INVESTIGATIONS ON TURMERIC IN RELATION TO N P K FERTILIZATION AND RHIZOSPHERE BACTERIAL POPULATION

BY

P. K CHELLAPPAN NAIR

THESIS

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C E R T I F I C A T E

This is to certify that the Thesis herewith submitted contains the results of bona fide research work carried out by SRI. P.K. CHELLAPPAN NAIR under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

K. Madhavan Nair

C.K.N. NAIR,
PRINCIPAL.

K. MADHAVAN NAIR,
PROFESSOR OF AGRONOMY.

Agricultural College and
Research Institute,
Vellayani, Trivandrum.
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P.K. CHELLAPPAN NAIR

C O N T E N T S

INTRODUCTION

Compared to the economic importance of turmeric the investigations reported so far on its manurial and other aspects of culture are very few. Recently the crop has gained prominence as a foreign exchange earner. The figures for 1961-62 and 1962-63 reveal that Rs. 42.5 lakhs and Rs. 45.6 lakhs worth of this commodity was exported in the respective years to foreign countries. The total area under cultivation in India is 1,24,000 acres distributed in the States of Orissa, Andhra Pradesh, Madras, Assam, Maharashtra, Mysore and Kerala. The area of the crop in Kerala is 12,000 acres. The annual production of turmeric is 1.25 lakhs tons out of which 10% alone is exported whereas 90% is consumed within the country itself.

Turmeric is essentially a crop of the tropics cultivated for the sake of its rhizome. CLARKE (1875) considers it to be indigenous to Parasnath in Bihar. WATT (1889) however thinks that it is of Chinese or Cochin Chinese origin. It is extensively used for culinary purposes. Its medicinal properties as carminative, laxative and anthelmintic have been recognised in indigenous medicine. It is also a component of the indigenous medicine prescribed for the treatment and cure of cholera. Its essential oil, turmerol is used in flavouring food products and perfume manufacture. The use of turmeric as cosmetic and also a material of sanctity on auspicious occasions is very common.

Therefore the need for intensification of studies on different aspects of culture of this important crop becomes self-evident.

The present knowledge in India of the nutritional requirements of turmeric is not very comprehensive. Some work on spacing, nature and size of planting material and cultural practices were reported from Bengal, Assam, Bombay and Andhra Pradesh recently. Attempts to investigate these cultural aspects together with the studies on the nutrition of the crop were reported to have been conducted in Orissa from 1945-46. From the experimental data released by the Turmeric Research Station, Udayagiri, Orissa, it could be seen that the application of nitrogen alone increased the yield by 87% over the control and phosphorus and potash were reported to have no effect. On the other hand the investigation carried out by PAUL and FERNANDO (1944) at Nugawela in Ceylon showed that turmeric responded positively to the application of organic manures and potash. Since investigation on the optimum fertilizer requirements of turmeric have been rare, the results obtained for a similar crop namely ginger, coming within the same family and having similar plant characteristics and yield, will be useful at least as an indicator of the trend of the nutritional requirements. But even in ginger about which some work has been done in this State, the results reported are contradictory. Manurial experiments conducted on ginger at the Agricultural Research Station, Ambalawayal in 1958-59 showed lack of response to nitrogen, phosphorus and potash individually or in combination. But Potaschemе (1960) reports that balanced fertilizer treatment has given substantial higher returns. Thus it could be seen that even the results obtained from the experiments on ginger are contradictory and hence the value of such results for adoption to turmeric is only very limited. Therefore, a separate study to assess the optimum nutritional requirements of turmeric becomes essential.

Mueller (1959) reported that the fertility of cultivated soil is generally dependent also on its microbiological activity. Considerable work has been accumulating on the qualitative and quantitative nature of microorganisms in the rhizosphere and on the nature and significance of products secreted by plant roots. Basic information on the rhizosphere microflora of various crop plant is a necessary prerequisite for the study of problems associated with certain methods of increasing soil fertility such as azotobacterisation, phosphobacterisation, mineralisation of macro as well as micro-nutrients. Lochhead (1957) reported that the actual site of interaction between plants and microorganisms was the rhizosphere and as such any variation in the population of microorganisms in the rhizosphere would ultimately be reflected in the uptake of nutrients by the plants. Since Ramaprasad and Sirsi (1956) have reported that the colouring matter curcumin, as well as the essential oil turmerol are both bactericidal as well as bacterio static, one can normally expect a certain amount of diffusion of these materials in the rhizosphere region of the turmeric plant and thereby some influence on bacterial numbers there. Hence it was thought that a study of the bacterial population in the rhizosphere of turmeric and its surroundings will throw some light on its relationship with the nutrition of turmeric.

