NUTRITIONAL MANAGEMENT IN COLEUS
(*Coleus parviflorus* Benth)

BY
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D E C L A R A T I O N

I hereby declare that this thesis entitled 'NUTRITIONAL MANAGEMENT IN COLEUS (Coleus parviflorus Benth.)' is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title at any other University or Society.

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CERTIFICATE

Certified that this thesis, entitled 'NUTRITIONAL MANAGEMENT IN COLEUS (Coleus parviflorus Benth.)' is a record of research work done independently by Kumari GEETHA, K. Under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

INTRODUCTION

Tuber crops are the third most important food crops of man after cereals and grain legumes. They constitute either the staple or important subsidiary food for about a fifth of the people of the world. The tuber crops are important because they possess high potentiality for yielding large amount of food per unit area and are biologically efficient producers of calories. The importance of these crops can be judged from their world coverage of about 50 million hectares and production of about 500 million tonnes of tubers. In India, they are grown in over 1.3 million hectares and production of about 16.4 million tonnes of tubers (Nayar and Nair 1983). The tropical tuber crops including cassava and sweet potato account for about a half of this area and production. Area and production figures for the other tropical tuber crops are not available, but they are known to be cultivated throughout India. These include the yams (Dioscorea spp.), aroids (Amorphophallus Colocasia, Xanthosoma etc.) coleus and arrow root which are grown in homesteads or in framented holdings under mixed and multiple cropping systems.

Among the minor tuber crops Coleus parviflorus (syn. C. tuberosus) is an important one grown extensively as a vegetable in most of the homestead gardens in Kerala and in parts of Tamil Nadu and Karnataka. It is commonly known as Koorka or Cheeva kizhangu, Chinease potato or poorman's potato. It is grown for its small edible tubers which can be used as a substitute for potato.

Coleus is believed to be a native of Africa. The crop thrives well under tropical and subtropical conditions. The total area and production in Kerala are not correctly estimated as its cultivation is mostly restricted to homesteads. So a survey on this aspect is essential to bring out its importance. Coleus is being cultivated in various parts of Palghat, Malappuram, Wyanad and Trivandrum districts of Kerala. The tuber is a common vegetable in all households and its food value compares favourably with most of the other tuber crops. Being a short duration crop with the growing period extending upto five months, it can be cultivated during the rabi season.

The yield of minor tuber crops in Kerala is only 20-80 q/ ha (Hrishi and Nair 1972). These yields are very low compared to that registered in other tuber-crop growing countries and the average yield can, no doubt, be increased by two to three fold with the use of improved varieties and crop management practices. Research work on minor tuber crops in Kerala is meagre and for coleus only little published data regarding various agronomic practices are available. Package of practices for the scientific cultivation of this crop has to be developed. Though there are a number of agronomic problems which require investigation with regard to this crop, immediate attention is to be focussed on the nutritional requirement and their time of application for fetching high yields.

Thyagarajan (1969) reported the beneficial effects of application of fertilizers to coleus. The results from his studies indicate that further investigation with various levels of nitrogen and potassium are necessary to arrive at the optimum and economic dose of fertilizer under different agroclimatic conditions. The spacing and manurial trial conducted at Coconut Research Station, Nileswar, Kerala indicated that optimum requirement of nitrogen and potassium were 80 kg/ha each for that region. At present there are no proper recommendations on nutrition aspect and time of application of nutrients to this crop for the Southern districts.

So the present investigation was undertaken with the following objectives:

1. To fix an optimum dose of N, P and K for *Coleus parviflorus*
2. To assess the effect of the major nutrients on growth and yield of the crop;
3. To find out a suitable time of application of fertilizers to this crop;
4. To investigate the effect of N, P and K on quality of tubers;
5. To work out the economics of production of *Coleus parviflorus*.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Though coleus (*Coleus parviflorus*) is being grown as a vegetable in many part of the world only a few works seems to have been done on this crop and reported data available as to its manurial requirements are meagre. However, the significance of fertilizer application in increasing the yield of other tuber crops has been brought out by experiments conducted in India and abroad which are chiefly concerned with the effects produced by nitrogen and potassium. The review of these works done on potato, sweet potato and *Dioscorea spp* are given below.

NITROGEN

1. Effect on growth characters

a) Height and spread of plant

With the application of 56 kg N/ha the length of vines in sweet potato significantly increased over no nitrogen (Purewal and Dargan 1959).

Dubey and Bhardwaj (1971) noted that nitrogen increased plant height in potato compared with control receiving no nitrogen.

Field trials were conducted by Krishnappa and Shivashankara (1981) with potato, cv. Kufri Chandramuki to study the responses of potato to two levels of nitrogen (80,120 kg/ha) and its time and method of application on red laterite soils of Bangalore. They had shown that application of nitrogen increased plant height significantly.

Nambiar et al. (1976) reported that increasing rate of applied nitrogen had no significant effect on the length of vines in sweet potato at Vellayani.

b) Number of branches and leaves

Significant increase in vine production in sweet potato was observed for each increment of nitrogen applied from '0' to 134.4 kg/ha (Johnson and Ware 1948).

Morita (1967) had shown that high proportion of nitrogen resulted in vigorous growth of sweet potato.

In a trial conducted by Dubey and Bhardwaj (1971) on potato it was noted that nitrogen increased number of branches per plant.

Krishnappa and Shivashankara (1981) obtained increased fresh weight of haulms with increased nitrogen application.

On the contrary Nambiar _et al._ (1976) reported no significant effect on weight of vines in sweet potato at harvest with increasing rate of nitrogen application.

II. Effect on yield and yield attributes

Increased yield of sweet potato tubers was noted by Purewal and Dargen (1959) by the application of 56 kg N/ha

Gupta (1969) had shown that application of 50,100 and 150 kg N/ha to potato cv-K-122 increased the tuber yields by 37.1, 59.6 and 81.2 q/ha respectively, compared to plots given no nitrogen (18.7 q/ha).

An experiment with coleus crop laid out by Singh and Maini (1969) with six levels of nitrogen (0,20,40, 60, 80 and 100 kg/ha) showed that the tuber yield increased significantly with increase in nitrogen from 0 to 60 kg/ha and beyond that there was no positive response.

Dubey and Bhardwaj (1971) in trials with potato using a basal dressing of 50 kg P_2O_5 and 75 kg K_2O/ha and 0, 100 or 200 kg N/ha had pointed out that nitrogen increased the fresh and dry weight of tubers per plant compared with controls given no nitrogen. Yield of tubers was 48.6 per cent and 42.0 per cent higher than the controls, with 100 kg and 200 kg N/ha respectively.

Mandal et al. (1971) observed that for sweet potato in the red loam soils of Kerala maximum tuber yield was obtained at 100 kg N/ha which was not significantly superior to 75 kg nitrogen/ha. Maximum drymatter content was noticed at the nitrogen dose of 75 kg/ ha.

Dasgupta and Ghosh (1973) revealed that increasing the rate of nitrogen from 0 to 200 kg/ha applied in addition to a basal dressing of 89 kg P_2O_5 + 68 kg K_2O/ha produced linear increases in tuber yield of potato cultivars.

Trials on the effect of different levels of nitrogen (0,20,40,60, 80 and 120 kg/ha) on Dioscorea alata were laid out at Central Tuber Crop Research Institute, Trivandrum for two years. The results showed that nitrogen levels upto 60 kg/ha along with the farm yard manure at 25 tonnes/ha and P_2O_5 and K_2O at 80 kg/ha had significantly influenced the tuber yield and quality constituents of yams (Singh et al. 1973).

Nambiar et al. (1976) reported that increasing rate of applied nitrogen significantly increased the number of tubers per plant in sweet potato. Tuber yield increased with increasing the rate of applied nitrogen, being 8.1 t at 50 kg N/ha 9.4t at 75 kg N/ha and 10.5t at 100 kg N/ha.

Talleyrand and Lugolopez (1976) conducted field trials with sweet potato cv. Blanquito using 0, 10, 20, 40 or 50 kg N/ha. Highest (14.5t/ha) and lowest (7.9t/ha) tuber yields were obtained with 40 kg N and 0 kg N/ha respectively.

Shukla and Singh (1976) pointed out that in potato increasing the nitrogen rates from 0 to 75, 150 and 225 kg/ha increased average tuber yields from 6.52 to 19.44, 26.50 and 27.71t/ha respectively.

In an experiment conducted at Nileswar (Anon 1978) on coleus it was found that raising the nitrogen level from 40 to 80 kg gave an additional yield of 692 kg tuber/ha which was significantly superior to 40 kg N/ha.

Grewal et al.(1979) reported that application of 0,40,80 and 120 kg N/ha to potato gave average tuber yields of 17.4, 28.4, 37.5 and 38.5 t/ha respectively; the difference between the last two nitrogen rates was not significant.

Krishnappa and Shivashankara (1981) also observed significant increase in potato tuber yield with increased nitrogen application. It also increased number of tubers per hill.

Effect of nitrogen on tuber size and number of marketable tubers

In an experiment by Gupta (1969) it was shown that the yield of "ware tubers" (diam > 5 cm) in potato increased linearly with increase in the nitrogen rate.

Dean (1971) observed that the size of tuber in sweet potato was influenced by the nitrogen content of the medium and that nitrogen had no effect on the number of tubers per plant. The presence of a high level of nitrogen in the absence of potash was responsible for long tubers while the presence of potash in the medium reduced tuber length considerably.

Dasgupta and Ghosh (1973) did not obtain any proportional increase in the number or size of tubers in potato. Nitrogen application in general was found to stimulate the initiation of more tubers of bigger size in each variety tried. The greater growth of the tubers under high nitrogen fertilization possibly indicated greater translocation of photosynthates from a relatively large source formed to the ever increasing sink.

Shukla and Singh (1976) reported that increasing nitrogen rates from 0 to 75, 150 and 225 kg/ha increased tuber grade in potato.

Talleyrand and Lugolopez (1976) conducted trials in potato using 0,10,20,40 and 50 kg N/ha. Highest marketable tuber yields (146t/ha) were obtained with the application of 40 kg/ha of nitrogen.

In another experiment with potato at several locations using nitrogen from 0 to 336 kg/ha, Munro et al. (1977) got increased percentage of 'A' size tubers by the application of nitrogen upto 134 kg/ha.

Grewal et al. (1979) also reported that applied nitrogen increased tuber size in potato.

Effect on nitrogen content and uptake

A positive correlation between nutrient contents of sweet potato tubers and vegetative parts during the growth period was observed by Mica (1969).

Nair et al. (1976) in their study on the effect of levels and time of application of nitrogen on the uptake of nitrogen by three sweet potato varieties found that there was increase in total nitrogen uptake upto 100 kg N/ha, differences in uptake by tubers contributing to differences between levels of application. Mica and Vokal (1978) had shown that application of 150 kg N/ha gave best results in total nitrogen uptake.

Grewal *et al.* (1979) pointed out that applied nitrogen increased leaf nitrogen content and nitrogen uptake by tubers.

Rao and Arora (1979) observed that increase in nitrogen rates increased the total nitrogen uptake and tuber nitrogen contents.

Input trials with potato, Wunsch and Hunnius (1980) reported that applied nitrogen increased the nitrogen content of haulms considerably and increased that of tubers less markedly. The highest rate of applied nitrogen increased the nitrogen content of leaves, stems and tubers by 1.5, 1 and 0.5 per cent respectively, compared with untreated controls.

But Mica (1969) reported that there was however, no significant relation between nutrient content of tuber and rate of fertilizer application.

Quality of Tubers

Significant decline in both sugars and starch in sweet potato tubers resulted as a consequence of nitrogen supply (Dean and Lasheen 1969).

Singh and Maini (1969) reported that coleus dry-matter content increased with increase in nitrogen level upto 60 kg/ha while maximum carbohydrate and crude protein content were noted at 40 and 80 kg N/ha respectively.

Wilcox and Hoff (1970) had shown that 84 kg N/ha increased tuber crude protein content from 9.5 per cent to 12.9 per cent while the net increase of crude protein per acre in potato was 223 lb. (250 kg/ha) Added nitrogen was effectively converted to crude protein (48 per cent incorporation) at the 75 lb (84 kg/ha) rate but poorly (5 per cent incorporation) at higher rates.

Mandal et al. (1971) obtained an increase in crude protein content of sweet potato tuber upto 100 kg N/ha though nitrogen supply beyond 75 kg/ha failed to bring about significant yield response.

According to Verma et al. (1975) there was a negative linear relationship for nitrogen content and starch content.

Shukla and Singh (1976) stated that increasing nitrogen application increased tuber protein content but decreased starch content in potato.

Wunsch and Hunnius (1980) also noted that starch content was unchanged or slightly decreased by higher rates of nitrogen, with no relation to the nitrogen using ability of the cultivar used. Nitrogen fertilization increased the protein nitrogen content by 15-90 percent

Effect of split application of nitrogen on growth of plants

Favourable effect of split application of nitrogen once at planting and again 30 days after planting on moderating top growth during tuber forming period and enhancing top growth during tuber development period has been reported by Morita (1967).

In a similar experiment he observed vigorous top growth as a consequence of early application of nitrogen on clay loam soils (Morita 1970). He also observed that delay in the application of nitrogen increased vine elongation.

Effect on yield and yield attributes

In an experiment conducted at Central Tuber Crop Research Institute, Trivandrum on coleus six levels of nitrogen (0, 20, 40, 60, 80 and 100 kg/ ha) along with three methods of application (full dose as soil, full dose as foliar spray, and half dose as soil + 1/2 dose as foliar spray) were tried. The results showed that maximum tuber yield was recorded at 60 kg N/ha when applied half dose as soil + half dose as foliar application (Singh and Maini 1969).

Sikka and Singh (1969) stated that in potato application of nitrogen in two split dressings at planting and thirty days after with the first irrigation gave average yields of 230-231 q/ha of tubers compared with 211 q/ha on plots where the full nitrogen was broadcasted at planting. It appears that the nitrogen applied at planting alone was not wholly available to the plant. On the other hand earlier emerging plants from the treatments receiving split doses or where nitrogen had been applied thirty days after planting would be given photosynthetic activity earlier and accelerate tuberization and bulking. Supplemental nitrogen helped in maintaining the functional life of foliage during tuberization and resulted in final yield increase. Split doses of nitrogen extended functional life of potato foliage permitting more tubers to reach a marketable size.

Ram (1976) pointed out that top dressing with 50 kg N/ha 35 days after planting increased the yield of crops, given a basal dressing of 100-150 kg N/ha. The optimum economic rate of nitrogen was 150 kg/ha. Application of nitrogen in two split dressings was superior to application in a single dressing at planting.

Krishnappa and Shivashankara (1981) stated that application of 80 kg N/ha to potato ie. 40 kg/ha applied to the soil at planting + 40 kg/ha applied to the soil at earthing up recorded the highest yield and appeared to be optimum dose.

Sagar and Singh (1973) conducted trials in potato using 0-150 kg N/ha at planting with and without top dressing with 50 kg N/ha at 35 days after planting. Application of 100 kg N/ha at planting gave the highest tuber yields.

Grewal _et al_. (1979) stated that application of upto 80 kg N/ha to potato in a single dressing at planting was superior to its application in split dressings but for 120 kg N/ha the split application was better.

On nitrogen uptake and quality of tubers

In an experiment with coleus by Singh and Maini (1969) it was shown that full dose of nitrogen application in the soil gave the highest value of carbohydrate content whereas half dose as soil and half dose as foliar spray recorded the highest crude protein content. In field trials Hunnius and Munzert (1979) found that starch yields are maximum when applied at 80 + 40 kg N than when applied in a single dressing. Although starch content was decreased by increase in applied nitrogen, at 160 kg N/ha it was further increased by splitting and dressing.

In the trials by Sagar and Singh (1973) two potato cultivars were given 0-150 kg N/ha at planting with or without top dressing with 50 kg N/ha at 35 days after planting. Application of 100 kg N/ha at planting gave the highest values for N uptake and tuber starch contents. Nair et al. (1976) reported that time of application of nitrogen was found to have no conspicuous effect on nitrogen uptake by sweet potato.

POTASSIUM

Effect on growth characters

Potassium increased the size of the leaves in the early part of the growing season, though this effect had disappeared at harvest and that this initial increase was sufficient to account for the differences in yield of roots without having to assume any effect of potassium on the efficiency of photosynthesis (Watson 1947).

Russel (1973) stated that adequate supply of potassium in the leaf is probably essential for the photosynthetic process to go on efficiently. Potassium acts as a corrective to the harmful effects of nitrogen and is therefore often required for crops receiving high levels of nitrogenous manures.

Godfrey-Sam-Aggrey and Garber (1976) stated that fertilizers containing high potassium rates gave low vine yield in sweet potato. Potassium application increased growth of tubers (Bautista and Santiago 1981).

Effect on yield and yield attributes

In an experiment with potato it was reported that higher application of potassium was found to improve tuber efficiency. Higher tuber efficiency was given by 180 and 120 kg K_2O/ha than 60 kg K_2O/ha. Application of 180 kg K_2O/ha gave significantly higher rate of bulking over others (Shukla and Singh 1975).

Sharma et al. (1976) noted that yields increased with increasing K_2O rates in one year and upto 84 kg K_2O/ha in the other year.

Coleus was found to respond to potassium applications. Over pooled analysis application of potassium at the rate of 120 kg/ha increased the yield by 627 kg over potassium applied at 40 kg/ha (Anon 1978).

Verma and Grewal (1979) stated that application of 33-100 kg K_2O/ha increased tuber yields in potato. Optimum rate was found to be 77-79 kg K_2O/ha. Bautista (1981) in a pot culture study had shown that potassium application increased tuber yield from 0.36 kg/pot with no potassium to 0.57 kg with 600 ppm potassium.

Effect on tuber size and marketable tubers

Potash fertilizers influenced size and shape of Sweet potato (Scott 1950).

High percentage of mårketable tubers was obtained by potassium fertilizations to Dioscorea spp. (Obigbesan et al. 1982).

Sharma et al. (1976) reported that applied potassium increased yield of large tubers and had no significant effect on yields of medium and small tubers in potato.

Verma and Grewal (1979) got increased tuber yields in potato mainly by increasing tuber size by potassium fertilization.

Effect on uptake and quality

Applied potassium increased tuber potassium contents and uptake in potato (Sharma et al. 1976)

Belyaev et al. (1982) got highest tuber starch contents in potato with 20-25 mg K_2O/100 g soil. The optimum K_2O contents in tubers and tops at harvest were 2.9 - 3 and 4.7 -6.6 per cent respectively, to obtain highest tuber yields and 1.8 - 2.2 and 1.9 - 3.6 per cent for highest starch content. The starch contents on potassium deficient soil without applied potassium were 8.8 -10.7 per cent. They were increased to 13.4 -15.4 per cent with optimum rates of applied potassium and were decreased to 11.1 - 13.4 per cent with further increases in potassium rates.

Scott (1950) revealed that potash had no significant influence on the starch content of sweet potato.

Effect of split application of potassium on growth, yield and uptake

Highest yield of dry matter/ha was obtained for potato at fertilizer levels of 150 kg N, 80 kg P_2O_5 and 90 kg K_2O/ha with split application of potassium at sowing, at earthing and bulking. Recovery of applied potassium was highest (45 per cent) with three split application and lowest with a single basal dressing at sowing (Shukla and Rao 1974).

Potassium has been identified as being necessary for rapid translocation of nutrients at the later stage of tuberization and bulking. Split application of potash is associated with efficient absorption and translocation of nutrients from the soil and foliage. This technique achieves quick recovery of the applied nutrients and comparatively better control over equilibrium between vegetative growth and bulking of tuber (Shukla and Singh 1975).

Shukla and Singh (1976) obtained highest yield and best nutritive value of potato tubers with 180 kg K_2O/ha given half to the soil and half as foliar application. Split application of potassium resulted in the greatest uptake of potassium. They also revealed that tuber starch, protein and ascorbic acid contents increased with increasing potassium application and were greatest with 50 per cent to the soil + 50 per cent as foliar spray.

