STUDIES ON THE RESPONSE OF KOORKA
(*Coleus parviflorus* Benth)
TO GRADED DOSES OF FERTILIZER APPLICATION

BY

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THESIS

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Shri. V. Thyagarajan, under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

INTRODUCTION

Coleus parviflorus, also mentioned as *Coleus tuberosus* is known in Kerala as *Koorka* or *Cheevakizhangu*. In other parts of the world like Malaya, Java, etc., it is called, "ubi kemili", "kentang kechil" (Klichi) "Kembili" and kumbili java" (Sheik Daud 1947). It is believed to be a native of Africa, probably Abyssinia. Possibly the Arabs brought it into India through the Malabar coast. It is now widely cultivated in Kerala and contiguous areas of Mysore and Madras. Outside India it is cultivated in Ceylon, Malaya, Java, Indochina, and parts of Tropical Africa.

The plant belongs to the family Labiatae and is grown for the small edible tubers, which are used as a substitute for potato (Raghavachari, 1918). The stems and leaves are thick, juicy and faintly fragrant. The flowers are small, pale violet in colour and are produced on an elongated terminal raceme. The dark brown tubers are borne in clusters at the base of the stems.

The tuber is a very common vegetable in all house holds, being prepared in as many ways as we do with colocasia or potato (Raghavachari, loc.cit). It is also very popular among the local Malays and Chinese (Sheik Daud, loc.cit). Its food value compares favourably with most of the other tuber crops (Appendix IX).

Appreciation is lacking in India about the important part that some of the miscellaneous tuber crops can play in human as well as animal dietary. While efforts are made in increasing the production of cereals due to the acute food shortage, it is of no less importance to develop ways and means for producing more of tuber crops which can certainly supplement our predominant cereal food. The per capita availability of starchy roots in India is only 40 gm. per day as against 229 gm. in other under developed countries and 316 gm. in the developed countries; the world average being 227 gm. (Rao, 1966). Our minimum requirement of starchy roots for a minimum standard of diet is estimated to be 85 gm. per head per day as estimated by Sukhatme (Rao, 1966). To reach this level we must produce double the quantity produced at present. Extensive cultivation is ruled out by shortage of land. The other alternatives are improved strains and intensive cultivation. Development of improved strains through plant breeding techniques, though time consuming, is certainly to be attempted. The immediate solution at hand for doubling the production is, no doubt, intensive cultivation by proper manuring and adoption of other improved agronomic practices.

Comparatively research work on the miscellaneous tuber crops in Kerala is meagre, and as for Koorka, only little published data regarding the manurial or agronomic aspect are available. Ordinarily manuring with ashes is done (Raghavachari; loc.cit). Even in Malaya no manure is supplied to this tuber crop and the local belief there on this point is that any manure applied to normally fertile soils tends to produce deformed tubers and seldom, if ever, increases yields (Sheik Daud, loc.cit). The farmers in Kerala use only organic manures such as farm yard manure and ashes for manuring this tuber. With the advancement of fertilizer use and growing scarcity of farm yard manure and other organics, some of the farmers have started using artificial fertilizers for manuring Koorka crop also. It has been noticed by them that higher yields are obtained from Koorka by the application of artificial fertilizers.

Though there are a number of problems that require investigation with regard to this crop (Sheik Daud, loc.cit), it will be quite advantageous to formulate a manurial schedule using artificial fertilizers.

Preliminary studies on the agronomic and breeding aspects of this crop have been initiated by the Central Tuber Crops Research Institute, Trivandrum.

Eventhough practically no information on the manurial requirements of this crop is available, there are many works to show the beneficial effects of the major plant nutrients applied through fertilizers on other tuber crops like potato, tapioca, sweet potato, colocasia etc.

The present investigation was therefore undertaken with the object of studying the response of Koorka (Coleus parviflorus) to graded doses of nitrogen, phosphorus and potash, under the agroclimatic conditions of Vellayani.

APPENDIX-XI

Meteorological data recorded during the crop period (30th June to 11th December 1968) at Agricultural College Farm, Vellayani.

Number of weeks.	Period	Rain-fall in mm. (Total)	Number of Rainy Days.	Temperature °C (Weekly average)		Relative Humidity % (Weekly average)
				Maximum	Minimum	
1	June 25 - July 1	598.0	7	28.2	22.3	91.3
2	July 2 - July 8	451.00	5	28.2	22.3	92.3
3	July 9 - July 15	251.0	4	29.2	22.6	87.7
4	July 16 - July 22	616.0	7	27.4	22.0	93.3
5	July 23 - July 29	128.0	4	28.0	23.1	89.1
6	July 30 - Aug. 5	20-0	1	29.1	23.4	90.3
7	Aug. 6 - Aug. 12	150.0	4	29.1	23.2	92.0
8	Aug. 13 - Aug. 19	196.0	6	29.2	22.4	92.0
9	Aug. 20 - Aug. 26	Nil	Nil	29.3	23.1	88.0
10	Aug. 27 - Sept. 2	Nil	Nil	29.6	23.2	74.0
11	Sept. 3 - Sept. 9	166.9	4	29.7	23.2	88.0
12	Sept.10 - Sept.16	180.0	5	28.5	23.1	89.0
13	Sept.17 - Sept.23	Nil	Nil	29.1	23.7	89.0
14	Sept.24 - Sept.30	345.0	4	29.0	23.7	92.0
15	Oct. 1 - Oct. 7	33.8	4	29.1	23.6	89.0
16	Oct. 8 - Oct. 14	Nil	Nil	30.1	23.2	87.0
17	Oct. 15 - Oct. 21	256.0	3	30.3	23.7	91.0
18	Oct. 22 - Oct. 28	75.0	2	30.7	24.1	86.0
19	Oct. 29 - Nov. 4	377.0	5	29.5	23.4	92.0
20	Nov. 5 - Nov. 11	173.0	3	29.3	22.8	90.0
21	Nov. 12 - Nov. 18	29.0	1	30.5	22.8	88.0
22	Nov. 19 - Nov. 25	117.2	3	30.7	23.0	92.0
23	Nov. 26 - Dec. 2	Nil	Nil	31.2	22.9	91.0
24	Dec. 3 - Dec. 9	79.0	3	31.0	23.0	94.0
25	Dec. 10 - Dec. 16	Nil	Nil	30.4	21.3	90.3

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Though Koorka (Coleus parviflorus) is being grown as a country potato in many parts of the world, very little work seems to have been done on this crop and no reported data are available as to its manurial requirements. However, the significance of fertilizer application in increasing the yield of tuber crops has been well brought out by experiments conducted in India and abroad on many tuber crops like potato, sweet potato, yams, tapioca, sugarbeet etc. the review of which is given below:-

Effect of Nitrogen:

Research workers agree that plant growth probably is limited more often by deficiency of nitrogen than of any other nutrient. Regarding its influence on the pattern of growth, Black (1957) observed that within the range of practical interest, an increase in the supply of nitrogen caused the growth of the above - ground portion of plants to increase relatively more than the growth of the roots. However, crops grown for their carbohydrates, such as the root crops and the cereals, benefited from nitrogen manuring through the increased leaf area brought about by the nitrogen. (Russel, 1956).

Potato:-

Beneficial influence of nitrogen in increasing the yield of potato was reported widely (Singh, 1952; Ellison, 1954; Pehl, et al. 1955; Rauter, 1955; Pushkarnath, et al. 1960; Loginow et al. 1964; Chapman, 1965; Hanley et al. 1965; Andersen, 1966; Benepal, 1967).

Singh (1952) obtained increased yield of potato due to the application of nitrogenous fertilizers and he observed that the nitrogenous fertilizers acted best with early planting. Beneficial effect due to application of nitrogenous fertilizers to potato crop was also obtained by Ellison (1954) for side dressing with 30 to 60 lb. nitrogen per acre during rainy season. A total yield of 400 quintals per hectare of early potatoes could be obtained by Pehl, et al. (1955) for heavy application of nitrogen along with irrigation. Rauter (1955) observed that with the application of Ammonium sulphate at the rate of 4-5 quintals per hectare to potato, an increased starch yield of 15-16 quintals per hectare was obtained which worked out to 16-18 Kg. of starch for each Kg. of nitrogen applied. Rauter's observation is supported by the results reported by Hanley, et al. (1965) who also obtained increased yield of potato due to the application of nitrogen supplied as ammonium sulphate. The experiments of Pushkarnath, et al. (1960) at Patna showed that nitrogen gave highly significant yield responses, particularly with the variety of potato 'Kufri Red'. Experiments on the sandy loam soils in Punjab (Benepal, 1967), besides recording significant yield response of potato to nitrogen application has also revealed that the nitrogen had the greatest effect on plant and tuber development.

Odland and Sheehan (1956) working on potato crop obtained a linear response to nitrogen applicatio upto 130 lb. per acre. In the acid loamy soils of Punjab the greatest response to potato was for 100 lb. nitrogen per acre (Kanwar, 1962). According to Pushkarnath and Sardana (1964) 140-150 lb. nitrogen per acre was the optimum economic dose for maximum yield of potatoes. They found further that a second degree parabola was a satisfactory fit to the underlying relationship between the amount of nitrogen applied and the corresponding yield with regard to the economics of nitrogen fertilization in potatoes. Investigation on potatoes in alluvial light loam soils of Rajasthan with low nitrogen, Jaisinghani, et.al. (1964) found that application of 45 lb. per acre and 90 lb. per acre of nitrogen increased the yield by 31 and 48.1 maunds respectively. After trying three levels of nitrogen viz. 70 Kg, 140 Kg. and 210 Kg. per hectare, Valentin (1964) reported significant increase in the yield of potatoes between the levels tried.

A depression in yield of potato was noticed in Nilgiris by Raju, et al. (1954) due to a reduction in the application of nitrogen below 80 lb. per acre. Decrease in yield of potato was reported for higher rates of nitrogen also. (Henderson, 1965; Tabata and Takase, 1968). In his eleven experiments in Scotland on soils of medium texture, moderately to highly fertile, Henderson (1965) observed that high nitrogen rate reduced seed and total yield of potato. When the application of nitrogen exceeded 153 Kg. per hectare, Tabata and Takase (1968) found that the increasing nitrogen decreased the number of tubers in the case of potatoes.

Sweet potato:

Beneficial influence of nitrogen on sweet potato crop was reported by many workers (Johnson and

Ware 1948, Landrau and Samuels 1951, Kunjan 1957, Izava and Okamoto 1959, and anonymous 1962).

Johnson, et al. (1948) recorded significant increase in the yield of sweet potato upto 120 lb. of nitrogen per acre.

Landrau and Samuels (1951) from their investigations on sweet potato found that 82 lb. of nitrogen per acre was the optimum dose for raising the yield considerably. They further observed that increasing the level of nitrogen to 165 lbs. or above led to low yield of poor quality tubers.

The experiments of Kunjan (1957) and the manurial trials conducted at Coimbatore (Anonymous, 1962) showed that 50 lb. of nitrogen per acre was the optimum dose for sweet potato. However Kunjan could not get any significant increase in tuber yield by further additions of nitrogen.

Izava and Okamoto (1959) while working on the role of applied nitrogen on sweet potato, stressed the importance of nitrogen on the formation and translocation of sugars. The rate of phytosynthesis in sweet potato was reported to be increased with increase in leaf nitrogen (Fujise and Tsuno, 1962).

No response to application of nitrogen to sweet potato was reported by Breda Filho, et al. (1966) in Sao Paulo. Their experiments on "cerrado" soils showed that response to nitrogen was positive on one site only where no fertilizers had been applied before.

Other tuber crops:

The effect of nitrogen on other tuber crops was studied by various workers. (Varma and Bajpai 1965, Baldwin, et al. 1966, and Mathur, et al. 1966).

Increased root yield of carrots was reported by Varma and Bajpai (1965) due to application of nitrogen at the rate of 22.5 Kg. per hectare. The increase recorded was 20.1 and 40.75 quintals per hectare in the first and second years of trial.

Maximum yield of sugarbeet was obtained by Baldwin, et al. (1966) when nitrogen was applied as basal dressing at the rate of 90-120 lb. per acre.

Mathur, et al. (1966) reported that the yield of colocasia increased with increasing levels of nitrogen upto 224 Kg. per hectare. But they recommended that the economic optimum dose would be 200 Kg. nitrogen per hectare as ammonium sulphate.

<u>Effect of phosphorus:</u>

The early workers were so impressed with the great increase in the yield of roots obtained by phosphatic fertilizers, that they considered the phosphate had a specific action in encouraging root development.

Root crops suffering from severe phosphate shortage were found very stunted (Russel 1956) and it was rported that the effect of added phosphate was spectacular. However the earlier reports of Russel revealed that excess of phosphate over the amount required by the crop sometimes depressed crop yield. This usually occured on light soils in dry years and it was attributed to the hastening of the maturation process and consequent reduction of vegetative growth.

Beneficial influence of phosphorus on root crops was also reported by Black (1957). He found that phosphorus fertilization usually increased the yield of roots more than that of the above ground parts. This behaviour was explained to be due to the fact that maximum leaf weight was attained at a later date by phosphorus deficient plants than by the phosphorus fertilized plants, with the result that carbohydrate translocation to the storage tissue proceeded for a longer period of time in the phosphate - fertilized plants than in the phosphorus - deficient plants.

The effect of phosphorus on specific root crops was reported by many workers in India and abroad. The results of the previous experiments show that the response obtained for phosphorus application was dependent mainly on the P status of the soil.

Potato:

Increased yield of potato due to the application of phosphatic fertilizers was reported by Zacek (1965), Henderson (1965), Nandpuri (1966), Andersen (1966), and Benepal (1967).

Henderson (1965) in Scotland reported that on soils of medium texture and moderately to highly fertile, application of higher rates of phosphorus increased the yield of potato significantly. The results obtained in Ludhiana, as reported by Nandpuri (1966) showed that when phosphorus and nitrogen were applied to potato, though both increased potato yields significantly, only phosphorus significantly increased total carbohydrates. In the experiments conducted by Benepal (1967) on the sandy loam soils in Punjab, significant increase in yield of potato could be obtained due to application of P_2O_5 upto 75 lb. per acre.

