leaves	M ₁	30.87	20.02	22.50	20.53	26.96	24.57	19.24	23.95	23.51				
	M ₂	21.62	25.68	24.62	20.15	21.37	19.33	19.49	27.87	22.68				
	Average	26.25	22.85	23.56	20.34	24.16	21.95	19.37	25.91	23.10				
Shoots	M ₁	42.49	52.52	49.18	47.04	42.96	41.83	47.94	52.67	47.20				
	M ₂	41.86	41.32	39.46	47.95	44.23	44.83	45.13	50.00	44.63				
	Average	42.13	46.93	44.32	47.49	43.59	43.33	46.55	51.34	45.94				
Rhizome	M ₁	13.89	19.50	18.62	21.97	21.66	23.45	19.04	16.92	19.32				
	M ₂	25.84	21.47	24.62	20.99	25.32	23.36	21.66	16.41	22.65				
	Average	19.89	20.48	21.62	21.48	23.49	23.40	20.35	16.66	21.00				
Roots	M ₁	12.75	7.96	9.70	10.46	8.42	10.15	13.78	6.46	9.98				
	M ₂	10.68	11.53	11.30	10.91	9.08	12.48	13.72	7.72	9.94				
	Average	11.72	9.74	10.50	10.69	8.75	11.32	13.75	7.09	9.96				
Clump	M ₁	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00				
	M ₂	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00				
	Average	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00				

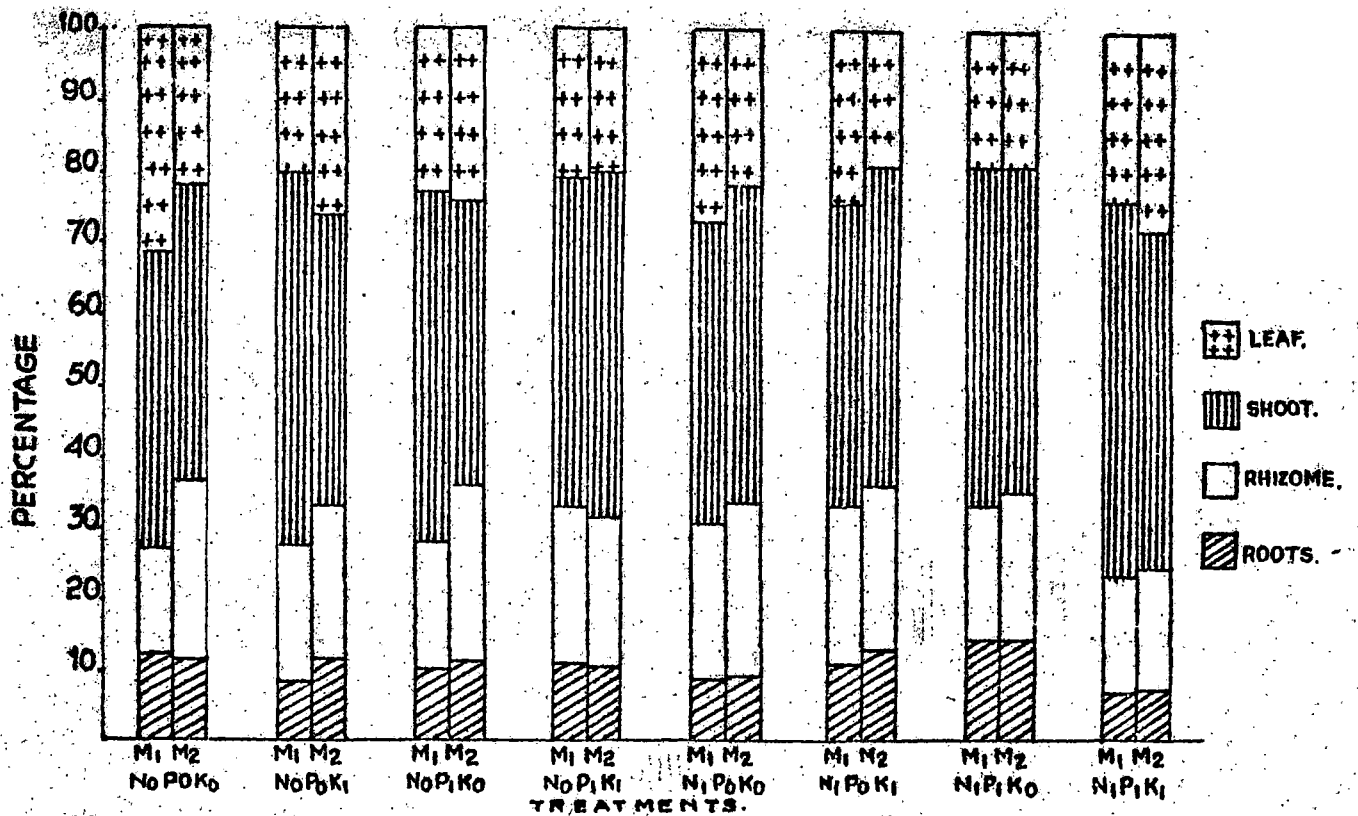


Fig. VI a. PERCENTAGE CONTRIBUTION OF FRESH WEIGHT BY DIFFERENT PARTS OF THE CLUMP TO THE WHOLE CLUMP AS INFLUENCED BY NPK AND THEIR MODE OF APPLICATION AT THE END OF 11 MONTHS.

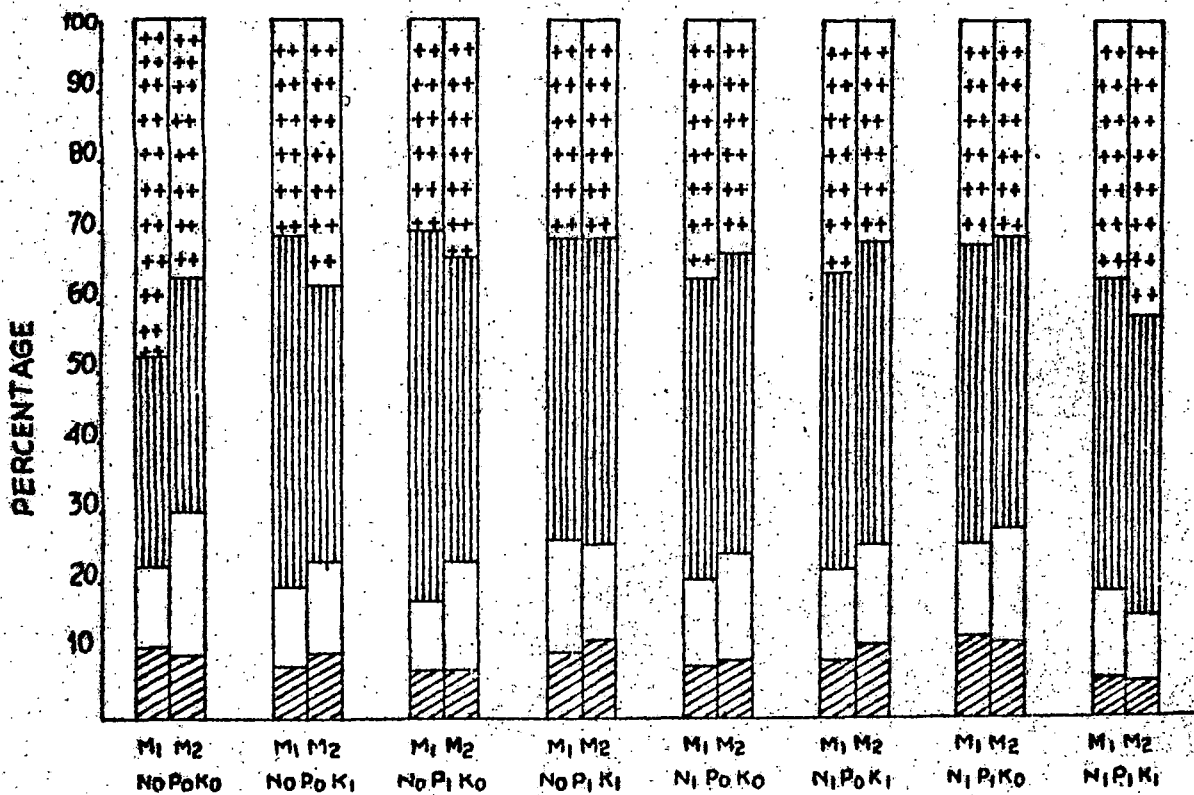


Fig. VI b. PERCENTAGE CONTRIBUTION OF DRY WEIGHT BY DIFFERENT PARTS OF THE CLUMP TO THE WHOLE CLUMP AS INFLUENCED BY NPK AND THEIR MODE OF APPLICATION AT THE END OF 11 MONTHS.

While the percentage of fresh weight of shoots to the fresh weight of whole clump was highest (51.34%) in case of $N_1P_1K_1$ it was found to be the lowest (42.13%) in case of control.

The fresh weight of the rhizome of N_1 accounted to 23.49 per cent as against only 16.66 per cent in the plants grown with $N_1P_1K_1$ treatments. The percentage fresh weight of the roots of the plants supplied with N_1P_1 constituted highest value of 13.75 and a minimum of 7.09 per cent of fresh weight of roots was found in $N_1P_1K_1$.

IV.8.2. Dry weight

In general, the dry matter produced by the different parts of the plants that constituted a clump of cardamom consisted of 34.92 per cent as leaf, 42.80 per cent as shoots, 14.05 per cent as rhizome and 8.23 per cent as roots. These percentages were worked out taking average of all the treatments (Table XI).

The percentage dry weight of leaves to the dry weight of whole clump was highest in control (42.48) and this was followed by $N_1P_1K_1$ (39.39%), N_1 (35.06%), K_1 (34.34%), and lowest percentage was found in P_1K_1 (30.83%).

Shoots of the plants grown under P_1 constituted maximum of 48.65 per cent of the total dry matter. A minimum of 31.31 per cent of dry weight of shoot was found in control. The contribution of dry weight of shoots in other treatments namely, K_1 , $N_1P_1K_1$, P_1K_1 , N_1K_1 and N_1P_1 was close to the general average.

Table XI. Effect of NPK and their mode of application on percentage composition of dry matter in different parts of the cardamom clump

Part	Main treatments	Sub-treatments										Average
		N ₀ P ₀ K ₀	N ₀ P ₀ K ₁	N ₀ P ₁ K ₀	N ₀ P ₁ K ₁	N ₁ P ₀ K ₀	N ₁ P ₀ K ₁	N ₁ P ₁ K ₀	N ₁ P ₁ K ₁	N ₂ P ₁ K ₀	N ₂ P ₁ K ₁	
Leaves	M ₁	48.00	30.68	30.15	30.59	37.06	36.36	31.68	36.92	35.18		
	M ₂	36.96	38.17	33.79	31.06	33.05	31.67	30.73	41.86	34.66		
	Average	42.48	34.34	31.97	30.83	35.06	34.01	31.21	39.39	34.92		
Shoots	M ₁	30.00	50.57	53.69	44.12	43.12	42.15	43.22	45.44	44.00		
	M ₂	32.61	38.93	43.92	43.48	43.22	43.33	41.89	43.93	41.44		
	Average	31.31	44.75	48.65	43.80	43.17	42.74	42.55	44.68	42.80		
Rhizome	M ₁	12.00	11.93	10.05	15.88	12.93	14.05	14.20	12.17	12.90		
	M ₂	21.74	13.74	14.86	14.90	16.10	15.00	16.76	9.04	15.26		
	Average	16.87	12.83	12.46	15.39	14.52	14.53	15.48	10.61	14.05		
Roots	M ₁	10.00	6.82	6.41	9.41	6.89	7.44	10.90	5.47	7.92		
	M ₂	8.69	9.16	7.43	10.56	7.63	10.00	10.62	5.17	8.66		
	Average	9.30	7.99	6.92	9.98	7.26	8.72	10.76	5.32	8.23		
Clump	M ₁	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		
	M ₂	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		
	Average	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00		

In respect of percentage of dry matter of rhizome to the clump, highest value of 16.87 per cent was observed in control and this was followed by N_1P_1 (15.48%), P_1K_1 (15.39%) and N_1K_1 (14.53%). The lowest was in that of $N_1P_1K_1$ (10.61%).