Krishnappa and Muddappa Gowda (1979) stated that 100 kg K_2O/ha applied in three split dressings (50 per cent at planting and the remainder in 2 equal foliar sprays 40 and 54 days after planting) gave the highest average tuber yield of 32-54 t/ha compared with 28.65 t with NP; it also increased the proportion of large tubers produced.

Effect of combined application of N, P and K

N, P and K in various combinations increased yield of vines, while PK combinations decreased vine yield in sweet potato (Yong 1970).

Kamel (1975) reported that phosphorus and potash deficiency in soil decreased leaf area in potatoes.

Applied potassium increased growth, leaf area duration of photosynthetic activity of leaves and tuber yields.

Azih (1976) revealed that the maximum leaf area per plant was found in plants receiving 80 lbs nitrogen and 160 lbs potassium per acre. This was followed by plants supplied with 80 lbs nitrogen and 80 lbs potassium per acre.

Hafizuddin and Haque (1979) found out that length of vine per plot was not affected by nitrogen and potash treatments in sweet potato. The number of branches per plant and weight of vines per plot were maximum with 78.52 kg N/ha and no potassium.

<u>On yield and yield attributes</u>

Yong (1970) reported that N, K and NPK increased yield of tuber in potato, while P had no effect.

Misra and Mohanty (1973) obtained highest yield of tubers when potato variety <u>Kufri Sindhuri</u> received 160 kg N, 80 kg P_2O_5 and 160 kg K_2O/ ha.

The response of <u>Dioscorea esculenta</u> to four levels of nitrogen and five levels of potash was tested in a factorial experiment by Singh et al. (1973). The data revealed that the tuber yield increased progressively with the increase in nitrogen application upto 80 kg and 120 kg K_2O/ha but declined with further application of nitrogen and potassium.

Varis (1973) revealed that highest yield of tuber dry matter was obtained with 100 kg N/ha and 174 kg P_2O_5/ha while the effect of potassium was not significant.

Azih (1976) reported that nitrogen depressed the yield when it was combined with potassium at the highest levels of each. A gradual increase in weight of tubers was also noted along with the increment in nitrogen and potassium. Maximum weight of tubers was obtained in plants receiving 80 lb N and 160 lb K (179 kg/ha) per acre followed by plants receiving 80 lb N and 80 lb K per acre. (89.6 kg/ha)

Godfrey-Sam-Aggrey and Garber (1977) had shown that in sweet potato fertilizers containing high potassium rates and N/K ratio of 3:4 gave maximum tuber and low vine yields with low vine to tuber ratios on intensively cropped areas whereas fertilizers containing lower potassium rates and an N/K ratio of 3:1 gave maximum but relatively high vine tuber ratios in newly cropped areas after seven years bush fallow.

Highest tuber yields of 22.2 t/ha was obtained by application of 180 kg N + 50 kg P_2O_5 + 50 kg K_2O/ha followed by 20.4 t/ ha with 180 kg N + 50 kg P_2O_5/ha as compared with 10.7 t/ha without nitrogen, phosphorus and potash (Krishnappa and Gowda 1976).

Azih (1976) had observed that applications of 67.2 kg N + 134.4 kg K_2O to yellow yam gave the highest average tuber yields of 21 t/ha compared to 165 t/ha without N, P and K. Fertilizers had no adverse effect on tuber quality during storage.

Grewal and Trehan (1979) proved that tuber size and yield and phosphorus and potash uptake were significantly increased with their application. The direct and cumulative effects of phosphorus and potash were significantly better than their residual effects.

Hafizuddin and Haque (1979) obtained tuber yields ranging from 22.14 t/ha with no fertilizer to 29.13 t with 39.26 kg N + 84.14 kg K/ha in potato.

Loue (1979) reported that maximum tuber yield in potato was obtained with an application of 232 kg K_2O/ha. Positive nitrogen and potash interactions generally occurred, the optimum application of nitrogen being approximately 150 kg/ha.

Patel and Patel (1980) had shown that potato yields were highest with 150 or 200 kg/ha each of N, P_2O_5 and K_2O with no significant difference between these two N, P and K rates.

The results of Muthuswamy et al. (1981) indicated that in sweet potato nitrogen application had significantly increased the tuber yield over control but the difference between 50 and 100 kg N/ha was not appreciable. Potash levels though did not have any significant influence on the tuber yield had increased the starch content.

Purewal and Dargan (1959) on the other hand observed that application of 50 lb nitrogen per acre increased the weight of sweet potato tubers by 27.5 per cent and applications of phosphate and potash gave no response.

Effect on size of tubers

Application of 120 lb N + 90 lb P_2O_5 + 60 lb K_2O/acre produced the maximum number of grade 'A' tubers in sweet potato (Miah et al. (1974)

White et al. (1974) noted that increased rates of nitrogen and potash resulted in increased total yields and percentage of 'A' size tubers.

Proportion of small tubers decreased with increase in N P K fertilizers and that of medium and large tubers increased in sweet potato (Widdowson and Penny 1975).

Gupta and Saxena (1975) stated that increasing nitrogen rates from 0 to 240 kg/ha increased percentage of large tubers in potato. Application of 60-80 kg P_2O_5/ha had no effect on yield of various grades of tubers.

Loue (1979) pointed out that nitrogen and potash fertilizers increased the size of tubers but decreased the drymatter content in potato.

Effect on nutrient uptake and quality

In an experiment on Dioscorea esculenta it was found that the percentage of dry matter was not much affected by varying levels of nitrogen and potash fertilization. The starch content showed a slight increase upto 40 kg N per hectare and crude protein content increased upto 80 kg N per hectare. In the case of potash, starch content showed a slight increase upto 40 kg N per hectare and crude protein content increased upto 80 kg N per hectare. In the case of potash, starch content responded upto 120 kg K_2O per hectare while the sugar content increased upto 80 kg K_2O per hectare but the maximum crude protein content in tubers was recorded at 40 kg K_2O per hectare (Singh et al. 1973).

Varis (1973) revealed that nitrogen fertilization to potatoes increased the uptake of N, P and K, Ca and Mg. Phosphorus application increased the uptake of N, K, Ca and Mg. Potassium application had no effect on N, P or K uptake but the uptake of P was reduced by a heavy N K application.

Gupta and Saxena (1976) reported that nitrogen increased tuber protein contents and decreased starch and dry matter contents.

Muthuswamy and Krishnamoorthy (1976) stated that tuber protein contents were increased with 50 kg K_2O/ha and 100 kg K_2O/ha and were not affected with N or P.

As the rate of potassium but not phosphorus application was increased the percent dry matter was decreased. Potassium and Phosphorus applications reduced protein content and firmness of canned roots. Potassium slightly increased crude fibre content in potato (Constantin et al. 1977)

Loue (1979) reported that nitrogen and potash removal increased with increasing applications of nitrogen and potash fertilizers respectively.

Singh and Grewal (1979) observed that in potato translocation of nitrogen, phosphorus and potash to tubers increased upto harvesting. Uptake of Nitrogen and potash was highest during 30-60 days after planting and that of phosphorus increased linearly upto 80 days after planting.

MATERIALS AND METHODS

MATERIALS AND METHODS

The response of Coleus to different levels and timings of nitrogen and potassium application was investigated in a statistically laid out field experiment.

Experimental site

The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani. The area was under guinea grass for the past three years.

Soil

The soil of the experimental area is red loam. Mechanical composition and chemical properties of the soil are given below.

Mechanical composition

Table 1(a)

Gravel	2.9%
Coarse sand	25.4%
Fine sand	27.1%
Silt	24.8%
Clay	19.8%

Chemical properties

Table 1(b)

Total Nitrogen (kg/ha)	2520 kg/ha	Modified Microkjeldahl method
Available P_2O_5 (kg/ha)	65 kg/ha	Bray's method
Available K_2O (kg/ha)	64 kg/ha	Ammonium acetate method
pH	5.1	1: 2.5 soil solution ratio using pH meter

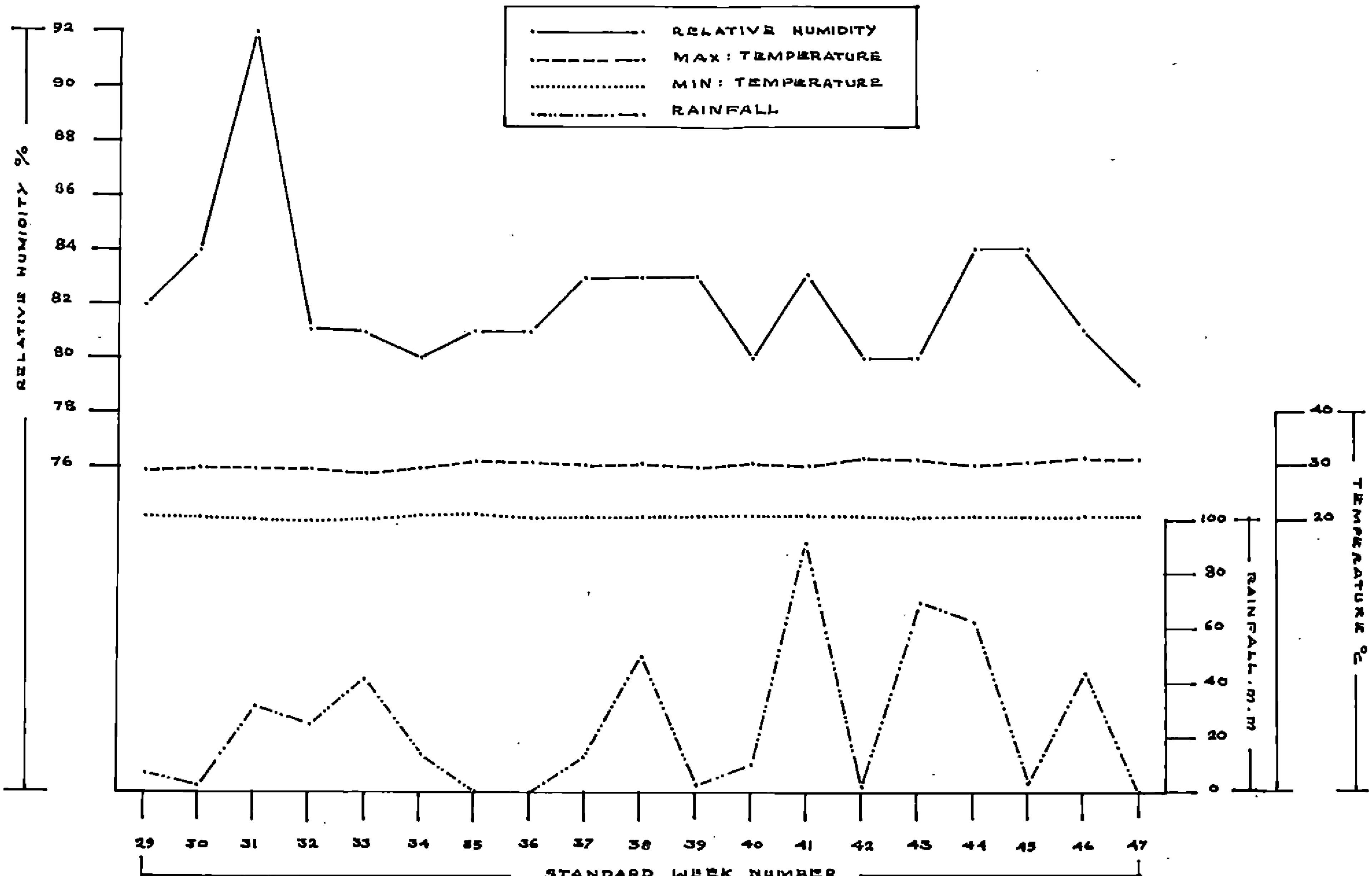
Season and weather

The experiment was started during the second week of July 1982 and completed by the last week of November 1982. The weekly average of temperature and relative humidity and weekly totals of rainfall during the cropping period and monthly averages for the past twenty four years are presented in Fig.I and Appendix I respectively.

Materials

Seed material

The tubers of the local variety of Coleus required for the experiment was obtained from the Instructional Farm, Mannuthy.



WEATHER CONDITIONS DURING CROPPING PERIOD (16th July - 25th Nov.

FIG: 1

Manures and Fertilizers

A uniform basal application of cattle manure at the rate of 10 tonnes per hectare was given to all the plots. Fertilizers containing the following analytical values were used in the experiment.

1. Urea - 46% Nitrogen
2. Superphosphate - 16% P_2O_5
3. Muriate of potash - 60% K_2O

Methods

Layout of the experiment

The experiment was laid out in a factorial $5^2 \times 2$ Randomised Block Design with 2 replications. The lay out plan is given in Fig.2.

Treatments

(a) Nitrogen levels (N)

N_0 - No nitrogen

N_1 - 30 kg N/ha

N_2 - 60 kg N/ha

N_3 - 90 kg N/ha

N_4 -120 kg N/ha

$N_1K_1T_1$	$N_2K_1T_2$	BULK
$N_4K_3T_1$	$N_0K_4T_1$	$N_0K_0T_2$
$N_0K_0T_1$	$N_3K_4T_2$	$N_2K_1T_1$
$N_1K_2T_2$	$N_4K_3T_2$	$N_4K_4T_1$
$N_3K_3T_2$	$N_0K_4T_2$	$N_4K_0T_1$
$N_2K_3T_2$	$N_3K_2T_1$	$N_1K_3T_2$
$N_2K_0T_1$	$N_3K_1T_1$	$N_3K_0T_2$
$N_0K_3T_2$	$N_2K_4T_2$	$N_4K_1T_1$
$N_3K_4T_1$	$N_1K_0T_1$	$N_4K_2T_2$
$N_2K_0T_2$	$N_2K_3T_1$	$N_1K_4T_2$
$N_3K_1T_2$	$N_0K_1T_2$	$N_0K_1T_1$
$N_2K_2T_2$	$N_4K_2T_1$	$N_0K_2T_1$
$N_3K_0T_1$	$N_3K_2T_2$	$N_4K_1T_2$
$N_0K_2T_2$	$N_1K_4T_1$	$N_0K_3T_1$
$N_1K_1T_2$	$N_1K_0T_2$	$N_4K_4T_2$
$N_1K_2T_1$	$N_2K_2T_1$	$N_1K_3T_1$
$N_4K_0T_2$	$N_2K_4T_1$	$N_3K_3T_1$

2.4 M

3.6 M

$N_1K_2T_1$	$N_0K_1T_1$	$N_1K_2T_2$
$N_1K_4T_2$	$N_3K_1T_1$	$N_3K_4T_1$
$N_0K_4T_2$	$N_1K_3T_2$	$N_0K_4T_1$
$N_3K_2T_1$	$N_1K_1T_1$	$N_1K_0T_2$
$N_0K_2T_1$	$N_2K_3T_2$	$N_4K_4T_2$
$N_4K_1T_2$	$N_4K_0T_2$	$N_0K_2T_2$
$N_0K_3T_2$	$N_2K_4T_1$	$N_4K_4T_1$
$N_2K_0T_1$	$N_0K_0T_1$	$N_2K_3T_1$
$N_3K_3T_1$	$N_4K_3T_1$	$N_2K_4T_2$
$N_0K_3T_1$	$N_2K_2T_2$	$N_2K_0T_2$
$N_3K_1T_2$	$N_1K_0T_1$	$N_3K_0T_1$
$N_4K_0T_1$	$N_4K_2T_2$	$N_3K_4T_2$
$N_2K_1T_1$	$N_1K_1T_2$	$N_3K_2T_2$
$N_1K_4T_1$	$N_4K_3T_2$	$N_3K_0T_2$
$N_4K_1T_1$	$N_3K_3T_2$	$N_2K_2T_1$
$N_0K_0T_2$	$N_0K_1T_2$	$N_1K_3T_1$
BULK	$N_4K_2T_1$	$N_2K_1T_2$

N

TREATMENTS

NITROGEN (kg / ha)

N_0 – 0

N_1 – 30

N_2 – 60

N_3 – 90

N_4 – 120

POTASH (kg / ha)

K_0 – 0

K_1 – 30

K_2 – 60

K_3 – 90

K_4 – 120

TIME OF APPLICATION

T_1 – ENTIRE DOSE BASAL

T_2 – ½ N, ½ K BASAL
½ N, ½ K 30 DAYS AFTER PLANTING

FIG: 2 LAY-OUT PLAN – RANDOMISED BLOCK DESIGN

(b) Potassium levels (K)

K_0 - No potassium

K_1 - 30 kg K_2O/ha

K_2 - 60 kg K_2O/ha

K_3 - 90 kg K_2O/ha

K_4 -120 kg K_2O/ha

(c) Time of application (T)

T_1 - Entire dose as basal

T_2 - 1/2 N, 1/2 K basal

- 1/2 N, 1/2 K 30 days after planting.

Phosphorus was applied as a uniform basal dose of 30 kg P_2O_5/ha to all plots.

Treatment combinations - 50

Replication - 2

Spacing - 60 cm x 15 cm

Gross plot size - 3.6 m x 2.4 m

Two border rows and one destructive row were left.

Net plot size - 1.8 m x 2.4 m

<u>Sampling technique</u>

Five plants were selected at random from each plot for recording periodical biometric observations leaving the border and destructive rows. Two plants were uprooted periodically from the destructive rows left out for observations on leaf area index and dry matter production.

Field culture

Preparation of field

The experimental area was dug twice, stubbles removed clods broken and the field was laid out into blocks and plots. Each plot was formed into a raised bed of 15 cm height. The beds were levelled and farm yard manure was incorporated uniformly to all beds.

Fertilizer application

Full dose of phosphorus as super phosphate was applied along with basal dose of nitrogen and potassium according to treatment. Among fifty plots, two plots were treated as control plots. Out of the balance 48 plots, half the number (24) received full nitrogen as urea and full potassium as muriate of potash as basal dose, while the other set of 24 plots received half of the nitrogen and potassium as basal and the balance 30th day after planting as top dressing.

Seeds and sowing

A nursery was raised for obtaining Coleus stem cuttings for planting in the main field. Tubers were sown first in nursery having good drainage facilities, after applying farm yard manure at the rate of one kg/ sq.metre during the last week of May 1982. Coleus stem cuttings collected from the nursery were cut into setts of 15 cm length. Healthy and vigorous cuttings from the top portion were used for planting. These cuttings were planted at a spacing of 60 cm between rows and 15 cm between plants. Planting was done on 22.7.'82. Shade was provided immediately after planting and uniform irrigation was given. Gap filling was done on the seventh day to secure uniform stand of the crop.

After care

One weeding was given one month after planting. Top dressing was done in bands on the two sides of the row. All the plots received a uniform earthing up two months after planting.

General condition of the crop

The stand of the crop was satisfactory throughout the period of growth. Plants showed yellowing in plots which received no nitrogen. Plants in plots which received no potassium showed tip burning symptoms.

Harvesting

The crop was harvested four months after planting (Maini, et al. 1975). Maturity was indicated by senescence of above ground parts. Marked observation plants were uprooted a day prior to harvest and border plants were removed before harvesting the net plots. Tubers were dug out from the net plot area after cutting and removing the above ground parts.

Observations recorded

1. Height of the plant

The height of the plant was recorded at thirty days interval. The height was measured from the base of the plant to the tip of the growing point and expressed in cm.

2. Number of branches per plant

Number of branches were counted at thirty days interval after planting and recorded.

3. Leaf number

Total number of functional leaves was counted at 30 days interval after planting.

4. Plant spread

Spread of the plant was recorded at monthly intervals.

The spread was measured from the tip of the largest branch to the tip of the growing point of the largest branch in opposite direction.

5. Leaf area index

Leaf area index was calculated at 60th and 90th days after planting by adopting punch method. Leaves from the uprooted plants were separated and punched. The discs as well as the remaining leaf portion were dried in an oven at 80 $\pm$ 5^{o}C and their respective dry weights were recorded. From this the leaf area and the leaf area index were worked out at the two stages.