Significant reduction in yield of potato was reported by Raju, et al. (1954) in Nilgiris, when the rate of application of phosphorus was below 200 lb. per acre. On the contrary, application of excess phosphorus was found to delay emergence of Russet Burbank potatoes grown in South East Idaho (Sommerfeldt, 1965). For optimum growth and tuber formation in potato, Hougland (1960) observed that abundant available phosphorus was required during the early phase of development. Heavy application of phosphorus was supported by Tabata and Takase (1968) due to the reason that it accelerated early growth and brought about early bulking of tubers in the case of potatoes.

However, no response in the yield of potato crop to the application of phosphorus could be obtained by Jaisinghani, et al. (1964) and Loginow, et al. (1964).

Sweet Potato:

In the case of sweet potato, significant increase in yield of tubers was reported by Morgan (1939) on the addition of phosphorus as superphosphate. Rao and Rao (1954) could obtain only an increase in size of tubers. The results of the experiments reported by Breda Filho, *et al.* (1966) showed that sweet potato responded to phosphorus only on sites where phosphorus had never been applied. It was further reported by them that phosphorus at 60 and 120 Kg. per hectare increased yields by 33 and 51% respectively in the case of sweet potato.

Landrau and Samuels (1951), and Purewal and Dargon (1959) could not get any response to phosphates on vine length, weight of vines, number of shoots and weight of tubers in sweet potato.

Other tuber crops:

Irving (1956) in Eastern Nigeria, Hodnet (1958) in Trinidad, Takegami (1962), Varma and Bajpai (1965) could not also obtain any response to the application of phosphorus on yarm, colocasia, sugarbeet, and carrots respectively.

Effect of potash:

The effect of potassium on root development received considerable attention because of the pronounced effect of potassium on root crops. Reviewing the analytical data of Wilfarth and Wimmer, Black (1957) observed that fully developed storage roots or tubers contained a substantial portion of the total potassium in the plant and a good crop of potato tubers contained about twice as much potassium as the tops, and that during development some of this potassium was transloca-ted from the tops. He therefore concluded that the tops initially must contain more potassium than was needed for their development to avoid the limitation of photo-synthetic activity that otherwise would ensue upon trans-location of potassium to the developing tubers or storage roots.

Hoffer and Carr (1923) and Hoffer and Trost (1923) found that iron and aluminium compounds accu-mulate in nodes of corn plants deficient in potassium. According to Hoffer and Carr (1923) large numbers of the conducting vessels in the affected areas were clogged, which hindered translocation.

Recent work by Tsuno and Fujise (1965), adduced evidence that potassium participated in protein meta-bolism, or in the hydration of tuber tissue or both pro-cesses. They therefore suggested that it was highly possible that the promotion of tuber growth by potassium might be associated with the promotion of photosynthetic activity through accelerated translocation of photosynthates from leaves to tubers. This finding adequately explained the earlier report of Russel (1956) which stressed that supply of potassium in the leaf was essential for the photosynthetic process to go on efficiently.

Significant increases in yield of potato tubers due to the application of potash were reported by Hanley, et al. (1965), Henderson (1965), Awan (1965), Lin (1966) and Andersen (1966). At the rate of 66 Kg. per hectare K_2O at planting time, Awan (1965) obtained an increased yield of potato tubers by 17.5 tonnes as against 5.65 tonnes in control. Though Andersen (1966) also got a generally increased tuber yield in potato, he noticed that higher rates of potassium sometimes gave a negative response.

However Landrau and Samuels (1951) reported that no consistent yield increase followed potash application to potato crop. The results of experiments reported by Loginow, et al. (1964) also recorded no significant effect on the yield of potato due to potash application.

Eventhough no response due to potash fertilisation to potato crop at the rate of even 75 lb/acre was noticed by Benepal (1967) he pointed out that potash applications were probably desirable to avoid soil depletion.

Sweet potato:

Duncon, *et al.* (1958) obtained increased yield of tubers with increasing doses of potash fertilisation. But no significant effect of potassium on sweet potato could be noticed by Breda Filho, *et al.* (1966) in Sao Paulo.

Other tuber crops:

There was general over all response to yams throughout Eastern Nigeria for application of potash at lower levels (Irving, 1956).

Colocasia also gave significantly higher yields for application of potash at 50 lb. per acre (Purewal and Dargon, 1957).

Chadha (1958) reported that the average response to potash in the yield of tapioca was 3 to 25 per cent for 80 lb. potash per acre, and 23 to 75 per cent for 160 lb. potash per acre.

Response of tuber crops to combined application of Nitrogen, phosphorus and potash:

The beneficial effect of the combined application of nitrogen, phosphorus and potash on tuber crops was well substantiated by Research workers both in India and abroad. However there were instances wherein lack of response to P and K was recorded by some authors when the crop depended mainly on the soil reserves of these nutrients for its growth and production.

Kanwar (1962) from his experiments in acid soils of Palampur in Punjab noticed maximum response from potato crop for application of 100 lb. nitrogen, 100 lb. phosphoric acid and 200 lb. potash per acre. Romagnoli, et al. (1964) in S. Italy recommended a fertiliser mixture 20:10:10 at the rate of 500 Kg. per hectare before planting for optimum yields of early potatoes.

In a two year experiment on potato, Popovic, et al. (1964) noticed greater yields with NPK + dung than with NPK alone in the first year, but in the second year the reverse was true. They also found that higher rates of application were more effective than applications containing just sufficient nutrients.

Maximum yield of potato was obtained by Pleshkov & Tavrovskaya (1965) from the field manured with 60:60:90 NPK.

The importance of a complete fertilizer was stressed by Awan (1965). The results of his two year experiments showed that the average yield of potatoes in Honduras of 2 t/hectare could be increased to 32 t /hectare by using a complete fertilizer.

Results of research work for 20 years on potato, reported by Mozhaeva (1966) revealed that application of both organic and mineral fertilizer gave higher crop yields than did organic manures alone. Different varieties of potato were found, to respond differently to varying levels of NPK (Ziegler, 1967). He also observed that the best levels of fertilizer for maximum yield of potato c v Gerlinde were 60 Kg. N, 60 Kg. P_2O_5 and 120 Kg. K_2O per hectare whereas with c v schwalbe double these levels was best.

It is particularly interesting to note that Chamberland and Scott (1968) found potatoes to derive much of their P and K requirements from soil reserves, especially those resulting from use of complete fertilizers. However they recommended application of P and K even though such requirements were not clearly justified by soil analysis.

When the soil status of any one of these nutrient elements was already high, it was found that application of fertilizer mixtures containing the other two nutrients contributed to significant increase in yield of tubers. (Lucas, 1954 and Svensson, 1964).

At Ludhiana in Punjab, the highest yield of colocasia was obtained by Purewal and Dargon (1957) for application of 100 lb. nitrogen, 50 lb. P_2O_5 and 50 lb. K_2O per acre.

Greig (1967) in Kansas reported that NPK at 25:50:50 lb. per acre gave the highest yield of sweet potato.

<u>Influence of Nitrogen, Phosphorus and Potash on certain yield attributes of tuber crops and quality of tubers:</u>

(1) <u>Leaf area:</u>

The rate of leaf production by beet, was found by Morton and Watson (1948) to be increased by about 20% due to high supplies of nitrogen. They also noticed that the total number of leaf cells were increased to double the number produced in the low nitrogen treatment. This earlier finding was well in conformity with the subsequent findings by Russel (1956) and Njoku (1957). According to Russel (1956), the ammonium ions and some of the carbohydrates synthesised in the leaves were converted into amino acids mainly in the green leaf itself.

Hence as the level of nitrogen supply increased, compared with other nutrients, the extra protein produced allowed the plant leaves to grow larger and hence to have a larger surface available for photosynthesis and in fact over a considerable range of nitrogen supply for many crops, the amount of leaf area available for photosynthesis was roughly proportional to the amount of nitrogen supplied. Njoku (1957) observed that high, as compared with low nitrogen supply, increased both the mean size and the total number of leaf epidermal cells in Ipomoea caerulea. In older leaves which would have been formed when nitrogen supplies were less limiting on growth, total cell numbers were about 50% greater and the size was about 30% greater with high than with low nitrogen. The differences together, he found, accounted for double the leaf area.

The importance and essentiality of good foliage development for increased potato yields were recognised by Tabata and Takase (1968) and they noticed that foliage growth increased with increasing doses of nitrogen upto 230 Kg. per hectare; and irrespective of nitrogen supply with increasing phosphorus upto 700 Kg. per hectare.

(2) Dry matter content:

Increase in the dry matter content in tubers of potato due to application of nitrogen was reported by Hanley, et al. (1965). But, Sheard and Johnson (1958), Andersen (1966) and Johansson (1967) found that application of nitrogen reduced the dry matter yield in potato tubers.

Phosphorus also was found to increase the dry matter percentage in potato tubers by Sheard and Johnson (1958) Andersen (1966) and Johansson (1967).

Terman (1953) reported that the dry matter content of potato tubers, grown without potash in the fertilizer increased upto levels of 200-300 lb. per acre of exchangeable potash in the soil and decreased at higher levels. The dry matter content of tubers grown with 180 lb. potash as potassium chloride in the fertiliser decreased in all years with increase in exchangeable potash per acre. The yield of dry matter per acre of tubers grown with fertilizers containing potash increased only slighty above a level of 200-400 lb. exchangeable potash in the soil. Increase in dry matter yield of tubers in potato, due to addition of potash was also reported by Harrap (1960), Henderson (1965) and Andersen (1966). However, a decrease in the dry matter content of potato tubers was observed by Sheard and Johnson (1958), Hanley, *et al.* (1965) and Johansson (1967).

(3) Starch content:

Application of nitrogen was found to increase the starch content of tubers in Tapioca and Potato by Rauter (1955) and Loginow, *et al.* (1964) respectively.

Experiments conducted by Zacek (1965) showed that application of phosphatic fertilizers improved the starch content of industrial potato. Nandpuri (1966) also observed that the total carbohydrates in potato tubers were significantly increased due to application of phosphatic fertilizers.

Response of tuber crops to NPK under the agroclimatic conditions of Vellayani:

1. Sweet potato:

Thomas (1965) from his experiments at Vellayani on four varieties of sweet potato concluded that higher level of nitrogen (80 lb. nitrogen per acre) significantly increased the root numbers in combination with 80 lb. potash per acre. The weight of tubers was maximum in plants receiving 80 lb. nitrogen and 160 lb. potash per acre.

The best fertilizer combination for sweet potato was found to be 80 lb. nitrogen, 80 lb. potash per acre over a basal dressing of 50 lb. P_2O_5.

2. <u>Tapioca</u>:

Gopalakrishna Pillai (1967) from his experiments on Tapioca at Vellayani found significant response in yield due to the application of incremental doses of Nitrogen, Phosphorus, potash and calcium. For optimum yield of tapioca application of 150 Kg. nitrogen, 130 Kg. phosphorus, 250 Kg. potash and 1100 Kg. calcium per hectare was found necessary. The economic dose of individual nutrients for tapioca was also found to be as 130 Kg. nitrogen, 105 Kg. phosphorus and 235 Kg. potash applied in conjunction with 900 Kg. of calcium per hectare.

3. <u>Colocasia</u>:

Chidananda Pillai (1967) from his studies on colocasia at Vellayani found that application of nitrogen, phosphorus and potash and their combination significantly increased the yield of corms. There was a linear response in yield due to application of 40 and 80 Kg. nitrogen, 25 and 50 Kg. phosphorus and 60 and 120 Kg. potash per hectare.

MATERIAL AND METHODS

MATERIAL AND METHODS

I. Experimental site:

The investigation was carried out at the Central Farm attached to the Agricultural College and Research Institute, Vellayani. The soil was red loam with the following analytical values.

Total nitrogen	...	0.058 %
Total phosphoric acid	...	0.049 %
Total potash	...	0.069 %
Available phosphoric acid	...	0.004 %
Available potash	...	0.0016%
CaO	...	0.159 %
pH	...	5.8

The procedure followed for the chemical analysis of soil was that outlined by the A.O.A.C. (1955).

II. Season:

The experiment was conducted from June 1968 to December 1968. The meteorological observations recorded during this period are given in APPENDIX-XI.

III. Planting material:

Healthy and uniform seed tubers of the commonly grown *Koorka* in Kerala were obtained and sown in nursery. Uniform cuttings with three internodes taken from the seedlings raised in the nursery were used for planting the experimental plot.

IV. Manures and Fertilizers:

A uniform dose of well rotted cattle manure, at the rate of 5000 Kg. per hectare was applied uniformly in all the plots. Lime was also applied uniformly in all plots at the rate of 200 Kg. per hectare after determining the lime requirement of the soil.

Nitrogen, phosphoric acid and potash as per treatments were applied in the form of Ammonium sulphate, Superphosphate and Muriate of potash respectively. The chemical analysis of the manures and fertilizers used are given below.