The dry matter produced by the roots was highest in the plants under N_1P_1 (10.76%), followed by P_1K_1 (9.98%), control (9.30%) and N_1K_1 (8.72%). The lowest percentage of dry matter contribution was made by the roots of the plants fertilized with $N_1P_1K_1$ (5.32%).

IV.9. Chemical composition of different parts of cardamom plant

Data on chemical composition of different parts of the plants as influenced by NPK and their mode of application are presented in Table XIIa, XIIb, XIIc, XIIId and XIIe.

IV.9.1. Nitrogen (Table XIIa)

Soil application of fertilizer mixture N_1K_1 and soil-cum-foliar application of N_1 resulted in higher percentage of N (3.76%) in leaves, followed by 3.44 per cent of N in case of soil application of N_1P_1 , soil-cum-foliar application of N_1K_1 and $N_1P_1K_1$. The lowest N content (1.63%) in leaves was found in the treatment P_1 applied through soil.

The percentage of N in shoots varied from 0.66 (P_1K_1 -soil application) to 1.63 in case of N_1 through soil application, N_1P_1 and $N_1P_1K_1$ through soil-cum-foliar application.

Table XIIIa. Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application

Treatments	Nitrogen (Percentage dry weight basis)							
	Leaf		Shoot		Rhizome		Root	
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂
N ₀ P ₀ K ₀	3.11	3.11	0.98	0.83	1.47	1.30	0.98	0.98
N ₀ P ₀ K ₁	2.78	2.94	0.82	0.81	0.81	0.81	0.65	0.81
N ₀ P ₁ K ₀	1.96	1.63	0.82	0.98	0.81	0.97	0.98	0.81
N ₀ P ₁ K ₁	2.94	3.11	0.66	0.81	0.81	0.81	0.65	0.48
N ₁ P ₀ K ₀	3.26	3.76	1.63	1.47	1.47	1.80	1.46	1.31
N ₁ P ₀ K ₁	3.76	3.44	1.31	1.47	1.63	1.80	1.14	1.31
N ₁ P ₁ K ₀	3.44	3.27	1.31	1.63	1.63	1.64	1.14	1.31
N ₁ P ₁ K ₁	3.43	3.44	1.15	1.63	1.47	1.47	1.31	1.63
Average	3.09	3.09	1.09	1.20	1.26	1.33	1.04	1.08

In the rhizome, N percentage was highest in plants receiving N_1 through soil-sum-foliar application (1.8%) and N_1K_1 through soil-cum-foliar application (1.8%). It was followed by N_1P_1 through soil-cum-foliar application (1.64%). A minimum N (0.81%) was recorded in the plants receiving K_1 , P_1 and P_1K_1 (applied through soil and K_1 and P_1K_1 (soil-cum-foliar application)).

Plants receiving $N_1P_1K_1$ through soil-cum-foliar application were found to have highest nitrogen (1.53%) in their roots, while plants receiving K_1 (through soil) and P_1K_1 (soil-cum-foliar application) had lowest N percentage (0.65%).

IV.9.2. Phosphorus (Table XIIb)

Percentage of P in the leaves varied from 0.32 (N_1K_1 -soil-cum-foliar application) to 0.75 (soil-cum-foliar application of P_1 and N_1P_1).

In the shoots, maximum P (0.75%) was found in the plants receiving soil-cum-foliar application of P_1 and minimum (0.15%) was in the plants grown under control (soil application).

Rhizome of the plants supplied with P_1K_1 (soil application) had 0.47 per cent P, followed by the plants which received P_1K_1 -soil-cum-foliar application (0.40%). A minimum P (0.20%) was recorded in the plants receiving soil application K_1 , N_1 and soil-sum-foliar application of N_1 .

A maximum of 0.37 per cent P was recorded in the roots of the plants with soil-cum-foliar application of P_1 and N_1P_1 . The roots of the plants of the following treatments recorded minimum

Table XXIIb. Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application

Treatments	(Phosphorus Percentage dry weight basis)							
	Leaf		Shoot		Rhizome		Root	
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂
N ₀ P ₀ K ₀	0.40	0.40	0.15	0.20	0.37	0.35	0.25	0.20
N ₀ P ₀ K ₁	0.42	0.40	0.52	0.52	0.20	0.25	0.20	0.27
N ₀ P ₁ K ₀	0.60	0.75	0.67	0.75	0.37	0.37	0.27	0.37
N ₀ P ₁ K ₁	0.55	0.50	0.42	0.60	0.47	0.40	0.27	0.32
N ₁ P ₀ K ₀	0.40	0.42	0.37	0.27	0.20	0.20	0.20	0.20
N ₁ P ₀ K ₁	0.40	0.32	0.42	0.55	0.35	0.25	0.20	0.20
N ₁ P ₁ K ₀	0.60	0.75	0.40	0.32	0.37	0.37	0.27	0.37
N ₁ P ₁ K ₁	0.42	0.50	0.20	0.22	0.27	0.37	0.25	0.20
Average	0.47	0.51	0.39	0.42	0.33	0.32	0.24	0.27

of 20 per cent of P namely, soil application of K_1 and N_1 , soil-cum-foliar application of N_1K_1 , $N_1P_1K_1$ and control.

IV.9.3. Potassium (Table XIIc)

Soil application of fertilizer mixture N_1K_1 and K_1 resulted in higher percentage of K in the leaves (4.20%) as against the lowest percentage of K in the leaves of the plants receiving soil application of N_1P_1 (2.80%).

Potassium in the shoots varied from 3.5 per cent under control (soil application) to 9.4 per cent in the plants which received soil application of K_1 .

In the rhizome, maximum percentage of K (4.90%) was found in the plants receiving K_1 and N_1 treatment through soil application and soil-cum-foliar application of $N_1P_1K_1$ followed by 4.80 per cent in the rhizome of the plants with soil application of $N_1P_1K_1$ and soil-cum-foliar application of K_1 , P_1K_1 and N_1 . A minimum percentage of K (3.60%) was found in the N_1P_1 (soil application) treatment.

Plants receiving K_1 , N_1 through soil, and P_1K_1 through soil-cum-foliar application were found to have highest K (3.20%) in the roots, while plant receiving $N_1P_1K_1$ (soil-cum-foliar application) has lowest percentage of K (1.20%).

IV.9.4. Calcium (Table XIIId)

Calcium percentage was found to be maximum (1.40%) in the leaves of N_1P_1 (soil-cum-foliar application) which was closely

Table XIIc. Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application

Treatments	Potassium (Percentage dry weight basis)							
	Leaf		Shoot		Rhizome		Root	
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂
N ₀ P ₀ K ₀	3.50	3.90	3.50	4.10	4.20	4.20	2.20	1.70
N ₀ P ₀ K ₁	4.20	3.90	9.40	8.40	4.90	4.80	3.20	3.00
N ₀ P ₁ K ₀	3.50	3.00	3.60	3.40	3.60	3.80	3.00	2.50
N ₀ P ₁ K ₁	3.90	3.30	9.20	7.20	4.20	4.80	3.00	3.20
N ₁ P ₀ K ₀	3.70	3.60	9.40	8.40	4.90	4.80	3.20	3.00
N ₁ P ₀ K ₁	4.20	3.90	4.20	5.10	3.80	4.20	2.90	3.20
N ₁ P ₁ K ₀	2.80	3.30	4.20	4.10	3.60	3.80	2.40	2.50
N ₁ P ₁ K ₁	3.50	3.20	4.70	4.30	4.80	4.90	1.70	1.20
Average	3.66	3.51	6.03	5.62	4.25	4.41	2.70	2.54

Table XIId. Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application

Treatments	Calcium (Percentage dry weight basis)							
	Leaf		Shoot		Rhizome		Root	
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂
N ₀ P ₀ K ₀	1.10	1.15	0.60	0.66	0.46	0.40	0.40	0.39
N ₀ P ₀ K ₁	0.93	0.73	0.60	0.50	0.66	0.70	0.49	0.60
N ₀ P ₁ K ₀	0.82	1.00	0.59	0.60	0.50	0.49	0.49	0.42
N ₀ P ₁ K ₁	1.20	0.89	0.60	0.70	0.60	0.56	0.40	0.50
N ₁ P ₀ K ₀	1.19	1.18	0.50	0.49	0.49	0.45	0.40	0.42
N ₁ P ₀ K ₁	1.03	0.80	0.66	0.66	0.60	0.62	0.43	0.40
N ₁ P ₁ K ₀	1.23	1.40	0.66	0.66	0.66	0.56	0.39	0.39
N ₁ P ₁ K ₁	1.10	0.80	0.66	0.66	0.60	0.42	0.40	0.45
Average	1.07	0.99	0.61	0.62	0.57	0.52	0.43	0.45

followed by the leaves of the plants receiving soil-cum-foliar application of N_1P_1 (1.23%). A minimum percentage of Ca was found in the plants receiving K_1 (0.73%), $N_1P_1K_1$ (0.80%) and N_1K_1 (0.80%) through soil-cum-foliar application.

In the shoots, calcium percentage varied from 0.49 (N_1 -soil-cum-foliar application) to 0.70 (P_1K_1 -soil-cum-foliar application).

Maximum Ca percentage in the rhizome was recorded in the plants fertilized with K_1 through soil-cum-foliar application (0.70%) followed by 0.66 per cent in the plants receiving K_1 (soil application) and N_1P_1 (soil-cum-foliar application). A minimum Ca percentage (0.40%) was found in the rhizome of the plants grown under control (soil application).

In the roots, highest percentage of calcium (0.60%) was recorded in the plants fertilized with K_1 (soil application), which was followed by 0.50 per cent of Ca in P_1K_1 (soil-cum-foliar application). Lowest percentage of Ca (0.39%) was found in the roots of the plants grown under control (soil-cum-foliar application), N_1P_1 (soil application) and N_1P_1 through soil-cum-foliar application.

IV.9.5. Magnesium (Table XIIe)

Magnesium percentage in the leaves varied from 0.13 (P_1K_1 -soil application) to 0.31 (control-soil-cum-foliar application).

In the shoots highest percentage of magnesium (0.17%) was found in plants fertilized with N_1P_1 (soil-cum-foliar application)

Table XIIIe. Chemical composition of the dry matter in different parts of the cardamom clump as influenced by NPK and their mode of application

Treatments	Magnesium (Percentage dry weight basis)							
	Leaf		Shoot		Rhizome		Root	
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂
N ₀ P ₀ K ₀	0.30	0.31	0.16	0.15	0.10	0.09	0.09	0.08
N ₀ P ₀ K ₁	0.29	0.28	0.15	0.10	0.12	0.10	0.09	0.10
N ₀ P ₁ K ₀	0.25	0.22	0.13	0.12	0.10	0.09	0.90	0.10
N ₀ P ₁ K ₁	0.13	0.20	0.14	0.13	0.12	0.11	0.09	0.07
N ₁ P ₀ K ₀	0.26	0.25	0.16	0.16	0.13	0.11	0.09	0.10
N ₁ P ₀ K ₁	0.20	0.24	0.16	0.15	0.13	0.12	0.10	0.09
N ₁ P ₁ K ₀	0.30	0.28	0.15	0.17	0.10	0.12	0.12	0.09
N ₁ P ₁ K ₁	0.29	0.30	0.16	0.51	0.11	0.10	0.10	0.09
Average	0.25	0.26	0.15	0.14	0.11	0.11	0.09	0.09

and lowest (0.10%) quantity of Mg was noticed in the plants receiving K_1 (soil-cum-foliar application).

Mg content as high as 0.13 per cent was found in the rhizome of the plants receiving N_1 and N_1K_1 through soil application. A minimum of 0.09 per cent Mg was noticed in the rhizome of the plants under control (soil-cum-foliar application) and P_1 through soil-cum-foliar application.

The roots of the plants fertilized with N_1P_1 (soil application) had 0.12 per cent Mg which was the highest recorded. The lowest, 0.07 per cent of Mg was found in the roots of the plants receiving P_1K_1 through soil-cum-foliar application.

IV.10. Uptake of nutrients by different parts of the plants as influenced by NPK and their mode of application

The data on the uptake of nutrients by different parts of the plants namely, leaves, shoots, rhizomes and roots are presented in Table XIIIa, XIIIb, XIIIc, XIId and XIIE.