REVIEW OF LITERATURE

Experiments conducted in India and abroad showed that the yield of rhizomatous crops like turmeric and ginger could be increased by the application of fertilizers. Miller (1938) stated that the rhizome is the region of food storage and the great bulk of foods which accumulate in plants can be classified into carbohydrates, fats and proteins. According to Thomas and Richardson (19[illegible]9) the cells of storage tissue are not passive reservoirs. In them various compounds of carbohydrates are formed from primary sugars. Curtis (19[illegible]9) reported that the development of storage organs is greatly influenced by day length, temperature and available nutrient supply. Robert (1951) stated that the effect of light on mineral nutrition of plants is chiefly an indirect one resulting from the temperature rises concomitant with the absorption of light and from the basic photo-chemical reactions occuring in plants. Light can affect the physiology of growth through various photo-chemical effects such as alteration of permeability, changes in protoplasmic streaming and various photo-chemical oxidations. The most conspicuous indirect role of light in mineral metabolism is through photosynthesis. Carbohydrate supply is necessary as a source of energy for the accumulation of nutrients by roots and for carrying out all other chemical reactions. The mineral elements enter into synthesis with materials derived from carbohydrate to form metabolic and structural components. It therefore follows that mineral nutrient requirement of plants is directly dependant upon the carbohydrate and, in turn, upon photosynthesis.

Bakhuyzen (1939) states that under favourable growing conditions, the phase of rapid vegetative enlargement in plants is characterised by progressive increments in absolute amounts of inorganic elements, carbohydrates and proteins. Blackman (1948) reported that beneficial effects of soil fertilization are primarily due to increase in foliar area and of assimilation tissue rather than to increase in efficiency of assimilative process.

During the vegetative phase of growth there is an intimate connection between the synthesis of carbohydrate and protein. Not only are carbohydrates and nitrogen used in the synthesis of proteins, but a portion of the soluble hexose provides the respiratory energy necessary for the chemical reduction of nitrate as an antecedent to amino acids and protein formation. Mothes (1931) has shown that all conditions such as light, photosynthesis and open stomata, which tend to raise internal oxygen tension favour protein formation. Thus, the rate of photosynthesis as a source of both carbohydrates and oxygen is closely bound up with nitrate reduction and protein synthesis. Bakhuyzen (1937) stated that during the later phase of active vegetative growth, the plant rapidly accumulates carbohydrates and appear to become relatively less efficient in protein than in carbohydrate elaboration.

Broyer and Hoagland (1943) reported that maximum rhizome formation occure when carbohydrate is not required for new tissue formation or maintenance of existing tissues. The inhibition of growth may be due to lack of vigour or reductic of respiration. Maximum rhizome development takes place when there is intermediate long days, medium light intensity and abundant nitrogen supply. Long days and high temperature and large nitrogen supply will result in abundant shoot growth and poor rhizome development. Temperature, length of day and nitrogen supply significantly influence rhizome - top ratio. Hence rhizomatous crops respond differently to fertilizers according to the soil and climatic condition where it is grown.

Swaran Singh Purewal (1957) showed that there was highly significant and positive correlation between plant height and plant yield in tuberous plants like colocasia. Ihra (1959) reported that the growth of rhizome and tuber is closely associated with that of shoot.

<u>Application of inorganic fertilisers</u>:

Experiments conducted at the Turmeric Research Station, Udayagiri, Orissa showed that nitrogen alone increased the yield by 87% over the control while phosphoric acid and potash did not show any positive effects. Application of Ammonium sulphate at the rate of 90 lb. nitrogen per acre doubled the yield over the control. Sharma (1960) recommends an application of 220 lb . of Ammonium sulphate per acre under Coimbatore conditions.

Ashby (1948) reported that increased dose of nitrogen increased the rate of leaf production in all cultivated crops. Insufficient nitrogen reduces yield drastically and also decreases the quality of plant products whereas excess nitrogen delays flowering. Excess nitrogen reduces cell thickness and hence plants are more susceptible to the attack of insect pests and disease organisms.

Abraham (1960) reported that turmeric and ginger are supposed to be similar in their plant food requirements as they belong to the same family Zingiberaceae. In the fertilizer trials conducted under the technical collaboration between Kerala Agricultural Department and PotaScheme in 1957-60, the the application of 50 lb. nitrogen, 50 lb. phosphorus and 100 lb. potash per acre gave maximum yield in the case of ginger. Hence a balanced application of nitrogen, phosphorus and potash is recommended for ginger by the PotaScheme. Original trials conducted in 1959-60 at the Agricultural Research Station, Ambalawayal with nitrogen and phosphorus alone showed that the application of nitrogen and phosphorus either alone or in combination had no response. Later series of experiments conducted at Ambalawayal and Thodupuzha showed that the application of complete fertilizer was better than the application of nitrogen, phosphorus and potash separately.

In rhizomatous and tuberous crops, the main constituent of which is carbohydrate, the benefit from nitrogen manuring is brought about by increased leaf area and consequent shoot growth. Russel (1961) reports that the effect of nitrogen on rhizome development will be perceptible only on long duration crops. But in short duration crops the effect of nitrogen is only on the top. Since turmeric is a long duration crop the effect of nitrogen can be distinctly seen both on the top and the underground rhizome.