(a) Cattle manure:

0.51% N

0.29% P_2O_5

0.47% K_2O

(b) Lime:

54.3% CaO

(c) Fertilisers:

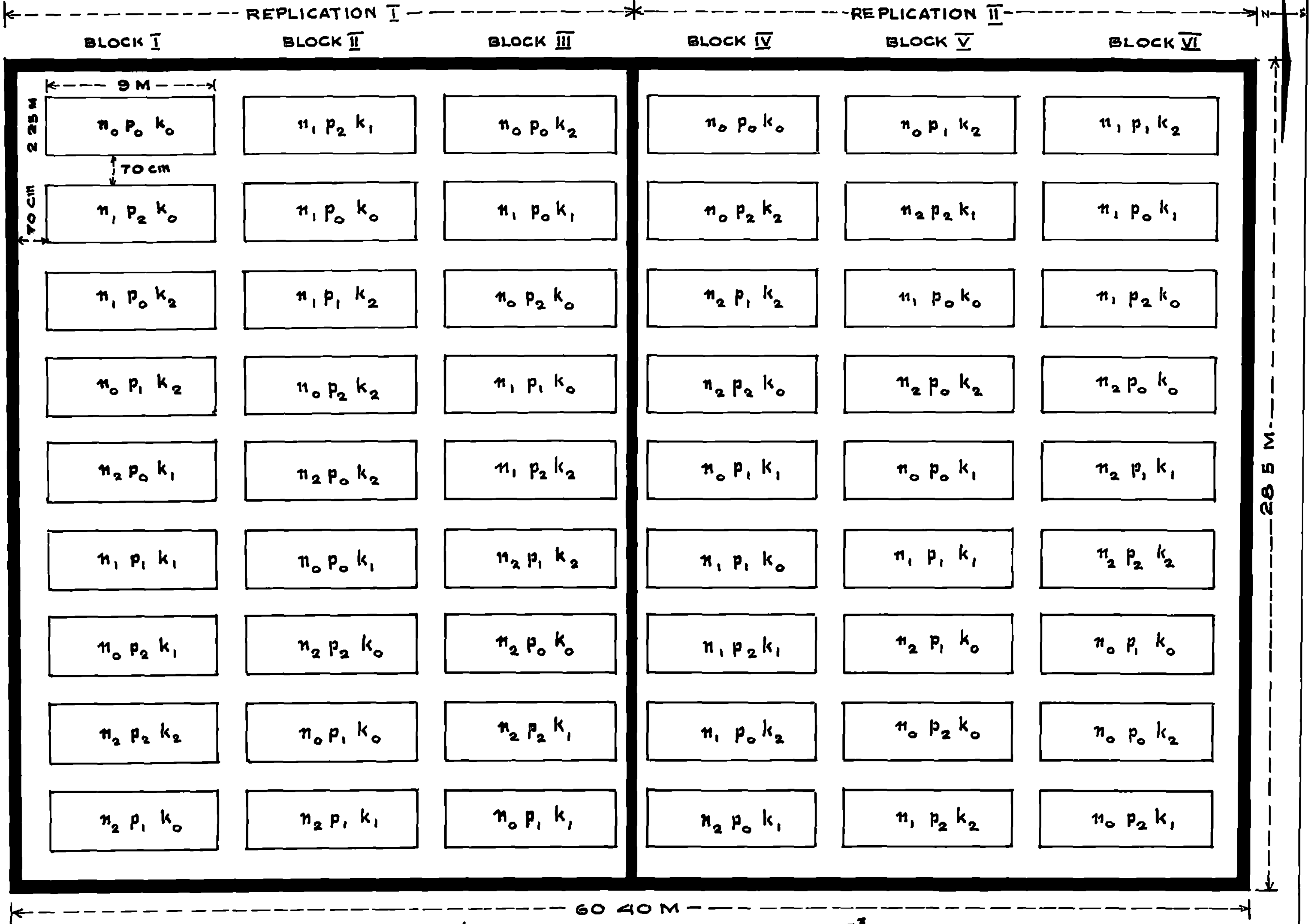
Ammonium sulphate	...	20.6% N
Superphosphate	...	16.1% P_2O_5
Muriate of potash	...	59.1% K_2O

V. Lay out:

The experiment was laid out as a 3^3 factorial with two replications. The higher order interactions NPK and NP^2K were partially confounded in replications I and II respectively. The procedure followed for allocation of the various treatments to different plots was in accordance with Yates (1937). The plan of the lay out is given in Fig.I. The details of the lay out are furnished below.

Total experimental area	...	1694.22 sq.m.
Plot size	...	9 m x 2.25 m.
Plot area	...	20.25 sq.m.
Number of plots	...	54
Number of Blocks	...	6
Replications	...	2
Spacing between plants	...	25 cm.
Spacing between rows.	...	30 cm.

LAYOUT PLAN



CROP KOORKA

(*Coleus parviflorus*)

LEVELS OF NUTRIENTS / HECT

N_0	00	P_0	00	K_0 -	00
N_1	30 kg	P_1	30 kg	K_1 -	60 kg
N_2	60 kg	P_2	60 kg	K_2 -	120 kg

SPACING

BETWEEN PLANTS — 25 Cm
BETWEEN ROWS — 30 Cm
PLOT SIZE — 9 M x 2 25 M
PLOT AREA — 20 25 Sq M = 0 002 HECTARE

3^3 CONFOUNDED FACTORIAL EXPERIMENT
REPLICATION 2

CONFOUNDING — NPK IN REP I
NP^2K IN REP II

FIG I

VI. Treatments:

There were 27 treatments in the trial comprising of all the possible combinations of 3 levels each of nitrogen, phosphorus and potash.

Levels of fertilizers:

Nitrogen:	(1)	N_0	=	0 Kg/hectare
	(2)	N_1	=	30 Kg/hectare
	(3)	N_2	=	60 Kg/hectare
Phosphoric acid:				
	(1)	P_0	=	0 Kg/hectare.
	(2)	P_1	=	30 Kg/hectare.
	(3)	P_2	=	60 Kg/hectare.
Potash:				
	(1)	K_0	=	0 Kg/hectare.
	(2)	K_1	=	60 Kg/hectare.
	(3)	K_2	=	120 Kg/hectare.

VII. Field culture:

(a) Nursery:

Seed tubers were planted in nursery two months before planting. Small shallow pits 15 cm. deep and 45 cm. diameter were dug 60 cm. apart and filled with soil mixed with farm yard manure and ash enough to make each pit slightly higher above ground level. Five tubers were planted in each pit 4 in four corners and one in the centre. Germination was completed in ten days.

(b) Main field:

(i) Preparatory cultivation:

The experimental site was ploughed twice with a tractor. Raised beds of size 9 m. x 2.25 m. were laid out in six Blocks, each raised bed forming a plot, and each block comprising 9 such beds or plots. These beds were separated by drainage channels of 70 cm breadth and the entire experimental area was separated from the neighbouring field by bunds of 40 cm. breadth.

(ii) Manures and manuring:

Cattle manure @ 5000 Kg/ha. and lime @ 200 Kg/ha. were applied uniformly in all the plots a week before planting and were incorporated into the soil by light digging.

Nitrogen, phosphoric acid and potash as per various treatments were applied as Ammonium sulphate, Superphosphate and Muriate of potash respectively in a single dose as basal dressing a day before planting and were incorporated into the surface layer of the soil by light digging.

(iii) Planting:

Uniform and healthy cuttings of vine each with three internodes were taken from the seedlings (two months old) in nursery and were used for planting in the experimental plots. The planting was done on 30th June 1968 in drizzling rain. The cuttings were planted on the beds in line with a spacing of 25 cm. x 30 cm. and with two nodes going under the surface of soil leaving top node above ground. Gap filling was done wherever necessary.

(iv) Intercultivation, weeding and earthing up:

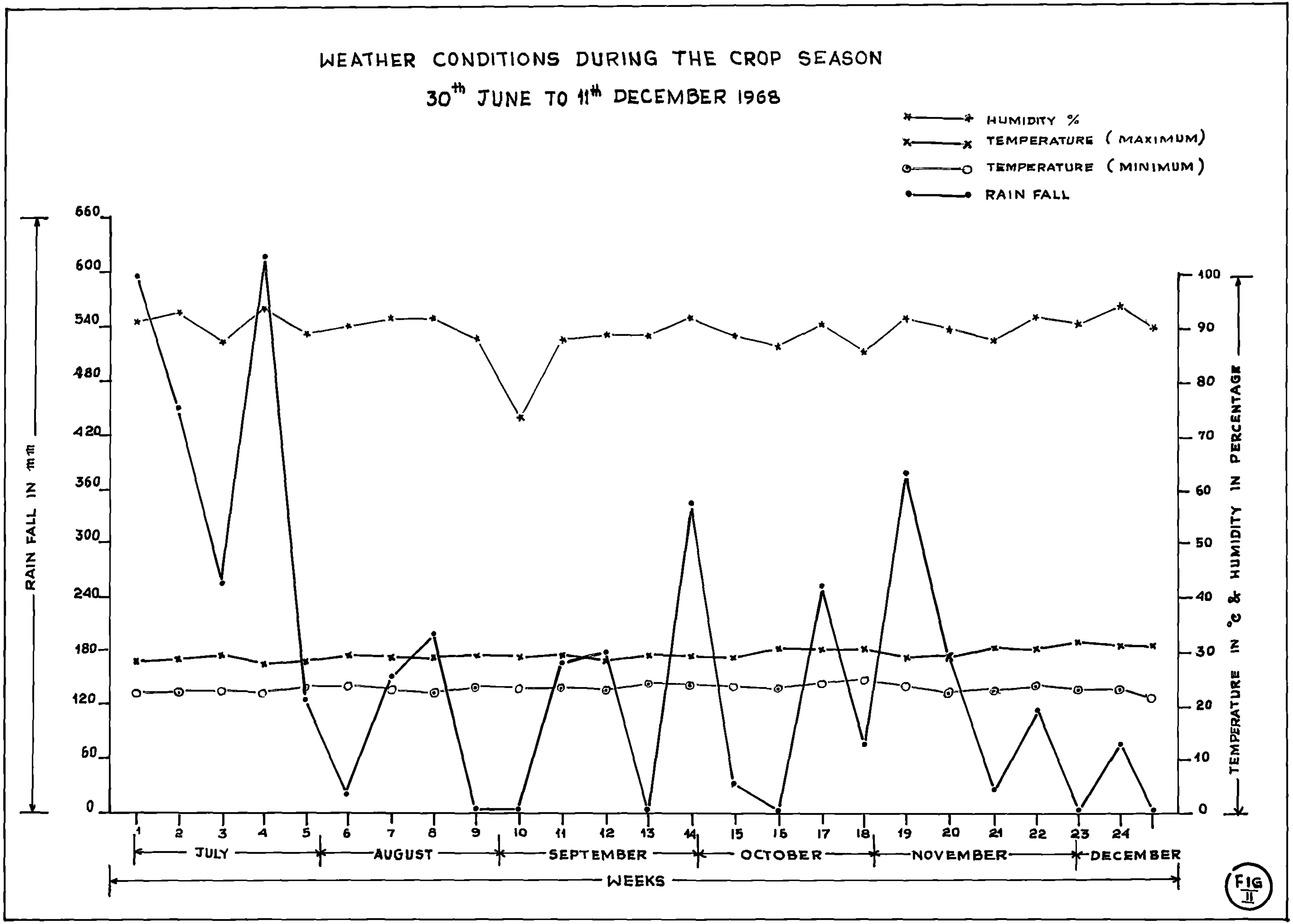
The first intercultivation and weeding was done on 12--7--1968, followed by two more weedings on 30--7--1968 and 25--8--1968 respectively. One earthing up was given on 18--9--1968.

(v) Plant protection:

There was no incidence of attack of any pest or disease.

(vi) General conditions of the crop:

The crop was grown purely under rainfed conditions and the general stand throughout the growth period was quite satisfactory.



WEATHER CONDITIONS DURING THE CROP SEASON
30th JUNE TO 11th DECEMBER 1968
HUMIDITY %
TEMPERATURE (MAXIMUM)
TEMPERATURE (MINIMUM)
RAIN FALL
RAIN FALL IN mm
660
600
540
480
420
360
300
240
180
120
60
0
TEMPERATURE IN °C & HUMIDITY IN PERCENTAGE
100
90
80
70
60
50
40
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
WEEKS

FIG II

(vii) Harvest:

The maturity of the crop was indicated by the falling of the leaves and yellowing of the vines. The crop was harvested on 10th and 11th of December 1968, and the yields were recorded on the same dates.

VIII. Sampling technique adopted for biometric studies:

Four plants were selected at random in each plot for studying the biometrical characters.

IX. Observations made:

(i) Leaf area:

The leaf area was recorded after all the plants had flowered. The three leaves down from the base of the receme were taken for measurements from each observation plant. The length of the leaf was measured in cm. from the base of the leaf to the leaf tip and was recorded as '2a' and the maximum width of the leaf was recorded as '2b'. From this data the leaf area per leaf was calculated using the formula "Leaf area = π x a x b" and was recorded in sq.cm.

(ii) Number of branches per plant:

The total number of branches in the observation plants were counted immediately before harvest and the average number of branches per plant of each treatment was calculated and recorded.

(iii) Number of tubers per plant:-

The total number of tubers from each of the observation plants were counted and the average was recorded as the number of tubers per plant under different treatments.

(iv) Yield of tubers per plot:

The total weight of tubers obtained from each plot was recorded as yield of tubers in Kg/plot and from this data the yield of tubers in tonnes/hectare for each treatment was calculated and recorded.

(v) Starch content:

The percentage of starch contained in the oven dried samples of tubers from individual plots was estimated following A.O.A.C. (1956) method.

(vi) Dry matter and moisture content of tubers:

A known weight of fresh tubers from each treatment were chipped into pieces and dried in sun for two days. The sun dried chips were kept in an air oven for 8 hours at 105°C and the final weight was noted. This final weight was expressed as percentage of dry matter content of tubers and recorded. The loss in weight was expressed as a percentage and was recorded as the moisture content of tubers.

RESULTS

RESULTS

The data relating to the observations made during the present investigation to study the response of Koorka to graded doses of fertilizer application are presented in Tables I to VIII.

I. Leaf area:

The analysis of variance for the mean leaf area per leaf is presented in Appendix-I. It shows that there was significant increase in leaf area due to application of nitrogen. But phosphorus and potash independently or their interactions had no significant effect in increasing the leaf area.

The data regarding the mean leaf area per leaf as influenced by various treatment combinations are summarised and presented in Table-I. The increase in leaf area due to application of both lower and higher levels of nitrogen was found to be significant over control. The increase was also significant between the lower and higher levels of nitrogen. The higher level of nitrogen (n_2) increased the leaf area by 49.4% over control and 20% over lower level (n_1). As to the combination, n_2k_1 was found to give a significant increase in leaf area over

n_2k_0 and n_0k_2. The largest leaf area of 29.27 sq.cm. was also recorded in the combination of n_2k_1.

On further study of the data regarding the leaf area and levels of nitrogen it was found that these two factors were strongly related giving a significant positive correlation ($r = 0.87$) between the two (Appendix-VIII). The regression of leaf area on level of nitrogen was given by the expression.

$$L = 36.36 + 0.0298\ N$$

where L = mean leaf area in sq.cm. per leaf

N = level of nitrogen in kg/ha.

II. Number of branches per plant:

The analysis of varience for number of branches per plant is presented in Appendix-II. It revealed that the effect of nitrogen in increasing the number of branches per plant was highly significant. The direct effects of phosphorus and potash independently were not found significant. So also their interactions except N x K which was found significant.