IV.10.1. Nitrogen (Table XIIIa)

In general, the uptake of nitrogen in a cardamom clump of 11 months age was maximum in the leaves (2.358 g) compared to shoots (1.093 g), rhizome (0.365 g) and roots (0.185 g).

In the leaves of the plants receiving $N_1P_1K_1$ through soil, maximum uptake of nitrogen was recorded (6.398 g) as against the leaves of the plants grown under control with soil-cum-foliar application (0.669 g).

Table XIIIa. Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application

Treat- ments	Nitrogen (g)										Ave- rage
	Leaf		Shoot		Rhizome		Root		Whole clump		
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	
N ₀ P ₀ K ₀	1.082	0.669	0.211	0.154	0.128	0.164	0.070	0.042	1.491	1.036	1.260
N ₀ P ₀ K ₁	1.762	1.706	0.856	0.480	0.199	0.169	0.091	0.113	2.903	2.468	2.688
N ₁ P ₀ K ₀	1.390	0.905	1.030	0.708	0.191	0.237	0.148	0.106	2.759	1.956	2.357
N ₀ P ₁ K ₁	1.990	2.101	0.644	0.766	0.284	0.260	0.135	0.110	0.053	3.237	3.145
N ₁ P ₀ K ₀	2.000	1.918	1.000	0.997	0.368	0.388	0.155	0.154	3.523	3.457	3.545
N ₁ P ₀ K ₁	1.723	1.393	0.804	0.811	0.333	0.345	0.123	0.167	2.983	2.716	2.849
N ₁ P ₁ K ₀	2.524	2.450	1.448	1.665	0.514	0.670	0.270	0.336	4.756	5.210	4.940
N ₁ P ₁ K ₁	6.398	6.362	2.640	3.163	0.903	0.588	0.362	0.372	10.303	10.485	10.349
Average	2.358	2.230	1.079	1.093	0.365	0.352	0.174	0.185	3.972	3.809	3.593

In the shoots, the plants fertilized with $N_1P_1K_1$ (soil-cum-foliar application) had highest uptake of N (3.163 g) while plants grown under control (soil-cum-foliar application) were found to be lowest in uptake of N (0.154 g).

The maximum uptake of N (0.903 g) was recorded in the rhizome of the plants receiving $N_1P_1K_1$ through soil followed by soil-cum-foliar application of N_1P_1 (0.670 g). A minimum uptake of nitrogen (0.128 g) was noticed in the plants grown under control (soil application).

In the roots, uptake of nitrogen were found to be more in the plants fertilized with $N_1P_1K_1$ through soil-cum-foliar application (0.372 g). It was closely followed by the plants provided with $N_1P_1K_1$ through soil (0.362 g) and soil-cum-foliar application of N_1P_1 (0.336 g). A minimum uptake was observed in the roots of the plants under control with soil-cum-foliar application (0.049 g).

IV.10.2. Phosphorus (Table XIIIb)

In general, the maximum uptake of P was found in the shoots (0.407 g) followed by leaves (0.365 g), rhizome (0.092 g) and roots (0.041 g).

In the leaves, the uptake of P was highest in the plants fertilized with $N_1P_1K_1$ through soil-cum-foliar application (0.924 g) and lowest uptake of P (0.086 g) was found in the plants under control (soil-cum-foliar application).

Table XIIIb. Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application

Treat- ments	Phosphorus (g)										Ave- rage
	Leaf		Shoot		Rhizome		Root		Whole clump		
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	
N ₀ P ₀ K ₀	0.139	0.086	0.033	0.037	0.032	0.044	0.018	0.010	0.222	0.177	0.200
N ₀ P ₀ K ₁	0.266	0.232	0.543	0.308	0.049	0.052	0.028	0.034	0.886	0.626	0.756
N ₀ P ₁ K ₀	0.426	0.417	0.842	0.542	0.088	0.090	0.041	0.045	1.397	1.094	1.250
N ₀ P ₁ K ₁	0.372	0.337	0.413	0.567	0.165	0.126	0.056	0.073	1.006	1.103	1.055
N ₁ P ₀ K ₀	0.284	0.214	0.309	0.180	0.050	0.049	0.027	0.026	0.670	0.469	0.569
N ₁ P ₀ K ₁	0.211	0.116	0.257	0.304	0.071	0.048	0.021	0.025	0.560	0.493	0.526
N ₁ P ₁ K ₀	0.440	0.562	0.442	0.327	0.117	0.151	0.064	0.096	1.063	1.136	1.099
N ₁ P ₁ K ₁	0.783	0.924	0.419	0.426	0.166	0.147	0.069	0.045	1.437	1.543	1.490
Average	0.365	0.361	0.407	0.336	0.092	0.088	0.040	0.041	0.905	0.830	0.868

The uptake of P in the shoots of plants provided with P_1 through soil (0.842 g) recorded highest value, it was followed by soil-cum-foliar application of P_1K_1 (0.567 g), P_1 (0.542 g) and soil application of K_1 (0.543 g). The lowest uptake of P (0.033 g) was found in the shoots of plants under control (soil application)

In the rhizome of the plants fertilized with $N_1P_1K_1$ through soil (0.166 g) recorded maximum uptake of P as against the plants under control - soil application (0.032 g).

The uptake of P as high as 0.096 g was recorded in the roots of the plants receiving N_1P_1 (soil-cum-foliar application), followed by soil-application of $N_1P_1K_1$ (0.069 g) and soil-cum-foliar application of P_1K_1 (0.075 g). A minimum uptake of P (0.010 g) was noticed in the roots of the plants under control (soil-cum-foliar application).

IV.10.3. Potassium (Table XIIIc)

In general, the uptake of K was maximum in shoots (5.966 g) compared to leaves (2.767 g), rhizome (1.208 g) and roots (0.421 g).

The uptake of K was maximum in the leaves of the plants receiving $N_1P_1K_1$ through soil application (6.528 g), followed by $N_1P_1K_1$ through soil-cum-foliar application (5.918 g). A minimum uptake of K (0.840 g) was recorded in the leaves of the plants under control (soil-cum-foliar application).

In the shoots, the plants fertilized with $N_1P_1K_1$ through soil application (10.793 g) recorded maximum uptake of K as against

Table XIIIc. Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application

Treat- ments	Potassium (g)										Ave- rage
	Leaf		Shoot		Rhizome		Root		Whole clump		
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	
N ₀ P ₀ K ₀	0.886	0.840	0.761	0.779	0.365	0.531	0.159	0.086	2.171	2.236	2.204
N ₀ P ₀ K ₁	2.661	2.263	9.430	4.973	1.206	1.002	0.450	0.418	13.747	8.656	11.200
N ₀ P ₁ K ₀	2.482	1.666	4.522	1.206	0.851	0.925	0.452	0.304	8.307	5.349	6.825
N ₀ P ₁ K ₁	2.460	2.230	8.984	6.812	1.476	1.553	0.624	0.732	13.724	11.327	12.525
N ₁ P ₀ K ₀	2.661	1.835	6.025	3.531	0.903	0.762	0.334	0.318	9.923	6.446	8.185
N ₁ P ₀ K ₁	2.223	1.580	2.576	2.827	0.776	0.802	0.314	0.409	5.889	5.618	5.754
N ₁ P ₁ K ₀	2.055	2.472	4.644	4.188	1.137	1.552	0.568	0.647	8.404	8.859	8.632
N ₁ P ₁ K ₁	6.528	5.918	10.793	8.345	2.952	1.957	0.469	0.274	20.742	16.495	18.625
Average	2.767	2.350	5.966	4.240	1.208	1.135	0.421	0.398	10.363	8.161	9.244

0.761 g in the shoots of the plants grown under control (soil application).

Plants receiving $N_1P_1K_1$ through soil application was found to have maximum uptake of K in the rhizome (2.952 g) followed by $N_1P_1K_1$ through soil-cum-foliar application (1.951 g). A minimum uptake of K (0.365 g) was noticed in the plants under control (soil application).

Roots of the plants provided with P_1K_1 through soil-cum-foliar application recorded maximum uptake of K (0.732 g), and minimum uptake of K (0.086 g) was observed in the plants under control (soil-cum-foliar application).

IV.10.4. Calcium (Table XIIIId)

In general, the uptake of Ca was maximum in the leaves (0.857 g) followed by shoots (0.655 g), rhizomes (0.171 g) and roots (0.072 g).

The calcium content of the leaves of the plants receiving $N_1P_1K_1$ through soil application (2.051 g) was found to be maximum. It was followed by $N_1P_1K_1$ through soil-cum-foliar application (1.476 g) and lowest uptake of Ca (0.247 g) was observed in the leaves of plants under control (soil-cum-foliar application).

Uptake of Ca in the shoots varied from 0.130 g (control - soil application) to 1.608 g ($N_1P_1K_1$ -soil application).

In the rhizome, the uptake of Ca (0.430 g) was maximum in plants fertilized with $N_1P_1K_1$ through soil application and minimum

Table XIIIId. Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application

Treat- ments	Calcium (g)										Ave- rage
	Leaf		Shoot		Rhizome		Root		Whole clump		
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	
N ₀ P ₀ K ₀	0.382	0.247	0.130	0.133	0.040	0.050	0.029	0.020	0.581	0.450	0.516
N ₀ P ₀ K ₁	0.552	0.422	0.549	0.386	0.137	0.114	0.070	0.082	1.308	1.004	1.156
N ₀ P ₁ K ₀	0.567	0.555	0.750	0.431	0.118	0.122	0.073	0.051	1.508	1.159	1.334
N ₀ P ₁ K ₁	0.812	0.608	0.585	0.662	0.211	0.194	0.082	0.114	1.690	1.578	1.634
N ₁ P ₀ K ₀	0.863	0.612	0.418	0.333	0.125	0.124	0.053	0.047	1.459	1.116	1.288
N ₁ P ₀ K ₁	0.529	0.324	0.426	0.347	0.122	0.115	0.043	0.051	1.123	0.837	0.960
N ₁ P ₁ K ₀	0.902	1.049	0.774	0.715	0.189	0.163	0.094	0.103	0.959	2.030	1.995
N ₁ P ₁ K ₁	2.051	1.476	1.608	1.355	0.430	0.246	0.111	0.114	4.200	3.191	3.694
Average	0.857	0.661	0.655	0.545	0.171	0.141	0.069	0.072	1.728	1.383	1.572

uptake of Ca (0.040 g) was noticed in the rhizome of the plants under control (soil application).

Plants receiving $N_1P_1K_1$ through soil and $N_1P_1K_1$ through soil-cum-foliar application recorded highest quantities of Ca (0.111 g and 0.114 g respectively) in the roots, as against lowest quantity of Ca (0.020 g) in the plants under control (soil-cum-foliar application).

IV.10.5. Magnesium (Table XIIIe)

In general, the maximum quantity of Mg was observed in the leaves (0.200 g) compared to shoots (0.156 g), rhizome (0.031 g) and roots (0.014 g).

The uptake of Mg by the leaves of the plants provided with $N_1P_1K_1$ through soil-cum-foliar application (0.559 g) recorded maximum, followed by $N_1P_1K_1$ through soil application (0.540 g) and minimum uptake of Mg (0.064 g) was noticed in plants under control (soil-cum-foliar application).

The maximum content of Mg in the shoots was recorded in the plants fertilized with $N_1P_1K_1$ through soil application (0.367 g) while the lowest content of Mg was found in the plants under control - soil-cum-foliar application (0.030 g).

Rhizomes of the plants receiving $N_1P_1K_1$ through soil application (0.067 g) recorded maximum uptake of Mg followed by $N_1P_1K_1$ through soil-cum-foliar application (0.044 g) and minimum uptake of Mg (0.012 g) was observed in control (soil application).