Yield and Yield components

1. Number of tubers per plant

Number of tubers from the observational plants were counted and their average worked out.

2. Weight of tubers per plant

The average weight of tubers per plant was recorded from the observational plants.

3. Number of marketable tubers per plant

Marketable tubers were fixed based on visual observations. The marketable tubers were separated from observational plants and their number recorded.

4. Weight of marketable tubers per plant

Marketable tubers were separated from observational plants and their weight recorded.

5. Percentage weight of marketable tubers per plant

Percentage weight of marketable tubers per plant was worked out from weight of tubers per plant and weight of marketable tubers per plant.

6. Yield of tubers per hectare

Yield of total tubers obtained from each net plot was recorded and expressed in tonnes per hectare.

7. Drymatter yield per hectare

Observational plants were removed from each plot and they were oven dried at $80 \pm 5^{o}C$. Their weight was recorded and expressed in kg/ha.

8. Bulking rate

The rate of bulking in tuber under each treatment has been worked out on the basis of increase in fresh weight of tuber (g) per plant per day (Shukla and Singh 1975).

9. Utilization Index or Tuber efficiency

According to Obigbesan (1973) this is an important yield determinant factor. It is the ratio of the tuber weight to the top weight. This was worked out from the tuber weight and top weight of the observational plants.

Plant analysis

Different plant parts were oven dried separately at 80 ± 5°C, powdered in a Willey mill and used for chemical analysis.

1. Nitrogen uptake

Plant parts and tubers were analysed for nitrogen by the modified microKjeldahl method (Jackson, 1967). The uptake of nitrogen was calculated based on the content of nitrogen in plant parts and their dry weights and expressed in kg/ ha.

2. Potassium uptake

One gram of the powdered sample was digested with triple acid mixture (HNO_3 + H_2SO_4 + $HClO_4$) (Jackson and Ulrich, 1959). The digest was filtered and made upto 100 ml and used for the estimation of potassium. Potassium was determined by using a flame photometer.

The uptake of potassium was calculated based on its content in plant parts and their dry weight and expressed in kg/ha.

3. Starch content of tuber

Starch content of tuber was estimated by using potassium ferricyanide method (Ward and Pigman, 1970). The values were expressed as percentage of the dry-weight.

4. Protein content of the tuber

The protein content of tuber was calculated from the percent of nitrogen in tuber by multiplying with the factor 6.25 (Simpson et al. 1965)

Soil Analysis

Total nitrogen and available potassium content of the composite soil sample collected prior to experiment was analysed. Total nitrogen was determined by modified microkjeldahl method and available potassium by ammonium acetate method (Jackson 1967).

Statistical analysis

The data pertaining to various characteristics were analysed statistically by applying the technique of analysis of variance for randomised block design and the significance was tested by 'F' test. Correlation analysis was also done (Snedecor and Cochran 1967).

RESULTS

RESULTS

An experiment was laid out on randomised block design with fifty treatments and two replications to find out the optimum doses and suitable time of application of nitrogen and potash to coleus (Koorka). The results of the study after statistical analysis are presented below:

1. Height of plants

The mean height of plants at various stages is given in Tables 2-5 and the analysis of variance in Appendix II. The effect of nitrogen on height of plants was significant in all observations. At 30th day after planting N_3 gave maximum height and was on par with N_4 and N_2 and superior to N_1 and N_o. But at the 60th and 90th day after planting all the levels of nitrogen were found to be significantly superior to control. At harvest the heights were nearly levelled off.

Potash levels had significant effect on height of plants, only at 30th day after planting. At that stage K_3 recorded maximum height and was on par with K_4 and significantly superior to K_2, K_1 and K_o.

Table 2. Plant height (cm) - 30 days after planting.

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	11.15	13.13	13.09	14.47	13.89	13.15
T_2	11.08	13.18	14.72	14.05	13.33	13.27
Mean	11.12	13.16	13.91	14.26	13.61	

T/K	K_0	K_1	K_2	K_3	K_4	
T_1	12.42	13.12	13.22	13.82	13.15	13.15
T_2	12.62	12.54	12.56	14.61	14.03	13.27
Mean	12.52	12.83	12.89	14.22	13.59	

N/K	K_0	K_1	K_2	K_3	K_4	
N_0	9.65	12.03	10.50	12.95	10.45	11.12
N_1	11.55	13.63	13.23	14.50	12.88	13.16
N_2	13.28	12.30	13.70	14.85	15.40	13.91
N_3	14.70	13.58	13.35	14.60	15.08	14.26
N_4	13.43	12.63	13.68	14.18	14.15	13.61
Mean	12.52	12.83	12.89	14.22	13.59	

S.E.M - 0.364

CD (0.05) for N and K marginal means - 1.034

Table 3. Plant height (cm) - 60 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	12.72	16.90	16.57	17.18	17.72	16.22
T_2	13.96	17.80	18.36	18.10	18.46	17.34
Mean	13.34	17.35	17.47	17.64	18.09	

T/K	K_0	K_1	K_2	K_3	K_4	Mean
T_1	14.91	16.64	16.92	16.67	15.95	16.22
T_2	16.40	17.60	17.94	17.20	17.54	17.34
Mean	15.65	17.12	17.43	16.93	16.75	

N/K	K_0	K_1	K_2	K_3	K_4	
N_0	12.70	13.00	13.55	12.65	14.80	13.34
N_1	15.70	18.20	18.90	18.20	15.75	17.35
N_2	16.30	17.55	18.05	16.68	18.75	17.47
N_3	15.88	17.35	19.55	19.15	16.28	17.64
N_4	17.69	19.50	17.10	18.00	18.15	18.09
Mean	15.65	17.12	17.43	16.93	16.75	

S.E.M. - 0.507

CD(0.05) for N marginal means = 1.441

Table 4. Plant height (cm) - 90 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	8.64	9.96	10.40	9.50	9.54	9.61
T_2	8.90	9.07	9.61	10.48	10.76	9.76
Mean	8.77	9.51	10.00	9.99	10.15	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	9.44	10.14	9.62	9.18	9.66	9.61
T_2	9.42	9.71	10.55	9.86	9.28	9.76
Mean	9.43	9.92	10.08	9.52	9.47	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	8.30	9.85	8.70	8.45	8.55	8.77
N_1	8.60	10.50	9.12	9.25	10.10	9.51
N_2	10.10	9.61	11.30	9.90	9.10	10.00
N_3	10.20	9.65	10.90	9.50	9.70	9.99
N_4	9.95	10.00	10.40	10.50	9.90	10.15
Mean	9.43	9.92	10.08	9.52	9.47	

S.E.M - 0. 337

CD (0.05) for N marginal means - 0.958

Table 5. Plant height (cm) - Harvest

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	14.25	16.75	14.78	15.11	14.19	15.01
T_2	15.36	17.34	16.81	16.55	16.12	16.43
Mean	14.81	17.04	15.79	15.83	15.15	
T/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
T_1	14.44	15.08	15.20	15.68	14.67	15.01
T_2	16.26	16.95	15.71	17.59	15.66	16.43
Mean	15.35	16.01	15.46	16.63	15.17	
N/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
N_0	14.27	15.65	15.30	15.74	13.08	14.81
N_1	15.64	18.23	16.75	17.70	18.89	17.04
N_2	16.09	16.10	14.65	16.07	16.05	15.79
N_3	15.13	14.86	16.11	18.31	14.71	15.83
N_4	15.63	15.23	14.46	15.34	15.10	15.15
Mean	15.35	16.01	15.46	16.63	15.17	

S.E.M. (T) — 0.322
S.E.M. (N) - 0.509
S.E.M. (NT) - 0.72
CD (0.05) for N marginal means - 1.447
CD (0.05) for NT combinations - 2.047
CD (0.05) for T marginal means — 0.915

The effect of different timings of application of N and K on plant height was not statistically significant ain all stages of growth except at harvest.

The interaction between levels of N and K was not significant at any stage. But the interaction between N and T was significant at harvest stage.

2. Number of branches

The data on number of branches at various stages are presented in Tables 6-9 and their analysis of variance in Appendix III.

The results show that effect of different levels of nitrogen on number of branches was statistically significant at all stages, except at harvest. At 30th day though N_4 recorded maximum number of branches, it was on par with N_3 and N_2 while N_2 was on par with N_1 and N_1 on par with N_o. At 60th day N_3 was on par with N_4 and N_2 and N_2 in turn on par with N_1 and all the N levels were superior to control. At 90th day N_3 was on par with N_4 and produced significantly more number of branches over lower levels (N_2, N_1 and N_o). The lower levels of

Table 6. Number of branches - 30 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	6.32	8.56	8.24	8.66	9.58	8.27
T_2	7.30	7.20	9.14	10.04	9.80	8.70
Mean	6.81	7.88	8.69	9.35	9.69	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	8.20	8.92	8.04	7.78	8.42	8.27
T_2	8.44	8.24	8.66	9.78	8.36	8.70
Mean	8.32	8.58	8.35	8.78	8.39	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	6.60	8.15	6.30	7.20	5.80	6.81
N_1	6.80	7.60	7.50	7.95	9.55	7.88
N_2	9.40	8.20	8.20	9.00	8.65	8.69
N_3	9.95	9.10	10.45	8.70	8.55	9.35
N_4	8.85	9.85	9.30	11.05	9.40	9.69
Mean	8.32	8.58	8.35	8.78	8.39	

S.E.M. - 0.511
CD (.05) for N marginal means - 1.452

Table 7. Number of branches - 60 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	10.93	13.87	15.98	16.96	17.00	14.95
T_2	11.87	15.78	15.21	18.42	18.31	15.92
Mean	11.40	14.83	15.60	17.69	17.66	
T/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
T_1	13.56	14.17	15.28	16.28	15.45	14.95
T_2	14.06	15.51	14.11	19.40	16.51	15.92
Mean	13.81	14.84	14.70	17.84	15.98	
N/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
N_0	9.70	12.65	10.83	12.05	11.78	11.40
N_1	9.45	15.30	14.15	15.45	19.78	14.83
N_2	15.75	13.20	14.05	19.78	15.20	15.60
N_3	17.65	16.65	16.85	20.25	17.10	17.69
N_4	16.50	16.45	17.60	21.68	16.05	17.66
Mean	13.81	14.84	14.70	17.84	15.98	

S.E.M - 0.935

CD(0.05) for N and K marginal means - 2.658

Table 8. Number of branches - 90 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	24.48	37.06	38.90	45.94	48.02	38.68
T_2	25.52	39.88	41.72	50.28	45.98	40.68
Mean	25.00	38.47	40.31	48.11	46.99	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	33.10	36.88	39.18	41.50	43.74	38.68
T_2	36.32	35.98	40.36	40.52	50.20	40.68
Mean	34.71	36.43	39.77	41.01	46.97	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	19.60	33.30	25.35	24.30	25.45	25.00
N_1	26.10	36.60	36.50	50.40	42.75	38.47
N_2	33.60	35.20	38.25	37.65	56.85	40.31
N_3	46.20	36.55	50.80	49.00	58.00	48.11
N_4	48.04	43.50	47.95	43.70	51.80	46.99
Mean	34.71	36.43	39.77	41.01	46.97	

S.E.M. - 2.371

CD (0.05) for N and K marginal means - 6.74

Table 9. Number of branches at Harvest.

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	22.08	25.66	27.80	25.42	23.55	24.90
T_2	23.07	22.98	25.45	22.78	25.39	23.93
Mean	22.57	24.32	26.62	24.10	24.47	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	24.59	26.39	23.90	27.10	22.52	24.90
T_2	22.62	23.76	25.31	22.78	25.20	23.93
Mean	23.61	25.08	24.61	24.94	23.86	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	20.30	22.45	15.23	27.13	23.75	22.57
N_1	20.95	25.63	26.15	24.83	24.05	24.32
N_2	26.25	24.20	29.15	25.25	28.26	26.62
N_3	23.88	22.50	25.00	26.55	22.58	24.10
N_4	26.65	30.60	23.50	20.95	20.65	24.47
Mean	23.61	25.08	24.61	24.94	23.86	

N.S.

nitrogen were on par and significantly superior to control. At harvest all the treatments showed more or less equal number of branches.

Potassium levels showed significant difference only at 60th and 90th day after planting. At 60th day K_3 and K_4 were on par and K_4 was on par with K_2 and K_1. At 40th day K_3 and K_4 were on par and K_3 was on par with K_2. K_1 and K_o were on par at both stages.

Timings of N and K application failed to produce any significant effect on number of branches at all stages of growth.

The interaction between doses of N and K and between timings and doses were also not significant.

3. <u>Number of functional leaves</u>

The data on number of functional leaves are presented in Tables 10-13 and their analysis of variance in Appendix IV.

Significant differences in the number of functional leaves were obtained between levels of nitrogen at all

Table10. Number of functional leaves – 30 days after planting

T_1	50.30	72.52	57.86	64.48	71.08	63.25
T_2	55.04	55.28	72.60	86.76	82.92	70.52
Mean	52.67	63.90	65.23	75.62	77.00	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	55.66	63.40	67.30	62.16	67.72	63.25
T_2	70.12	65.52	65.58	84.08	67.30	70.52
Mean	62.89	64.76	66.44	73.12	67.51	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	46.75	54.75	50.45	60.90	50.50	52.67
N_1	51.65	62.30	58.35	71.85	75.35	63.90
N_2	69.35	58.65	61.05	73.70	63.40	65.23
N_3	78.40	67.55	87.00	70.15	75.00	75.62
N_4	68.30	79.05	75.35	89.00	73.30	77.00
Mean	62.89	64.76	66.44	73.12	67.51	

S.E.M. (N) – 4.64
S.E.M. (NT) – 6.56
CD (0.05) for N marginal means – 13.19
CD (0.05) for NT combinations – 18.65

Table 11. Number of functional leaves - 60 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	74.33	100.22	105.62	122.25	119.38	104.36
T_2	90.98	106.82	125.02	120.36	125.21	113.67
	82.66	103.52	115.32	121.31	122.30	
T/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
T_1	98.63	86.56	109.50	104.55	122.56	104.36
T_2	110.14	96.24	116.14	135.08	110.79	113.67
Mean	104.39	91.40	112.82	119.92	116.68	
N/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
N_0	64.20	83.35	83.40	86.08	96.25	82.66
N_1	106.55	97.90	104.85	99.35	108.95	103.52
N_2	116.05	85.50	118.60	145.75	110.70	115.32
N_3	119.48	94.20	134.80	129.25	128.80	121.31
N_4	115.65	96.05	122.45	138.65	138.68	122.30
Mean	104.39	91.40	112.82	119.82	116.68	

S.E.M. - 5.96

CD(0.05) for N and K marginal means -16.93

Table 12. Number of functional leaves - 90 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	139.82	210.15	208.84	233.46	221.88	151.40
T_2	162.46	208.13	222.84	205.10	245.25	209.14
Mean	151.14	209.14	215.84	219.28	233.56	

T/K	K_0	K_1	K_2	K_3	K_4	
T_1	186.39	196.90	198.62	214.20	218.04	151.40
T_2	219.82	177.96	193.26	232.43	220.3	209.14
Mean	203.11	187.43	195.94	223.32	219.19	

N/K	K_0	K_1	K_2	K_3	K_4	
N_0	159.00	154.15	136.75	157.15	148.65	151.14
N_1	145.68	201.30	206.95	246.98	242.80	209.14
N_2	217.90	165.90	186.55	227.45	261.40	215.84
N_3	232.10	191.35	244.85	235.50	192.60	219.28
N_4	260.85	204.45	202.60	249.50	250.40	233.56
Mean	203.11	187.43	195.94	223.32	219.19	

S.E.M. (N) - 11.886

CD(0.05) for N marginal means - 33.79

Table 13. Number of functional leaves - Harvest

T/N	N_0	N_1	N_2	N_3	N_4	Means
T_1	149.69	208.67	211.81	177.95	177.42	185.11
T_2	179.27	182.68	182.15	180.58	178.38	180.61
Mean	164.48	195.68	196.98	179.27	177.90	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	178.55	211.06	185.55	187.12	163.28	185.11
T_2	161.05	184.04	200.10	187.01	169.97	180.61
Mean	169.80	197.99	192.82	187.06	166.62	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	162.33	184.27	158.58	156.98	160.25	164.48
N_1	166.88	244.75	221.16	177.10	168.50	195.68
N_2	171.25	184.87	188.5	215.17	225.13	196.98
N_3	180.00	154.45	193.56	230.13	138.19	179.27
N_4	168.54	221.65	202.33	155.94	141.05	177.90
Mean	169.80	197.99	192.82	187.06	166.62	

N.S.

stages except at harvest. At all stages N_4 gave the maximum number of leaves. But it was on par with other nitrogen levels and superior to control at 30th day. While at 60th day it was only on par with N_3 and N_2. Treatment N_2 in turn was on par with N_1. All the nitrogen levels showed their superiority in producing total number of functional leaves over control. At 90th day of planting N_4 continued to produce higher number of leaves and was on par with other N levels. All the levels of nitrogen were superior to control.

Potash levels in general had no significant influence on the total number of functional leaves except at 60th day. At this stage K_3 produced maximum number of leaves which was on par with K_4, K_2 and K_o and superior to K_1. However, there was no significant difference between K_o and K_1.

Though the time of application had no significant effect in producing total number of functional leaves, it is seen from the table that in general at all stages of growth T_2 produced more number of leaves than T_1, except at harvest stage where the variation was little.

Interaction between timings and doses of nitrogen was also significant at 30th day of planting. At this stage N_3T_2 showed maximum number of leaves which was on par with N_4T_2 and significantly superior to all other treatments. Treatment N_oT_1 produced minimum number of leaves.

4. Plant spread

The data on spread of the plant are given in Tables 14-17 and analysis of variance in Appendix V.

At 30th day of planting none of the treatments had any significant influence on the spread of the plant. At 60th day and 90th day N_2 produced maximum spread which was on par with N_1 and all were significantly superior to control. At harvest all the nitrogen levels produced better spread and were on par and were superior to control.

With regard to potash, there was no significant influence observed between levels.

There was no significant effect on the spread of plants due to timings of fertilizer application.

The interaction effect was also not significant.

Table 14. Plant spread (cm) - 30 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	
T_1	11.42	13.76	12.80	12.38	14.16	12.90
T_2	10.16	11.11	13.86	14.34	13.52	12.60
Mean	10.79	12.44	13.33	13.36	13.84	

T/K	K_0	K_1	K_2	K_3	K_4	
T_1	12.60	13.50	13.16	12.74	12.52	12.90
T_2	11.40	11.94	13.26	15.19	11.20	11.60
	12.00	12.72	13.21	13.97	11.86	

N/K	K_0	K_1	K_2	K_3	K_4	
N_0	11.70	11.00	9.80	12.60	8.85	10.79
N_1	10.50	11.80	14.85	12.43	12.60	12.44
N_2	13.65	12.95	13.95	14.75	11.35	13.33
N_3	11.95	13.05	13.10	14.05	14.65	13.36
N_4	12.20	14.80	14.35	16.00	11.85	13.84
Mean	12.00	12.72	13.21	13.97	11.86	

N.S.