The mean number of branches recorded per plant under different levels of nitrogen, phosphorus, potash and

TABLE-I

Mean leaf area per leaf in sq.cm.

	n_0	n_1	n_2	Mean
p_0	18.04	21.99	27.43	22.48
p_1	18.73	23.82	27.41	23.32
p_2	17.76	22.08	26.61	22.15
k_0	17.78	23.27	25.50	22.18
k_1	18.93	22.61	29.27	23.60
k_2	17.82	22.01	26.68	22.17
Mean	18.17	22.63	27.15	
	p_0	p_1	p_2	Mean
k_0	21.71	22.98	21.86	22.18
k_1	24.99	23.36	22.46	23.60
k_2	20.75	23.62	22.13	22.17
Mean	22.48	23.32	22.15	

C.D (.05 level) for comparison between marginal means 1.92

C.D (.05 level) for comparison between means of combinations. 3.38

their combinations is presented in Table-II. Significant increase in number of branches was obtained due to application of higher level of nitrogen viz. 60 kg/ha. No increase over the control was obtained due to application of nitrogen at the lower level viz. 30 kg/ha. The highest number of branches was recorded in combination of n_2k_2 which was found significant over n_2k_0 and n_0k_2.

III. <u>Number of tubers per plant:</u>

The analysis of variance for the number of tubers per plant is presented in Appendix-III. The effect of nitrogen was found to be highly significant in increasing the number of tubers per plant. The effects of phosphorus, potash, and the interactions were not significant.

The data regarding the mean number of tubers per plant under the various treatment combinations are summarised and presented in Table-III. The higher level of nitrogen (n_2) significantly increased the number of tubers per plant over control (n_0) and also over lower level of nitrogen (n_1). The response to nitrogen was increasing with increasing doses of nitrogen. While the lower level of nitrogen (n_1) increased the number of tubers by 16.7% over control (n_0) the higher level of nitrogen (n_2) registered 48.1% increase over control (n_0) and 26.9% increase over lower level (n_1).

TABLE-II

Mean number of branches per plant

	n_0	n_1	n_2	Mean
p_0	17.00	15.66	34.00	22.22
p_1	18.00	15.50	28.50	20.66
p_2	17.00	17.00	30.50	21.50
k_0	12.66	19.33	26.83	19.60
k_1	20.50	15.16	31.50	22.38
k_2	18.83	13.66	34.66	22.38
Mean	17.33	16.05	30.99	

	p_0	p_1	p_2	Mean
k_0	21.83	20.16	16.83	19.60
k_1	23.50	19.33	24.33	22.38
k_2	21.33	22.50	23.33	22.38
Mean	22.22	20.66	21.50	

C.D (.05 level) for comparison between marginal means 3.91

C.D (.05 level) for comparison between combinations 6.8

IV. Yield of tubers:

The analysis of variance for the yield of tubers is presented in Appendix-IV. The effect of nitrogen was highly significant in increasing the yield of tubers in Koorka. The effects of phosphorus and potash on the yield of tubers were not found significant. Similarly the interactions of these nutrients were also not significant.

The data regarding the mean yield of tubers as influenced by the various treatments are summarised and presented in Table-IV. A perusal of it makes out that both lower (n_1) and higher (n_2) levels of nitrogen viz. 30 kg/ha. and 60 kg/ha. increased the yield of tubers significantly over control (n_0) viz. no nitrogen. The increase was also significant between the lower and higher levels of nitrogen. The pattern of response to graded doses of nitrogen was found to be linear.

Correlation studies:

Correlations worked out between the level of nitrogen, leaf area and the final yield of tubers (Appendix-VIII) showed the following indications.

(a) Correlation between the level of nitrogen and yield of tubers:

A highly significant correlation ($r = 0.75$) was obtained between these two characters, indicating the positive relationship between them.

Th

TABLE-III

Mean number of tubers per plant

	n_0	n_1	n_2	Mean
p_0	34.8	30.4	49.2	38.1
p_1	30.1	34.4	45.9	36.8
p_2	25.0	39.9	38.0	34.3
k_0	28.4	34.5	44.0	35.6
k_1	34.1	35.0	46.2	38.4
k_2	27.4	35.2	43.0	35.2
Mean	29.9	34.9	44.3	

	p_0	p_1	p_2	Mean
k_0	34.8	38.0	34.1	35.6
k_1	38.6	43.1	33.7	38.4
k_2	40.9	29.4	35.2	35.2
Mean.	38.1	36.8	34.3	

C.D. (0.05 level) for comparison between marginal means 6.47

C.D (0.05 level) for comparison between means of combinations. ... 11.19

TABLE-IV

Mean yield of tubers in tonnes per hectare

	n_0	n_1	n_2	Mean
p_0	12.75	14.16	17.00	14.63
p_1	14.25	14.70	16.70	15.22
p_2	11.08	14.45	17.20	14.24
k_0	12.41	14.58	17.41	14.80
k_1	13.41	13.62	17.91	14.98
k_2	12.25	15.12	15.58	14.31
Mean	12.69	14.43	16.96	

	p_0	p_1	p_2	Mean
k_0	14.16	14.58	15.66	14.80
k_1	15.33	16.54	13.08	14.98
k_2	14.41	14.54	14.00	14.31
Mean	14.63	15.22	14.24	

C.D (0.05 level) for comparison between marginal means 1.555

C.D (0.05 level) for comparison between means of combinations... ... 2.685

(b) Correlation between mean leaf area per leaf and yield of tubers:

A highly significant positive correlation (r = 0.76) between these two characters was noticed.

Leaf area as an index of yield:

The mean leaf area per leaf of the three youngest leaves in order after the full emergence of flowers was found to influence positively the yield of tubers in Koorka (Coleus parviflorus) and the relationship between the yield of tubers and the mean leaf area per leaf obtained as a result of the present investigation is presented in Fig.V. The relationship between these two characters was found to follow the regression equation:

$$Y = 5.2279 + 0.41827\ L$$

where Y = yield of tubers in tonnes/ha, and
L = mean leaf area in sq.cm. per leaf.

(c) Partial correlation between yield of tubers and level of nitrogen, eliminating the effect of leaf area:

The partial correlation coefficient ($r_{yx_1 . x_2} = 0.28$) obtained between yield of tubers and level of nitrogen, eliminating the effect of leaf area was not significant.

(d) Partial correlation between yield of tubers and leaf area, eliminating the effect of nitrogen:

The partial correlation coefficient ($r_{yx_2 . x_1} = 0.33$) worked out between yield of tubers and mean leaf area per leaf, eliminating the effect of nitrogen was also not significant.

V. Starch content of tubers:

The analysis of variance for the percentage of starch content in tubers is presented in Appendix-V.

The individual effects of nitrogen, phosphorus and potash were not found to influence significantly the percentage of starch in tubers. Of the interactions, N x P interaction was found significant, while the others did not significantly influence this character. As to the combinations, n_1p_1 and n_1p_2 were found to significantly increase the starch content of tubers over n_1p_0.

VI. Moisture content of tubers:

The analysis of variance for the percentage of moisture content in tubers is presented in Appendix-VI.

The direct effects of nitrogen, phosphorus and potash or their interactions were not significant.

The mean percentage of moisture content under the various treatment combinations is presented in Table-VI.

The different levels of individual nutrients or their various combinations did not give significant difference in moisture content of tubers. However between the

TABLE-V

Mean percentage of starch content of tubers
(oven dry basis)

	n_0	n_1	n_2	Mean
p_0	60.79	56.90	62.48	60.05
p_1	60.75	60.93	62.39	61.35
p_2	61.44	62.32	59.79	61.18
k_0	61.27	59.98	61.78	61.01
k_1	61.77	59.36	61.42	60.85
k_2	59.94	60.80	61.45	60.73
Mean	60.99	60.04	61.55	

	p_0	p_1	p_2	Mean
k_0	60.50	61.09	61.43	61.01
k_1	59.86	61.54	61.16	60.85
k_2	59.79	61.44	60.95	60.73
Mean	60.05	61.35	61.18	

C.D.(0.05 level) for comparison between marginal means 1.75

C.D (0.05 level) for comparison between means of combinations 3.04

TABLE-VI

Mean percentage of moisture in tubers

	n_0	n_1	n_2	Mean
p_0	70.92	68.51	72.81	70.74
p_1	72.70	73.15	70.87	72.24
p_2	71.86	72.09	72.73	72.22
k_0	70.30	70.31	71.50	70.70
k_1	70.97	68.97	71.55	70.49
k_2	74.21	74.47	73.36	74.01
Mean	71.92	71.25	72.13	

	p_0	p_1	p_2	Mean
k_0	70.42	71.10	70.59	70.70
k_1	67.36	71.33	72.79	70.49
k_2	74.46	74.28	73.30	74.01
Mean	70.74	72.24	72.22	

C.D (0.05 level) for comparison between marginal means 4.31

C.D (0.05 level) for comparison between means of combinations ... 7.4

levels of potash, ~~the higher levels of potash~~, the higher level (k_2) recorded a 4.6% increase in moisture content over control (k_0).

VII. Dry matter content of tubers:

The analysis of variance for the mean percentage of dry matter content in tubers is presented in Appendix-VII.

No significant influence on the dry matter content was observed due to the direct effects or interactions of nitrogen, phosphorus and potash.

The data regarding mean percentage of dry matter in tubers as influenced by the various treatment combinations are presented in Table-VII.

Between the levels of individual nutrients or between their combinations no significant difference on percentage of dry matter could be observed. However there was a trend for decrease in dry matter content of tubers as the level of potash was raised from K_1 to K_2. A decrease in dry matter content by 11.9% was noted when the dose of potash was increased from 60 Kg/ha. to 120 Kg/ha.

Response curve and Economics of manuring:

The relationship between yield of tubers and level of nitrogen obtained as a result of the present investigation

TABLE-VII

Mean percentage of dry matter in tubers
(oven dry basis)

	n_0	n_1	n_2	Mean
p_0	29.07	21.49	27.18	29.24
p_1	27.29	26.85	29.13	27.75
p_2	28.13	27.90	27.27	27.76
k_0	29.69	29.69	28.50	29.29
k_1	29.02	31.03	28.45	29.50
k_2	25.79	25.52	26.63	25.98
Mean	28.16	28.74	27.86	

	p_0	p_1	p_2	Mean
k_0	29.57	28.90	29.40	29.29
k_1	32.63	28.66	27.21	29.50
k_2	25.54	25.71	26.69	25.98
Mean	29.24	27.75	27.76	

C.D (0.05 level) for comparison between marginal means 4.31

C.D (0.05 level) for comparison between means of combinations 7.4

TABLE-VIII

Economics of application of different levels of N, P & K for Koorka

Levels of nutrients in Kg. per hectare	Yield of tubers in tonnes per hectare.	Value of produce Rs.	Increase or decrease over the lowest level Rs.	Cost of fertilizers. Rs.	Extra cost of fertilizer over that of the lowest level. Rs.	Profit due to fertilizer application over the lowest level. Rs.
I. NITROGEN						
0 Kg/hectare	12.69	5076.00	...	...	...	...
30 Kg/hectare	14.43	5772.00	+ 696.00	82.50	82.50	+ 613.50
60 Kg/hectare	16.96	6784.00	+ 1708.00	165.00	165.00	+ 1543.00
II. PHOSPHORUS						
0 Kg/ha	14.63	5852.00	...	...	...	...
30 Kg/hectare	15.22	6088.00	+ 236.00	72.00	72.00	+ 164.00
60 Kg/hectare	14.24	5696.00	- 156.00	144.00	144.00	- 300.00
III. POTASH						
0 Kg/hectare	14.80	5920.00	...	...	...	...
60 Kg/hectare	14.98	5992.00	+ 72.00	51.00	51.00	+ 21.00
120 Kg/hectare	14.31	5724.00	- 196.00	102.00	102.00	- 298.00

Cost of 1 Kg. Nitrogen = Rs.2.75
Cost of 1 Kg. Phosphorus = Rs.2.40 Price of 1 Tonne

is shown in Fig.IV. The regression of yield of tubers on level of nitrogen was given by the expression.

$$Y = 12.56 + 0.071 N$$

where Y = Yield of tubers in tonnes/ha.

and N = level of nitrogen in Kg/ha.

The economics of application of different doses of nitrogen, phosphorus and potash is worked out and presented in Table-VIII.

Evidently the highest level of nitrogen (60 Kg. per hectare) gave the highest profit of Rs.1,543/per hectare.

DISCUSSION

DISCUSSION

The results obtained in the present investigation on the response of Koorka (Coleus parviflorus) to graded doses of nitrogen, phosphorus and potash under the agro-climatic conditions of Vellayani are discussed hereunder.

I. Leaf area:

The first point that calls for comment is the significant increase in mean leaf area per leaf under the different treatments due to application of nitrogen (Table-I and fig. I). Phosphorus and potash independently or their interactions do not manifest any significant difference on this character. The differences in leaf area between the different levels of nitrogen (0,30 and 60 Kg/ha) are also seen significant, giving an increase in leaf area with increasing doses of nitrogen.