Table XIIIe. Uptake of nutrients in different parts of cardamom clump as influenced by NPK and their mode of application

Treatments	Magnesium (g)										Average
	Leaf		Shoot		Rhizome		Root		Whole clump		
	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	M ₁	M ₂	
N ₀ P ₀ K ₀	0.104	0.064	0.034	0.030	0.008	0.012	0.006	0.004	0.152	0.110	0.131
N ₀ P ₀ K ₁	0.182	0.168	0.156	0.059	0.029	0.021	0.012	0.012	0.379	0.260	0.319
N ₀ P ₁ K ₀	0.174	0.122	0.163	0.095	0.280	0.029	0.013	0.011	0.378	0.257	0.317
N ₀ P ₁ K ₁	0.088	0.135	0.136	0.122	0.041	0.039	0.018	0.016	0.283	0.312	0.298
N ₁ P ₀ K ₀	0.187	0.127	0.134	0.106	0.032	0.027	0.012	0.012	0.365	0.272	0.319
N ₁ P ₀ K ₁	0.106	0.097	0.098	0.100	0.027	0.025	0.010	0.011	0.241	0.233	0.237
N ₁ P ₁ K ₀	0.220	0.209	0.166	0.170	0.031	0.041	0.023	0.026	0.440	0.446	0.443
N ₁ P ₁ K ₁	0.540	0.555	0.367	0.291	0.067	0.044	0.025	0.020	0.999	0.910	0.954
Average	0.200	0.185	0.156	0.121	0.030	0.029	0.014	0.014	0.404	0.350	0.377

The uptake of Mg in the roots varied from 0.004 g (control - soil-cum-foliar application) to 0.026 g (N_1P_1 - soil-cum-foliar application).

IV.11. Uptake of nutrients by plants as influenced by NPK and their mode of application

Data on total uptake of nutrients by plants on dry weight basis and per ha basis are presented in Table XIV and Fig.VII.

IV.11.1. Nitrogen

Mode of application of nutrients did not show any significant influence on the uptake of nitrogen by plants.

The uptake of nitrogen by the plants grown under sub-treatments differed significantly. The uptake of N by the plants provided with $N_1P_1K_1$ (10.35 g/plant and 93.78 kg/ha) and N_1P_1 (4.94 g/plant and 44.46 kg/ha) was found to be significantly higher compared to rest of the treatments. Plants grown under control had significant reduction in the uptake of N (1.26 g/plant and 11.61 kg/ha). Treatments N_1 , P_1K_1 , N_1K_1 and K_1 did not differ significantly. Further, none of the interactions showed significant difference with respect to nitrogen uptake.

IV.11.2. Phosphorus

The uptake of phosphorus by the plants grown under main treatment did not differ significantly.

Significantly higher uptake of P was noticed in the plants provided with $N_1P_1K_1$ (1.49 g/plant and 13.41 kg/ha), compared to

Table XIV. Effects of NPK and their mode of application on uptake of different nutrients (kg/ha) in cardamom

Treatments	Nitro- gen	Phos- phorus	Pota- ssium	Cal- cium	Magne- sium
<u>Main treatments</u>					
M ₁ (S)	108.63	11.39	279.81	15.66	3.68
M ₂ (S + F)	103.05	10.41	219.51	12.78	3.24
C.D. at 5%	NS	NS	NS	NS	NS
C.D. at 1%	NS	NS	NS	NS	NS
<u>Sub-treatments</u>					
N ₀ P ₀ K ₀	11.61	1.80	19.80	4.68	1.17
N ₀ P ₀ K ₁	24.21	6.84	100.80	10.35	2.88
N ₀ P ₁ K ₀	21.24	11.16	61.47	12.06	2.88
N ₀ P ₁ K ₁	28.44	9.90	112.77	14.76	2.76
N ₁ P ₀ K ₀	32.04	5.13	73.80	11.52	2.88
N ₁ P ₀ K ₁	26.91	4.77	51.84	8.91	2.34
N ₁ P ₁ K ₀	44.46	9.90	77.67	17.91	4.05
N ₁ P ₁ K ₁	93.78	13.41	167.49	33.48	8.55
C.D. at 5%	9.22	1.98	30.42	3.69	1.62
C.D. at 1%	12.42	2.70	41.04	4.95	2.16

NS = Non-significant

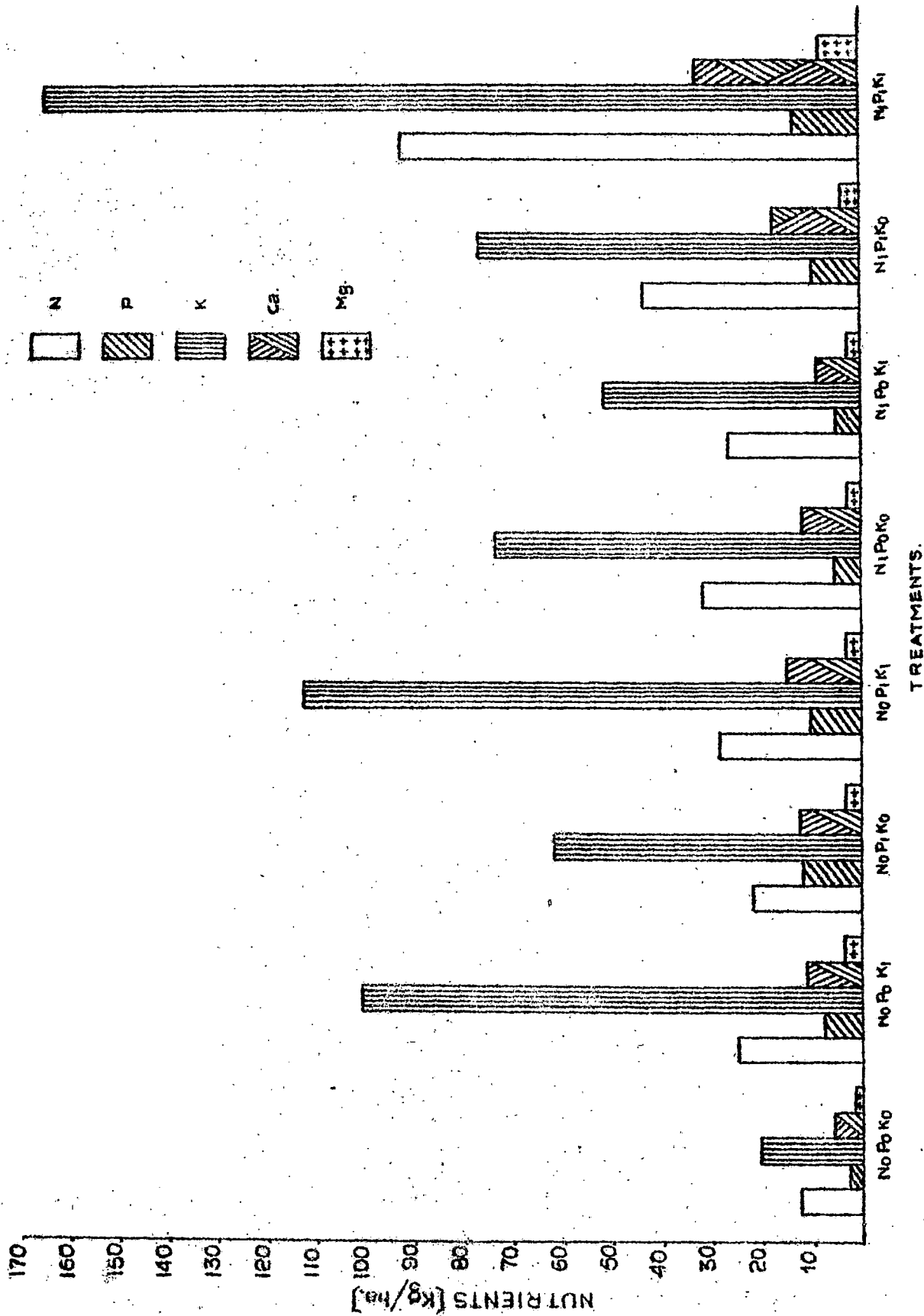


Fig. VII UPTAKE OF NUTRIENTS BY THE PLANTS AS INFLUENCED BY NPK AT THE END OF 11 MONTHS AFTER PLANTING.

rest of the treatments. The plants grown under control (0.20 g/plant and 1.80 kg/ha) recorded significantly lower amount of P compared to all other treatments. However, the uptake of P by the plants grown under P_1 , N_1P_1 and P_1K_1 did not differ significantly. Similar trend was also found in the following treatments namely, K_1 , N_1 and N_1K_1 .

None of the interactions was significant.

IV.11.3. Potassium

The mode of application of N, P and K did not significantly influence the uptake of K.

The uptake of K by the plants differed significantly among the sub-treatments. The plants fertilized with $N_1P_1K_1$ (18.62 g/plant and 167.49 kg/ha) were found to be maximum in the uptake of K compared to the rest of the treatments. The plants provided with P_1K_1 (12.53 g/plant and 112.77 kg/ha) and K_1 (11.2 g/plant and 100.80 kg/ha) recorded significantly more of K in the plants compared to that of plants under P_1 (6.83 g/plant and 61.47 kg/ha) and N_1K_1 (5.75 g/plant and 51.84 kg/ha). There were no significant differences in the uptake of K by the plants fertilized with N_1P_1 , N_1 , P_1 and N_1K_1 treatments. The plants grown under control (2.20 g/plant and 19.80 kg/ha) were significantly low in K uptake compared to all other treatments.

None of the interactions was significant.

IV.11.4. Calcium

Mode of application had no effect on Ca uptake by the plants under different treatments.

The plants grown with $N_1P_1K_1$ (3.69 g/plant and 33.48 kg/ha) recorded significantly higher quantity of Ca compared to that of other treatments. The uptake of Ca by the plants provided with N_1P_1 (1.99 g/plant and 17.91 kg/ha) and P_1K_1 (1.63 g/plant and 14.76 kg/ha) was significantly more than that of plants grown under K_1 (1.16 g/plant and 10.35 kg/ha) and N_1K_1 (0.96 g/plant and 8.91 kg/ha). No significant difference was found in the plants provided with P_1 , N_1K_1 and N_1P_1 in the uptake of Ca. Plants under control (0.52 g/plant and 4.68 kg/ha) recorded significantly lower Ca content compared to that of other treatments.

None of the interactions was significant.

IV.11.5. Magnesium

The main treatments had no significant effect on the uptake of Mg.

The highest uptake of Mg was found in the plants fertilized with $N_1P_1K_1$ (0.95 g/plant and 8.55 kg/ha) which differed significantly from that of all other treatments. The plants grown under control (0.13 g/plant and 1.17 kg/ha) were low in the uptake of Mg compared to that of other treatments. However, the uptake of Mg by the plants grown under N_1P_1 , N_1 , P_1 , K_1 and P_1K_1 were on par.

There were no significant differences between interactions.

IV.12. Chemical analysis of the soil at the end of the experiment

Data on chemical analysis of soil is presented in Table XV.

IV.12.1. pH:

The maximum pH (5.8) of soil was recorded in the treatment K_1 followed by P_1 (5.62), P_1K_1 (5.49), control (5.75) and minimum pH of soil was observed in the treatment N_1 (4.62).

IV.12.2. Organic carbon

Higher percentage of organic carbon was found in the treatment N_1 (1.76%). This was followed by N_1P_1 (1.64%), $N_1P_1K_1$ (1.62%), P_1K_1 (1.50%) and minimum percentage of organic carbon was noticed under control (1.18%).

IV.12.3. Total nitrogen

The treatments receiving N_1 , N_1K_1 and N_1P_1 recorded highest value of 0.13 per cent of total nitrogen as against lowest value of 0.06 per cent observed in control.

IV.12.4. Available phosphorus

Maximum quantity of P was found in the soil fertilized with N_1P_1 (16.00 kg/ha) followed by P_1 (14.00 kg/ha), P_1K_1 (13.00 kg/ha), $N_1P_1K_1$ (13.00 kg/ha) and minimum quantity of P was observed in the soil under control (6.5 kg/ha).