Table 15. Plant spread (cm) - 60 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	12.50	18.55	23.83	21.41	24.84	20.23
T_2	15.13	20.71	26.53	23.96	22.90	21.85
Mean	13.82	19.63	25.18	22.68	23.87	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	19.73	18.22	19.70	23.21	20.27	20.23
T_2	23.70	19.42	20.53	25.02	20.56	21.85
Mean	21.72	18.82	20.11	24.16	20.42	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	18.20	19.80	8.00	11.05	12.03	13.82
N_1	21.58	14.05	15.24	22.83	24.45	19.63
N_2	21.95	17.35	23.73	36.15	26.73	25.18
N_3	23.60	21.50	27.80	26.35	14.18	22.69
N_4	23.25	21.40	25.80	24.20	24.70	23.87
Mean	21.72	18.82	20.11	24.12	20.42	

S.E.M. - 1.86
CD (0.05) for N means - 5.345

Table 16. Plant spread (cm) - 90 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	38.46	48.28	54.44	54.30	54.88	50.07
T_2	44.02	47.45	54.78	52.76	54.14	50.63
Mean	41.24	47.87	54.61	53.63	54.51	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	46.88	49.44	51.28	52.14	50.62	50.07
T_2	48.72	50.78	50.24	52.49	50.92	50.63
Mean	47.80	50.11	50.76	52.32	50.77	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	41.50	46.80	38.75	41.05	38.10	41.24
N_1	40.00	50.50	46.95	47.38	54.50	47.87
N_2	53.85	50.05	51.75	57.45	59.95	54.61
N_3	53.40	51.95	57.70	57.85	46.75	53.63
N_4	50.25	51.25	58.65	57.85	54.55	54.51
Mean	47.80	50.11	50.76	52.32	50.77	

S.E.M - 2.197

CD (0.05) for N marginal means - 6.246

Table 17. Plant spread (cm) - Harvest

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	47.09	50.75	54.27	54.97	53.58	52.13
T_2	47.86	54.62	56.41	56.39	55.58	54.17
Mean	47.48	52.69	55.34	55.68	54.58	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	47.64	52.77	56.39	54.36	49.50	52.13
T_2	57.30	55.49	54.85	53.39	49.83	54.17
Mean	52.47	54.13	55.62	53.88	49.67	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	47.50	43.95	46.25	53.65	46.03	47.48
N_1	48.88	52.48	59.58	52.88	49.63	52.69
N_2	57.25	57.18	50.73	55.75	55.80	55.34
N_3	54.15	60.48	60.50	59.35	43.93	55.68
N_4	54.58	56.58	61.05	47.75	52.95	54.58
Mean	52.47	54.13	55.62	53.88	49.67	

S.E.M - 1.82

C.D(0.05) for N marginal means - 5.18

5. Leaf area index

The data on leaf area index are presented in Tables 18 and 19 and analysis of variance in Appendix VI.

Levels of nitrogen produced significant difference in the LAI, at 60th and 90th days of planting. The data reveal that N_4 produced maximum LAI at 60th day which was superior to all other levels of nitrogen, while N_3 was on par with N_2, N_2 with N_1 and N_1 with N_o. At 90th day, though N_4 showed maximum LAI it was on par with all the levels of nitrogen and significantly superior to control.

Significant difference in LAI was observed between different levels of potash only at 60th day. Treatment K_3 produced maximum LAI but was on par with K_2, K_4 and K_1 and superior to K_o.

There was no significant difference between T_1 and T_2 at both stages.

Interaction between doses of nitrogen and potash was significant at 60th day, but it failed to produce any significant influence on LAI at 90th day. Treatment N_4K_2 produced maximum LAI which was on par with N_4K_4 and superior

Table 18. Leaf area index - 60 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	2.14	2.52	3.85	4.22	5.65	3.68
T_2	2.74	3.19	3.42	3.37	4.70	3.48
Mean	2.44	2.86	3.63	3.80	5.17	
T/K	K_0	K_1	K2	K_3	K_4	
T_1	2.76	3.88	3.73	3.91	4.10	3.68
T_2	2.62	3.48	3.86	3.98	3.47	3.48
Mean	2.69	3.68	3.80	3.95	3.79	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	1.26	2.31	3.31	2.92	2.37	2.44
N_1	2.82	3.08	4.18	2.51	1.71	2.86
N_2	4.28	4.06	2.92	2.98	3.94	3.63
N_3	1.90	4.02	2.52	5.59	4.96	3.80
N_4	3.20	4.93	6.04	5.74	5.95	5.17
Mean	2.69	3.68	3.80	3.95	3.79	

CD (0.05) for N and K means = 0.864 S.E.M = 0.304
CD (0.05) for NK combinations=1.93 " = 0.679

Table No.19. Leaf area index 90 days after planting

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	1.04	1.53	1.50	1.62	1.33	1.41
T_2	0.86	1.39	1.39	1.49	2.06	1.44
Mean	0.95	1.46	1.44	1.56	1.70	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	1.14	1.45	1.47	1.43	1.54	1.41
T_2	1.39	1.64	1.22	1.38	1.57	1.44
Mean	1.26	1.54	1.34	1.41	1.55	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	0.71	0.97	1.11	1.01	0.96	0.95
N_1	1.33	1.56	1.34	1.70	1.38	1.46
N_2	0.71	1.08	1.48	1.21	1.74	1.44
N_3	1.23	1.75	1.43	1.72	1.65	1.56
N_4	1.33	2.36	1.34	1.41	2.03	1.70

S.E.M. (N) - 0.101
S.E.M. (NT) - 0.143
CD(0.05) for N marginal means - 0.287
CD(0.05) for NT combination - 0.407

to all other NK combinations, N_oK_o produced the lowest LAI.

Interaction between time of application and different doses of nitrogen was significant at 90th day after planting. Treatment N_4T_2 recorded maximum LAI and was on par with N_3T_1, while all other combinations were significantly lower than N_4T_2. Treatment N_oT_2 produced the lowest LAI.

Interaction between timings and doses of potash and between doses of N and K were not significant at both stages.

6. Number of tubers per plant

The data on number of tubers per plant are presented in Table 20 and Analysis of variance in Appendix VII.

Number of tubers per plant varied significantly between different levels of nitrogen. Among different levels N_4 recorded the maximum number and was superior to all other levels. Treatments N_2 and N_3 and N_3 and N_1 were on par and superior to N_o which produced lowest number of tubers.

Number of tubers per plant was also influenced by different levels of potash. K_4 produced maximum tubers

Table 20. Number of tubers/plant

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	39.00	62.30	77.30	64.60	90.10	66.66
T_2	51.90	72.00	90.40	82.20	102.60	79.82
Mean	45.45	67.15	83.85	73.40	96.35	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	47.10	52.60	79.90	75.20	78.50	66.66
T_2	50.80	75.20	88.10	88.20	96.80	79.82
Mean	48.95	63.90	84.00	81.70	87.65	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	21.00	19.50	53.00	48.75	65.00	45.45
N_1	51.50	76.00	48.25	92.00	68.00	67.15
N_2	54.25	71.50	116.50	73.50	103.50	83.85
N_3	41.50	67.75	108.00	73.50	76.25	73.40
N_4	76.50	64.75	94.25	120.75	125.50	96.35
	48.95	63.90	84.00	81.70	87.65	

S.E.M = 3.969 CD (0.05) for N and K marginal means = 11.28

" = 2.510 CD (0.05) for T marginal means = 7.14

" = 8.875 CD (0.05) for NK combinations = 25.23

per plant which was on par with K_2 and K_3 and superior to K_1 and K_o. Treatment K_1 also was found to produce more number than K_o.

Split application of N and K was significantly superior to single basal application.

The interactions were not significant.

7. Tuber yield per plant

The data on tuber yield per plant are presented in Fig.3, Table 21 and analysis of variance in Appendix VIII

The results showed significant difference in yield of tubers per plant between different levels of nitrogen. There was increase in yield of tubers per plant with increasing levels of nitrogen application, the maximum being at N_4 level. Treatment N_4 was on par with N_2 and N_3 and significantly superior to N_1 and N_o, while N_1 was on par with N_3 and N_2 and superior to N_o.

As in the case of nitrogen, potash levels also showed significant effect on tuber yield per plant. Treatment K_3 gave maximum yield and was on par with K_4 and K_2. Treatment K_1 and K_o were on par and significantly inferior to all other higher levels of K.

Table 21. Tuber yield - plant (g)

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	81.30	153.0	173.30	173.30	185.1	153.20
T_2	131.5	136.3	190.9	169.0	207.7	167.1
Mean	106.4	144.6	182.1	171.2	196.4	
T/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
T_1	97.7	108.3	194.6	222.9	142.5	153.2
T_2	116.0	131.9	167.5	196.2	233.7	167.1
Mean	106.8	120.1	181.31	209.6	183.1	
N/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
N_0	78.8	81.9	130.1	111.9	129.4	106.4
N_1	86.3	119.4	124.4	222.5	170.7	144.6
N_2	107.5	133.8	178.8	238.6	251.6	182.1
N_3	144.1	100.00	236.9	253.0	121.8	171.2
N_4	117.5	165.5	235.0	221.9	242.2	196.4
Means	106.8	120.1	181.1	209.6	183.1	

S.E.M. - 15.58

CD(0.05) for N and K marginal means - 44.28

The timings of application of N and K failed to produce significant effect on tuber yield per plant. However, split application showed an increasing trend on the tuber yield than basal application though they were on par.

The interaction between treatments was not significant.

8. Number of marketable tubers per plant

The data on number of marketable tubers per plant are presented in Table 22, Fig.4a and 4b and analysis of variance in Appendix IX.

Significant effect on number of marketable tubers per plant was observed between different levels of nitrogen. Highest number of marketable tubers per plant was produced by N_4 and it was superior to all other levels. Effect of N_2 and N_3 on marketable tubers were same, and superior to N_1 and N_o. Treatment N_1 in turn was superior to N_o.

As in the case of nitrogen, K levels also differed significantly in their effect on the production of marketable tubers. Treatment K_4 produced maximum number of marketable tubers per plant and was on par with K_2 and K_3 and

Table 22. Number of marketable tubers/plant

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	17.60	30.20	41.00	34.70	54.20	35.54
T_2	25.10	34.60	47.50	48.20	62.50	43.58
Mean	21.35	32.40	44.25	41.45	58.35	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	21.70	27.90	42.30	40.50	45.30	35.54
T_2	23.40	37.90	51.60	51.30	53.70	43.58
Mean	22.55	32.90	46.95	45.90	49.50	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	5.50	14.75	29.00	23.00	34.50	21.35
N_1	23.75	31.75	31.00	41.75	33.75	32.40
N_2	24.75	42.50	55.25	47.50	51.25	44.25
N_3	18.50	38.50	62.50	45.25	42.50	41.45
N_4	40.25	37.00	57.00	72.00	85.50	58.35
Mean	22.55	32.90	46.95	45.90	[illegible]	

S.E.M. (N & K) - 2.3
S.E.M. (T) - 1.45
S.E.M. (NK) - 5.14

CD(0.05) for N and K marginal means - 6.53
CD(0.05) for T marginal means - 4.13
CD(0.05) for NK combination - 14.61

superior to K_1 and K_o. Treatment K_1 was superior to K_o.

The timings of N and K application varied significantly in their effect on marketable tubers. Split application proved superior to single basal application.

Interaction between treatments was not significant.

9. Weight of marketable tubers per plant

The data on weight of marketable tubers are presented in Table 23 and their analysis of variance in Appendix X.

The results revealed that nitrogen levels had significant influence on weight of marketable tubers per plant. N_4 produced maximum marketable tuber weight per plant and it was superior to N_3, N_3 in turn superior to N_2, N_2 to N_1 and N_1 to N_o.

Potash levels also showed significant difference in the weight of marketable tubers per plant. Treatment K_4 produced maximum marketable tuber weight and was superior to all other levels of potash. K_3 and K_2 were on par and superior to K_1 and K_o. Treatment K_1 was superior to K_o.

Table 23. Weight of marketable tubers (g) plant

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	32.90	76.70	93.20	103.20	113.80	83.96
T_2	63.40	65.90	100.70	110.50	128.80	93.86
Mean	48.15	71.30	96.95	106.85	121.30	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	43.80	55.30	111.10	83.30	127.30	83.96
T_2	56.00	69.80	97.20	131.20	115.10	93.86
Mean	49.90	62.55	104.15	106.75	121.20	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	21.50	41.25	35.50	82.25	69.00	48.15
N_1	30.50	51.50	84.50	54.00	92.25	71.30
N_2	63.50	74.00	94.00	146.50	142.75	96.95
N_3	72.75	85.50	132.75	82.50	160.25	106.85
N_4	52.50	104.25	138.00	169.00	142.25	121.30
Mean	49.90	62.55	104.15	106.75	121.20	

S.E.M. - 2.89

CD (0.05) for N and K marginal means - 5.78

Though the timings of N and K application failed to produce any significant effect on weight of marketable tubers per plant, split application showed higher weight of marketable tubers over single application.

The interaction between treatments was not significant.

10. <u>Percentage weight of marketable tubers per plant</u>

The data on percentage weight of marketable tubers are presented in Table 24 and their analysis of variance in Appendix XI.

Significant difference between nitrogen levels on percentage weight of marketable tubers was observed in the data. N_3 produced maximum percentage of marketable tubers per plant and it was on par with N_4. These higher levels were superior to the lower levels (N_2, N_1 and N_0). N_2 was superior to N_1 and N_1 in turn to N_0.

Potash levels had significant difference on percentage weight of marketable tubers per plant. Treatment K_4 had the highest percentage and it was on par with K_3. Treatment K_3 was on par with K_2. These higher levels were superior to K_1 and K_0. Even lowest level was superior over control.

Table 24. Percentage weight of marketable tubers

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	40.8	50.8	51.4	58.9	58.9	52.2
T_2	43.6	47.9	56.0	63.9	61.9	54.7
Mean	42.2	49.4	53.7	61.4	60.4	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	44.5	47.6	54.3	56.5	57.9	52.2
T_2	49.5	50.8	58.1	57.2	57.7	54.7
Mean	47.0	49.2	56.2	56.9	57.8	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	27.0	47.75	45.25	57.5	57.5	42.2
N_1	36.5	41.0	60.5	53.5	54.5	49.4
N_2	48.0	59.8	52.5	62.0	58.8	53.7
N_3	47.8	47.0	58.0	67.0	64.5	61.4
N_4	51.8	51.30	52.3	67.0	66.8	60.4
Mean	47.0	49.2	56.2	56.9	57.8	

S.E.M = .42 CD (0.05) for N and K marginal means = 1.22

The timings of N and K application and the interaction between doses and timings and doses of N and K were not significant.

11. <u>Yield of tubers per hectare</u>

The data on yield of tubers (tonnes/ha) are presented in Table 25, Fig.5a and 5b and analysis of variance in Appendix XII.

There was increase in yield of tubers with increasing levels of nitrogen, the effect being statistically significant. Highest yield was given by N_4 followed by N_3. But these two levels were on par. N_3 was also found to be on par with N_2. All these three higher levels of nitrogen were found to be superior to lower nitrogen level and control. Lowest nitrogen level (N_1) was also found to be superior to N_o. The data reveals an increasing trend on the yield of tubers with the increase in nitrogen application.

The effect due to different potash levels on yield was also found to be significant. Treatment K_4 produced the maximum tuber yield and was significantly superior to the lower levels of potash. The pattern of tuber yield was found to be the same with regard to the lower levels.

Table 25. Yield of tubers (t/ha)

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	8.47	13.88	14.58	15.81	15.73	13.70
T_2	10.21	15.92	17.98	18.09	19.88	16.42
Mean	9.34	14.90	16.28	16.95	17.80	
T/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
T_1	8.45	12.83	13.66	15.27	18.27	13.70
T_2	9.84	14.42	17.53	19.03	21.29	16.42
Mean	9.14	13.62	15.59	17.15	19.78	
N/K	**K_0**	**K_1**	**K_2**	**K_3**	**K_4**	
N_0	6.71	8.22	10.01	10.36	11.40	9.34
N_1	9.20	14.28	15.28	15.86	19.90	14.90
N_2	10.01	13.83	15.78	18.88	22.92	16.28
N_3	9.89	15.05	19.10	19.48	21.23	16.95
N_4	9.89	16.73	17.80	21.18	23.44	17.80
Mean	9.14	13.62	15.59	17.15	19.78	

S.E.M. (N&K) - 0.474
S.E.M. (T) - 0.30
S.E.M. (N&K) - 1.06
CD(0.05) for N and K marginal means - 1.35
CD(0.05) for T marginal means - 0.853
CD(0.05) for N and K combination - 3.01

K_o produced the least tuber yield.

Split application of nutrients was significantly superior to single basal application in increasing yield of tubers.

The interactions between doses N and K were statistically significant. Treatment N_4K_4 produced maximum yield which was on par with N_2K_4 and N_3K_4. Minimum yield was given by control plots receiving no nitrogen and potash.

The interactions between timings and doses were not significant.

12. Total dry matter yield

The data on dry matter yield are presented in Table 26 and Fig. 6a and 6b and analysis of variance in Appendix XIII.

Nitrogen was found to have great influence in increasing total drymatter yield. Treatment N_4 produced maximum drymatter yield which was on par with N_2 and N_3, and superior to N_1 and N_o. N_3 in turn was on par with N_1 and superior to N_o.

The levels of potash also showed significant difference in drymatter yield. Highest drymatter yield was

Table 26. Total dry matter yield (Kg/ha)

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	2772.40	3925.40	4369.90	4200.10	4604.20	3974.39
T_2	3110.60	4236.20	4684.29	4783.69	5241.89	4411.33
Mean	2941.50	4080.80	4527.09	4491.89	4923.05	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	3111.10	3466.80	4021.60	4450.00	4822.50	3974.39
T_2	2932.80	4021.60	4736.50	4919.09	5446.70	4411.33
Mean	3021.95	3744.20	4379.05	4684.54	5134.60	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	2061.99	2760.75	3273.50	3071.75	3539.50	2941.50
N_1	2911.25	3826.75	4273.25	4349.99	5042.75	4080.80
N_2	3700.99	3860.25	4284.75	5437.99	5351.50	4527.09
N_3	3183.99	3920.25	4932.50	4781.25	5641.50	4491.89
N_4	3251.50	4352.99	5131.25	5781.75	6097.75	4923.05
Mean	3021.95	3744.20	4379.05	4684.54	5134.60	

S.E.M(N&K) - 156.01
S.E.M. (T) - 98.67
CD(0.05) for N and K marginal means 443.53
CD(0.05) for T marginal means - 280.52

obtained with K_4 and it was significantly superior to all other levels. K_3 and K_2 were on par and superior to K_1 and K_o. K_1 was also found to be superior to K_o.

The time of application of nutrients had significant influence on dry matter yield. T_2 was significantly superior to T_1. The interaction effects were not significant.

13. <u>Bulking rate</u>

The data on bulking rate are presented in Table 27, Fig.7 and appendix XIV.

The levels of nitrogen increased the bulking rate significantly, the maximum being at N_4 level. This was on par with N_3 and N_2. All the three higher levels were superior to N_1 and N_o which were on par.

As in the case of nitrogen significant effect on bulking rate was also found between different K levels. The highest level of potash gave the highest value of bulking rate and it differed significantly over other levels. K_3 and K_2 ; K_2 and K_1 and K_1 and K_0 were on par and the bulking rate was in the descending order.

Table 27. Bulking rate

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	1.57	2.13	2.80	3.17	3.27	2.59
T_2	2.23	2.60	4.20	2.85	4.73	3.52
Mean	1.90	2.36	3.50	3.50	3.99	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	1.74	1.98	2.70	2.66	2.85	2.59
T_2	1.74	2.79	3.38	4.60	5.09	3.52
Mean	1.74	2.39	3.04	3.63	4.47	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	1.33	1.42	1.34	2.83	2.57	1.90
N_1	1.51	1.81	3.10	2.46	2.93	2.36
N_2	1.95	2.68	2.92	4.28	5.68	3.50
N_3	2.19	2.78	3.87	4.21	4.46	3.50
N_4	1.70	3.25	3.97	4.38	6.70	3.99
Mean	1.74	2.39	3.04	3.63	4.47	

S.E.M. (N & K)	-0.24
S.E.M. (T)	-0.152
CD(0.05) for N and K marginal means	0.682
CD(0.05) for T marginal means	0.432

The application of N and K half basal and half thirty days after planting (T_2) significantly influenced bulking rate, over complete basal application (T_1).

Interaction between treatments was not significant.

14. <u>Utilisation index</u>

The data on utilisation index are presented in Table 28, Fig. 8 and analysis of variance in Appendix XV.