Work done so far in laterite soils shows that the application of phosphorus does not produce any significant result in crop yields. Stewart (1947) reported that the lack of response to phosphate application may be due to the immobility of phosphate in the soils. Now it is well established that phosphorus is of pre-eminent importance to the crops.

Williams (1948) and Rossitter (1952) showed that tuber and rhizome development were delayed at higher levels of phosphorus. Simpson (1961) reported that the weight of tubers of potato and rhizomes of rhubarb was little affected by the application of phosphorus.

Fred (1953) and Truog (1953) reported that on a given soil some crops responded to application of phosphate whereas others did not. The total demand for phosphorus by the plant, the extent of the plant's root system, and its ability to feed on the indigeneous phosphorus in the soil are all important factors in determining plant needs for supplemental phosphate.

Simpson (1961) showed that on low phosphorus soils with moderate application of super phosphate, the relationship between carbohydrate accumulation and phosphorus uptake was positive and curvilinear but on high phosphorus soils the relationship was strongly negative and the final yield of dry matter was often reduced by increasing rates of application above the critical level.

Selte (1959) reports that the non-response to a fertilizer treatment may also be due to a process originating from a reaction between soil and fertilizers. All the major elements, nitrogen, phosphorus and potash are subject to the phenomenon of fixation in various climatic regions of the world. Soils distinguished by such a fixation capacity do not show the usual progress on the yield curve while increasing quantities of a particular nutrient are applied. A yield increase becomes evident only after the fixation capacity of such soils is satisfied to a certain degree. The red and laterite soils, predominent in tropical zones with moist or alternating moist or dry season conditions belong to this group.

Jordan (1913) showed that up to a certain point the production of carbohydrate, protein and fat increased with the increased phosphorus supply but beyond certain limits phosphorus was not utilised. Nojku (1957) reported that the effect of phosphorus on the rhizomes of rhubarb was marked only in the presence of nitrogen.

Schwabe (1951) showed that phosphorus deficiency depressed the total dry weight under high potash nutrition and dry weight increases were observed under high potash when phosphorus levels were increased. The distribution of dry weight among root, rhizome, tuber and leaf was changed by nutrient treatment.

Sugawara (1939) reported from Japan that carbohydrate accumulation was increased in underground storage organs by heavy application of potash and was lowered by potash starvation. Jansen & Berthelomew (1930) indicated that maximum carbohydrate accumulation accurred in most herbaceous crops at levels of potash supply intermediate between deficiency and luxury consumption. The ratio of rhizome to tops is considerably increased by potash application. Potash is required for the synthesis of amino acids and protein from ammonium ions. Russel (1960) reports that moderate dressings of nitrogen and potassium doubles the weight of underground portions.

Russel (1950) stated that the content of potash in plant is larger than any other nutrient. Addition of higher dose of nitrogen and phosphorus to the soil reduces the absorption of potash especially when available potash is limited.

Wall (1940) and Nightingale (1942) have shown that potash is essential in carbohydrate assimilation and synthesis of various products of carbohydrates. Potash is the most important nutrient required in large quantities in tuberous and rhizomatous crops.

Application of organic manures:

Several investigations reported have shown the reed of organic matter application in turmeric cultivation. Experiments conducted at Turmeric Research Station, Udayagiri, Orissa in 1955-56 showed that manuring with fresh and rotten cattle dung, niger cake and sal-leaf on equal nitrogen basis were efficacious. Rao (1949) recommended application of 15 tons of farm yard manure per acre for turmeric.

Narasimhan (1931) reported that growing sunhemp as a green manure crop one and half months prior to sowing of turmeric and ploughing it in before planting is becoming popular in Madras State. This practice while providing for the supply of adequate quantities of green manure for the succeeding turmeric crop, is also beneficial in controlling organic matter loss from the field due to the shading effect of the previous sunhemp crop.

Paul and Fernando (1941) showed that a single rice straw mulch at planting time increased the yield of turmeric significantly. But higher levels of rice straw over 12 tons per acre did not show any corresponding increase. Karuna-Ratna (1937) recommended an application of 20 tons of Farm yard manure in the mixed cropping of ginger and turmeric in the central districts of Ceylon.

Misra and Mahapatra (1960) recommended an application of 20 maunds of groundnut cake before planting followed by top dressing with castor cake at 10 maunds per acre. In Orissa cultivators apply large quantities of wood ash to turmeric. But the experiments conducted at Turmeric Research Station in Orissa showed that the crop did not respond to the application of wood ash.

The results of experiments conducted on ginger at the Agricultural Research Station, Ambelavayal showed that the application of 10,000 lb. of green leaf per acre at the time of planting and a second application of 5,000 lb. per acre about 45 days after planting were highly beneficial. P.M. Sayed (1960) reported that the application of 10,000 lb. of powdered cattle manure to supply 50 lb. nitrogen had the same effect as applying half the quantity of nitrogen as cattle manure and the remaining 25 lb. nitrogen in the form of ammonium sulphate. For the maximum production of ginger, application of both organic and inorganic manures are essential.