IV.12.5. Available potassium

Maximum quantity of potassium (370.35 kg/ha) was recorded

Table XV. Chemical analysis of the soil at the end of the experiment

Contents	Main treatments	Sub-treatments							
		N ₀ P ₀ K ₀	N ₀ P ₀ K ₁	N ₀ P ₁ K ₀	N ₀ P ₁ K ₁	N ₁ P ₀ K ₀	N ₁ P ₀ K ₁	N ₁ P ₁ K ₀	N ₁ P ₁ K ₁
pH	M ₁	5.40	5.90	5.57	5.37	4.50	5.00	4.75	4.85
	M ₂	5.30	5.70	5.67	5.62	4.75	5.02	4.77	4.85
	Average	5.35	5.80	5.62	5.49	4.62	5.01	4.76	4.85
Organic carbon (%)	M ₁	1.26	1.54	1.30	1.62	1.82	1.40	1.65	1.62
	M ₂	1.10	1.33	1.20	1.39	1.70	1.20	1.63	1.63
	Average	1.18	1.43	1.25	1.50	1.76	1.30	1.64	1.62
Total nitrogen (%)	M ₁	0.07	0.10	0.10	0.11	0.14	0.14	0.14	0.12
	M ₂	0.06	0.08	0.10	0.11	0.13	0.12	0.12	0.12
	Average	0.06	0.09	0.10	0.11	0.13	0.13	0.13	0.12
Available phosphorus (kg/ha)	M ₁	6.00	8.00	14.00	12.00	10.00	10.00	18.00	12.00
	M ₂	6.00	6.00	14.00	14.00	8.00	9.00	14.00	14.00
	Average	6.00	7.00	14.00	13.00	9.00	9.50	16.00	13.00
Available potassium (kg/ha)	M ₁	197.60	395.20	190.25	296.40	190.25	370.50	197.60	325.65
	M ₂	148.20	345.50	170.25	222.30	180.25	296.40	148.20	314.75
	Average	172.90	370.35	180.25	259.35	185.25	333.45	172.90	320.70
Calcium (me/100 g)	M ₁	3.00	3.00	3.00	4.00	4.00	3.92	4.80	4.04
	M ₂	3.10	2.80	4.00	3.50	4.00	3.40	4.70	4.50
	Average	3.05	2.90	3.50	3.75	4.00	3.66	4.75	4.27
Magnesium (me/100 g)	M ₁	1.37	1.00	1.57	1.20	1.96	1.32	1.50	1.78
	M ₂	1.40	1.02	1.74	1.10	1.42	1.08	1.60	1.98
	Average	1.38	1.01	1.65	1.15	1.69	1.20	1.55	1.88

in the treatments K_1 and the lowest percentage of K was found in the soil under control (172.90 kg/ha).

IV.12.6. Calcium

The treatment receiving N_1P_1 (4.75 me) recorded maximum quantity of Ca followed by $N_1P_1K_1$ (4.27 me), N_1 (4.00 me) and minimum quantity of Ca was noticed in the soils fertilized with K_1 (2.90 me).

IV.12.7. Magnesium

Maximum quantity of Mg (1.88 me) was found in the soil fertilized with $N_1P_1K_1$. This was followed by N_1 (1.69 me), P_1 (1.65 me), N_1P_1 (1.55 me) and minimum quantity of Mg (1.01 me) was observed in the soil receiving K_1 treatment.

DISCUSSION

CHAPTER V

DISCUSSION

Judicious application of adequate quantity of well balanced fertilizer brings about maximum increase in growth and yield of a crop compared to any other input. In the present study, the influence of N, P, K and their mode of application on growth parameters, dry weights, chemical composition and uptake of nutrients in respect of cardamom, are evaluated and discussed here.

V.1. Vegetative growth parameters

On scrutinizing the data presented in Table IIa and IIb, and Fig.I, it is seen that there was no significant difference between the effects of two modes of application of NPK fertilizers on sucker production. Similar results were obtained when applications of fertilizer through soil, foliar and soil-cum-foliar application to Arabica coffee (Anon., 1967) and N through soil and foliage to banana by Shawky et al. (1974) were carried out.

The number of suckers produced among sub-treatments differed significantly. Plants fertilized with $N_1P_1K_1$ recorded significantly more suckers (31.84) compared to that of any other treatments, throughout the period of observation. This accounted for two times and a half more of suckers as compared to that of control which recorded lowest number of suckers (12.31). Production of significantly higher number of suckers as a result of application of all the three ingredients ($N_1P_1K_1$) gives a

positive indication of the response of the plants to all the three major ingredients. Zurbickij et al. (1969) observed better growth and development of tea when fertilized with NPK. Similar results were obtained in tea by Majorova (1960), Canukvadze (1970), Guseino (1973) and Mahalkal and Gupta (1973).

The sub-treatments N_1P_1 (23.74), P_1K_1 (22.31) and N_1K_1 (19.22) which followed $N_1P_1K_1$ consistently did not differ amongst themselves. Kuratti (1963) recorded maximum tillers in paddy fertilized with N_2 levels of 45 lb (20.25 kg) + P_2 level of 30 lb (13.50 kg) compared to control involving no fertilizer.

The main effects of N_1 (23.08), P_1 (24.01) and K_1 (22.87) were significantly superior in respect of the number of suckers produced compared to that of control (Table IIb). Krishnamurthy (1967) observed that linear increase in tiller production in H-22 ragi with increased levels of N from 0.00 to 90 kg per ha.

The data (Table IIIa and Fig. IIa and IIb) on number of leaves produced revealed that there was significant difference in the leaf production between main treatments during March and April. Soil application of NPK (110.62) produced significantly more number of leaves than that of soil-cum-foliar application of NPK (91.76). Alice et al. (1978) reported that soil application of complex fertilizers (Vijay, 17-17-17 NPK) to paddy resulted in increased straw and grain yield than the foliar application.

Sub-treatments significantly influenced the leaf production. Plants fertilized with $N_1P_1K_1$ produced significantly higher number of leaves (171.20) followed by that of P_1K_1 (116.66), N_1P_1 (110.62) etc., there being minimum number of leaves in control (62.00). Increase in number of leaves is mainly due to increase in the number of suckers. Cessare Guerra (1972) recorded maximum tea yield with NPK 180, 60 and 90 kg per ha respectively. Similar results were obtained by Mchakal and Gupta (1973), Guseinov (1973) and Maeharan et al. (1973) in tea. Decrease in number of leaves is obviously due to less number of suckers.

The main effects of N (111.74), P (123.33) and K (117.28) showed a positive response on the number of leaf production compared to control.

It is seen from Table IIa and IIb and Fig. IIIa and IIIb that the main treatments significantly influenced the total length of suckers per clump during February, March and April. Soil application of NPK recorded significantly higher total length (1045.32 cm) compared to that of soil-cum-foliar application of NPK (935.46 cm). This is mainly due to better growth of suckers under soil application. Foliar application of inorganic nutrients caused some scorching effect and as a result the growth was retarded. Rankhurb (1974) observed shorter growth and less tiller density in wheat by application of half soil and half foliar N.

Among sub-treatments the plants provided with $N_1P_1K_1$ recorded significantly higher total length (1791.70 cm). This was followed by P_1K_1 (1134.37 cm), N_1P_1 (1084.96 cm), P_1 (903.16 cm), K_1 (902.58 cm) and N_1K_1 (863.62 cm) and minimum total length of suckers per clump was found in the plants under control (549.75 cm). Increase in total length is mainly due to more suckers produced in the clump. Canukvadze (1970) reported that tea applied with NPK mixture 0.15, 0.10 and 0.10 g per kg of soil resulted in increased plant growth by 64 per cent over the control.

The main effects of N_1 (1045.70 cm), P_1 (1241.04 cm) and K_1 (1186.31 cm) significantly influenced the total length of suckers per clump, compared to that of control. The higher growth rate of coffee plant was found with N application (Ishigake, 1971). Similar results were obtained in the studies conducted by Jumbulingam and Ramaswamy (1975) who reported that application 360 g K_2O per plant resulted in increase in pseudostem height of banana. Significant increase in the pseudostem height (151 cm) was observed in banana with 40 g P_2O_5 per plant compared to control (Anon., 1978).

The sub-treatments significantly influenced the average height of sucker at the end of April (Table V and Fig. IV). The plants fertilized with P_1K_1 (65.53 cm) and $N_1P_1K_1$ (64.46 cm) recorded significantly higher average height as against the plants under control (50.51 cm). For the same reasons discussed in the preceding paragraph.

The main treatments were significantly influenced the leaf length at the end of April (Table VI). The soil application of NPK recorded significantly higher leaf length (31.38 cm) compared to that of soil-cum-foliar application of NPK (29.99 cm).

The leaf length and breadth were significantly influenced by sub-treatments only during February but the differences did not persist in the subsequent months.

V.2. Interaction effects

The number of leaves produced was significantly influenced by main x sub-treatment interaction at the end of April (Table IIIc). Soil application of $N_1P_1K_1$ produced significantly more number of leaves (181.00), nearly two times more compared to that of control (74.83). Cesare Guerra (1972) reported that application of NPK (180 + 160 + 90 kg/ha respectively) through soil resulted in an increased tea yield compared to that of control. Similar findings were reported by Mahalkal and Gupta (1973), Guseinov (1973) and Maeharan et al. (1974).

The plants provided with NPK (161.41) through soil-cum-foliar application produced nearly three times more leaves compared to that of control (49.16). This was followed by P_1K_1 (110.58) etc. Increase in cane yield of sugarcane by 13.69 and 17.29 metric tonnes respectively by spraying of N and P as sulphate of ammonia and superphosphate (Anon., 1956). Godoy (1958) reported that coffee seedlings sprayed with NPK resulted in more

number of branches, leaves and height compared to control. Similar findings in agreement with Chiang (1960) was observed in tea.

The plants fertilized with $N_1P_1K_1$ (181.00) through soil and soil-cum-foliar application of $N_1P_1K_1$ (161.41) produced more number of leaves compared to that of other treatments, irrespective of mode of application. The lowest number of leaves was produced under control.

The interaction effects on total length of suckers was found significant only during the month of March. But in the subsequent month, it was found to be non-significant.

A perusal of the data presented in Table VIII indicated that soil application of $N_1P_1K_1$ produced maximum number of panicles (20.50) as against only one panicle under control-(soil application). This is attributed to the better growth of plant as a result of the application of all the three major nutrients.

V.3. Total fresh weight and dry weight

A careful study of the data presented in Table IX and Fig.Va and Vb indicated that the sub-treatment significantly influenced the total fresh and dry weight of cardamom plants.

The plants fertilized with combination of $N_1P_1K_1$ recorded significantly highest fresh weight (2999.88 g) compared to rest of the treatments, except P_1K_1 (2065.47 g). The increase in fresh weight was nearly six times more than that in control which recorded

minimum fresh weight of 481.7 g. The treatments P_1K_1 (2065.47 g) N_1P_1 (1785.71 g), K_1 (1533.90 g), P_1 (1341.87 g), N_1 (1224.55 g) and N_1K_1 (1163.32 g) followed by $N_1P_1K_1$, in descending order but they did not differ amongst themselves. Increase in fresh weight is mainly due to more number of suckers coupled with higher total length of suckers per clump. Kimeu (1970) reported that application of NPK in terms of compound fertilizers (15 : 15 : 15 + trace elements) on coffee, resulted in increase in fresh weight and dry weight of coffee.

Total dry weight of plant was significantly influenced by the sub-treatments. Application of $N_1P_1K_1$ to cardamom plant was most effective in producing highest total dry weight (473.58 g) compared to that of other treatments. The level of $N_1P_1K_1$ fertilizer increased dry weight more than seven times compared to that of control (65.37 g). The high quantity of dry matter produced in $N_1P_1K_1$ is the result of high quantity of fresh weight and high dry weight, compared to that of other treatments. Maeharan *et al.* (1974) observed that tea plants with 10 split applications of NPK resulted in 17, 7 and 34 fold increase in dry weight of roots, stems and leaves, respectively as compared to control. The treatments receiving N_1P_1 (241.56 g), P_1K_1 (219.53 g), P_1 (199.86 g) K_1 (179.32 g) and N_1 (174.20 g) followed $N_1P_1K_1$, but they were on par with each other. The lowest dry weight under control is mainly attributed to inadequate supply of nutrients.

V.4. Percentage contribution of fresh weight and dry weight of different parts to the whole clump

The percentage composition of different parts of fresh weight and dry weight of whole clump varied under different sub-treatments (Table X and XI, and Fig.VIa and VIb). In general, maximum percentage of fresh weight was contributed by shoots (45.94%) followed by leaves (23.10%), rhizome (21.00%) and roots (9.96%). It is mainly due to more of suckers with advancing growth towards maturity.

The foliage of the plants grown under control accounted for 26.25 per cent of the total fresh weight followed by $N_1P_1K_1$ (25.91%), N_1 (24.16%), P_1 (23.56%), etc., and lowest percentage contribution of leaves was made by the plants applied with N_1P_1 (19.37%).

Highest percentage of fresh weight of shoots was recorded by the plants fertilized with $N_1P_1K_1$ (51.34%) as against 42.13 per cent under control. Increase in percentage of fresh weight of shoots may be due to production of more of suckers with advancing growth.