Significant influence on utilisation index was observed between different levels of nitrogen. N_4 gave maximum utilisation index which was on par with N_3 and N_2 and superior to N_1 and N_0. N_2 and N_1 were on par and N_1 in turn was on par with N_0.

Potash levels also showed significant difference in utilisation index. K_4 produced the maximum utilisation index and was on par with K_3 and superior to the lower levels. K_3 was found to be on par with K_2, and K_2 on par with K_1 and were superior to K_0.

The effect of timings of N and K application was not significant.

Interaction between doses of N and K was only significant. N_4K_3 produced the maximum utilisation index and the least by N_0K_0.

Table 28. Utilisation Index

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	2.05	2.47	2.79	2.83	3.31	2.69
T_2	2.19	2.74	3.54	3.63	3.45	3.11
Mean	2.12	2.61	3.16	3.23	3.38	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	1.59	2.44	2.96	3.26	3.31	2.69
T_2	1.78	2.85	2.95	3.61	4.28	3.11
Mean	1.68	2.64	2.95	3.43	3.79	
N/K	K_0	K_1	K_2	K_3	K_4	
N_o	1.09	2.51	2.11	2.52	2.39	2.12
N_1	1.45	1.89	2.58	3.75	3.36	2.61
N_2	1.68	2.77	3.75	3.17	4.45	3.16
N_3	2.71	2.76	3.15	3.23	4.28	3.23
N_4	1.50	3.27	3.17	4.51	4.46	3.38

S.E.M. (N and K) - 0.199
S.E.M. (NK) - 0.445
CD (0.05) for N and K marginal means 0.565
CD (0.05)for NK combinations - 1.265

15. Starch content

The data on starch content of tubers are presented in Table 29 and Appendix XVI.

The results reveal that there was no significant effect on starch content between different levels of nitrogen.

Potash levels showed significant influence on starch content. The highest starch content was obtained with K_3 which was on par with K_4. These two levels were superior to all other levels while K_2 was found superior to K_1 and K_o and K_1 in turn superior to K_o.

As regards time of application of N and K half the dose as basal and other half 30 days after planting was significantly superior to the entire dose applied as basal.

Interaction between doses of nitrogen and potash only was significant. Maximum starch content was obtained with N_1K_3 which was statistically equal to N_4K_3 and N_3K_4 and superior to other combinations; N_oK_o produced least starch content.

16. Protein content

The data on protein content of tubers are presented in Table 30 and analysis of variance in Appendix XVII.

Table 29. Starch contents

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	29.94	33.41	32.78	33.87	33.81	32.76
T_2	34.45	37.46	33.00	33.96	34.74	34.72
Mean	32.19	35.43	32.87	33.92	34.28	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	25.15	29.35	31.83	39.87	37.61	32.76
T_2	26.91	31.94	35.73	39.89	39.15	34.72
Mean	26.03	30.65	33.78	39.88	38.38	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	22.20	26.87	33.71	39.28	38.91	32.19
N_1	30.29	29.69	33.15	45.10	38.94	35.43
N_2	28.71	32.57	33.64	31.92	37.60	32.87
N_3	24.80	32.18	33.84	38.42	40.36	33.94
N_4	24.14	31.94	34.57	44.67	36.07	34.28
Mean	26.03	30.65	33.78	39.88	38.40	

S.E.M (K) - 1.01
S.E.M (T) - 0.641
S.E.M (NK) - 2.27
CD (0.05) for K marginal means - 2.88
CD(0.05) for T marginal means - 1.882
CD (0.05) for NK combinations - 6.45

Table 30. Protein content

T/N	N_0	N_1	N_2	N_3	N_4	
T_1	6.47	7.78	7.96	9.23	9.45	8.18
T_2	6.24	8.41	8.41	9.17	9.70	8.39
Mean	6.35	8.09	8.19	9.20	9.58	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	7.82	7.66	7.84	8.91	8.66	8.18
T_2	7.85	8.25	8.73	8.28	8.82	8.39
Mean	7.83	7.96	8.28	8.60	8.74	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	4.9	5.75	7.24	7.01	6.87	6.35
N_1	7.09	8.58	8.35	6.64	8.82	8.09
N_2	6.93	8.19	7.95	9.21	8.66	8.19
N_3	10.00	9.07	9.14	8.66	9.11	9.20
N_4	10.24	8.19	8.74	10.48	10.24	9.58
Mean	7.83	7.96	8.28	8.60	8.74	

S.E.M. - 0.286
CD (0.05) for N marginal means - 0.813

Significant difference in protein content due to nitrogen levels was observed the maximum being at N_4 level and it was on par with N_3 and significantly superior to other levels and control. N_2 was found to be on par with N_1 and superior to N_0. Increasing the nitrogen rate increased the protein content. The lowest protein content was obtained with control plants receiving no nitrogen.

Potash levels, time of application and their interactions were found to be not significant.

17. <u>Total nitrogen uptake</u>

The data on total nitrogen uptake are presented in Table 31, Fig.9 and analysis of variance in Appendix XVIII.

The results show that there was profound influence on total nitrogen uptake due to different N levels. The maximum uptake of nitrogen was obtained by the N_4 level. Each higher level (N_4 to N_1) was found to be superior to all the lower levels.

In the case of potash levels also similar pattern of N uptake was noted when potash levels were increased from K_0 to K_4 level.

The effect due to application of half nitrogen and potash as basal and half 30 days after planting (T_2)

Table 31.
Total nitrogen uptake (kg/ha)

T/N	N_0	N_1	N_2	N_3	N4	Mean
T_1	26.37	45.76	52.52	59.73	71.09	51.09
T_2	30.87	51.74	60.46	69.82	80.26	58.63
Mean	28.62	48.75	56.49	64.77	75.66	
T/K	K_0	K_1	K_2	K_3	K_4	
T_1	34.00	42.80	50.06	59.49	63.10	51.09
T_2	36.45	53.19	61.77	66.11	75.61	58.63
Mean	38.22	48.00	55.92	62.80	69.36	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	17.97	25.85	30.39	30.86	38.30	28.62
N_1	33.78	43.51	49.94	49.75	66.78	48.75
N_2	43.91	50.61	50.60	73.11	63.21	56.49
N_3	48.68	56.38	71.68	68.09	79.04	64.77
N_4	47.05	63.65	76.97	92.20	98.44	75.66
Mean	38.22	48.00	55.92	62.80	69.36	

S.E.M (N&K) - 2.44
S.E.M (T) - 1.54
CD(0.05) for N and K marginal mean - 6.93
CD(0.05) for T marginal means - 4.39

produced significant difference in N uptake compared to the application of entire dose as basal.

Interaction between treatments was not significant.

18. <u>Total K uptake</u>

The data on total potassium uptake are presented in Table 32, Fig.9 and analysis of variance in Appendix XIX.

Potassium uptake increased significantly with increase in nitrogen dose. Maximum potassium uptake was recorded by N_4 which was superior to all other levels. Treatments N_2 and N_3 were on par and superior to N_1 and N_o. N_o recorded minimum uptake.

Different levels of potash produced significant effect in K uptake, the maximum being at K_4 level. A decreasing trend in K uptake was noted with the decreasing rate of K application. Least uptake was noted at K_o level.

As per different time of application of nitrogen and potash, T_2 was significantly superior to T_1.

The interaction between levels of N and K was significant in K uptake. Highest uptake of K was got by N_4K_3 which was on par with N_1K_4 and N_2K_4. N_4K_3 was

Table 32. Total potash uptake (Kg/ha)

T/N	N_0	N_1	N_2	N_3	N_4	Mean
T_1	28.72	44.95	48.23	49.11	56.02	45.41
T_2	37.79	55.64	64.73	63.69	70.56	58.48
Mean	33.25	50.30	56.48	56.40	63.29	
T/K/	K_0	K_1	K_2	K_3	K_4	
T_1	23.14	39.43	47.32	54.48	62.66	45.41
T_2	25.74	49.92	60.59	72.21	83.94	58.48
Mean	24.44	44.68	53.96	63.34	73.30	
N/K	K_0	K_1	K_2	K_3	K_4	
N_0	15.17	26.74	35.87	40.19	48.31	33.25
N_1	22.86	42.69	49.23	50.37	86.33	50.30
N_2	33.04	49.40	53.99	63.73	82.24	56.48
N_3	26.92	43.86	65.22	72.26	73.74	56.40
N_4	24.20	60.70	65.48	90.16	75.90	63.29
Mean	24.44	44.68	53.96	63.34	73.30	

S.E.M. = 1.92 CD(0.05) for N and K marginal means = 5.45

" = 1.21 CD(0.05) for T marginal means = 3.45

" = 4.28 CD(0.05) for NK combination =12.18

found superior to all combinations and the lowest uptake was noted at N_oK_o level.

Economics of production

The data on economics of production is presented in Table 33.

The data revealed that the maximum net profit was given by the split application of nitrogen and potash at the rate of 120 kg/ha each followed by the split application of 60 kg N/ha and 120 kg K_2O/ha. In control plots there was a loss of Rs.6635/-

Correlation studies

The data on correlation coefficients are presented in Table 34. Correlation between nitrogen and potash uptake and yield of tubers number of marketable tubers and total drymatter production were studied.

The result show that nitrogen uptake and yield of tubers per hectare, nitrogen uptake and drymatter production nitrogen uptake and number of marketable tubers per plant are significantly and positively correlated.

The correlation studies indicate that significant and positive correlation were also found between potassium uptake and yield, potassium uptake and marketable tubers and potassium uptake and drymatter production.

Table 34. Correlation Coefficients

Sl. No.	Characters studied	Correlation coefficient
1	Nitrogen uptake x yield of tuber/ha	0.837**
2	Nitrogen uptake x number of marketable tubers/plant	0.704**
3	Nitrogen uptake x drymatter production	0.916**
4	Potassium uptake x yield of tuber/ha	0.903**
5	Potassium uptake x number of marketable tubers/plant	0.661**
6	Potassium uptake x drymatter production	0.837**

** Significant at 0.1 per cent.

DISCUSSION

DISCUSSION

1. Height of Plants

In general the height of plant was significantly influenced by the nitrogen levels whether it was applied in one dose or in two splits, indicating the influence of nitrogen on plant growth which is an established fact. Eventhough organic manure at the rate of 10 t/ha was applied at the time of planting it did not help to increase the height of plants in the absence of inorganic nitrogen in control plots. Nitrogen encourages plant height through its effect on rapid meristamatic activity. The present result on the height of plant is in agreement with the findings of Purewal and Dargan (1959) in sweet potato, Dubey and Bhardwaj (1971) and Krishnappa and Shivasankara (1981) in potato.

Potash also was found to have very little influence directly on plant growth. Higher levels of potash at 90 to 120 kg per hectare influenced the height only at early stages of growth.

Split application of fertilizers, was found to influence the height, may be because the nutrients were made available for a longer period when compared to giving the entire dose at the time of planting. This indicates that the split application is beneficial for the vegetative growth than single dose.

2. Number of branches

Coleus is a crop which branches profusely and produce a good cover canopy. Higher the number of branches more will be the spread more will be the number of leaves which will help in better photosynthetic activity. So the present study shows that nitrogen at higher levels (90 to 120 kg/ha) was found to increase the branches throughout the plant growth, compared to no nitrogen. Nitrogen applied at the rate of 120 kg/ha was found to produce 88% more number of branches over no nitrogen upto 90th day after planting after which the variations were considerably reduced. This shows that better branching takes place in the entire growth stage due to the influence of nitrogen. Similar observations were made by Dubey and Bhardwaj (1971) on potato where it was noted that nitrogen increased number of branches per plant.

Similar trend was also noted in the potash levels on the branch number during the growth period. So in general both nitrogen and potash helped in increasing the number of branches in coleus.

3. Number of functional leaves

The number of functional leaves was also influenced by the nitrogen levels over control throughout the growth period. Higher the number of functional leaves and longer the duration of their exposure better will be the photosynthetic activity. Onwueme (1978) observed that fertilization with nitrogen enables the Dioscorea crop to develop as large a leaf area as possible so that when tuber initiation occurs there is sufficient photosynthetic area to make the tuber growth rapidly.

In the case of potash also it helped in maintaining the total number of functional leaves only at 60th day of planting. Watson (1947) pointed out that potassium increase the size of the leaves in the early part of growing season, though this effect had disappeared at harvest and that this initial increase was sufficient to account for the differences in yield of roots.

Though the time of application of these nutrients did not help significantly on functional leaves there was an increase of 11.5%, 8.9% and 27.6% for split application over basal application during 30th to 90th day of planting respectively.

4. Plant spread

As in the case of number of branches and total number of functional leaves the spread is also an important factor which helps in the physiological activity of the crop. Nitrogen alone was found to influence the spread from the 60th day of planting upto harvest. The role of nitrogen on plant growth is an already established fact. As the nitrogen helped in increasing the branches, it helped to increase the spread. Similar observations were made by Purewal and Dargan (1959) where they found that application of 50 lb nitrogen increased the length of vines in sweet potato. With regard to potash or the time of application there was no significant influence.

5. Leaf area index

The leaf area index was found to be significantly increased by the nitrogen application during 60th and 90th day of planting. Higher the nitrogen application, higher was the number of branches and functional leaves. This shows that nitrogen application helped to increase the leaf area significantly. Thus more LAI was made available to the crop for the various physiological activities of the crop including photosynthesis. Russel (1973) stated that for many crops the amount of leaf area available for photosynthesis is roughly proportional to the amount of nitrogen supplied.

In the case of potash it was found to influence LAI only at 60th day. This was in agreement with the finding of Watson (1947) where he observed that potassium increased the size of the leaves. LAI was also found to be influenced by the combined effect of N and K at 60th day and higher level of nitrogen applied in two split doses was also found to influence the LAI at 90th day.

The split application might have helped in increasing leaf area during later stages of plant growth.

6. <u>Tuber yield per plant</u>

The number of tubers as well as their weight per plant were ([illegible]) influenced by nitrogen application (Fig.3). Higher the nitrogen level, higher was the number as well as weight. Application of 120 kg N/ha was found to be signifi-

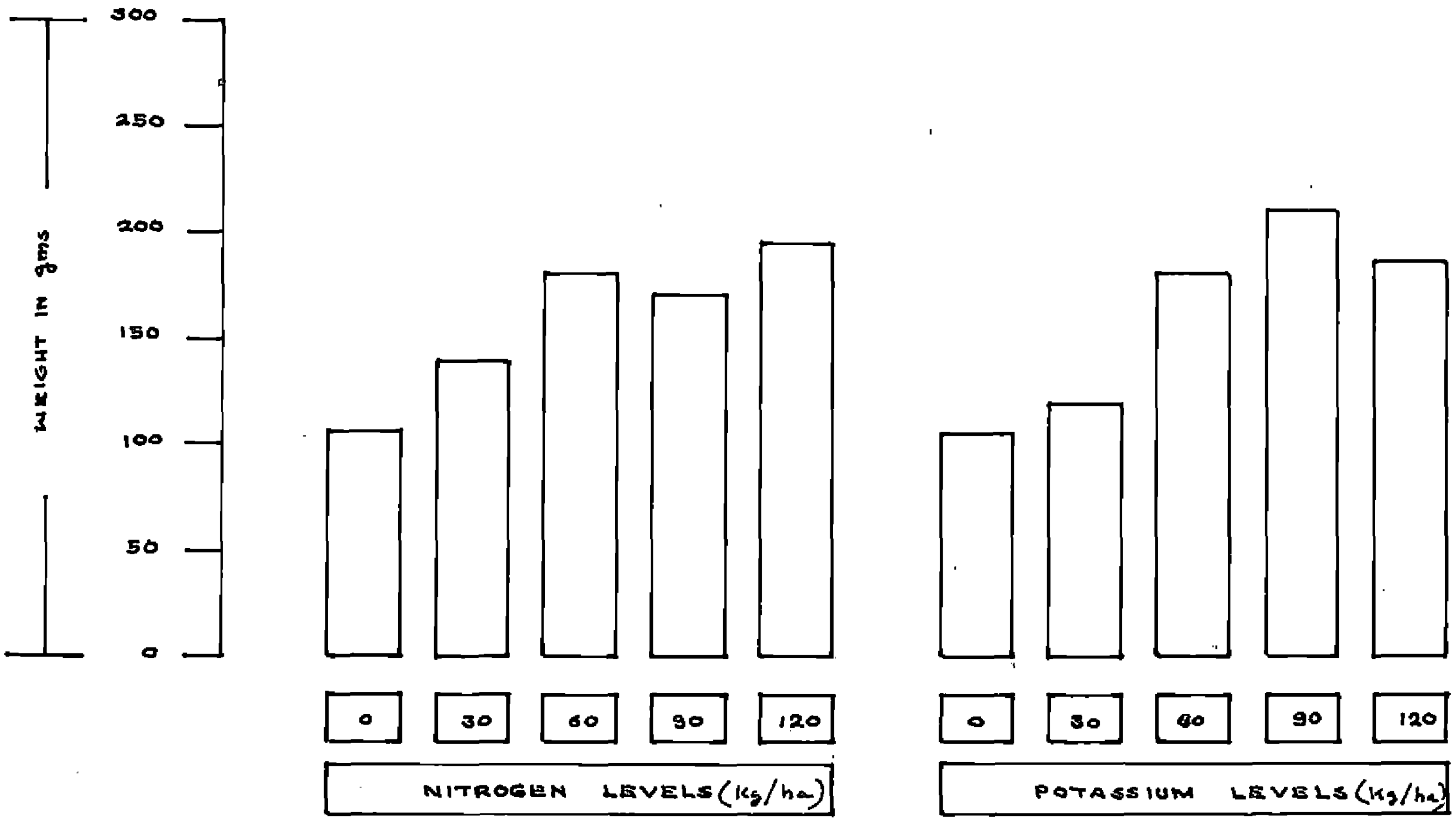


FIG: 3 TUBER YIELD PER PLANT

cantly superior to 30 kg N/ha and control in both aspects. It gave 112% more tubers and 84.6% more weight of tuber compared to control. This was in agreement with the finding of Dubey and Bhardwaj (1971) where they found that nitrogen increased the fresh and dry weight of potato tubers per plant compared with controls given no nitrogen. Nambiar et al. (1976) also reported that increasing rate of applied nitrogen significantly increased the number of tubers per plant in sweet potato.

In the case of potash higher levels of potash (60 to 120 kg K_2O/ha) were on par and superior over 30 kg and control in both aspects (Fig.3). The highest level of 120 kg potash increased the number by 79% and tuber weight by 71% over control. Similar observations were made by Bautista (1981).

Though split application significantly increased the number of tuber per plant over basal dressing the weight of tubers was not significantly affected.