Curing of Turmeric:

Rhizomes which are brownish yellow in colour consists of a central bulbous portion bearing a number of finger like lateral off-shoots. The bulbous and finger shaped parts are separated and the long fingers which generally command a high price in the market, are broken into convenient bits. The curing consists in cooking the rhizomes in water until they become soft. The water in the cooking vessel is covered with turmeric leaves to increase the steaming effect. Srivastava (1959) reports that the cooking should be thorough. Otherwise the product is liable to insect attack. Rajaratnam (1935) says that the duration of cooking adopted in different localities varies from 30 minutes to 6 hours. The cooked rhizomes are dried in the sun. The dried rhizomes are either rubbed on a rough surface or trampled upon to remove the outer skin and to produce the desired attractive colour.

Sarma and Krishnamurthy (1960) defined the curing percentage as the proportion of cured and dried produce to hundred units by weight of green turmeric or the percentage recovery of cured produce from a given weight of raw turmeric.

Gogiraju (1951) reports a curing recovery of 25% in the local longa variety of Guntur district. Sambasiva Rao (1949) gives the mean proportion of cured produce to raw rhizome as 1 : 4 for Cuddappah and Guntur districts. Yegnanarayana Iyer (1956) mentions that the outturn of dried product varies with the quality and ripeness of the rhizomes and that it ranges from 17 to 25% of the fresh material.

Chenlal (1944) quotes a recovery of 17% from the types grown in Madhya Pradesh. Desai (1939) describes two distinct varieties of turmeric in Bombay. One of these cures badly with shrivelled up constricted surface and low percentage of curing, namely, 16 - 17%. The other cures normally with the curing percentage of 21 - 24%. Chaugule (1957) reports that the variety 'Soni' gives a curing percentage of 20 - 25% in the Agricultural College Farm, Poona. Stockdale reports a curing recovery of 20% from the turmeric grown in Ceylon. Sangameswara Sarma (1960) reports that the percentage of curing varies with groups of turmeric types, the highest values having been recorded by the early duration aromatic types and the lowest by the medium duration Pontha types. The long duration longa types recorded medium values. He also stated that the moisture content in the raw rhizomes also varied between different types and duration groups.

Flowering:

Turmeric is a short day plant and it does not general flower under South Indian conditions. Patnaik (1960) reports that turmeric responded to eight hour photoperiod treatment. Plants treated with 24 hour photoperiod produced greatest height and put out larger number of leaves and sprouts per plant.

Cooper (1952) divided the attainment of competence to respond to photoperiod into three, namely the initiation of inflorescence, its elongation and differentiation. After ear initiation the rate of development is influenced by temperature. Gardner and Loomis (1953) have shown that low temperature treatment must be concurrent with or immediately follow short days. Cochran (1936) demonstrated that temperature, soil moisture level and nitrogen supply affected reproductive development in capsicum.

Jasper and Smith (1961) showed that certain levels of nitrogen, phosphorus and potash in proper balance produced maximum flowers in chrysanthemum. Detrimental effects on growth and yield resulted from high nitrogen and low potash ratios but such effects were not seen when high level of potash and low level of nitrogen were applied.

Microorganisms in the Rhizosphere:

Mueller (1959) reported that the fertility of our cultivated soils form a parallel to the soil microbial activities. According to Welte (1959) the non-response to a fertilizer treatment may also be due to a process originating from a reaction between soil and fertilizers. All the major nutrient elements, nitrogen, phosphorus and potash are subject to the phenomenon of fixation in various climatic zones of the world. The phenomenon of fixation of the above elements is also common in laterite and red soils. The nutrients fixed can be released for the use of growing plants by altering the microbial population of root zone. All growing plants secrete some substances, in the soil, which increase or depress the microbiological activity in the rhizosphere.

Miltner (1904) introduced the term rhizosphere to denote the region in the immediate vicinity of roots. Subsequently Clark (1949) included in the definition of rhizosphere the external surface of the plant roots with the microflora. Rhizosphere effect is the ratio of the number of organisms in the rhizosphere and the number in the soil outside the rhizosphere calculated on soil dry weight basis. This is expressed as a positive effect, if the ratio exceeds one and negetive, if fractional. Lochhead and his associates in Canada have shown the rhizosphere to be a region important for the growth and health of plants.

The increased microbial population and activity in the root zone has been ascribed to one or more of the following reasons (1) the decomposition of the plant roots; (2) excretion of organic acids, amino acids, vitamins, auxins and other allied growth promoting substances; (3) liberation of carbon dioxide by roots; and (4) modification of physical properties of the soil which make a more favourable medium for the growth of organisms.

Recent Research work indicated that rhizosphere microflora differed qualitatively and quantitatively from that in the soil more distant from the roots. Katzanelson (1946) showed that the rhizosphere was very favourable for microbial proliferation. Timonin (1940), Rangaswami and Vasantharajan (1962) have observed great accumulation of bacteria, actimomycetes and fungi in the rhizosphere and the consequent positive rhizosphere effect.