Rhizomes of the plants provided with N_1 developed higher percentage of fresh weight (23.49%), followed by N_1K_1 (23.40%), P_1 (21.62%), K_1 (20.48%), etc., and lowest percentage of fresh weight of rhizome in plants fertilized with $N_1P_1K_1$ (16.66%).

The maximum percentage of fresh weight of roots was produced in the plants receiving N_1P_1 (13.75%) treatment against lowest percentage of roots (7.09%) in plants fertilized with $N_1P_1K_1$. It

could be attributed to better development of root system under N_1P_1 treatment.

In general, maximum percentage of dry weight was contributed by shoots (42.80) to the total dry weight. This was followed by leaves (34.92%), rhizome (14.05%) and roots (8.23%). This is mainly attributed to increase in fresh weight.

The foliage of the plants under control accounted for 42.48 per cent of the total dry weight, followed by $N_1P_1K_1$ (39.39%), N_1 (35.06%) etc. The lowest percentage contribution of dry weight of leaves was recorded in the plants provided with P_1K_1 (30.83%). This is mainly due to increase in fresh weight with the above said nutrients. Maeharan et al. (1974) observed that tea plants fertilized with NPK resulted in increased dry weight of leaves.

All the treatments showed higher percentage composition of dry weight of shoots compared to that of control. The higher percentage composition of dry weight of shoots was observed in P_1 (48.65%), K_1 (44.75%) and $N_1P_1K_1$ (44.68%) compared to control (31.31%). It may be attributed to more of suckers with higher rate of driage. Maeharan et al. (1974) noted increase in dry weight of shoots of tea with application of NPK fertilizer mixture.

The percentage composition of rhizome to the total dry weight of the clump in case of control was highest (16.87%). This value

was lowest in case of $N_1P_1K_1$ (10.61%).

The maximum percentage composition of dry weight of roots was accounted in the plants fertilized with N_1P_1 (10.76%) followed by P_1K_1 (9.99%) etc., and lowest percentage was found in the plants provided with $N_1P_1K_1$ (5.32%). It is mainly attributed to high percentage of fresh weight as a result of better development of root system.

V.5. Chemical composition

The chemical composition of different parts of the plants was found to be influenced by NPK and their mode of application. There was maximum percentage of N (3.76%) in the leaves of the plants fertilized with N_1 through soil-cum-foliar application and N_1K_1 through soil application. This was followed by 3.44 per cent in N_1P_1 (soil application) and soil-cum-foliar application of N_1K_1 and $N_1P_1K_1$. A minimum percentage of N (1.63%) was found in the leaves of the plants provided with P_1 (soil-cum-foliar application). Increase in percentage of N is mainly due to N fertilization.

Bangoo et al. (1962) found that nutrients contents of banana plant increased in direct proportion to NPK fertilizer applied. Ananth and Iyengar (1965) reported that leaf N increased from 3.3 per cent to 4.00 per cent in coffee by foliar application of urea. Similar results were obtained by Iyshigaki (1971) in coffee and Rao and Iyengar (1975) also, in coffee. Krishnamurthy Rao et al. (1976) reported significant increase in N content of coffee leaves

with increased concentration of urea sprays. Similar results were observed from the findings of Lin (1977) in tea.

Amongst the different sub-treatments at fixed level of main treatments consisting of soil-cum-foliar application of P_1 and N_1P_1 recorded maximum of 0.75 per cent of P. This was followed by P_1 (0.60%) applied through soil, N_1P_1 (0.60%) - soil application, soil-cum-foliar application of P_1K_1 (0.50%) and $N_1P_1K_1$ (0.50%). A minimum percentage of N (0.32%) was recorded in soil-cum-foliar application of N_1K_1 treatment. Ananth (1961) stated that P content in the coffee leaves increased with concentration of foliar applied P solution. Decrease in percentage of P is attributed to low content of P in the soil. Similar trend was observed in the shoots, rhizome and roots.

It is seen from Table XIIc that the maximum of 4.20 per cent of K was recorded in the leaves of the plants fertilized with K_1 and N_1K_1 applied through soil followed by 3.90 per cent in P_1K_1 (soil application), K_1 , N_1K_1 and control under soil-cum-foliar application. It may be attributed to more availability of K due to K fertilization. Jumbulingam and Ramaswamy (1975) reported that soil application of 360 g K_2O per banana plant resulted in higher K content in the leaf. Increase in K percentage in control may be due to limited growth, wherein the tissue composition is

not subjected to dilution effects. A minimum percentage of K (3.00%) was found in the leaves of the plants provided with P_1 through soil-cum-foliar application.

In shoots, maximum percentage of K (9.40%) was recorded in the treatments K_1 and N_1 applied through soil as against 3.50 per cent in control and 3.40 per cent in P_1 . Increase in K percentage is mainly due to decrease in Mg content of K treated plant. Lahav (1977) reported that increase in the level of K fertilizer was followed by a decrease in the Mg level in the sucker, and antagonism between K and Mg (blade $r = -0.272$, petiole $r = -0.549$) was found to be greater than that of K and Ca (blade $r = -0.235$, petiole $r = -0.377$). It was confirmed with the results of Lahav (1973).

Maximum percentage of K (4.90%) was found in the rhizome of the plants fertilized with K_1 , N_1 applied through soil and $N_1P_1K_1$ (soil-cum-foliar application). Minimum percentage of K (3.60%) was noticed in the treatments P_1 and N_1P_1 applied through soil.

Roots of the plants fertilized with K_1 , N_1 through soil and N_1K_1 , P_1K_1 through soil-cum-foliar application recorded maximum percentage of K (3.20%) as against 1.20 per cent in $N_1P_1K_1$ (soil-cum-foliar application). Decrease in percentage of K is attributed to more dilution effect due to better growth of plants.

On the whole, the average content of K in shoots, rhizome, leaves and roots works out to be 6.03, 4.41, 3.66 and 2.70 respectively.

The data on Ca composition of the plant tissue revealed that the maximum percentage of Ca (1.40%) was found in the leaves of the plants fertilized with N_1P_1 through soil-cum-foliar application followed by N_1P_1 (1.23%), P_1K_1 (1.20%) and N_1 (1.19%) applied through soil. A minimum percentage of Ca was observed in K_1 (0.73%) (N_1K_1 (0.80%) and $N_1P_1K_1$ (0.80%) applied through soil-cum-foliar application. Lahav (1973) demonstrated the antagonism between K and Ca in banana. It was confirmed with the results of Lahav (1977) in banana.

The tissue composition of Mg was confined to comparatively a narrow limit ranging from 0.31 to 0.08. No definite trend was observed in case of shoots, rhizomes and roots of plants due to the influence of NPK level with regard to percentage of Mg.

V.6. Uptake of nutrients by the plants

A perusal of the data furnished in Table XIII and Fig.VII reveals that the uptake of nutrients were significantly influenced by sub-treatments.

V.6.1. Nitrogen

Significantly higher uptake of N (93.78 kg/ha) was recorded in the plants fertilized with $N_1P_1K_1$. This was nearly nine times more than that of control (11.61 kg/ha). The uptake of N in $N_1P_1K_1$ treatments was nearly seven, three and eleven times more than that of P (13.41 kg/ha), Ca (33.48 kg/ha) and Mg (3.55 kg/ha) respectively. But compared to potassium the uptake of N was less. This

indicates that N is next in importance to K from the point of view of quantities of major ingredients held by the plant tissues. Based on plant analysis study, Kulkarni et al. (1971) reported that uptake of N by cardamom plant was more but next in importance to K.

Lower uptake of N in control is expected in view of lower availability of N and also due to less dry weight. The treatments N_1P_1 (44.46 kg/ha), N_1 (32.04 kg/ha), P_1K_1 (28.44 kg/ha) followed $N_1P_1K_1$.

V.6.2. Phosphorus

Nearly six times more uptake of P was recorded by the plants fertilized with $N_1P_1K_1$ (13.41 kg/ha) compared to that of plants under control (1.80 kg/ha). This was followed by P_1 (11.16 kg/ha), N_1P_1 (9.90 kg/ha), P_1K_1 (9.90 kg/ha). The uptake of P by plant was only one-seventh, one-twelfth and one-half compared to N, K and Ca respectively, but slightly more than that of Mg when compared to $N_1P_1K_1$ treatment was recorded. Obviously P requirement of cardamom is very less and it is surprising that the plants give favourable response to added doses in initial stage. Therefore, it is necessary to emphasise that supply of P in available form is of greater importance from the point of view of the plant growth, particularly when soil pH is low. Increase in uptake of P in $N_1P_1K_1$ is mainly due to increase in dry weight.

V.6.3. Potassium

The data furnished in Table XIII and Fig.VII revealed that the uptake of K by the cardamom plants was maximum in all the treatments compared to that of any other ingredients such as N, P, and others. The plants fertilized with $N_1P_1K_1$ recorded significantly more uptake of K (167.49 kg/ha), which accounted nearly 2, 12, 5 and 20 times to that of N (93.78 kg/ha), P (13.41 kg/ha), Ca (33.48 kg/ha) and Mg (8.55 kg/ha). The uptake of potassium in $N_1P_1K_1$ treatments increased nearly by eight times compared to that of the uptake of K by the plants under control. It is evident that cardamom plant is a heavy feeder of K than any other nutrients. Therefore, application of more of K fertilizers is justified. Kulkarni *et al.* (1971) stated that uptake of K by the cardamom plant was more compared to any other nutrients.

V.6.4. Calcium

Significantly higher uptake of Ca (33.48 kg/ha) was found in the plants provided with $N_1P_1K_1$. This was nearly eight times more than that of control (4.68 kg/ha). This was followed by N_1P_1 (17.91 kg/ha), P_1K_1 (14.76 kg/ha), P_1 (12.06 kg/ha), N_1 (11.52 kg/ha) etc. Increase in uptake of Ca is mainly due to higher dry weight.

V.6.5. Magnesium

Uptake of Mg also followed the similar trend like that of Ca. Significantly higher uptake of Mg (8.55 kg/ha) was found in

the plants fertilized with $N_1P_1K_1$ compared to that of control (1.17 kg/ha). Increase in Mg in $N_1P_1K_1$ accounted nearly eight times more than that of control.

In the present investigation the uptake of N, P, K, Ca and Mg by the plants fertilized with combination of $N_1P_1K_1$ was in the ratio of 7:1:12.3:2.4:0.89. Kulkarni *et al.* (1971) reported that the ratio of N, P, K, Ca and Mg in cardamom was 6:1:12:3:0.80.

V.7. Chemical analysis

On scrutinizing the data presented in Table XV it is seen that soil pH, organic carbon, N, P, K, Ca and Mg were found to be influenced by treatment effect during the course of this experiment.

The decrease in pH of soil from 5.10 to 4.62, 4.76 and 4.10 in the treatments receiving N_1 , N_1P_1 and $N_1P_1K_1$ respectively was observed due to addition of nitrogenous fertilizers in the form of urea. It may help in the formation of acid during the nitrification process and loss of bases due to the replacement of basic cations of liberated H^+ and NH_4 ions. Bangoo *et al.* (1962) reported that application of 90-112.5 kg of N decreased the soil pH from 5.57 to 5.53 in banana. This indicates that whenever nitrogenous fertilizers are applied to acid soils, care should be taken to rectify the soil pH by using suitable amendments. Slight increase in pH of soil ranging from 0.70 to 0.25 was found in the treatments K_1 , P_1 , P_1K_1 and control. This is due to absence of nitrogenous fertilizers and the residual effect of lime that was added at the time of planting.

Only marginal increase in organic carbon content in soils receiving treatments N_1 , N_1P_1 and $N_1P_1K_1$ respectively over the original status of soil.

Increase in percentage of total N from 0.10 per cent (original status of soil) to 0.13 per cent was observed in the soil fertilized with N_1 , N_1K_1 , N_1P_1 and $N_1P_1K_1$ treatments. Decrease in percentage of total N was found in control (0.04%) compared to that of other treatments. Increase in percentage of total N is mainly due to addition of N through fertilizers.