Russel (1956) has reported that as the level of nitrogen supply increases, compared with other nutrients, the extra protein produced allows the plant leaves to grow larger and hence to have larger surface available for photosynthesis. In fact over a considerable range of nitrogen supply for many crops the amount of leaf area available for

MEAN LEAF AREA PER LEAF AND NUMBER OF BRANCHES PER PLANT

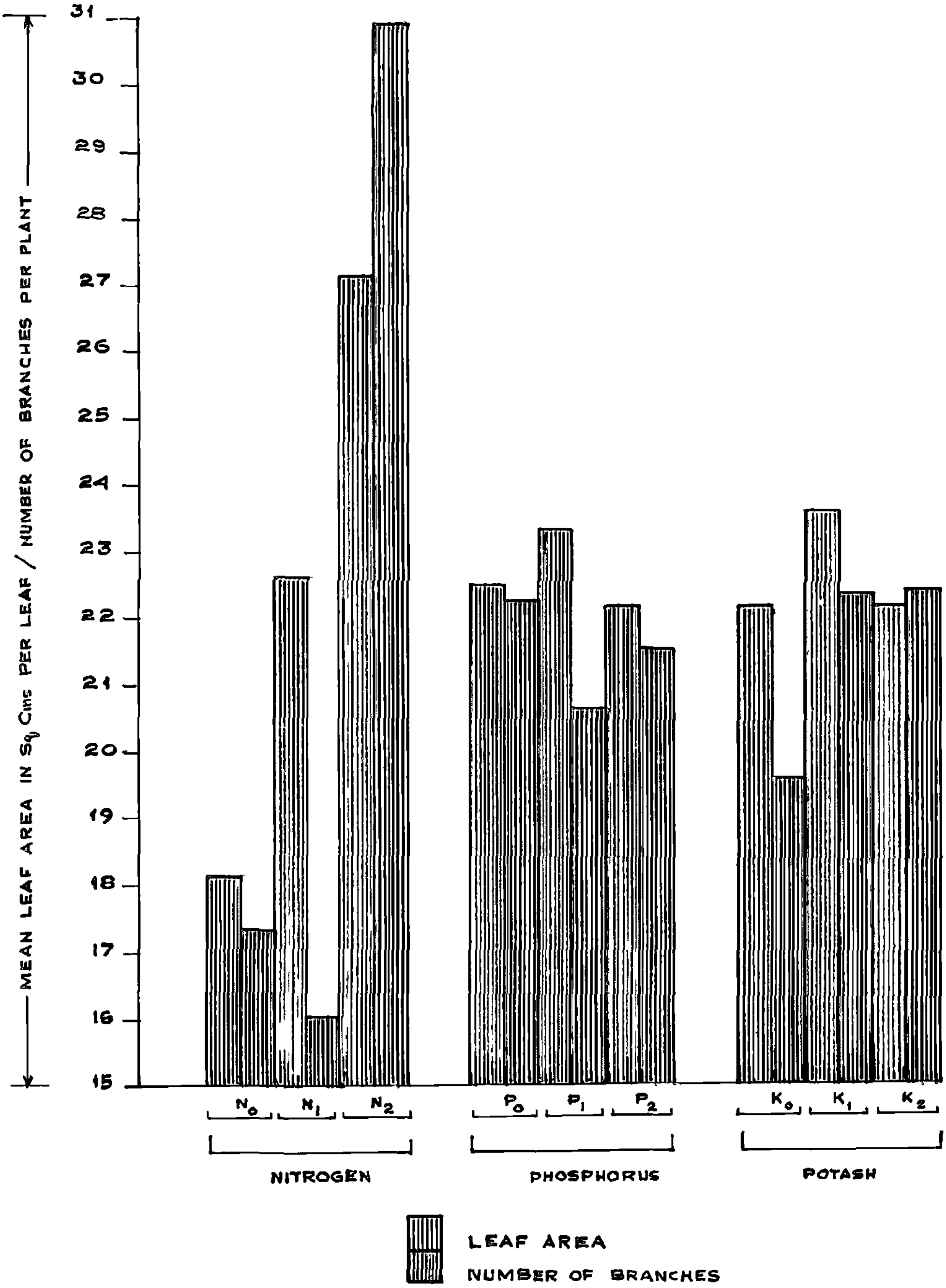


FIG III

photosynthesis is roughly proportional to the amount of nitrogen supplied. The first objective in nitrogen fertilisation of root crops, according to Black (1957) is to obtain rapid elaboration of leaves in the early part of the growth cycle. Another interesting finding reported in this regard is that of Njoku (1957). He observes that high levels of nitrogen supply as compared with low levels increase both the mean size and the total number of leaf epidermal cells in *Ipomoea caerulea*.

The increase in leaf area due to higher levels of nitrogen supply recorded in the present investigation is well in agreement with the above findings. This is further substantiated by the highly significant positive correlation ($r = 0.87$) noted between these two factors and the linear regression ($L = 36.36 + 0.0298 N$) of leaf area on the level of nitrogen.

The increase in leaf area noted here for high level of nitrogen supply (60 Kg/ha) over no nitrogen is 49.4% and over low level of nitrogen (30 Kg/ha) is 20%. This also is in conformity with the results obtained by Njoku (loc.cit) who reported a 30% increase in leaf size with high than with low nitrogen supply.

Though potash independently has not shown any significant effect on the mean leaf area, the largest leaf area of 29.27 sq. cm. is recorded for the combined application of 60 Kg/ha. of nitrogen and 60 Kg/ha. of potash. The increase in leaf area noted for this combination is significant over the treatments giving 60 Kg/ha. of nitrogen with no potash or 60 Kg/ha. of potash with no nitrogen. It evidently indicates that the combined application of nitrogen and potash is definitely beneficial. Since no increase in leaf area is obtained by application of potash alone, its effect in combination might probably be due to its role in the better utilisation of nitrogen. This is substantiated by the observations reported by Meyer and Anderson (1952); Russel (1956); Black (1957); and Tsuno and Fujise (1965) that for the conversion of amino acids into proteins and for translocation of photo synthates potash plays a definite role.

II. Number of branches per plant.

The data presented in Table-II and Fig.I reveal that higher level of nitrogen has a significant effect in increasing the number of branches per plant, whereas phosphorus and potash independently have not. The N x K interaction also manifests significant difference in the mean number of branches. Combined application of 60 Kg. of nitrogen and 120 Kg. of potash per hectare is seen to have resulted in the highest mean number of branches registering a significant increase over treatments giving 60 Kg. of nitrogen with no potash or no nitrogen with 120 Kg. of potash per hectare. Here also the result goes to show that combined application of nitrogen and potash is definitely superior.

It has been observed by Black (1957) that an abundance of available nitrogen promotes vegetative growth. This happens because an abundant supply of nitrogenous foods to any actively growing vegetative meristem produces large quantity of protoplasm (Meyer and Anderson, 1952) which encourages growth. These findings adequately explain the increase in the number of branches obtained in the present investigation due to application of nitrogen.

The beneficial effect of the combined application of nitrogen with potash may be due to the fact that potassium is involved in the synthesis of proteins from amino acids as discussed earlier.

III. <u>Number of tubers per plant.</u>

A perusal of Table-III reveals a significant increase in the number of tubers per plant due to the effect of nitrogen. No such effect is noted for phosphorus, potash or the interactions. Though the highest level of nitrogen (60 Kg/ha) alone has significantly increased the number of tubers, the lower level of nitrogen (30 Kg/ha) is also seen to have registered a positive trend on this character. This is in agreement with the results obtained by Gopalakrishna Pillai (1967) on tapioca under the agroclimatic conditions of Vellayani.

Russel (1956) has pointed out that crops grown for their carbohydrates such as root crops benefit from nitrogen manuring through the increased leaf area brought about by the nitrogen, which enables a higher rate of photo synthesis. Same seems to be the reason for the increase in the number of tubers noted in the present investigation for higher level of nitrogen.

IV. Yield of tubers.

It is evident from the data in able-IV that the effect of nitrogen is highly significant increasing the yield of tubers. Phosphorus, potash or ir interactions have not influenced the yield of tubers nificantly. The bar diagram (Fig. V) brings out more cle the effect of these nutrients on the yield character.

The mean yield recorded as a rt of application of 30 Kg. and 60 Kg. of nitrogen per hec is seen to be 14.43 tonnes and 16.96 tonnes of tubers hectare respectively while that for no nitrogen is 12.69 tonnes per hectare. It merits mention that thcease in yield for each incremental dose is found to bificant.

with the results obtained by Gopalakrishna Pillai (1967) on tapioca under the agroclimatic conditions of Vellayani.

Russel (1956) has pointed out that crops grown for their carbohydrates such as root crops benefit from nitrogen manuring through the increased leaf area brought about by the nitrogen, which enables a higher rate of photo synthesis. Same seems to be the reason for the increase in the number of tubers noted in the present investigation for higher level of nitrogen.

IV. Yield of tubers.

It is evident from the data in Table-IV that the effect of nitrogen is highly significant in increasing the yield of tubers. Phosphorus, potash or their interactions have not influenced the yield of tubers significantly. The bar diagram (Fig. V) brings out more clearly the effect of these nutrients on the yield character.

The mean yield recorded as a result of application of 30 Kg. and 60 Kg. of nitrogen per hectare is seen to be 14.43 tonnes and 16.96 tonnes of tubers per hectare respectively while that for no nitrogen is only 12.69 tonnes per hectare. It merits mention that the increase in yield for each incremental dose is found to be significant.

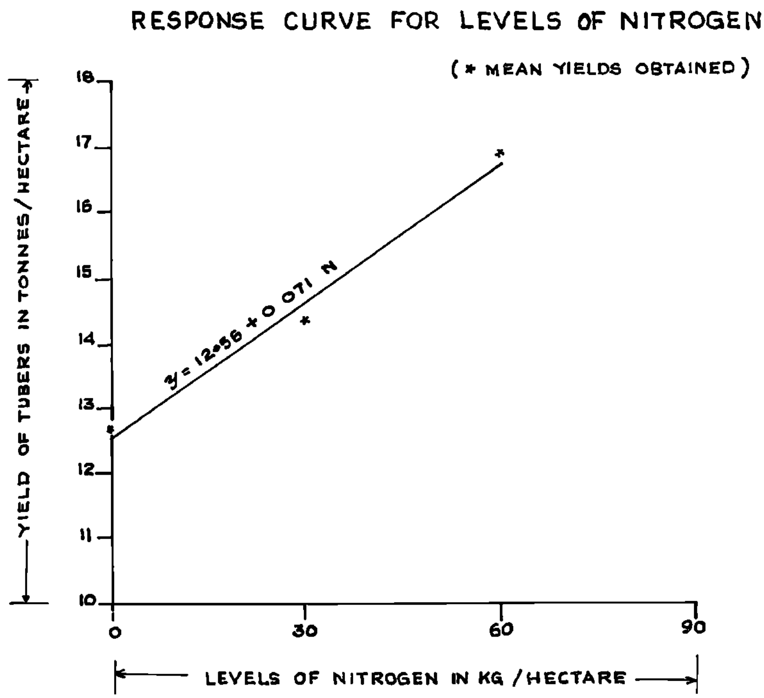

RESPONSE CURVE FOR LEVELS OF NITROGEN
(* MEAN YIELDS OBTAINED)
YIELD OF TUBERS IN TONNES/HECTARE
18
17
16
15
14
13
12
11
10
y = 12.56 + 0.071 N
0
30
60
90
LEVELS OF NITROGEN IN KG/HECTARE

FIG IV

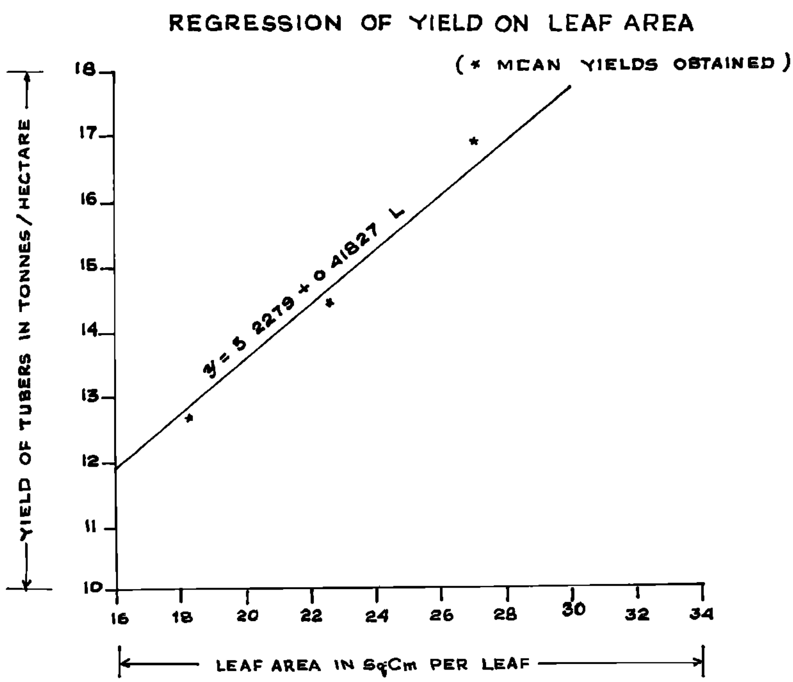

REGRESSION OF YIELD ON LEAF AREA
(* MEAN YIELDS OBTAINED)
YIELD OF TUBERS IN TONNES/HECTARE
18
17
16
15
14
13
12
11
10
y = 5.2279 + 0.41827 L
16
18
20
22
24
26
28
30
32
34
LEAF AREA IN SqCm PER LEAF

FIG V

The above results on the effect of nitrogen are in agreement with the results obtained on potato crop by Sing (1952); Ellison (1954); Pohl, et al. (1955); Rautor (1955); Pushkarnath, et al. (1960); Loginow, et al. (1964); Chapman (1965); Hanley, et al. (1965), Andersen (1966) and Benepal (1967), and on sweet potato by Johnson and Ware (1948); Landrau and Samuels (1951), and Izava and Okamoto (1959).