7. Marketable tubers

The data presented in table 22 and Fig. 4a & 4 b indicate the number of marketable tubers. There was in general an

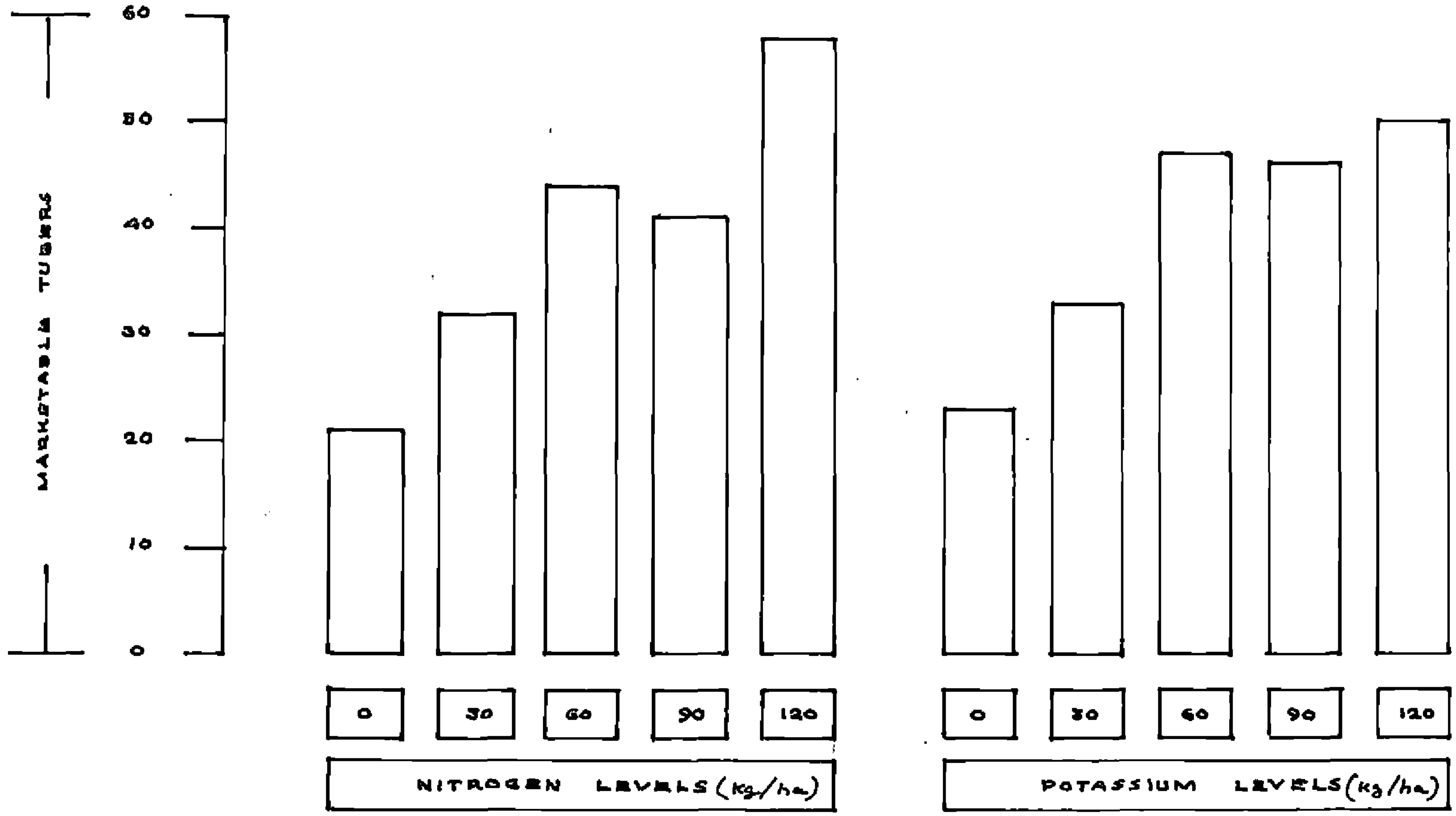


FIG: 4a. MARKETABLE TUBERS PER PLANT

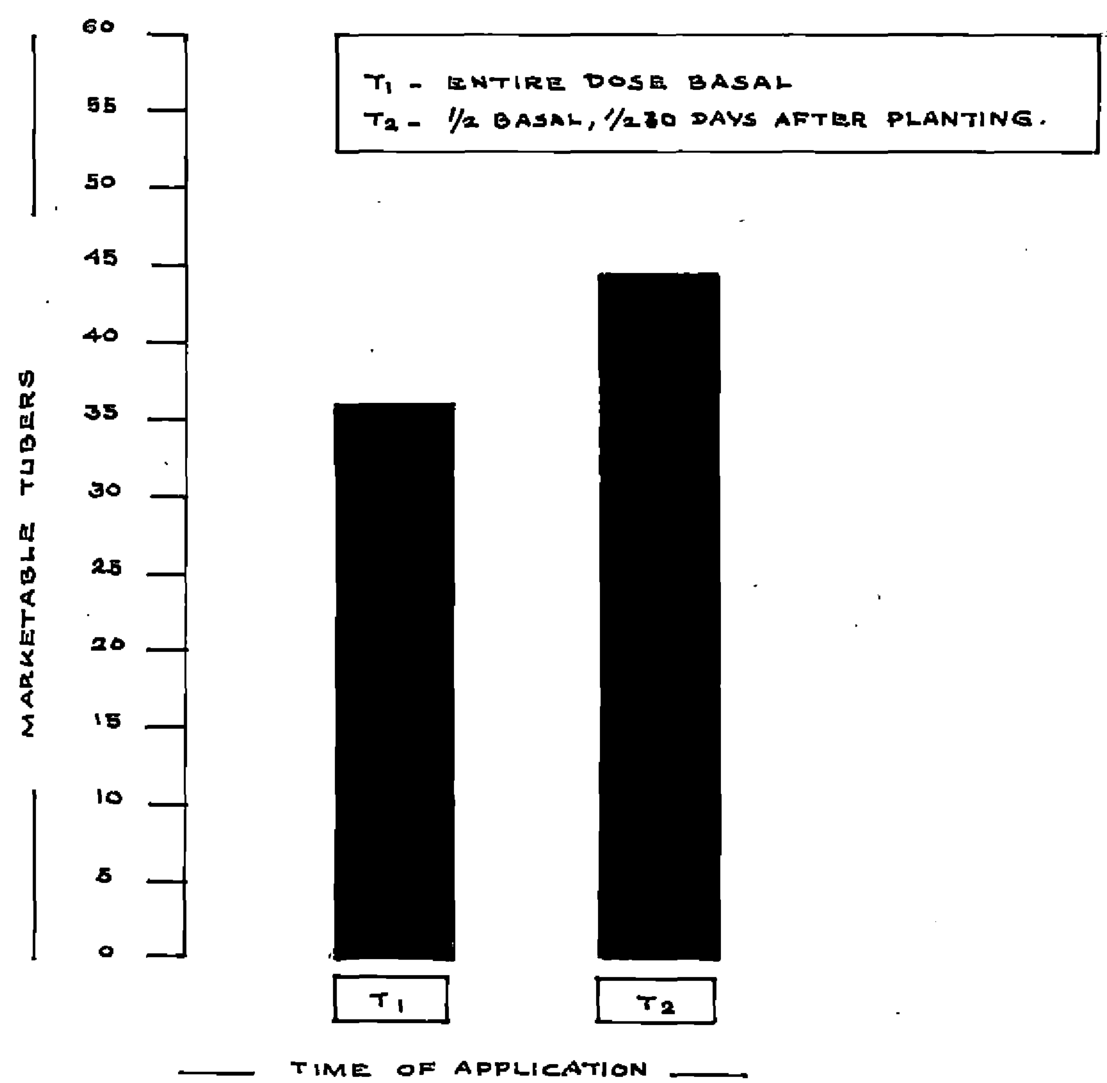


FIG: 4b. MARKETABLE TUBERS PER PLANT

increasing trend noted by the application of nitrogen from zero to 120 kg/ha which indicate that nitrogen application helped in converting more number of roots into storage organs. The number of tubers by nitrogen application has increased from 21.4 to 58.4 . N uptake and number of marketable tubers were positively correlated also. Das Gupta and Ghosh (1973) also obtained more tubers of bigger size by nitrogen application to potato. They opioned that greater growth of the tubers under high nitrogen fertilization possibly indicated greater translocation of photosynthates from a relatively large source formed to the ever increasing sink. With regard to potash application beyond 60 kg of K there was no positive effect on marketable tuber number. The number of marketable tubers was increased from 22.6 to 49.5 from control to highest K application.

The data presented in table 23 indicate the weight of marketable tubers. The weight of marketable tubers was increased by the increase in nitrogen application which shows the influence of nitrogen on tuber weight. Tuber weight was increased from 48.15 to 121.30 g by the increase in nitrogen application from 0 to 120 kg kg/ha. With regard to K application 120 kg K_2O/ha produced maximum weight of tubers. But 60 kg and 90 kg K_2O were on par. The tuber weight was also substantially increased from 49.90 to 121.29 by the increase in K application from 0 to 120 kg/ha. Sharma et al. (1976) also obtained similar results in potato.

Percentage weight of marketable tubers was also increased by nitrogen application. For higher percentage weight of marketable tubers nitrogen level can go upto a maximum of 90 kg/ha, after which it declined slightly. The increase in percentage weight of marketable tubers varied from 42.2 to 61.4 per cent by the increase of nitrogen from 0 to 90 kg. Potassium application beyond 60 kg K_2O/ha, had no significant effect in increasing the percentage weight of tubers. It increased from 47 per cent to 56.2 per cent by the K application from zero to 60 kg/ha. Obigbesan et al. (1982) also obtained higher percentage of marketable tubers by potash fertilization to Dioscorea spp: Time of application did not help in increasing the percentage weight of marketable tubers.

8. Yield of tubers per hectare

The yield of tuber is the combined influence of total number as well as weight of tuber. Studies on the number and weight of tubers per plant also showed an increase with

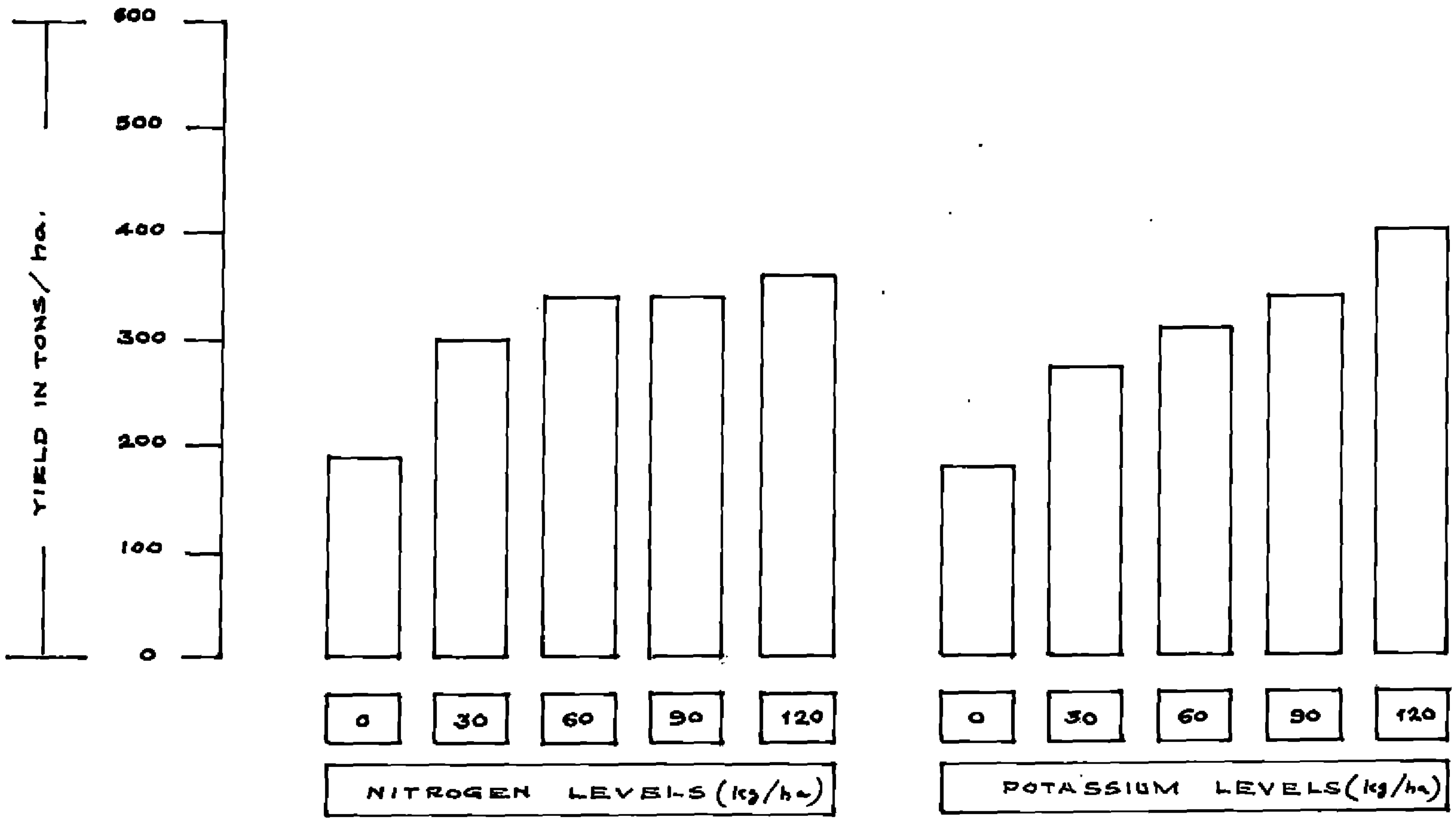


FIG: 5a. YIELD OF TUBERS PER HECTARE

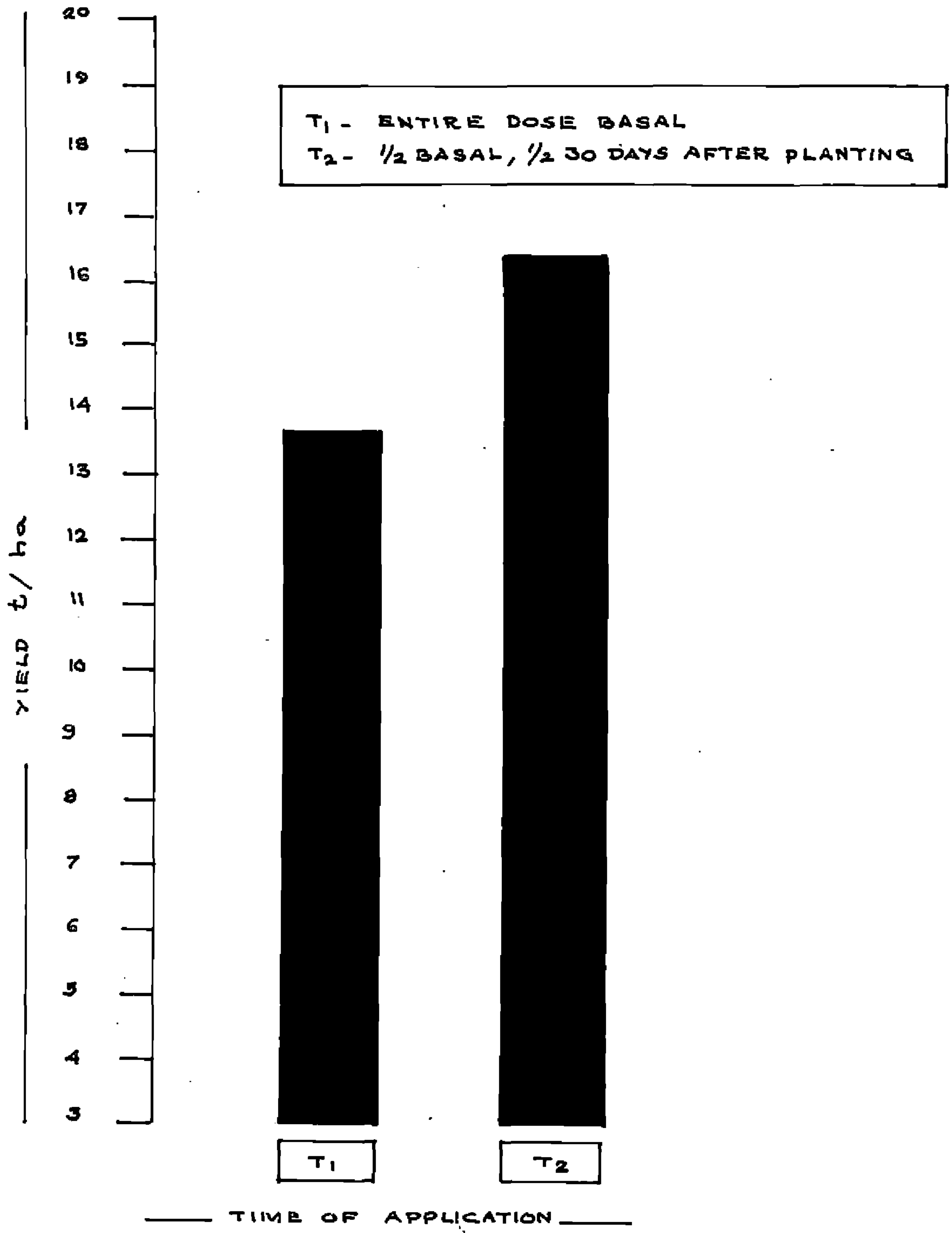


FIG: 5b. YIELD OF TUBERS PER HECTARE

increasing nitrogen levels, potash levels as well as the time of application. When 30 kg N/ha was added yield was increased by 5560 kg over the control, (Fig. 5a) which works out to an average of 185.3 kg tuber per kg of nitrogen added. When the nitrogen application was increased from 30 kg to 60 kg and from 60 kg to 90 kg and from 90 kg to 120 kg the increases were 46.0, 29.0 and 28.7 kg per kg of nitrogen added. This shows that when coleus is fertilized with a basal dressing of 10t farm yard manure per hectare, it will be sufficient to apply 30 kg N/ha to give a substantial yield per kg of N, after which the increase in yield was proportionately reduced. Nitrogen can be applied to a maximum of 60 kg/ha for total tuber yield which was on par with the higher levels. Similar trend was noticed in bulking rate, utilisation index and number and weight of tubers also. This shows that application of 60 kg N/ha was sufficient and further increase was more utilised for top growth rather than for storage purpose. Significant and positive correlation was obtained between nitrogen uptake and tuber yield/ha. Similar results were obtained in coleus by Singh and Maini (1969) indicating that beyond 60 kg N/ha was not necessary. Thyagarajan (1969) also found that in coleus there was linear increase in tuber yield upto 60 kg N/ha.

The role of potash in tuberization has been substantiated in this experiment by the uniform increase in tuber yield when the nutrient level was proportionately increased. In control plots it recorded an yield of 9.14 t/ha and with every increase of K_2O level, the yield was proportionately increased to 13.62, 15.59, 17.15 and 19.78 t/ha which was equal to an increase of 49 percent, 70.7 per cent 91.58 per cent and 116.4 per cent respectively over control. Potash uptake and yield of tubers per hectare was positively correlated. Similar results were obtained in a trial conducted at Coconut Research Station, Nileswar where it was found that coleus responded to potash applications at the rate of 120 kg/ha by giving an yield increase of 627 kg over potash applied at 40 kg/ha (Anon 1978).

Split application of nutrients was also found to increase the yield by 2.72 t/ha over basal application (Fig. 5b). This shows that split application was beneficial in coleus than a single basal application. Similar observations were made by Shukla and Singh (1975) in potato and Singh and Maini (1969) in coleus. Split application of potash was associated with efficient absorption and translocation of nutrients from the soil and foliage (Shula and Singh, 1975).

In the presence of highest level of 120 kg K_2O/ha levels of nitrogen N_2, N_3 and N_4 were found to influence the yield, significantly compared to other combinations as well as control. A linear increase in tuber yield was recorded with the incremental dose of potash application. In the presence of nitrogen also the same trend was noted. The influence of potash on tuberisation is an established fact and the nitrogen was helpful in the development of foliage which enhanced photosynthetic activity and tuber bulking. Therefore in the presence of adequate amount of nitrogen the crop was able to convert more of photosynthates in the better tuber development and tuber yield. So coleus crop was found to give substantially higher yields at higher levels of potash in the presence of medium level of nitrogen. Though N_4K_4 combination gave the highest yield of 2344 tonnes/ha it was found on par with N_3K_4 and N_2K_4 combination. N_4K_4 produced an yield which was nearly 249 per cent more than the control. From the table 33 it can be noted that difference in the average profit between N_4K_4 and N_2K_4 is only marginal.

N_2K_4 combination also gave an yield as high as 241.6 per cent over control.