The increased microflora within the rhizosphere is predominently bacterial. Starkey (1930) reported that bacteria were 200 times more numerous in the rhizosphere of sweet clover than in the root free soil and fungi and actinomycetes were 10 times more numerous. Adati (1939) showed that rhizosphere effect on fungi and actinomycetes was negligible. Gerhard Grummer and Horst Beyer (1955) reported that the roots of camelina released bacteric.dal substance which inhibited bacterial growth in the rhizosphere.

Katznelson & Richardson (1943) reported that bacteria, actinomycetes and fungi are stimulated differently in the rhizosphere. Starkey (1929) and Timonin (1940) showed that in several annuals the bacterial population in the rhizosphere increased till the plant flowers, which corresponded to the grand stage of vegetation and high physiological activity and later when the vegetative growth stopped the population decreased. Rouatt (1960) has analysed statistically and established the preferential stimulation of micro organism both qualitatively and quantitatively in the rhizosphere.

<u>The Microflora of the Rhizosphere and Plant growth.</u>

Hiltner (1904) claimed that the increased activity of the microorganisms near the root zone was due to the root excretions. West (1939) found that certain bactorial isolation from the rhizosphere of flax and tobacco that failed to develop in a basal medium, developed well when the above was enriched with amino acids or vitamins.

Katznelson (1946) reported that the microflora in the rhizosphere will be greatly affected by various organic substances which are excreted by plant roots or formed by decomposing root cells. The tension of carbon dioxide, oxygen, water vapour, hydrogen ions and other inorganic ions which will vary in the close vicinity of the roots will also affect the rate of proliferation of micro-organisms.

Starkey (1929) noted that rhizosphere population of individual crops differed at successive stages of plant growth. He found relatively small number of organisms in the early growth stage, increased numbers after the plant had reached considerable size and decreased numbers after fruiting. Greatest numbers were noted at the stage of maximum vegetative growth and at fruiting.

Virtanen (1952) has found anti-fungal agents in seedlings of rye and other plants which contribute to the resistance of the plant to fungi.

Katznelson (1954) reported that plant roots secrete various amino acids and reducing sugars. Bhuvaneswari and Subha Rao (1957) reported differences in the root excretions of Sorghuam Vulgare var irungu and Brassica juncea. Sorghum vulgare exuded 8 amino acids in high concentration where as Brassicca juncea exuded only 6 in low, concentration. Sulochana (1958) also stressed the importance of root excretions in the stimulation of microorganisms in the rhizosphere which varied with plant species.

Rovira (1959) reported that the exudation of amino acids by tomato and subterranean clover was influenced by light, temperature, age, etc. Sunder Rao and Venkitaraman (1963) observed distinct rhizosphere effect for azotobacter in wheat.

Effect of Manures on Rhizosphere Organisms.

Clark and Thom (1939) believed that the effects of organic manuring were primarily on soil microflora and that the root microflora was relatively little affected. Timonin (1940) Katznelson and Richardson (1943) also showed that organic manures did not greatly affect the rhizosphere microflora. In some cases, however, there do exist indirect influences of manurial treatments. Katznelson (1946) has pointed out that manuring may affect the growth rate, vigour and maturity of the plant and that active growth period is known to influence the flora of the rhizosphere. Various inorganic and physical treatments have been reported to affect at least some fraction of the root microflora. Pohlman (1946) noted that nodules on roots of alfalfa were largely concentrated in the soil layer receiving a high lime treatment.

Lochhead and Chase (1948) determined the characters of bacterial flora of the soil by growing them in media of varying compositions. They found that there is an equillibrium between various groups of organisms as influenced by various nutrients. Wallace and Lochhead (1949) reported that characteristic changes occur in the equilibrium between nutritional groups by the rhizosphere effect. They also reported that the outstanding feature of this changes of equilibrium are due to the preferential stimulation of organisms by amino acids secreted by plants.

Vagnerova (1960) showed that bacteria in the rhizosphere of wheat was increased by the secretion of amino acids from the roots of the plant.

West and Lochhead (1940) reported that the bacteria of the rhizosphere of flax and tobacco needed more complex nutritive requirements than those of the corresponding control soils. Thus the bacteria of the rhizosphere and non-rhizosphere region differ in their nutritive requirements.

Woldendrop (1962) reported that joint action of lime, potash and magnesium had a beneficial influence on the maintenance of the number of bacteria in the soil.

Experiments conducted in laterite soils of Orissa in 1955 showed that bacteria increased due to the application of nitrogen and phosphorus while it was depressed under potash application.

Sunder Rao and Venketaraman (1963) observed that the application of farm yard manure increased the population of azotobacter in the rhizosphere as well as control soils of wheat plants.

MATERIALS AND METHOD

This chapter deals with the materials employed and methods adopted in carrying out the investigation.

Experimental site:

The experiment was conducted at the Central Farm, Agricultural College and Research Institute, Vellayani during the second half of 1963.

The soil in which the investigation was carried out was the typical red loam, characteristic of the tract. The soils are highly leached and low in nitrogen, phosphorus and potash. Soil analysis was conducted for the following constituents.