Just as in the case of N, there was increase in P content of soil, where soil fertilized with N_1P_1 (16.00 kg/ha), P_1 (14.00 kg/ha), P_1K_1 (13.00 kg/ha) and $N_1P_1K_1$ (13.00 kg/ha) as against 6.5 kg per ha in original status of soil and control (6.00 kg/ha). The difference is attributed to increase in P content applied through fertilizers.

Maximum quantity of K (370.35 kg/ha) was observed in the soil fertilized with K_1 . It was followed by N_1K_1 (333.45 kg/ha), $N_1P_1K_1$ (320.70 kg/ha), P_1K_1 (259.35 kg/ha) and lowest quantity of K was found in control (172.90 kg/ha). Increase in the quantity of K in the soil is mainly due to application of K through fertilizers.

In general, increase in Ca content of soil was observed in all the treatments. This was mainly due to application of lime at the time of planting. The maximum increased from 2.74 to 4.75,

2.74 to 4.27 and 2.74 to 4.00 me. was found in the treatments N_1P_1 , $N_1P_1K_1$ and N_1 , respectively. Just as in the case of Ca, there was increase in Mg content of soil observed in all the treatments compared to that of original soil. Highest quantity of Mg (1.88 me.) was recorded in the soil fertilized with $N_1P_1K_1$ as against 0.85 me. in original against 1.01 ppm in K_1 treatment. Decrease in Mg content is mainly due to antagonism between Mg and K.

SUMMARY

CHAPTER VI

SUMMARY

The experiment was conducted at the Regional Research Station, Mudigere, to study the effects of various combinations of NPK and their mode of application on the production of cardamom suckers. The experiment consisted of two main treatments viz., soil application of NPK and soil-cum-foliar application of NPK with 8 sub-treatments namely, $N_0P_0K_0$, $N_0P_0K_1$, $N_0P_1K_0$, $N_0P_1K_1$, $N_1P_0K_0$, $N_1P_0K_1$, $N_1P_1K_0$, and $N_1P_1K_1$, derived from 2^3 factorial combination. The first level was maintained at '0' for all the ingredients and second level was maintained at 32.5 g N (N_1), 25.0 g of P_2O_5 (P_1) and 50 g of K_2O (K_1) as urea, superphosphate and muriate of potash, respectively.

Main treatment effects did not differ significantly in respect of number of suckers produced till the last observation was made at the end of one year. But they revealed significant differences in respect of leaf production, total length of suckers per clump and average length of sucker, at the latter stages of the experiment. Soil application of NPK produced significantly higher number of leaves (110.62), total length (1045.32 cm) and average leaf length (31.38 cm) as compared to that of soil-cum-foliar application of NPK (91.76 cm, 935.46 cm and 29.99 cm respectively).

Among the sub-treatments, application of 32.5 g of N + 25 g of P_2O_5 + 50 g of K_2O per plant was found most effective in bringing about better growth and development of cardamom plant. The combination

of these ingredients promoted the plants to produce suckers in significantly higher numbers (31.84), leaves (171.20), total length (1791.70 cm) of suckers per clump and average height (64.46 cm) of sucker, compared to that of control. The sucker production, leaf production and total length of suckers in the clump under $N_1P_1K_1$ were two and a half times more than that of control. The treatments N_1P_1 , P_1K_1 and N_1K_1 were followed by $N_1P_1K_1$ consistently.

The main effects of N, P and K were significantly superior to those under control in respect of the number of sucker production, leaf production and total length of suckers in a clump.

Interactions consisting of combination of $N_1P_1K_1$ with soil application helped the plants to record significantly higher number of leaves (181.00) compared to any other treatments.

The plants under treatments fertilized with soil application of $N_1P_1K_1$ produced maximum number of panicles (20.50/treatment) compared to any other treatments.

The plants fertilized with $N_1P_1K_1$ recorded significantly higher quantities of both fresh matter (2999.88 g) and dry matter (473.58 g) and this was followed by P_1K_1 and N_1P_1 treatments. The fresh weights and dry weight production in $N_1P_1K_1$ were 6 and 7 times more than those of control, respectively. This is mainly attributable to the production of significantly more suckers, leaves and highest total length of suckers in a clump as a result of the application of three major ingredients.

Sub-treatment effects influenced the clump structure of plants as indicated by the percentage composition of fresh weight and dry weight of different parts to the whole weight of clump. Fresh and dry weights of foliage constituted 26.25 and 42.48 per cent to the whole clump, respectively. This proportion of foliage observed in case of control was found to be the highest for the corresponding figures in case of other treatments. Shoots of the plants fertilized with $N_1P_1K_1$ contributed maximum of both fresh weight (51.34%) and dry weight (44.68%) compared to that of control, wherein 42.13 and 31.31 per cent of fresh and dry weight respectively, were recorded. The rhizome of N_1 treatment made the highest contribution of fresh weight of 23.49 per cent as against 16.66 per cent in $N_1P_1K_1$ treatment. The highest percentage of dry weight of rhizome (16.88%) was contributed by plants under control. The plants provided with N_1P_1 increased the percentage fresh weight (13.75%) and dry weight (10.76%) of roots compared to that of 7.09 and 5.32 per cent in $N_1P_1K_1$ treatments, respectively.

The treatments consisting of N_1 (soil-cum-foliar application) and N_1K_1 (soil application) increased the percentage of N in the leaves (3.76%) as against 1.63 in P_1 (soil-cum-foliar application)-The N percentage in the shoots was high (1.63%) under the treatments N_1 (soil application), N_1P_1 (soil-cum-foliar application) and $N_1P_1K_1$ (soil-cum-foliar application) compared to 0.66 per cent in P_1K_1 applied through soil. Similar trend was noticed in rhizome

and roots. Application of P_1 and N_1P_1 through soil-cum-foliar application increased the P percentage in the leaves (0.75%) as compared to that of control (0.40%) and N_1K_1 through soil-cum-foliar application (0.32%). Similar trend was observed in shoots, rhizome and roots.

Higher percentage of K was found in the leaves (4.20%), shoots (9.40%), rhizome (4.90%) and roots (3.20%) of the plants fertilized with K_1 through soil as against lowest percentage of 2.8 in the leaves (N_1P_1 - soil application), 3.40 per cent in shoot (P_1 - soil application) and 1.2 per cent in roots ($N_1P_1K_1$ soil-cum-foliar application).

The Ca percentage of leaves and shoots of the plants fertilized with N_1P_1 , N_1 and P_1K_1 was higher compared to that of control, K_1 and P_1 treatments.

The percentage of Mg in the tissues of various parts of the plant ranged within a narrow limit of 0.08 to 0.31 per cent.

Among the sub-treatments, application of $N_1P_1K_1$ influenced the plants to draw significantly higher quantities of N (93.78 kg/ha), P (13.41 kg/ha), K (167.49 kg/ha), Ca (33.48 kg/ha) and Mg (8.55 kg/ha) as compared to the rest of the treatments. Significantly very less uptake of N (11.61 kg/ha), P (1.80 kg/ha), K (19.8 kg/ha), Ca (4.68 kg/ha) and Mg (1.17 kg/ha) was recorded by the plants under control.

In general, the uptake ratio in $N_1P_1K_1$ was 7:1:12.3:2.4:0.89 of N, P, K, Ca and Mg respectively.

Marked decrease in soil pH from 5.10 which was the initial stage to 4.62 was observed in the treatments receiving N_1 , N_1P_1 and $N_1P_1K_1$ respectively.

Marginal increase in the organic carbon content was noticed in the soils receiving N_1 , N_1P_1 , N_1K_1 and $N_1P_1K_1$ treatments, compared to that of original status of soil and control.

Maximum percentage of total nitrogen (0.13%) was found in the soils fertilized with N_1 , N_1K_1 , N_1P_1 and $N_1P_1K_1$ treatments. The soils provided with N_1P_1 , P_1 , P_1K_1 and $N_1P_1K_1$ recorded maximum amount of P content ranging from 16-13 kg per ha. Highest quantity of K (370.35 kg/ha) was found in the soil fertilized with K_1 treatment as compared to that of control (172.90 kg/ha).

In general, increase in Ca and Mg content of soil was observed in all the treatments compared to that of original status of soil. This is the result of application of lime at the time of planting.

Future line of work

1. Study of the effects of graded dose of NPK and their mode of application on maturity, yield and yield components.
2. Determination of optimum dose of NPK fertilizers.

3. Study of the effects of soil application of NPK vs split application in combination with soil + foliar application of NPK on growth, maturity, yield and yield components.

REFERENCES

CHAPTER VII

REFERENCES

- Abdul, K.K.B. and Mohamed Sayed, A.A., 1977, Fertilizing cardamom - its importance. Cardamom, 9(1):13-14.
- Abraham, P., 1965, The cardamom in India. ICAR Farm Bull., 37:6-8.
- Aduayi, E.A., 1972, The role of phosphorus on the growth and mineral nutrient composition of young Arabica coffee grown in sand culture. Kenya Coffee, 37(440):336-340.
- Ahenkorah, Y. and Akrotit, G.S., 1968, Amazon cacao shade x manurial experiment (K₂O₁) at the Cacao Research Institute of Ghana. Agron. J., 60:591-594.
- Alice Abraham and Koshy, M.M., 1978, The comparative efficiency of foliar and soil application of complex fertilizers on paddy. Agric. Res. J., Kerala, 16(2):249.
- Ananth, B.R., 1961, Preliminary note on foliar nutrition of coffee. Indian Coffee, 25:235-236.
- Ananth, B.R. and Iyengar, B.R.V., 1965, Foliar nutrition of Arabica coffee. Indian Coffee, 29:11-20.
- Anonymous, 1955, Indian Tea Association, Toeklai. Agric. Brar. Indian Tea Res. Dept. Toeklai.
- _____, 1956, Effect of placement of nitrogen and phosphorus on sugarcane. Ann. Rep. IISR. pp57-58.
- _____, 1966, Effect of foliar application and placement of urea on the yield and juice - quality of sugarcane. Ann. Rep. IISR. p.42.
- _____, 1967, Studies to determine the comparative efficacy of soil vs. foliar application of nutrients on coffee. 7th Ann. Tech. Rep 1973-74. pp.10-11.

Anonymous, 1977a, Cardamom culture. Pub. Cardamom Board, Cochin India. p.13.

_____, 1977b, Cardamom in Karnataka. U.A.S. Tech. Rep. Series No.4:8-9.

_____, 1978, Investigation on the nutritional requirement of Basrai banana. All India improv. Proj. Fruit Res. Workshop, Bangalore. p.78.

Bangoo, F.G., Attman and Karon, M.L., 1962, Effect of nitrogen, phosphorus and potassium on fruit yield in relation to nutrient contents of soil and leaf tissues in Honduras. Trop. Agri. Trin., 39:189-201.

* Bayua, D.N., 1960. Soil fertility and illumination response of the tea bushes. A.R. Toklai Exp. Stat P 64-8.

* Beridze, A.E., Dzugeli, A.I. and Kokasvil, T.G., 1969, The determination of potassium and phosphorus in leaves for different agricultural crops in the humid sub-tropics. Sub. Trop. Kul'tury. No. 5:160-173.

Cain, J.C., 1957, Absorption and metabolism of urea by leaves of coffee, cocoa and banana. Ann. Rev. Physiol., 67:279-286.

* Canukvadze, F.S., 1970, The effectiveness of humic fertilizer on young tea plants. Subtropiki Kul'tury, 4:158-162.

* Cesare Guerra, O., 1972, Fertilizer study in mature tea in Tingo Marua. Rev. Universidad Nat. Agraria Selva, 2:1-5

* Chaudhury, S.H., Hassan, K.A. and Karim, A., 1968, Formative effects of trace elements Zn on the growth of tea plants. Tea J. Pakistan, 6(1):5-10.

* Chiang, Y.H., 1960, Foliar application of urea and manganese to tea bushes. Soils Ferti, Taiwan, 7:79-84.

* Crocomo, O.J., 1959, Estudo sobre o metabolismo de ureia ¹⁴C aplicada as folhas de cafeeiro (Coffea arabica L. var. Bourbon). Tese piracicaba Brasil, p.83.