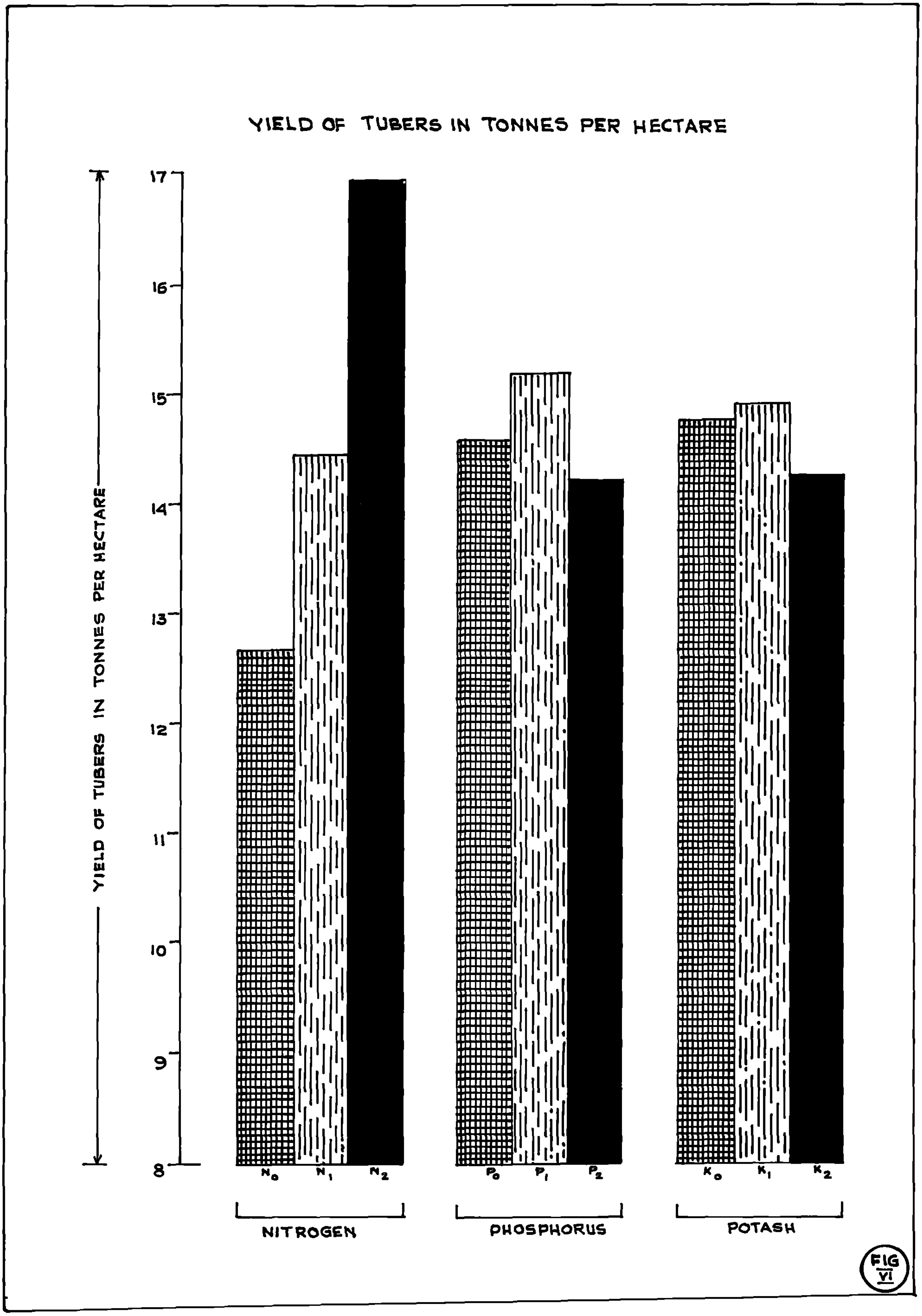
The linear pattern of yield response to graded doses of nitrogen noticed in the present investigation is in conformity with the results obtained by Odland and Sheehan (1956) who have also observed a linear response to nitrogen application upto 130 lb. per acre to potato crop.

The fact that no significant effect on the yield of tubers has been noted due to the application of phosphorus either at 30 Kg/ha. or 60 Kg/ha. is not quite surprising. In potato crop no significant response has been noted to phosphorus upto 72 Kg/hectare by Loginow, et al. (1964) and upto 90 lb/acre by Jaisinghani, et al. (1964). Landrau and Samuels (1951) and Purewal and Dargon (1959) could not also get any response to phosphates on yield of tubers in sweet potato.

Experiments conducted on miscellaneous tuber crops like yam, colocasia, sugar beet and carrots, by Irving (1956); Hodnet (1958); Takegami (1962); Varma and Bajpai (1965) respectively have also revealed lack of response to the application of phosphorus.

The analytical values of the soil in the experimental plot prior to the treatment show that the total phosphoric acid content is 0.049% and the available phosphoric acid content 0.004% (80 lbs/acre). According to the rating chart for soil test data in India (Muhr, et al. 1965) the soil under study is testing high for available phosphoric acid. Tomhane, et al. (1964) has reported that the probability of obtaining a profitable response from the use of a nutrient on soils testing high in that nutrient is lesser. Therefore the lack of significant response to applied phosphorus in the present investigation might be due to the initial high status of the soil phosphorus.

Table-IV further brings out that the yield is not significantly increased by potash application. Some of the earlier works also have revealed lack of response to potash, by tuber crops like potato, sweet potato etc. (Landrau and Samuels, 1951; Loginow, et al. 1964; Benapal, 1967;



YIELD OF TUBERS IN TONNES PER HECTARE
YIELD OF TUBERS IN TONNES PER HECTARE
17
16
15
14
13
12
11
10
9
8
N0
N1
N2
P0
P1
P2
K0
K1
K2
NITROGEN
PHOSPHORUS
POTASH
FIG VI

Breda Filho, et al. (1966). The recent finding by Chamberland and Scott (1968) that potatoes derive much of their K requirement from soil reserves, throws much light into the result obtained in the present investigation. The same might be one of the reasons for lack of response to added potash on Koorka crop also.

Another reason that may be attributed to the failure of response to potash is that the optimum level of potash for Koorka crop might have been below the lower level of potash tried viz. 60 Kg/ha. This may be probable because a perusal of Tables I to IV not withstanding the fact that there is no statistical significance, however, points invariably to a positive trend from the zero level (K_0) to the first level (K_1) of potash and then a negative trend from the frist level (K_1) to the second level (K_2) of potash. This peculiar nature of the trend of potash invariably noted on all the plant characters so far discussed in the investigation suggests a possibility that the response noted for K_1 and K_2 levels might have been on the declining side of a response curve, with its peak somewhere between K_0 and K_1. Unfortunately no middle levels between K_0

(no potash) and K_1 (60 Kg/ha. of potash) have been tried which would have saved the obliteration of a significant response to potash. The probability for this cannot be totally ruled out since Purewal, et al. (1957) and Creig (1967) have observed the maximum yield on colocasia and sweet potato at 50 lb. of potash per acre respectively, and Andersen (1966) has even reported a negative response for higher rates of potash on potato.

Correlation studies:

A perusal of the correlations worked out between the yield of tubers and level of nitrogen or leaf area elucidates the fact that yield is positively correlated with the level of nitrogen as well as mean leaf area per leaf.

Nitrogen being an important constituent of protoplasm is one of the major nutrients required in larger quantities for plant growth. Higher levels of nitrogen therefore might have contributed to better growth of the plant resulting ultimately in better yield and this explains the positive and significant correlation ($r = 0.75$) obtained between the yield and levels of nitrogen.

The correlation (r = 0.76) between the yield and mean leaf area per leaf is also positive and highly significant.

This crop is grown for its carbohydrates stored in tubers and the manufacture of carbohydrates depends on photosynthesis. In vascular plants photosynthesis occurs chiefly in the leaves, and a large expanded surface in leaf permits the display of a large number of chloroplast-containing cells to light which enhances the rate of photosynthesis resulting in a greater amount of carbohydrate (Meyer and Anderson, 1952). This phenomenon adequately explains the significant correlation between the increase in leaf area and the corresponding increased yield of tubers obtained in the present investigation.

The partial correlations worked out between yield and level of nitrogen or mean leaf area reveal another interesting fact. The partial correlation coefficient between the yield of tubers and level of nitrogen eliminating the effect of leaf area is found not significant. Similarly the partial correlation coefficient between the yield and mean leaf area eliminating the effect of nitrogen is also found not significant. This observation evidently suggests that these two factors viz. level of nitrogen and mean leaf area are mutually complementary in the manifestation of their effects on yield.

Leaf area asan index of yield:

An observation of much practical importance that merits comment in the present investigation is the relation of yield of tubers with the mean leaf area per leaf of the three leaves down from the base of the receme. The reason for selecting these leaves for the study is that the tuberisation in Koorka occurs only after the full emergence of flowers and at the active tuberisation phase these are the leaves at an advantageous position for maximum exposure to light. It may be recalled here that a strong positive correlation has been noticed between the yield and the mean leaf area.

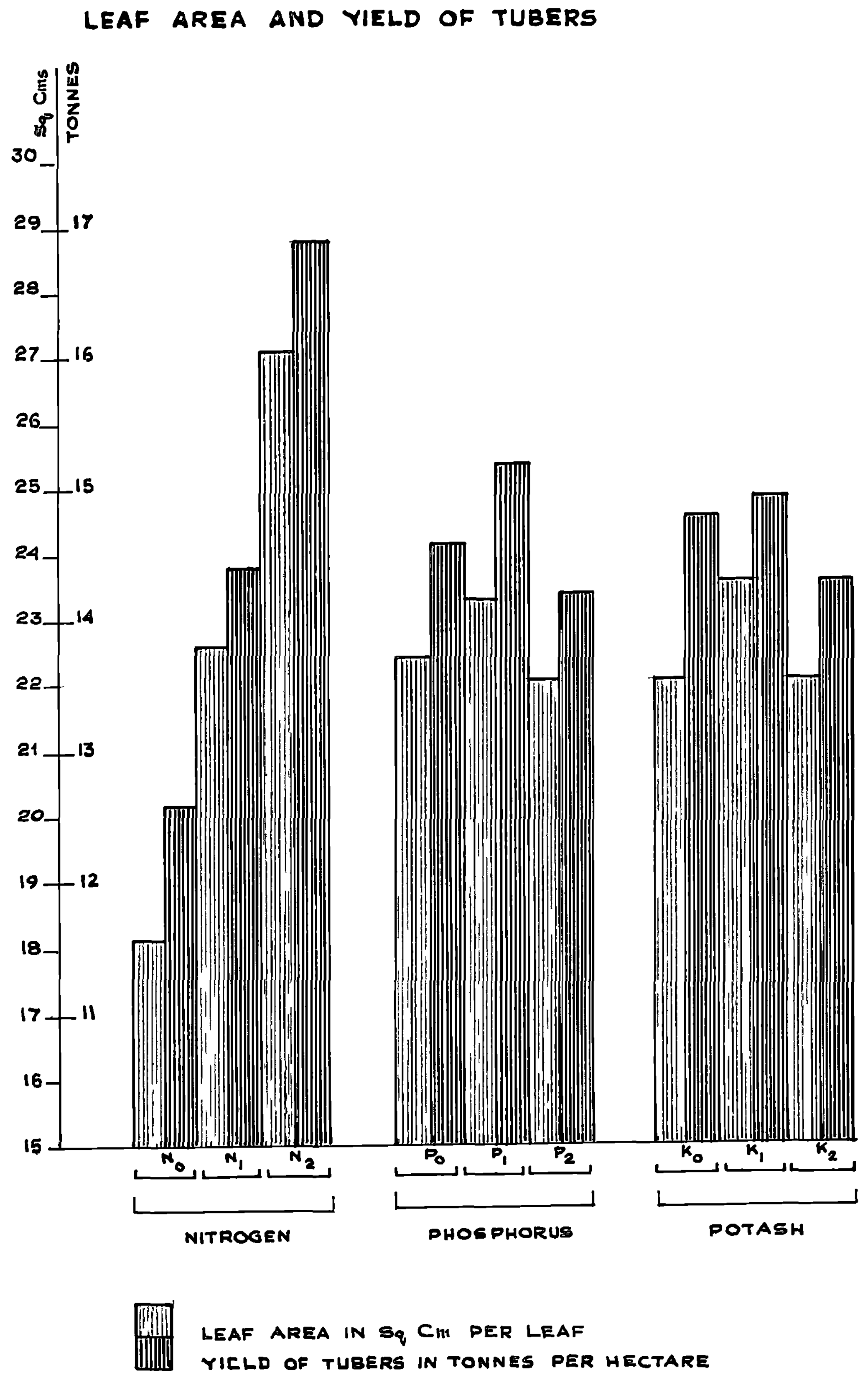
The regression equation:

$$Y = 5.2279 + 0.41827 L$$

$$(r = 0.76^{**})$$

(where Y = yield of tubers in tonnes per hectare

and L = mean leaf area in sq. cm. per leaf)



LEAF AREA AND YIELD OF TUBERS
Sq Cms
TONNES
30
29 17
28
27 16
26
25 15
24
23 14
22
21 13
20
19 12
18
17 11
16
15
N0 N1 N2
P0 P1 P2
K0 K1 K2
NITROGEN
PHOSPHORUS
POTASH
LEAF AREA IN Sq Cm PER LEAF
YIELD OF TUBERS IN TONNES PER HECTARE

FIG VII

gives a fairly reliable estimate of tuber weight in tonnes per hectare (Appendix-X).

This finding is in conformity with the results obtained by Reddy, _et al_. (1968) on _Colocasis esculenta_. They have noticed positive correlation between the measurements of the second youngest leaf in sq.cm. and the corm weight. The regression equation worked out by them has also given reliable estimate of corm weights.

The practical importance of the regression equation of yield obtained in the present investigation, lies in the fact that the yield of a standing mature crop of _Koorka_ can be estimated with reasonable degree of accuracy in advance of harvest and this would facilitate the sale or purchase of a standing crop or the advancement of credit to farmers by Marketing Cooperative Societies based on a Scientific estimate of yield.

V. _Starch content of tubers:_

The data in Table V reveal that the different levels of nitrogen, phosphorus and potash have not significantly influenced the mean percentage of starch content of tubers. But the combined application of 30 Kg. nitrogen and 30 Kg.