Total nitrogen

Total phosphoric acid

Total potassium

Available phosphoric acid

Available potassium

PH

The values obtained are furnished in table I. The procedure followed in soil analysis is that outlined by the A.O.A.C.(1955).

Manures and Fertilizers:

Farm yard manure purchased locally was applied as basal dose at the rate of 12,000 lb. per acre.

Ammonium Sulphate, Superphosphate and Muriate of potash, purchased from the Fertilizers and Chemicals Travancore Ltd., was used for the experiment.

EXPERIMENTAL TECHNIQUE.

Lay out:

The experiment was laid out in a 3^3 factorial experiment in the randomised block design involving 27 treatments in one block and replicated twice. The lay out is given in fig. (1). The procedure for allocation of the various treatment combinations to different plots was in accordance with the instructions of Yates, (1937).

1. Total area under the experiment		..	0.560 Hectare
2. Gross plot size	..	..	3.60 x 2.4 (Metres)
3. Net plot size	..	..	3.04 x 1.82(do)
4. Harvested area	..	..	6.5 Square metres.
5. Number of plots	..	..	54
6. Replications	..	..	2

Plot Treatment:

Three fertilizers at three levels and their factorial combinations.

Nitrogen at 3 levels:

NO	....	0 level
N1	....	50 lb. per acre as Ammonium Sulphate.
N2	....	100 lb. per acre as Ammonium Sulphate.

Phosphorus at 3 levels:

PO	....	0 level
P1	....	45 lb. per acre as single super phosphate
P2	....	90 lb. -do- -do-

Potash at 3 levels:

K0	..	0 level
K1	..	60 lb. per acre as muriate of potash.
K2	..	120 lb. do do

Agricultural Operations:

The land, kept fallow for the last 2 years, was dug with mammutty and plots of 3.60 x 2.4 metres were laid out.

Date	Operation
2--5--63 -- 6--5--63	Digging
14-5--63	Breaking clods
11-6--63 -- 16-6--63	Laying out plots
20-6--63 -- 21-6--63	Planting

Manuring:

A basal dose of Farm yard manure at the rate of 12,000 lb. per acre was applied on 11-6-1963. The analysis of cattle manure used for basal dressing is given below:

Nitrogen (Total)	..	0.62%
Phosphoric acid (Total)	..	0.30%
Potash (Total)	..	0.50%

Application of Fertilisers:

The nutrients N, P_2O_5 and K_2O were applied in the form of ammonium sulphate, Super (single) and muriate of potash, out of which the latter two were applied two days ahead of planting rhizomes. Half dose of ammonium sulphate was applied one and half months after planting along with the first weeding and the second dose one and half months after the first application.

Planting material and Planting:

Primary fingers of turmeric of uniform size and quantity collected from Adoor, weighing 50 rhizomes per Kg. were used as planting material. The above fingers were cut transversely into 2 equal parts and planted them at a distance of 30 Cm. apart on 20--6--1963.

Intercultivation:

There were 3 hoeings and weedings as shown below:

Date	Hoeings and Weeding
5--8--1963 to 6--8--1963	First hoeing and weeding.
20-9--1963 to 22-9--1963	Second hoeing and weeding.
22-10-1963 to 24-10--1963	Third hoeing and weeding.

Pests and diseases:

The occurence of stem borer Dichocrosis Punctiferalis was noticed on 12-9-1963 in 7 plots, all of which had received higher dose of nitrogen. There was practically no attack in plots receiving balanced fertilizers. The stem borer was completely controlled by spraying Endrin. But the crop was completely free from any disease.

Harvest of the crop.

The crop was harvested on 7-1-1964 and 8-1-1964 and the separate weights of rhizome and bulb under each treatment were recorded.

Pre and Post Harvest Studies.

A study of the following characters was made both during pre and post harvest period.

Characters studied	Number of observation	Days after planting					
1. Germination	6	20	22	24	26	28	30
2. Height of the plants	4	60	90	120	150		
3. Number of leaves	4	60	90	120	150		
4. Number of flowers	1	140					
5. Number of tillers	1	150					
6. Number of bacteria in the rhizosphere	1	120					
7. Number of bacteria in respective control	1	120					

Post Harvest Studies.

1. Weight of rhizomes from net area.
2. Weight of bulb from net area.
3. Curing percentage.

Regression studies.

1. Regression of yield on height.
2. Regression equation of yield on nutrients and bacteria.

Sampling technique.

For studying height and number of leaves 16 plants were selected at random excluding border plants. The plants were marked and labelled.

Procedure followed in the study of characters.

1. Germination: Germination of rhizomes started from 20th day of planting and continued upto 30th day. Germination count was recorded on alternate days till germination was completed.

2. Height: It was measured in centimetres from the base of the plant from ground level to the tip of the longest leaf.

3. Number of leaves: Total number of leaves were counted systematically in each of 16 plants selected for the observation. The average height and number of leaves were taken for the statistical analysis.