9. Total dry matter yield

Nitrogen had already been found to influence the height of plant, number of leaves, number of branches and spread of plant and better yield. Thus it had indirectly helped in increasing total dry matter yield (Fig. 6a). Higher levels of nitrogen in general helped to increase the dry matter compared to lowest level or control and among higher levels the difference was only very little and so it indicated that 60 kg N/ha was as good as 120 kg N for dry matter accumulation. The data in table 31 also indicate the N uptake by the crop at different levels of nitrogen. A positive correlation was also found to exist between N uptake and dry matter production. Mandal et al. (1971) had made similar observations where they found that maximum dry matter content was noticed at the nitrogen dose of 75 kg/ha in sweet potato.

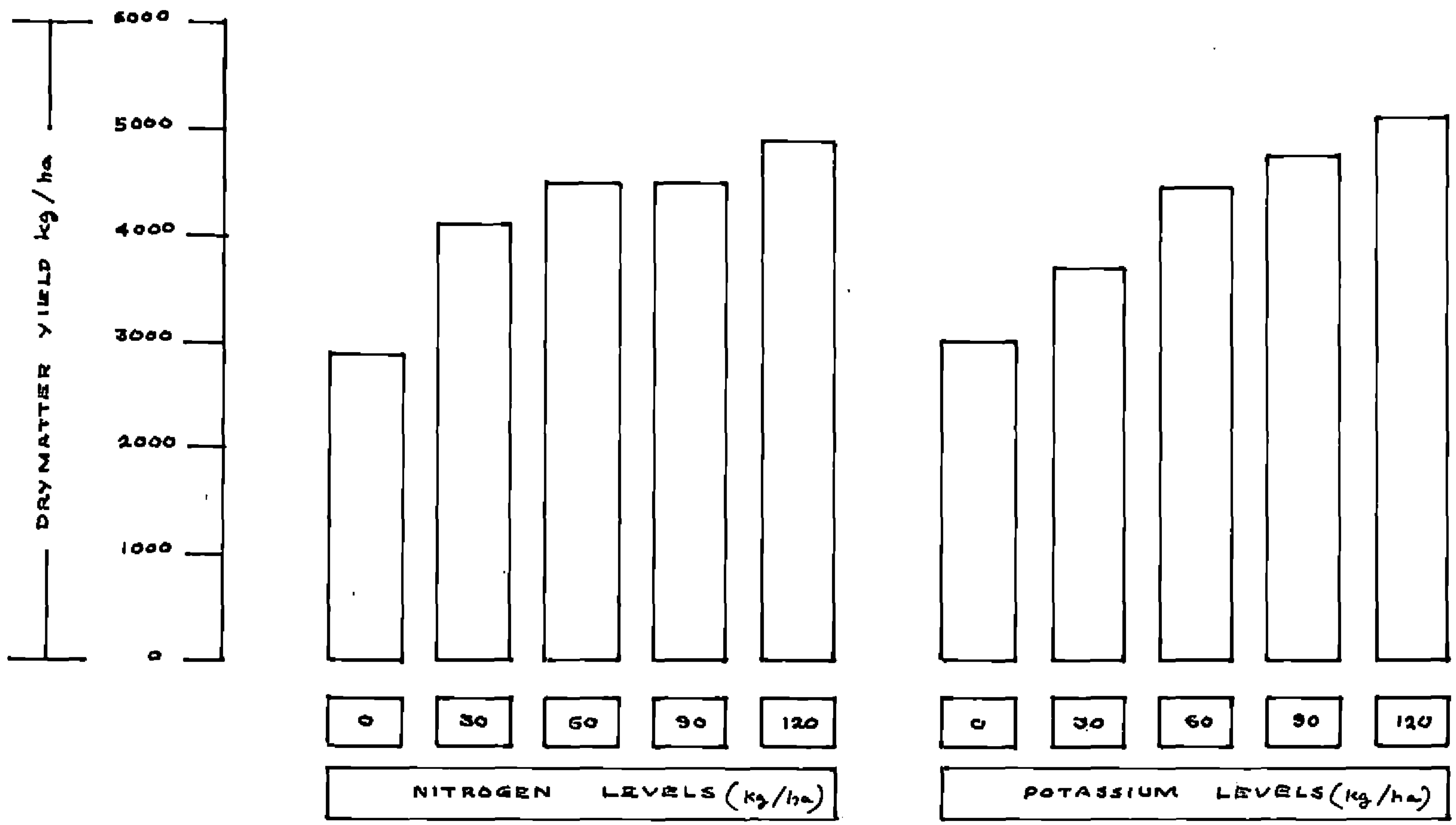


FIG: 6a. TOTAL DRYMATTER YIELD PER HECTARE

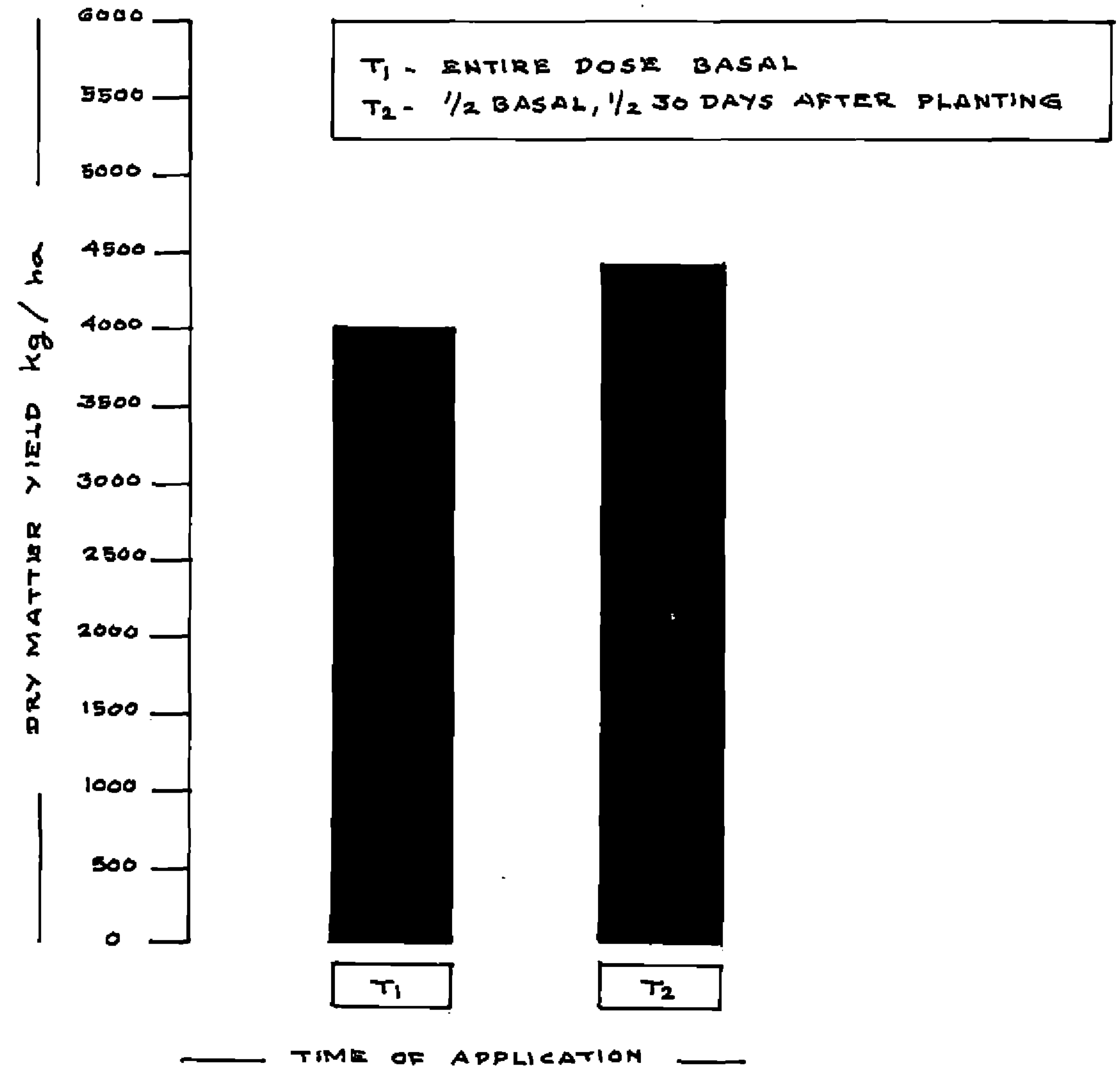


FIG: 6b. TOTAL DRYMATTER YIELD

Similarly an increasing trend in dry matter production was noted by the K application (Fig. 6a). Positive correlation was obtained between potash uptake and yield of tubers/ha. A maximum of 120 kg potash was found to be superior over all other treatments, may be because it helped in better tuberization and tuber yield.

Split application of fertilizers was found to be more efficient than a single basal application in dry matter accumulation (Fig. 6b). Split application helped the plant in accumulating more nutrients and thereby helping more photosynthesis and dry matter accumulation. Similar observations were made by Singh and Maini (1969) in coleus.

10. Bulking rate

From the data (table 27) and Fig. 7 it may be noted that application beyond 60 kg N had no influence on the bulking rate. All the higher levels (60,90 and 120 kg N/ha) were superior over 30 kg N and control. Nitrogen at the rate of 60kg/ha increased the bulking

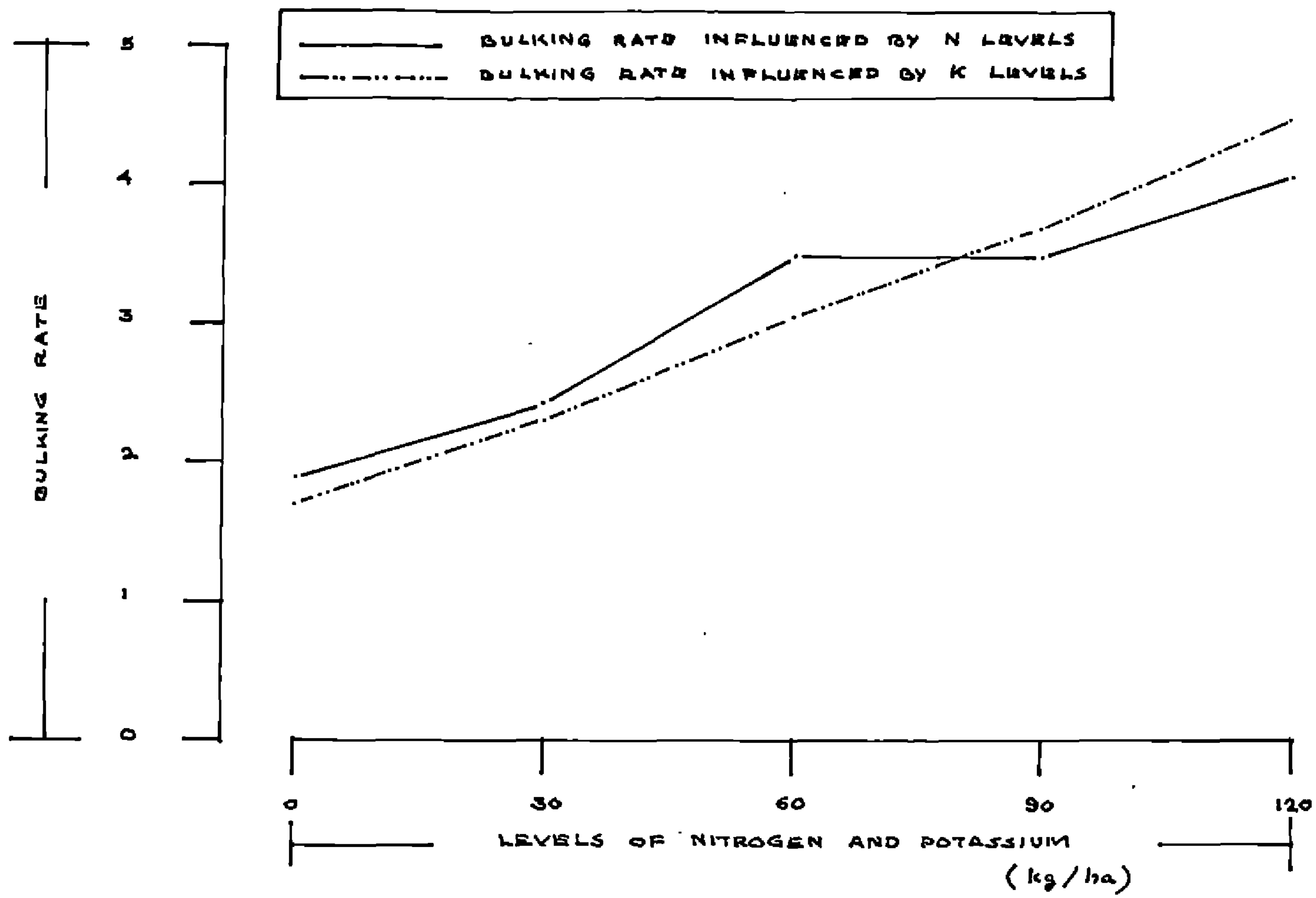


FIG: 7 BULKING RATE

rate by 84. 2 per cent over control and 48.3 per cent over 30 kg N. Tuber bulking rate might have been influenced by the leaf area index (Table 18-19) and nitrogen uptake (Table 31). Similar observations were made by Russel (1973) where he stated that root crops benefitted from nitrogen manuring through the increased leaf area brought about by the nitrogen.

The highest level of 120 kg K_2O/ha was found to be superior over all the levels and control. K was found to influence directly the tuber weight and tuber size. Potash at the rate of 120 kg/ha increased the tuber bulking rate by 156.9 per cent over control. This is in agreement with the finding of Shukla and Singh (1975) in potato where they found that application of 180 kg K_2O/ha to potato gave significantly higher rate of bulking over others.

11. <u>Utilisation Index</u>

Utilisation index (Fig.8) shows how much of the food material synthesised have been utilised for tuber development. In coleus it was found that there was no significant variation in this aspect when the nitrogen application

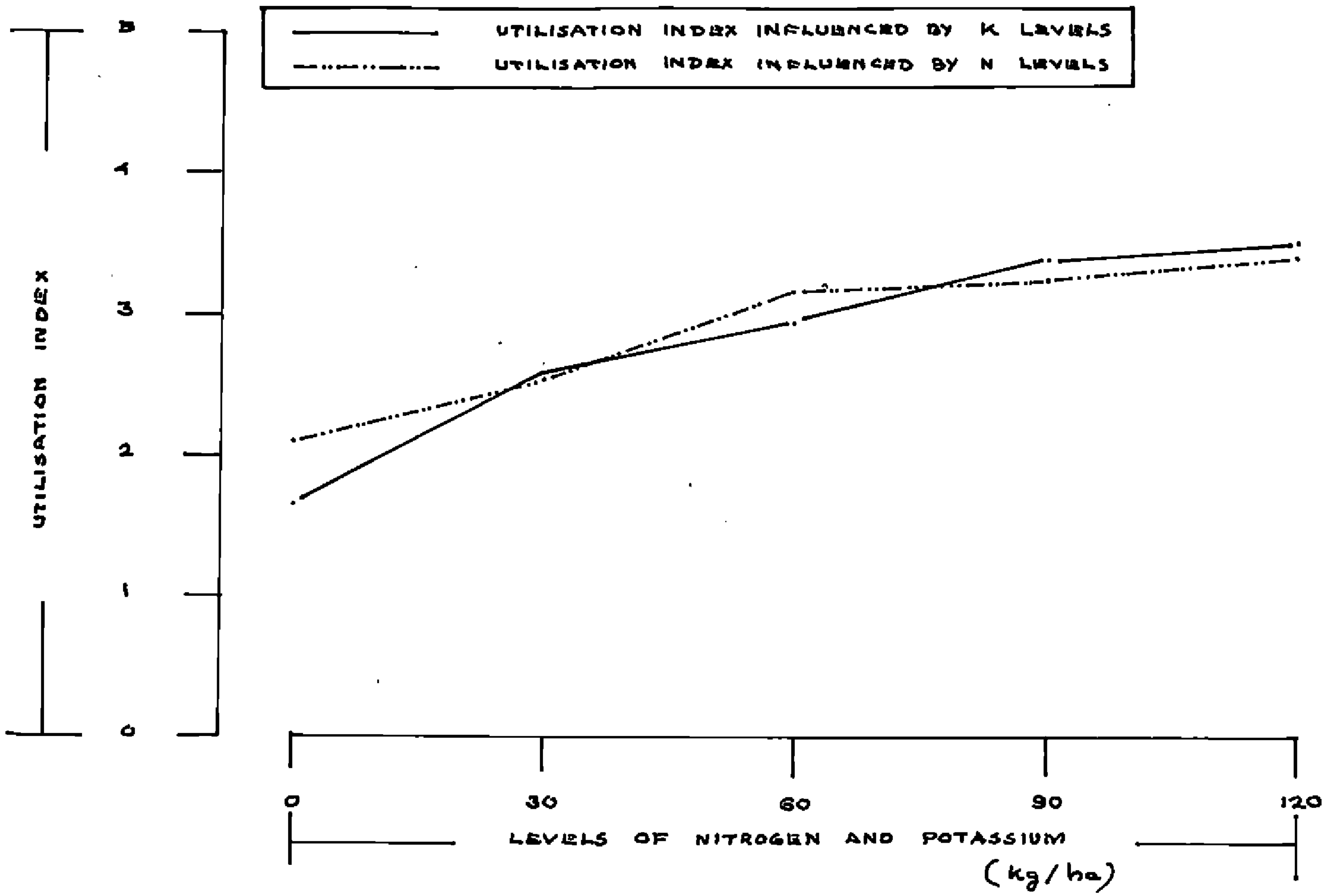


FIG. 8 UTILISATION INDEX

was increased from 60 kg to 120 kg N/ha (Fig.8). Since 90 kg and 120 kg were on par and superior to 30 kg and control, it will be sufficient to apply 60 kg N to coleus with regard to this factor. Nitrogen at the rate of 60 kg/ha gave an index of 3.16 which was about 21 per cent and 49 per cent more efficient than 30 kg N and control respectively.

Though all the levels of potash were found superior to no potash application, with regard to utilisation index the variation between the consecutive levels were not significant. May be that the variation in the doses were small to show any drastic variation in the index. This can be seen from the table where 120 kg was superior over 60 kg and 30 kg and 90 kg was found to be superior over 30 kg N/ha (Fig.8). Shukla and Singh (1975) also found that higher application of K improved the tuber efficiency.

The combined effect of N and K were also found to be significantly influencing the utilization index. The highest index was expressed by 120 kg N and 90 kg potash and the least index of 1.08 by control.

Time of application did not show any effect on this aspect.

12- Starch content

Though the starch content was not significantly influenced by nitrogen application 30 kg N/ha produced maximum starch content. The starch content decreased with increasing levels of nitrogen application. This was in agreement with finding of Verma et al. (1975) where there was a negative relationship for nitrogen content and starch content.

Starch content of tuber has been found to be influenced by higher levels of potash over lower levels and the control. Since the difference between K_3 and K_4 being very little it is enough that 90 kg K_2O/ha be applied to substantially increase starch content in coleus.

Split application has also been found to be efficient in the production of starch compared to basal application. This is in agreement with the finding of many workers viz. Belyaev et al. (1981) and Shukla and Singh (1976).

13. Protein content

The direct influence of nitrogen on protein content of tubers can be seen from the data. The variation in the protein content between 90 and 120 kg N/ha and 30 kg and 60 kg N/ha were very little. So application of 90 kg N will be sufficient to substantially increase the protein content compared to lower levels and control. This was in agreement with the findings of Singh and Maini (1969) in colour. Wilcox and Hoff (1970) in potato.

14. Total N uptake

The total nitrogen uptake by the crop was found to be directly influenced by N and K application as well as split application as seen from table 31 and Fig.9.

By increasing N levels from 0 to 120 kg/ha , the uptake was also increased from 28.62 to 75.66 kg/ha. In the case of K also the increase in N uptake from control to the highest level of 120 kg K_2O/ha was from 38.22 to 69.36 kg/ha. Loue (1979) also reported that nitrogen and potash removal increased with increasing applications of nitrogen and potash fertilizers respectively in potato.