PERCENTAGE OF MOISTURE AND DRY MATTER IN TUBERS

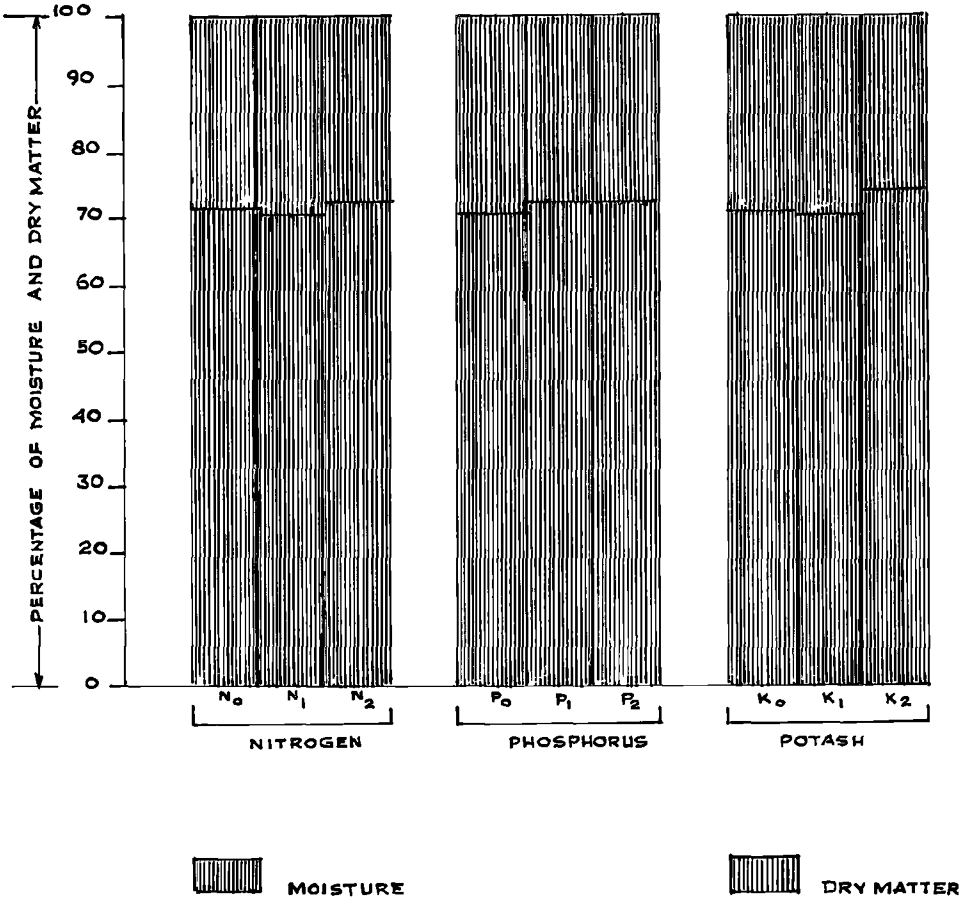


FIG VIII A

STARCH CONTENT OF TUBERS

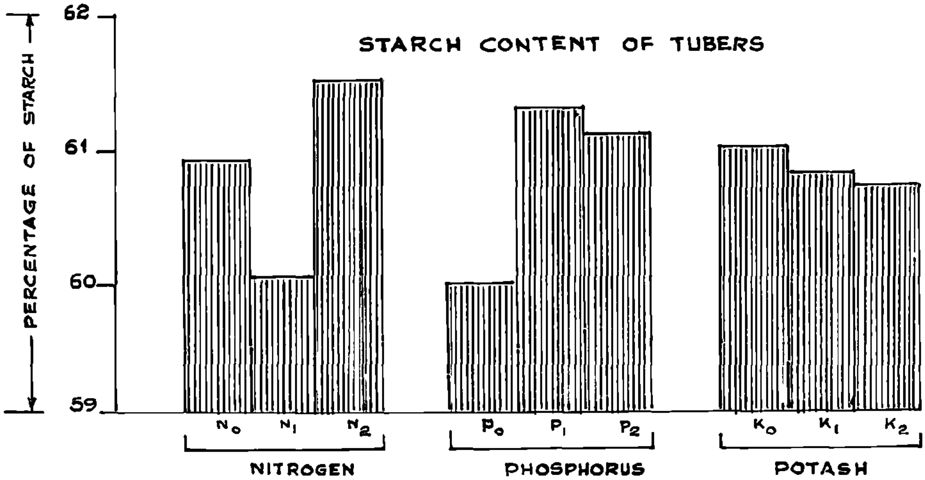


FIG VIII B

phosphorus or 30 Kg. nitrogen and 60 Kg. phosphorus per hectare is seen to have increased the starch content significantly over the same level of nitrogen without phosphorus. It may be recalled here that the N x P interaction on this character has been found significant which also goes to show that phosphorus in combination with nitrogen increases the starch content of tubers. Mayer and Anderson (1952) have reported that phosphorus is involved in the transformations connected with the synthesis of starch.

VI. Moisture content of tubers:

Table-VI shows that the mean percentage of moisture in tubers is not significantly influenced by any of the levels of nutrients tried.

It has been reported by Tsuno and Fujise (1965) that potassium is involved in the hydration of tuber tissue. The 4.6% increase in moisture content of tubers due to the higher level of potash over that of control noticed in the present investigation may be a reflection of the hydration effect of potash mentioned above.

VII. Dry matter content of tubers:

Table-VII shows that no significant difference in mean percentage of dry matter content of tubers is obtained due to application of nitrogen, phosphorus or potash. The decrease of 11.9% dry matter content in tubers, recorded for higher level of potash may be due to the hydration effect of potash mentioned earlier.

Economics of manuring:

Table-VIII brings out the economics of manuring this crop with fertilizers. Maximum profit of Rs.1,543/- per hectare is recorded for application of nitrogen at higher level (n_2).

It is also noted that response in yield to nitrogen is positive and linear under all levels tried. However it is further noticed that the higher levels of P and K tried were at a loss.

The high net profits obtained for higher levels of nitrogen indicate the high responsiveness of this crop to nitrogenous fertilizers.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

To study the response of Koorka (*Coleus parviflorus*) to graded doses of nitrogen (0,30 and 60 Kg. per hectare), phosphorus (0,30 and 60 Kg. per hectare) and potash (0,60 and 120 Kg. per hectare), a field experiment was laid out in red loam soils at the Central Farm attached to the Agricultural College and Research Institute, Vellayani, during the year 1968. All the twenty seven treatment combinations were tried in a 3^3 partially confounded factorial experiment.

The following conclusions were drawn from the study:-

1. The leaf area was significantly increased by application of nitrogen.

2. The combined application of 60 Kg. of nitrogen and 60 Kg. of potash per hectare gave the largest leaf area.

3. There was significant increase in the number of branches per plant at 60 Kg. of nitrogen per hectare.

4. Combined application of 60 Kg. of nitrogen and 120 Kg. of potash per hectare resulted in the maximum number of branches.

5. Application of nitrogen at 30 and 60 Kg. per hectare resulted in significant increase in yield of tubers and the response was linear.

6. The levels of P and K tried had no significant effect on the yield of tubers.

7. There was a positive correlation between the yield and level of nitrogen as well as the yield and mean leaf area.

8. Level of nitrogen and mean leaf area were found to be mutually complementary factors of yield.

9. The leaf area was found to be an index of yield giving the following relationship:

$$Y = 5.2279 + 0.41827 L$$

10. The percentage of starch and dry matter in tubers was not affected by the application of fertilizers.

11. A net profit of Rs.1,543/- was obtained by application of 60 Kg. nitrogen per hectare.

Eventhough the studies revealed the high beneficial effect due to application of nitrogenous fertilizers to this crop, the results indicate that further investigations with still higher levels of nitrogen and lower levels of potash are necessary to arrive at the optimum and economic dose of fertilizers under different agroclimatic conditions.

The positive correlation between leaf area and yield of tubers noticed in the present study suggests the necessity for conducting further investigations on this aspect.

REFERENCES

REFERENCES

Andersen, I.L.	1966	Fertilizer trials with potatoes in Troms and Finn mark. Abs. 2279. Soils & Fertilizers 30:(3).
Anon	1962	National index of Agricultural field experiments. Indian Council of Agric. Res. 5 (Part I):1948-1953.
Awan, A.B.	1965	The effect of fertilization on potato yields. Ceiba 11: (i) 18-21.
Baldwin, C.S., and Davis, J.E.	1966	Effect of time and rate of application of nitrogen and date of harvest on the yield and sucrose content of sugar beets. Agron. J. 58: (4).
Benepal, P.S.	1967	Interrelations among plant nutrients application levels on yield of potatoes. Ann. Potatoe. J. 44: 187-194.
Black, C.A.	1957	Soil plant relationship. John Wiley & Sons Inc., N.Y.
Breda Filho, J., Freire, E.S., and Abramides, E.	1966	Responses of sweet potatoe to increasing rates of nitrogen, phosphorus and potassium. Abs: 1455. Soils & Fertilizers 31: (2).
Caesar, K., and Ganesan, S.	1964	Interrelationship of potash fertilization and starch content in potato. Trop. Agric. Mag. Ceylon agric. soc. 120: 143-144.

Chadha, T.R.	1958	Fertilizer experiments on Tapioca in Kerala State. <u>J. Indian Soc.</u> of <u>Soil. Sci. 6</u>:53-65.
Chamberland, E. and Scott, A.	1968	N - P - K experiments with potatoes in the lower St. Lawrence region of Que bec. Abs. 3717. <u>Soils</u> & <u>Ferti. 31</u>:(5).
Chapman, T.	1965	Experiments with Irish potatoes in Trinidad. <u>Trop. Agri. Trin. 42</u> (3).
Chaudhuri, H.C. & Chaudhuri, S.R.	1958	Fertilizer trials with different planting distances. <u>Amer. Potato. J. 35</u>: (6).
Chidananda Pillai, M.R	1967	"Studies on the effect of N, P, and K Fertilization on the yield and quality of Colocasia". M.Sc.(Ag.) Thesis, Dn. of Agronomy, 1967, Agrl. College, Vellayani.
Duncon, A.A	1958	Effect of KC1 and K_2SO_4 on yield and quality of sweet potatoes. <u>Proc. Amer. Soc. Hort. Sci. 71</u>:391-8
Ellison, J. Howard and Watter C. Jacob.	1954	Fertilizer studies concerning the influence of investigation on the N_2, P_2O_5 and K_2O requirement of 6 potato varieties. <u>Am. Potato. J. 31</u>: 141-51.

Fujise, K., and Tsuno, Y. 1962 Studies on the dry matter production of sweet potato. Proc. Cro. Sci. Soc. Japan 31:(2) 145-49.

Gopalakrishna Pillai, K. 1967 "Studies on the response of N, P and K in conjunction with Ca on the growth, yield and quality of Tapioca" M.Sc. (Ag.) Thesis, Dn. of Agronomy 1967, Agricultural College, Vellayani.

Greig, J.K. 1967 Sweet potato production in Kansas Abs. 3854. Soils & Ferti. 30:(5);

Hanley, F., Jarvis, R.H., and Ridgman, W.J. 1965 The effects of fertilizers on the bulking of Majestic potatoes. Abs. No 1415, Soils and Fertilizers. 29: (2).

Harrap, F.E.G. 1960 Some aspects of the potash nutrition of the potato. J.Sci.Fd. Agric. 11 (6)

Hendersen, R. 1965 Effect of type of potash, and rates of nitrogen, phosphate and potassium in fertilizers on growth, yield and quality of potato crops. Abs. No. 665. Soils & Fertilizers. 29: (1)

Hodnet, G.E. 1958 A fertilizer experiment on Dasheen. Trop. Agric. 35: (3) Trinidad.

* Hoffer, G.N. and Carr, R.H.	1923	Accumulation of alluminium and iron compounds in corn plants and its probable relation to roots rots. Jour. Agr. Res. 23: 801-823.
* Hoffer, G.N. and Trost, J.F.	1923	The accumulation of iron and alluminium compounds in corn plants and its probable relation to root rots. Jour. Amer. Soc. Agron. 15:323-331.
Hougland, G.V.C.	1960	The influence of phosphorus on the growth and physiology of potato plant. Amer. Potato. J. 37: (4).
Irving, H.	1956	Fertilizer experiments with yam in Eastern Nigeria. Trop. Agric. 33: (17).
Izava, G. and Okamoto, S.	1959	Effect of mineral nutrition on organic constituents in Sweet potato plants during growth. Soils and Pl Fd 4: (4) 153-70.
Jaisinghani, C.L. Jain, S.V. and Mehta, K.M.	1964	Response of potato to fertilizers in Rajasthan. Indian Potato J. 6: (1) 13-18.
Johansson, O.	1967	Potato fertilizing. Abs. 3849. Soils & Ferti. 30:(5)
Johnson, W.A. and Ware, L.M.	1948	Effects of rates of nitrogen on the relative yields of sweet potato vines and roots. Proc. Amer. Soc. Hort. Sci. 52: 313 - 316.

Kanwar, J.S.	1962	Manuring of potato in acid soils of Palampur (Kangra - Punjab). Indian Potato. J. 4: (11)
Kunjan, M.N.	1957	Studies on sweet potato. M.Sc. Thesis submitted to the University of Travancore.
Londrau, P., and Samuels, G.	1951	The effect of fertilizers on the yield and quality of sweet potatoes. J. Agri. University, Puerto Rico 35 (2):
Lin, T.C.	1966	Report on Irish potato K test. Abs: 2281, Soils & Ferti. 30:(3)
Loginow, W., Misterski, W., and Klupczynski, Z.	1964	Effect of high rates of mineral fertilizers on potato yields and starch and protein contents in tubers. Abs. No. 2879 Soils and fertilizers 29: (4)
Lucas, R.E.	1954	Effect of potassium carriers and phosphate potash ratios on the yield and quality of potatoes grown in organic soils. Amer. Potato. J. 31: (11).
Mathur, P.N. Chibber, K.N. and Harikishore.	1966	Response to nitrogen levels in relation to the time of application in Colocasia. Indian. J. Agron. XI: (2)189-92
Meyer S. Bernard and Anderson D. Donald.	1952	Plant Physiology. Second Edition. D. Van Nostrand Company Inc. Princeto, New Jersey, New York.

Morgan, N.D.	1939	Relation of fertilization to the yield and keeping quality of Sweet potatoes. <u>Proc</u>. <u>Amer</u>. <u>Soc</u>. <u>Hort</u>. <u>Sci</u>. <u>37</u>: 849 - 54.
Morita, T.	1964	Effects of heavy application of N and K on top growth, tuber formation and tuber thickening of sweet potatoes grown on different types of soil. <u>J</u>. <u>Jap</u>. <u>Soc</u>. <u>Hort</u>. <u>Sci</u>. <u>33</u>:(1)75-80.
Mortan, A.C., & Watson, D.J.	1948	Quoted by E.J. Hewitt in "Essential nutrient elements for plants". Plant Physiology. Edited by F.C. Steward. 1963
Moursi, M.A., and Tayel, M.A.	1957	The distribution of the dry matter and starch in corms of Dasheen. <u>Ann</u>. <u>Agri</u>. <u>Sci</u>. <u>2</u>: (2).
Mozhaeva, K.A.	1966	Results of work for 20 years (1945 - 1965) on the potato crop by the Dept. of plant production and the Timiryazev expt. Station for field crops. <u>Abs</u>: 1452. <u>Soils</u> & <u>Ferti</u>. <u>30</u> (2).
Muhr, G. <u>et al</u>	1963	Soil Testing in India. U.S. Agency for International Development, Mission to India. New Delhi.
Nandpuri, K.S. and Sing, M.	1966	Yield and quality of potato as affected by chemical fertilizers. <u>Indian</u> <u>J</u>. <u>Agron</u> <u>11</u>: 226-228.
Narasimha Rao, R., and Narasinga Rao, M.B.V	1954	Preliminary studies on tuber development of sweet potato grown in Sandy soils. <u>Andhra</u>. <u>Agric</u>. <u>J</u>. 279-290.