- Dale, 1971, Effect of different levels of nitrogen on the yield of made tea. Two and a bud, 17:21-45.
- Deponte, A.M. and others, 1965, Preliminary results of a factorial NPK fertilizer trial in a coffee plantation established in China. Proc. Siow. Agron. Liboa Chianya, p.18.
- *Daraselia, M.K., 1976, Soil cultivation as a factor affecting the yields. Trans. 9th Inst. Congr. Soil Sci., 3:347-355.
- Dey, S.K. and Sharma, B.C., 1970, Behaviour of T.V.18 and four other clones in Cachor and other Dooras. Two and a Bud, 17:53-55.
- *Denys, G., 1966, The effects of different shading intensities on the early growth of coffee. Proc. Carib. Reg. Amer. Soc. Hort. Sci., 10:21-45.
- Despande, R.S. and Kulkarni, D.S., 1973, Deficiency symptoms in cardamom (Elettaria cardamomum). Mys. J. Agric. Sci., 7(2):246-249.
- *Derez Zamora, A. and Reyes, E.H., 1965, Results obtained from unshaded cacao nurseries. Proc. Cariv. Reg. Amer. Soc. Hort. Sci., 3(2):159-167.
- *Faizullah, M., Hassan, K.A. and Ali, M.M., 1966, Effect of NPK on young tea. Tea J. Pakistan, 4(2):18-26.
- *Fernando, 1967, A reappraisal of practices in the cultivation of low country tea. Tea Q., 38:241-244.
- *Gamkrelidze, M.M., 1970, The effect of pruning on the variation in carbohydrate and free amino acid production in tea leaves. Sub-tropiki Kul'tury, 4:153-157.
- *Gaspar, A.M., 1966, Sudden death of coffee. Inst. Invest. Agron. Angola, p.21.

- *Godoy, C. Jr., 1958, Forcamento al mudas de cafe (Forcing coffee seedlings for transplanting). Riv. Agric. Praccicaba, 33:179-85.
- *Godoy, C. and Graner, E.A., 1967, Fertilizing of irrigated and non-irrigated coffee plots. Coffee Prod. Prot. Rio-de-Janairo, p.3.
- Gokhale, N.G., 1958, The rate of calcium loss resulting from ammonium sulphate treated tea soil. Nature, 191:426.
- *Guseinov, R.K., 1973, The effect of long term application on soil fertility and on tea metabolism and productivity. Product. Sevo. Moscow, U.S.S.R., Kolos, 4:305-354.
- *Guseinov, R.K. and Mirzojan, A.T., 1967, The effect of long term application of fertilizers on changes in chemical soil properties, yield and quality of tea leaf. Vestn. Sel-hoz. Nauki, 12(6):18-23.
- Hadfield, H., 1968, Progress report on a shade and manuring experiment. Two and a Bud, 15:49-52.
- *Ishigaki, K., 1971, Evaluation of ammonium and nitrate nitrogen as nitrogen sources for tea plant. Tea, 42:27-34.
- Jackson, M.L., 1958, Soil Chemical Analysis. Prentice Hall Pvt. Ltd., New Delhi.
- Jagirdar, S.A.P. and Ansari, A.K., 1966, Effect of NPK on growth and production of Cavendish banana (Musa cavendish). Proc. Agric. Symp. Atomic. Energy Centre, Dacca, pp.71-78.
- Jumbulingam, A.R. and Ramaswamy, N., 1975, Studies on the effect of potassium on Robusta banana. Potash Rev., 27:4-6.
- Kololgi, S.D., 1977, All India Seminar on Cardamom. Cardamom News May-June, p.3.
- Kimeu, B.S., 1970, The effects of NPK foliar sprays on total dry matter and NPK content of potted coffee seedlings. Kenya Coffee, 35:383-385.

- Kimeu, B.S., 1974, Response to soil applied NPK compared to fertilizers in coffee small holdings. Kenya Coffee, 32(461):222-228.
- Kohli, R.R., Chacko, E.K. and Randhawa, C.S., 1968, Effect of spraying and nutrition on growth and yield of Robusta banana. Ind. J. Agric. Sci., 46(8):382-386.
- Krishnamurthy, K., 1967, Observation on the relation of tillering to nitrogen levels in fingermillet (Eleusine coracana). Mys. J. Agri. Sci., 1:37-42.
- ✓ Krishnamurthy Rao, W., Iyengar, B.R.V. and Krishnappa, C.S., 1976, Foliar sprays of urea and superphosphate to Arabica coffee in south India. J. Coffee Res., 6(1):22-25.
- Kulkarni, D.S., Kulkarni, S.V., Suryanarayana Reddy, B.G. and Pattan Shetty, H.V., 1971, Nutrient uptake of cardamom (Elettaria cardamomum). Int. Nat. Symp. Soil-ferti. Eval. Proc., New Delhi (India), 1:293.
- Kuratti, 1965, Effect of different levels of N and P fertilization in paddy. M.Sc.(Agri) Thesis, College of Agriculture, Dharwad.
- Lahav, E., 1973, Phosphorus and potassium penetrability in the soil and their influence in a mature banana plantation. Trop. Agri., 50:297-301.
- _____, 1977, Effect of manure and fertilizer treatments on Williams Hybrid banana and its mineral content. Trop. Agri., 54:113-118.
- Lee, G.L., 1975, Irrigated upper Amazon cocoa in the lower Shire valley of Malawi. 1. NPK factorial trial. Trop. Agri., 52(1):65-69.
- *Lin, C.F., 1967, Plant testing leaf analysis as an aid in the NPK fertilization of tea bushes. J. Agric. Ass. China, 60:90-95.
- Maeharan, M. and Hakamara, K., 1974, The seasonal absorption of mineral nutrients in relation to growth of one year old tea plants. Study of tea plants. Study of Tea, 47:100-118.

- *Mahalkal, K. and Gupta, P.K., 1973, Effect of N alone and in combination with P and K on growth of Basrai banana (Musa cavendish). PKV Res. J., 1(2):188-190.
- *Majorova, G.N., 1969, The effect of nitrogen on productivity and on hastening the starting of cropping of young tea plantations. Sub-tropiki Kul'tury, 1:51-57.
- *Malavolta, E. and Coury, T., 1957, Note on spray application of urea of coffee bushes. Bol. Super. Surv. Cafe Sao Paula, 32:14-15.
- *Martin-Prevel, P., 1969, A systematic variants trials on the banana. Fruits d'centre Mer., 24:193-215.
- Montoya, L.A., Sylvain, P.G. and Umana, 1961, Effect of light intensity and nitrogen fertilization upon growth differentiation balance of coffee Arabica. Coffee, Turrialba, 3:97-100.
- *Murray, D.B., 1954, A shade and fertilizer experiment with cacao III. Rep. on Cacao Res., 1953, Trinidad, pp.30-37.
- Panje, R.R., Mathur, P.S. and Singh, B., 1967-68, Effect of placement and foliar sprays of urea on juice quality and yield of cane. Ann. Rep. IISR., pp.23-24.
- *Parra, H.J., 1972, Correlations between coffee and gross dry weights and soil analysis. Cenicafe, 22(1):13-92.
- Piper, C.S., 1950, Soil and Plant Analysis. University of Adelaide, Adelaide.
- Rahman, F. and Roy, R.N., 1970, Response to potash at Borbetta. Two and a Bud, 17:3-4.
- Raju, L. and Subramanian, T.R., 1969, Studies on leaf analysis in NPK nutrition of Arabica coffee. Turrialba, 19:49-56.
- Ramaswamy, N., 1976, Studies on the effects of different levels of phosphoric acid on the yield and quality Robusta banana. Ann. Agric. Res. Annu., 6:30.

- Ramaswamy, N. and Ranganathan, N., 1977, Studies on the effect of different levels of potassium on the growth and yield of caven-dish banana. Ann. Agric. Rep. Annu., 6:30.
- * Ramkhub, 1974, Studies on the relative efficiency of soil and foliar application of nitrogen on wheat var. Kalyansona. M.Sc.(Agri) Thesis, College of Agriculture, Solan.
- *Ramos, P.R., 1969, The effect of chemical fertilizers on the yield of Arabica coffee. Philip. J. Plant Ind., 1967, 32:165-175A.
- *Ranganathan, N., 1971, Phosphorus nutrition of tea. Proc. 17th Sci. Conf. UPASI, pp.31-44.
- Ranganathan, V. and Ganeshan, M., 1975, Frequency of potassium application. Tea Sci. Bull. UPASI, 32:72-77.
- Rao, W.K.M. and Iyengar, B.R.V., 1975, Leaf analysis - a A diagnostic tool in coffee. Indian Coffee, 39(6):175-178.
- Ratnavala, M.V.S., 1968, Value of soil and plant analysis. Cardamom News, 2(3):8-10.
- Sen, A.R., 1967, Response of mature tea to phosphate and potash in north-east India. Exp. Agric., 3:55-62
- Shanmugavelu, K.G. and Madhava Rao, V.N., 1977, Spices and Plantation Crops. I ed. Popular Book Depot, Madras, pp.143-167.
- Shawky, Z. Zidan and Riad, M., 1974, Comparative studies concerning foliar and soil nitrogen on banana plants. Egypt. J. Hort., 1(2):157-159.
- Srivastava, K.C., Bopaiah, M.G. and Ganapathy, M.M., 1968, Soil and plant analysis as a guide to fertilization in cardamom. Cardamom News., 2(3):4-5.
- *Stephens, D., 1967, A note on the correlation between coffee yields and soil analysis in Uganda. E. Afr. Agri. For. J., 32:456-458.

- Steiner, K.G., 1972, The effect of foliar fertilizers on the development of CBD and on the yield of coffee. Kenya Coffee, 36(434):160-161.
- Suarez Decastro, F., 1962, Influence of shade, Organic matter and planting distance on growth of coffee seedlings. Turrialba, 4:26-35.
- Subramanian, T.R. and others, 1969, Effect of a few source of nitrogen on soil characteristics, leaf nutrition status and yield of coffee. J. Ind. Soc. Soil Sci., 17(1):33-7.
- *Talybly, G.A., 1969, Nitrogen as the most important factor improving tea yields in the Lenkaran. Sub-tropiki Kul'tury, 4:143-152.
- *Thung T Jiang Pek, 1966, Decrease in the tea yield due to withholding fertilization in relation to shade. Menaropek, 35:49-53.
- United States Department of Agriculture, 1956, Soil Survey Manual.
- *Visser, T., 1961, Inter-planting in tea. II. Interaction of shade with fertilizer applications. Tea G., 32:113-128.
- Wilson, K.C., 1969, The mineral nutrition of tea. Potash Rev., 27(49):18.
- *Wargadipura, R. and Sukandis, K., 1973, Influence of several plucking rounds and NP fertilization on tea yields. Perkebunan., 41(4):155-159.
- * _____ and _____, 1974, The influence of shade and trees NP fertilization on the yield of tea. Monoraperkeb Unan, 42(1):5-9.
- *Wight, W., 1951, Summary of ten years research on the use of ammonia under shade... proc. 9th Ann. Conf. Ind. Tea Ass. Tocklai, pp.4-12
- _____, 1961, Shade, manuring and kind of tea. Two and a Bud, 8(4):13-15.

Wilson, K.C. and Choudhury, R., 1968, Fertilizers and tea quality.
Tea, 9(3):17-49.

_____ and _____, 1969, Fertilizers and tea quality.
Two and a Bud, 15:92-95.

*Zurbickij, Z.I. and Gamkrelidze, M.M., 1969, The synergistic effect
of nutritional elements on the growth and formation of tea
flushes. Agrohimiija, 12:87-92.

*Original not seen

APPENDICES

APPENDIX I

Weather data of Regional Research Station, Mudigere

	1977	Rainfall (cm)		Temperature	
		Average for 15 years	Effect (cm)	Maximum (°C)	Minimum (°C)
January	-	1.03	-1.03	27.53	14.37
February	3.40	3.05	+0.35	29.37	16.12
March	48.40	8.65	+39.75	30.70	18.35
April	37.00	72.12	-38.22	30.68	18.20
May	90.20	123.24	-35.04	28.58	18.00
June	559.40	416.11	+143.29	22.50	17.66
July	657.20	808.98	-151.78	22.62	18.56
August	652.80	456.77	+196.03	22.67	18.12
September	265.00	233.78	+21.22	24.18	17.70
October	166.20	163.27	2.93	26.23	17.66
November	58.40	56.15	2.25	26.63	16.43
December	14.20	13.48	0.72	27.17	12.88
Total	2552.20	2359.73	+192.47		

Th. 821