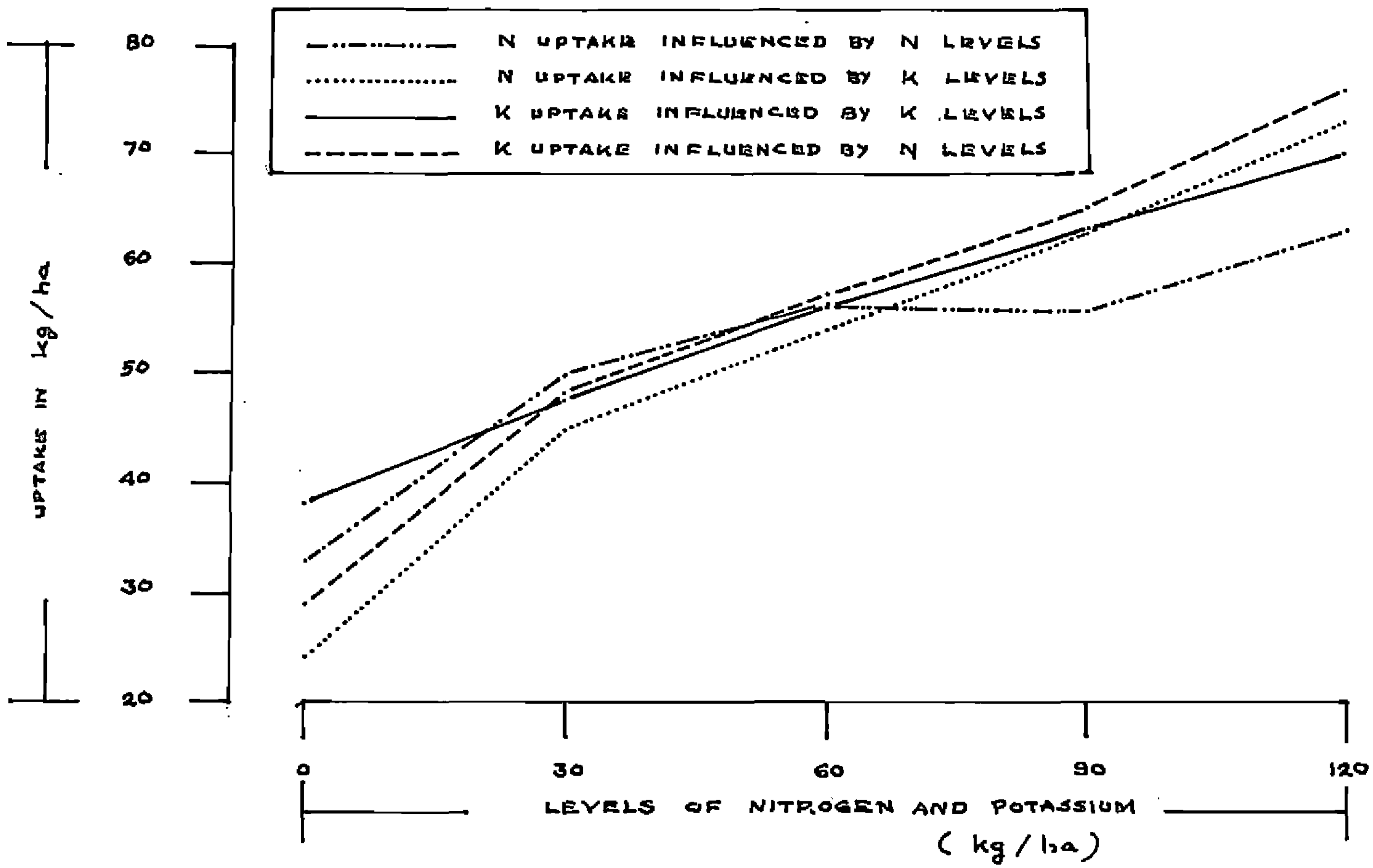


FIG: 9 NITROGEN AND POTASSIUM UPTAKE

Thus it may be noted that N and K fertilizer application help to increase the uptake of N in coleus. Similar results were obtained by Nair *et al.* (1976) in sweet potato and Grewal *et al.* (1979) in potato.

Split application of nutrients as well as higher levels of nutrients (N and K) directly help in the uptake of N. This has been shown by Singh and Maini (1969) in coleus and Sagar and Singh (1973) in potato.

15. K uptake

In the case of total uptake of K also the same trend was also noted (Fig.9). Highest levels of N helped to increase the uptake of potash by 30.04 kg over control. In the case of potash an increasing trend had been noted from control to highest level and the variation between control and highest level was 48.87 kg/ha. Varis (1973) also showed that nitrogen fertilization increased N, P and K uptake in potato. Sharma *et al.* (1976) proved that applied K increased K uptake in potato.

Split application of nutrients was found to favour the K uptake compared to single basal application.

Similarly Shukla and Rao (1974) reported that recovery of applied potassium was highest with the three-splits and lowest with single basal dressing to potato.

16. Economics of production

From the data on economics of production it was found that maximum net profit (Rs.19,470.10) was obtained by the split application of 120 kg/ha each of nitrogen and phosphorus. But it was closely followed (Rs.18,720.20) by the split application of 60 kg N and 120 kg K_2O/ha. The yields obtained by 60 kg N/ha was as good as that obtained by 90 kg N or 120 kg N/ha. So the economical dose of fertilizer combination for coleus can be 60 kg N, 30 kg P_2O_5 and 120 kg K_2O/ha applied half nitrogen and potash as basal and balance 30 days after planting.

SUMMARY

SUMMARY

An investigation was carried out in the Instructional Farm, College of Agriculture, Vellayani, during 1982 with the objective of fixing an optimum dose and suitable time of application of nitrogen and potash to coleus. The different levels of nitrogen and potash tried were 0,30,60,90 and 120 kg/ha. The two times of application were entire dose as basal and half basal and half thirty days after planting. The experiment was laid out in a randomised block design with two replications. The results of the study are summarised below:

1. The effect of nitrogen on plant height was significant in all observations. But the effect of potash on plant height was significant only at 30th day after planting. The time of application of nutrients had no effect on plant height.

2. Nitrogen levels increased number of branches at all stages except at harvest. Potash levels showed significant difference on number of branches only at 60th day and

90th day after planting. The time of application of nitrogen and potash had no effect on number of branches per plant.

3. Nitrogen at the rate of 120 kg/ha gave the maximum number of functional leaves at all stages. Potash levels had no significant influence on number of functional leaves except at 60th day. Nitrogen at the rate of 90 kg/ha applied in two split doses gave the maximum number of functional leaves.

4. Nitrogen levels in general produced better spread and superior to control except at the early stage. Potash levels and time of application of nutrients had no effect on plant spread.

5. Nitrogen at the rate of 120 kg/ha produced the maximum LAI. Potash levels influenced LAI at 60th day of planting. The timings of nitrogen and potash application had no effect on LAI at any stage.

6. Number of tubers per plant was the highest at 120 kg N/ha. Potash at the rate of 60 kg/ha was as good as 90 kg and 120 kg/ha in producing number of tubers per plant.

7. Nitrogen at the rate of 60 kg/ha produced as much weight of tubers per plant as that of 90 kg and 120 kg/ha. So also 60 kg K_2O/ha was sufficient to produce higher weight of tubers per plant. The time of application of N and K had no significant effect on tuber yield per plant, though Split application of nutrients showed an increasing trend in tuber yield per plant than basal application.

8. Highest number of marketable tubers per plant were produced by the application of nitrogen at the rate of 120 kg/ha. Potash at the rate of 60 kg/ha was as good as 120 kg/ha in the production of number of marketable tubers per plant. Split application of nutrients produced higher number of marketable tubers per plant.

9. Highest weight of marketable tubers was produced by nitrogen at the rate of 120 kg/ha and potash at the same rate. Increasing trend in weight of marketable tubers was shown by split application.

10. Highest percentage weight of marketable tubers was given by nitrogen at the rate of 90 kg/ha. Potash at the rate of 90 kg/ha was as good as 120 kg/ha in the production of percentage weight of marketable tubers. Timings of N and K application had no effect in percentage weight of marketable tubers.

11. Nitrogen at the rate of 60 kg/ha was sufficient to produce higher tuber yield/ha. Highest level of potash (120 kg/ha) produced maximum yield of tubers/ha. Split application of nutrients produced the highest yield over the single basal application.

12. Nitrogen at the rateof 60 kg/ha and potash at the rate of 120 kg/ha is sufficient to produce highest drymatter yield. Maximum drymatter yield was given by split application.

13. Nitrogen at the rate of 60 kg/ha was as good as 90 kg and 120 kg/ha in producing higher bulking rate. The highest value of bulking rate was given by potash at the rate of 120 kg/ha. Split application of nutrients increased the bulking rate over single basal application.

14. Utilisation index was also higher at 60 kg N/ha and was at par with 90 kg and 120 kg/ha in this respect. Potash at the rate of 90 kg/ha was as good as 120 kg/ha in producing higher utilisation index. Timings of N and K application had no effect on utilisation index.

15. Nitrogen had no effect on starch content of tubers. Potash at the rate of 90 kg/ha gave higher starch content of tubers. Split application was superior to single basal application.

16. Protein content was higher at 90 kg N/ha and was as good as 120 kg N/ha. Neither potash levels nor time of application had any effect on protein content.

17. Highest nitrogen uptake was noticed at 120 kg N/ha and potash at the same rate. Split application increased nitrogen uptake over single basal application.

18. Highest potash uptake was also observed in treatments where nitrogen and potash were applied at the rate of 120 kg/ha. Split application increased the uptake of potash.

19. It was clear from the economics of production that a fertilizer dose of 60 kg N, 30 kg P_2O_5 and 120 kg K_2O/ha applied in split doses can give a net profit of Rs.18,720/hectare.

FUTURE LINE OF WORK

Based on the present study the following future line of work are suggested.

1. Different N, P, K ratios may be studied taking into account the present investigation.
2. More number of splits of N, P, K may be studied.
3. Agro-techniques may be developed to increase the percentage of marketable tubers, so as to give maximum net return.

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* Original not seen.

APPENDICES

Appendix I

Weather Data : Average values for past 24 years (1956-1980)

	Rainfall (mm)	Temperature °C		Humidity (percent)
		Maximum	Minimum	
January	34.62	30.93	22.46	79.88
February	36.00	31.34	22.87	82.05
March	35.06	32.17	24.00	81.36
April	89.16	32.27	25.02	83.29
May	197.70	31.75	24.92	85.07
June	292.20	30.42	23.95	85.13
July	220.90	29.72	23.46	87.18
August	138.63	29.77	23.22	86.02
September	150.28	30.12	23.36	85.77
October	264.14	29.70	23.76	87.41
November	208.05	29.91	23.81	86.97
December	71.85	30.66	23.26	84.78

Appendix II

Analysis of variance - Height of the plants

Source	df	Mean square			
		30th day	60th day	90th day	120th day
Block	1	41.35	30.51	6.45	19.45*
N	4	30.72**	75.46**	6.40*	14.62*
K	4	9.42*	9.21	0.67	7.2
T	1	0.51	31.35	0.61	50.47**
N x K	16	3.12	5.30	4.76	3.28
N x T	4	3.82	0.84	1.90	1.74
K x T	4	2.64	0.89	0.76	2.00
N x K x T	16	1.64	2.91	2.28	3.21
Error	49	2.66	5.15	2.18	5.18

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix III

Analysis of variance - Number of branches

Source	df	Mean square			
		30th day	60th day	90th day	120th day
Block	1	137.36**	341.87**	633.75	1.441
N	4	27.09**	133.5**	1709.7**	41.96
K	4	0.77	48.16*	450.87*	8.59
T	1	4.55	23.69	81.06	23.5
N x K	16	3.32	16.94	143.89	36.4
N x T	4	5.83	5.29	29.84	24.16
K x T	4	4.99	11.92	48.83	42.39
N x K x T	16	3.79	9.69	96.29	44.79
Error	49	5.22	17.48	112.37	26.69

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix IV

Analysis of variance - Number of functional leaves

Source	df	Mean square			
		30th day	60th day	90th day	120th day
Block	1	1754.12*	3023.99*	1218.00	1219.00
N	4	1961.97**	5461.99**	20267.47**	3697.50
K	4	306.86	2608.75*	4645.75	3903.99
T	1	1323.06	2173.99	908.99	511.00
N x K	16	203.29	543.63	2989.75	3277.19
N x T	4	1136.05*	375.00	2351.50	2920.00
K x T	4	540.63	1132.49	2074.99	1427.75
N x K x T	16	296.57	327.63	1665.44	2988.00
Error	49	430.41	709.25	2825.77	2667.26

** Significant at 1.00 per cent
* Significant at 5.00 per cent

Appendix V

Analysis of variance - Spread of the plants

Source	df	Mean square			
		30th day	60th day	90th day	120th day
Block	1	330.22**	156.89	16.88	255.69
N	4	29.23	410.25*	673.94**	228.48*
K	4	15.25	80.52	54.11	101.14
T	1	2.50	65.91	8.81	104.69
N x K	16	6.75	107.18	78.66	87.11
N x T	4	16.85	19.99	41.02	6.48
K x T	4	13.91	10.11	5.81	103.88
N x K x T	16	11.26	32.82	29.44	60.88
Error	49	22.15	70.70	96.52	66.45

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix VI

Analysis of variance - Leaf area index

Source	df	Mean square 60th day	Mean square 90th day
Block	1	16.56**	0.459
N	4	22.07**	1.58**
K	4	5.13*	0.322
T	1	0.93	0.29
N x K	16	4.41*	0.329
N x T	4	3.04	0.751*
K x T	4	0.514	0.198
N x K x T	16	1.69	0.150
Error	49	1.85	0.206

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix VII

Analysis of variance - Total number of tubers/plant

Source	df	
Block	1	125.25
N	4	7280.2**
K	4	5361.19**
T	1	4329.44**
N x K	16	1176.42**
N x T	4	40.29
K x T	4	287.11
Nx K x T	16	148.06
Error	49	315.08

** Significant at 1.00 per cent

Appendix VIII

Analysis of variance - Tuber yield/plant

Source	df	
Block	1	5813.99
N	4	25223.73**
K	4	39264.21**
T	1	4808.99
N x K	16	5255.75
N x T	4	3346.75
K x T	4	9950.75
N x K x T	16	4841.43
Error	49	4852.06

** Significant at 1.00 per cent

Appendix IX

Analysis of variance - Number of marketable tubers/plant

Source	df	
Block	1	27.062
N	4	3807.51**
K	4	2636.54**
T	1	1616.06**
N x K	16	331.37*
N x T	4	57.23
K x T	4	66.70
N x K x T	16	61.92
Error	49	105.65

** Significant at 1.00 per cent

* Significant at 1.00 per cent

Appendix X

Analysis of variance- Weight of marketable tubers

Source	df	M.S
Block	1	68.9
N	4	1274.66**
K	4	488.53**
T	1	125.92
N x K	16	156.26
N x T	4	50.2
K x T	4	23.67
N x K x T	16	21.38
Error	49	74.79

** Significant at 1.00 per cent

Appendix XI

Analysis of variance - Percentage weight of marketable tubers

Source	df	M.S.
Block	1	1.005
N	4	17035.5**
K	4	19048.98**
T	1	1937.47
N x K	16	2450.26
N x T	4	1114.13
K x T	4	3252.87
N x K x T	16	1661.79
Error	49	1671.52

** Significant at 1.00 per cent

Appendix XII

Analysis of variance - Yield of tubers/ ha

Source	df	M.S.
Block	1	46.242**
N	4	226.85**
K	4	320.09**
T	1	185.66**
N x K	16	9.68*
N x T	4	5.15
K x T	4	6.86
N x K x T	16	1.92
Error	49	4.49

** Significant at 1.00 per cent

* Significant at 1.05 per cent

Appendix XIII

Analysis of variance - Total drymatter yield

Source	df	Mean square
Block	1	3055870.0*
N	4	11563892.0**
K	4	13678064.0**
T	1	4773112.0**
N x K	16	422751.84
N X T	4	127807.9
K x T	4	631871.68
N x K X T	16	408911.68
Error	49	486781.12

** Significant at 1.00 per cent

* Significant at 1.00 per cent

Appendix XIV

Analysis of variance- Bulking rate

Source	df	Mean square
Block	1	14.3**
N	4	15.55**
K	4	22.56**
T	1	21.91**
N x K	16	1.848
N x T	4	1.052
K x T	4	2.565
N x K x T	16	0.902
Error	49	1.15

** Significant at 1.00 per cent

Appendix XV

Analysis of variance - Utilisation Index

Source	df	Mean square
Block	1	2.91
N	4	5.76**
K	4	8.38**
T	1	1.708
N x K	16	1.96*
N x T	4	0.423
K x T	4	0.151
N x K x T	16	0.654
Error	49	0.792

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix XVI

Analysis of variance - Starch content

Source	df	Mean square
Block	1	0.00
N	4	31.64
K	4	641.11**
T	1	96.5*
N x K	16	40.97*
N x T	4	22.84
K x T	4	10.06
N x K x T	16	14.95
Error	49	20.55

** Significant at 1.00 per cent

* Significant at 5.00 per cent

Appendix XVII

Analysis of variance - Protein content

Source	df	Mean square
Block	1	4.398
N	4	31.363**
K	4	3.119
T	1	1.137
N x K	16	2.768
N x T	4	0.606
K x T	4	1.662
N x K x T	16	1.846
Error	49	1.639

** Significant at 1.00 per cent

Appendix-XVIII

Analysis of variance - Total nitrogen uptake

Source	df	Mean square
Block	1	912.44**
N	4	6298.25**
K	4	2991.25**
T	1	1419.37**
N x K	16	182.32
N x T	4	25.80
K x T	4	217.27
N x K x T	16	86.59
Error	49	119.01

** Significant at 1.00 per cent

Appendix- XIX

Analysis of variance - Total potassium uptake

Source	df	Mean square
Block	1	762.75**
N	4	2606.09**
K	4	6998.01**
T	1	4275.37**
N x K	16	290.33**
N x T	4	46.97
K x T	4	256.52
N x K x T	16	54.20
Error	49	73.42

** Significant at 1.00 per cent

NUTRITIONAL MANAGEMENT IN COLEUS
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VELLAYANI, TRIVANDRUM
1983

ABSTRACT

An experiment was conducted at the College of Agriculture, Vellayani with the objective of finding out the optimum doses of nitrogen and potash and also their suitable time of application to coleus (Coleus parviflorus) The levels of nitrogen and potash tried were 0, 30, 60, 90 and 120 kg/ha each. The two timings tried were entire dose as basal, and half basal and half thirty days after planting.

Nitrogen had significant effect on plant height, number of branches, number of functional leaves, plant spread and leaf area index whereas levels of potash had not much effect on these aspects except at early stage. Time of application of nutrients had no effect on these growth characters.

Nitrogen at the rate of 60 kg/ha was sufficient to produce higher yield of tuber per plant and higher number of marketable tuber per plant. Highest weight of marketable tubers was obtained at 120 kg N/ha and highest percentage weight of marketable tubers was given by 90 kg N/ha.

Nitrogen at the rate of 60 kg/ha was sufficient to produce higher yields, high dry matter yields, maximum bulking rate and the highest utilisation index. When nitrogen level was increased to 90 kg/ha protein content has reached the maximum. Nitrogen levels had no significant effect on starch content of tuber. Highest yield of tuber and highest dry matter yield/ ha were obtained at the rate of 120 kg K_2O/ha. Split application of nitrogen and potash proved to be the best method for obtaining higher weight of marketable tubers, higher tuber yield per plant, maximum drymatter yield and highest tuber yield /ha. Bulking rate was also increased by split application of nutrients.

The study revealed that for economic production of coleus, a fertilizer dose of 60 kg N, 30 kg P_2O_5 and 120 kg K_2O/ha may be applied in two split doses, half nitrogen, half potash and full phosphorus as basal and the balance 30 days after planting.