4. Number of flowers: Turmeric, a non-flowering plant under south Indian conditions, flowered in certain treatments. First flowering was noticed on 20-10-1963 and it continued up to 2-11-1963. Percentage of plants flowered was recorded.

5. Number of Tillers: Different number of tillers were found under different treatments. Total number of tillers produced were counted in 16 plants selected at random in each plot and average calculated for statistical analysis.

6. Estimation of rhizosphere bacteria: To examine rhizosphere bacteria 2 - 3 turmeric plants, 4 months old, were pulled out at random and gently shaken to remove excess soil particles adhering to them. They were inserted in polythene bags and brought to the laboratory. Roots were clipped and put into 100 c.c. of sterile water in a conical flask. Sufficient quantity of roots were added to obtain a turbidity equivalent to the addition of 2 to 3 g. of soil (Wallace and Lochhead 1949). The conical flask was shaken thoroughly for half an hour. 10 c.c. of the solution was transferred to 90 c.c. of sterile water. This process was continued till a dilution of one lakh was obtained. Aliquots of the suspension were plated in quadruplicate in soil extract agar medium and incubated for seven days at room temperature (Taylor and Lochhead 1938). The count of bacteria was taken after the period of incubation.

The original rhizosphere suspension from which 10 c.c. had been removed was evaporated to dryness over a water bath and finally in the air oven. The total bacterial population was calculated on dry weight basis for one gram of soil with correction for aliquot removed.

7. Determination of Bacteria in Control Plots: For comparison, soil samples were collected approximately from the same depth as that of the rhizomes of plant but outside root zone. 5 g. of sample was transferred to the conical flask containing 100 c.c. of sterile water and shaken for

half an hour. 10 c.c. of the suspension was transferred to 90 c.c. and this process continued until one lakh dilution was obtained. Quadruplicate plates were made with aliquots of the suspension using the medium of Taylor and Lochhead (1958) and incubated at room temperature. Final count was taken after 7 days as done in the case of rhizosphere bacteria.

Preparation of Soil agar medium.

About one Kg. of garden soil was taken in a porcelain jar and added one litre of water to it. Autoclaved for 30 minutes at 15 lb. pressure and 120°C. Filtered after adding a little $CaSO_4$. The volume was made up to one litre and 0.2 g. of K_2HPO_4 and 15 g. of agar were added. PH was adjusted to seven by addition drop by drop of sulphuric acid and sterilized in an autoclave at 120°C and 15 lb. of pressure for half an hour. The medium was transferred to culture tubes at 10 c.c. each and were sterlised and kept ready.

Curing of rhizome.

The plants were harvested when they were fully mature, indicated by the drying up of the leave. 200 g. of rhizome was taken at random from each treatment and boiled for half an hour in an earthen pot. Cooked rhizomes were sun dried until two consecutive weighings agreed. The curing percentage was calculated and used for statistical analysis.

EXPERIMENTAL RESULTS

The observations made on turmeric and the data collected during this investigation were analysed statistically and are presented in the tables below:-

The data of chemical analysis of soil is given in table I.

Table No. I

Total nitrogen	1..	0.046%
Total phosphoric acid	..	0.032%
Total potash	..	0.660%
Available phosphoric acid	..	0.002%
Available potash	..	0.0007%
PH	..	5.6

Analysis of variance tables for each of the character studied, namely, height of plant, number of leaves, number of suckers, number of bacteria in the rhizosphere and non-rhizosphere, number of plants flowered, yield and curing percentage are furnished in the appendices I to X.

Germination:

The percentage of germination under different periods from 20th day of planting is given in the table No. II.

The analysis of variance table (Appendix I) shows that all treatments and interactions are not significant. There is no significant difference in germination percentage under different treatments. Germination of rhizome started from 20th day of planting and continued up to the 30th day.

PERCENTAGE OF GERMINATION

Table II

Treatment	Number of days					
	20	22	24	26	28	30
Nitrogen:						
0	48.60	60.50	71.00	91.40	100.00	100.00
50	49.00	61.20	70.40	95.30	97.42	99.40
100	48.50	60.80	71.90	94.00	98.43	100.00
Phosphorus:						
0	47.60	59.00	69.40	95.40	100.00	100.00
45	48.40	62.00	72.20	90.00	99.40	100.00
90	49.54	64.50	70.50	92.40	98.73	99.16
Potash:						
0	49.00	61.54	71.40	90.05	97.50	100.00
60	46.75	60.30	70.36	94.00	98.40	99.68
120	49.64	64.00	71.25	96.35	99.45	100.00

Height of Plant:

The analysis of variance table (Appendix II) shows that the effect of nitrogen and potash on plant height is significant. Neither phosphorus nor the interaction of various combinations of nitrogen, phosphorus and potash have any significant effect. The mean height of plants under different levels of nitrogen, phosphorus and potash at intervals of 30 days from the 60th day of planting is given in table No. III. The percentages of increase in height over the respective controls in different treatments are also given. The response to potash is greatest giving 15.10% increase for 60 lb. potash and 38.50% of increase for 120 lb. potash over the control of zero level.