Njoku, E. 1957 The effect of mineral nutrition and temperature on leaf shape in *Ipomoea caerulea.* Quoted by Hewitt, E.J., Plant Physiology. Edited by F.C. Steward 1963.

Odland, T.E. and Sheehan, J.E. 1956 Studies on the nutrient requirements of potatoes. *Am. Potato. J.* **33**: (2).

* Pehl, P. and Buchner, A. 1955 Nitrogen manuring and irrigation influence on yield and quality of early potatoes on *Kartoffelban* **6**: (3).

Pleshkov, B.P., and Tavrovskaya, O.L. 1965 The effect of N and P on the forms of N in potato tubers. *F.C.A.* **19**: (2).

Popovic, Z., and Galijasevic, H. 1964 The yield of potatoes fertilized with large amounts of commercial fertilizers and farm yard manure. Abs: 663, *Soils & Ferti.* **29**: (1)

Purewal, S.S. and Dargon, K.S. 1957 The effect of various fertilizers in relation to spacing on development and yield of colocasia. *Indian J. Agron.* **1**: (4).

Purewal, S.S., and Dargon, K.S. 1959 Effect of sowing dates, fertilizers and spacing on development and yield of sweet potato. *Ind. J. Agron.* **3**: (3).

Pushkarnath, Choudhury, R.R., Pritam Singh, and Chhabria, G.T. 1960 Fertilizer responses of potato varieties in relation to irrigation. *Ind Potato J.* **2** (2) 94 - 99

Pushkarnath and Sardana, M.G.	1964	Economics of Nitrogen fertilisation of potato. The Indian Potato J 6: (2).
Raghavachari, K.	1918	Koorkan (Coleus parviflorus) - a root crop of the west coast. Madras agric. J., 1918, 6: 24.
Rajat De	1960	Effect of Potassium on the yield, mineral composition and carbohydrate content of potato varieties. Ind. Potato. J. 2: (2).
Raju, M.S.	1954	Fertilizer studies with potatoes. (Studies on the reduction of manure without detriment to crop yield on the productivity of the soil). Mad. Ag. J. 41: (7)
Rao, V.K.R.V.	1966	India's long term food problem. Kerala University, The Mathai Memorial Lecturers. 1966.
Rauter	1965	Nitrogen manuring and starch yield. Kartofelban 6: (3).
Reddy, V.B. et al.	1968	A note on the relationship between corn yield and certain leaf measurements in taro (Colocasia esculenta (L) Schott). Trop. Agr. Trinidad 45:3, 243-5
Romagnoli, G., and Trovato, G.	1964	The use of foliar diagnosis in testing fertilizer effect on early potato. F.C.A. 19 L (2).
Russel, E. Walter	1956	Soil conditions and plant growth. 1?th edition. Longmans, Green and Co. Ltd. London. W.1.

Schneider, E.	1966	Investigations on the effect of phosphate fertilizer on yield of early potato in relation to application of nitrogen fertilizer. Abs. 1453, Soils & Ferti. 30: (2).
Sheard, and Johnson, G.R.	1958	Influence of N, P and K on the cooking quality of potato. Canad. J. Pl. Sci. 38: (4).
Sheik Daud	1947	UBI KEMILI (Coleus tuberosus) Malay. agric. J. 1947, 30:130.
Singh, M.	1952	Influence of cultural and manurial factors on plant development and yield of potato. Imp. J. of Exp. Agri. 20: (80).
Sommerfeldt, T.G., and Krutson, K.W.	1965	Effect of nitrogen and phosphorus on the growth and development of Russet Burbank potatoes grown in South East Idaho. Amer. Potato. J. 42: (12).
Svensson, B.	1964	The quality of table potatoes.7. Influence of ammonium sulphate and potassium sulphate on the yield and quality of table potatoes. F.C.A. 19: (2).
Tabata, K., and Takase, N.	1968	Effect of heavy application of nitrogen and phosphoric acid on the growth and yield of potatoes. Abs. 3718. Soils & Ferti 31: (5).
Takegami, S.	1962	Studies on the root development of sugarbeet (1) Effects of fertilizers upon the root habits of young plants. Proc. Crop. Sci. Soc. Japan 30:(2)

Tamhane, R.V., Motiramani, D.P., Bali, Y.P. and Roy L. Donahue. 1964 "Soils: Their Chemistry and Fertility in Tropical Asia.". Prentice - Hall of India Private Limited, New Delhi.

Terman, G.L. 1953 Relation of soil and fertilizer potassium to dry matter content and yield of potatoes. Soil Sci. 75 (6).

Thomas, C.V. 1965 "Studies on the response of certain varieties of sweet potato to fertilizer application". M.Sc. (Ag.) Thesis, Dn. of Agronomy, 1965, Agrl. College, Vellayani.

Tsuno, Y. and Fujise, K. 1965 The effect of potassium on the dry matter production of sweet potato. Proc. Crop. Sci. Soc. Japan 33:(3)

Valentin, R. 1964 Nitrogen, Potash, and potato yield and measuring the quality of stored tubers. Potasse 317: 147-55.

Verma, J.K., and Bajpai, M.R. 1965 Response of stock carrots to levels of nitrogen and phosphorus. Ind. J. Agron. 10: 51-4.

Wilcox, E.V. 1912 Annual report Hawaii A.E.S. 56-58.

Zacek, M. 1965 The effect of phosphate fertilizers on the quality of starch in industrial Potato. Abs. 672. Soils & Fertilizers (1).

* Ziegler, G. 1967 Mineral fertilizing and its importance in potato growing. Kuhn Arch 78: 259-67.

* - Originals not seen.

APPENDICES

APPENDIX-I

Analysis of variance

(Leaf area)

Source	Sum of squares	D.F	Variance	F
Total	1213.83	53		
Block	161.01	5	32.20	4.03*
N	724.35	2	362.17	45.38**
P	12.98	2	6.49	0.81
N x P	5.36	4	1.34	0.16
K	24.51	2	12.251	1.53
N x K	30.04	4	7.51	0.94
P x K	37.06	4	9.26	1.16
NPK	3.99	2	1.99	0.24
$N P K^2$	2.96	2	1.48	0.18
$N P^2 K$	21.98	2	10.99	1.37
$N P^2 K^2$	13.85	2	6.92	0.86
Error	175.74	22	7.98	

** - Significant at 1 per cent level.

* - Significant at 5 per cent level.

APPENDIX-II

Analysis of variance

(Number of branches per plant)

Source	Sum of squares	D.F	Variance	F
Total	4575.43	53		
Block	117.43	5	23.48	0.72
N	2470.48	2	1235.24	38.05**
P	21.81	2	10.90	0.33
N x P	83.30	4	20.82	0.64
K	92.59	2	46.29	1.42
N x K	401.52	4	100.38	3.09*
P x K	154.19	4	38.54	1.18
N P K	122.30	2	61.15	1.88
N P K^2	275.59	2	137.79	4.24*
N P^2K	99.55	2	49.77	1.53
N P^2K^2	22.70	2	11.35	0.34
Error	714.27	22	32.46	

* - Significant at 5 per cent level.

** - Significant at 1 per cent level.

APPENDIX-III

Analysis of variance

(Number of tubers per plant)

Source	Sum of squares	D.F	Variance	F
Total	7903.16	53		
Block	1670.43	5	334.08	3.79*
N	1935.25	2	967.62	10.98**
P	133.85	2	66.92	0.75
N x P	824.50	4	206.12	2.33
K	113.91	2	56.95	0.64
N x K	79.57	4	19.89	0.22
P x K	577.78	4	144.44	1.63
N P K	144.47	2	72.23	0.81
N P K^2	30.91	2	15.45	0.17
N P^2K	373.54	2	186.77	2.11
N P^2K^2	80.47	2	40.23	0.45
Error	1938.48	22	88.11	

* - Significant at 5 per cent level

** - Significant at 1 per cent level

APPENDIX-IV

Analysis of variance
(Yield of tubers)

Source	Sum of squares	D.F	Variance	F
Total	1671.04	53		
Block	131.42	5	26.28	1.30
N	666.04	2	333.02	16.47**
P	34.48	2	17.24	0.85
N x P	92.52	4	23.13	1.14
K	17.12	2	8.56	0.42
N x K	102.13	4	25.54	1.26
P x K	146.02	4	36.50	1.80
N P K	14.38	2	7.19	0.35
N P K^2	7.90	2	3.95	0.19
N P^2K	6.02	2	3.01	0.14
N P^2K^2	8.23	2	4.11	0.20
Error	444.78	22	20.21	

** - Significant at 1 per cent level

APPENDIX-V

Analysis of variance
(Percentage of starch content in tubers)

Source	Sum of squares	D.F.	Variance	F
Total	104.05	26		
N	10.44	2	5.22	1.98
P	9.03	2	4.51	1.71
N x P	53.48	4	13.37	5.08*
K	0.36	2	0.18	0.06
N x K	8.41	4	2.10	0.79
P x K	1.25	4	0.31	0.11
Error	21.08	8	2.63	

* Significant at 5 per cent level

APPENDIX-VI

Analysis of variance
(Percentage of moisture in tubers)

Source	Sum of squares	D.F	Variance	F
Total	297.52	26		
N	3.62	2	1.81	0.11
P	13.22	2	6.61	0.41
N x P	34.32	4	8.58	0.54
K	70.20	2	35.10	2.21
N x K	12.25	4	3.06	0.19
P x K	37.14	4	9.28	0.58
Error	126.77	8	15.84	

APPENDIX-VII

Analysis of variance

[Percentage of dry matter in tubers (on oven dry basis)]

Source	Sum of squares	D.F	Variance	F
Total	297.52	26		
N	3.64	2	1.82	0.11
P	13.24	2	6.62	0.41
N x P	34.28	4	8.57	0.54
K	70.21	2	35.10	2.21
N x K	12.22	4	3.05	0.19
P x K	37.11	4	9.27	0.58
Error	126.82	8	15.85	

APPENDIX-VIII

Correlation studies

Sl. No.	Correlation.	Correlation co-efficient	Critical value 0.05 level	Critical value 0.05 level
1.	$r_{y x_1}$	0.75**	0.38	0.48
2.	$r_{y x_2}$	0.76**	0.38	0.48
3	$r_{x_1 x_2}$	0.87**	0.38	0.48
4	$r_{y x_1 \cdot x_2}$	0.28	0.38	0.48
5	$r_{y x_2 \cdot x_1}$	0.33		

** Significant at 0.01 level

y - Yield of tubers

x_1 - Level of nitrogen

x_2 - Leaf area

APPENDIX - IX

Constituents in percentage

	Moisture	Carbo-hydrate	Pro-tein	Fat	Mine-rals	Fibre
Koorka	77.6	19.7	1.3	0.1	0.9	0.4
Potato	74.7	22.6	1.6	0.1	0.6	0.4
Colocasia	73.1	22.1	3.0	0.1	1.7	1.0
Sweet potato	68.5	28.2	1.2	0.3	1.0	0.8
Tapioca	59.4	38.7	0.7	0.2	1.0	0.6
Elephant yam	78.7	18.4	1.2	0.1	0.8	0.8
Ordinary yam	69.9	26.0	1.4	0.1	1.6	1.0

(Source: The Wealth of India, Vol II, CSIR, Government of India, 1950.

The Nutritive Value of Indian Food and

The Planning of Satisfactory Diets, Indian Council of Medical Research, New Delhi, 1963)

APPENDIX-X

Actual yield and estimated yield of tubers

Treatment	Mean leaf area in sq. cm.	Actual yield of tubers in tonnes/ha.	Estimated yield of tubers in tonnes/ha. ($Y = 5.2279 + 0.41927\ L$)
$n_0 p_0 k_0$	15.88	11.25	11.87
$n_0 p_0 k_1$	19.58	14.37	13.41
$n_0 p_0 k_2$	18.68	12.62	13.04
$n_0 p_1 k_0$	19.47	13.25	13.37
$n_0 p_1 k_1$	20.37	16.75	13.74
$n_0 p_1 k_2$	16.35	12.75	12.06
$n_0 p_2 k_0$	17.99	12.75	12.75
$n_0 p_2 k_1$	16.86	9.12	12.27
$n_0 p_2 k_2$	18.45	11.37	12.94
$n_1 p_0 k_0$	20.95	14.25	13.99
$n_1 p_0 k_1$	24.60	13.62	15.57
$n_1 p_0 k_2$	20.42	14.62	13.76
$n_1 p_1 k_0$	26.20	14.87	16.18
$n_1 p_1 k_1$	21.24	13.62	14.11
$n_1 p_1 k_2$	24.03	15.62	15.27
$n_1 p_2 k_0$	22.67	14.62	14.71
$n_1 p_2 k_1$	22.00	13.62	14.42
$n_1 p_2 k_2$	21.57	15.12	14.24
$n_2 p_0 k_0$	26.32	17.00	17.07
$n_2 p_0 k_1$	30.80	18.00	18.11
$n_2 p_0 k_2$	23.17	16.00	14.91
$n_2 p_1 k_0$	23.26	15.62	14.95
$n_2 p_1 k_1$	28.48	19.25	17.14
$n_2 p_1 k_2$	30.48	15.25	17.97
$n_2 p_2 k_0$	24.93	19.62	15.65
$n_2 p_2 k_1$	28.53	16.50	17.16
$n_2 p_2 k_2$	26.39	15.50	16.26