Response to nitrogen is also significant giving 12.2% increase in height for 50 lb. nitrogen and 22.8% for 100 lb. nitrogen over zero level. Even though the response to phophorus is not significant, an increase of 4% for 90 lb. phosphorus was noticed. The maximum height of 53.37 cm. was seen when higher dose of nitrogen, phosphorus and potash were applied. Mean response to nitrogen, phosphorus and potash are 3.990, 0.780 and 6.365 cm. respectively on 150th day.

Number of leaves:

The mean number of leaves per plant at different periods are given in the table No. IV.

The analysis of variance table (Appendix III) shows that all treatments and interactions are not significant. There is no significant difference in the number of leaves per plant under different treatments. Maximum number of leaves were produced between 90th and 120th days. No leaf production was noticed after 150th day.

MEAN HEIGHT IN CM. AT DIFFERENT PERIOD

Table III

Treatment	Mean height in Cm. 60 days	90 days	120 days	150 days	Percentage increase over zero level.	Mean response in Cm.
Nitrogen:						
0	13.220	18.350	35.770	35.955	—	
50	15.168	20.050	38.550	39.550	10.20	3.990
100	15.330	20.650	43.000	43.935	22.80	
Phosphorus:						
0	14.550	20.050	37.770	37.770	—	
45	14.440	20.250	38.550	38.550	1.90	0.780
90	14.220	20.140	39.330	39.330	4.00	
Potash:						
0	14.330	21.040	32.944	33.220	—	
60	14.000	21.000	38.611	38.702	15.10	6.365
120	15.880	22.120	45.770	45.950	38.50	

MEAN NUMBER OF LEAVES PER PLANT AT DIFFERENT PERIODS

Table IV

Treatment	Mean number of leaves per plant			
	60 days	90 days	120 days	150 days
Nitrogen:				
0	4.50	6.25	9.50	10.00
50	4.45	6.00	9.00	10.25
100	4.50	6.75	9.45	10.25
Phosphorus:				
0	4.45	6.00	8.95	10.25
45	4.35	6.80	9.00	10.00
90	4.40	6.35	9.50	10.35
Potash:				
0	4.50	6.45	9.65	10.42
60	4.40	6.50	9.70	10.78
120	4.40	6.00	9.75	10.70

Number of suckers:

The analysis of variance table (Appendix IV) shows that the effect of nitrogen and potash alone are significant. The mean number of suckers per plant under different treatments and the percentage increases over the corresponding zero levels of nutrients are also given in table No. IV. The increases in percentage of the number of tillers over zero level due to the application of 60 lb. potash are 55.8 and 63.9 for 120 lb. potash.

The response to nitrogen is also significant giving 58.30% increase for 50 lb. nitrogen and 60.60% increase for 100 lb. nitrogen over zero level. Even though the response to phosphorus is not significant there is an increase of 14.1% for 90 lb. phosphorus over the zero level. Maximum number of tillers, viz. four were produced by plants receiving the highest dose of nitrogen, phosphorus and potash. Mean response to nitrogen, phosphorus and potash are 0.425, 0.100 and 0.350 respectively.

Number of bacteria in the rhizosphere region of turmeric:

The analysis of variance table (Appendix V) shows that the effect of nitrogen and potash is significant. The effect of phosphorus and other interactions are not significant. The mean number of bacteria in lakhs under different treatment and percentage increase over the respective control are given in the table V.

The mean number of bacteria in lakhs are 14.66, 22.10 and 20.6 for three levels of nitrogen 0, 50 and 100 lb.

per acre respectively. Maximum number of bacteria is seen between the levels 50 and 100. The corresponding figures for potash are 14.1, 20.2 and 23.4 for 0, 60 and 120 lb. per acre respectively. Even though the effect of phosphorus is not significant, the bacterial counts for the levels 0, 45 and 90 are 20.1, 19.64 and 14.68 lakh respectively. This shows that nitrogen and potash increase the bacterial count in the rhizosphere whereas phosphorus reduces them. Mean response to nitrogen, phosphorus and potash are 2.970, -2.40 and 4.650 lakhs respectively.

MEAN NUMBER OF SUCKERS PER PLANT

Table V

Treatment	Mean number of suckers per plant	Percentage increase over zero level	Mean response
Nitrogen:			
0	1.20	—	
50	1.90	58.3	0.425
100	2.05	66.6	
Phosphorus:			
0	1.42	—	
45	1.60	13.30	0.100
90	1.62	14.10	
Potash:			
0	1.11	—	
60	1.73	55.80	0.350
120	1.82	63.90	

MEAN NUMBER OF BACTERIA IN THE RHIZOSPHERE OF TURMERIC

Table VI

Treatment	Mean number of bacteria in lakhs	Percentage increase over zero level	Mean response in lakhs
Nitrogen:			
0	14.66	—	
50	22.10	51.40	2.970
100	20.60	41.10	
Phosphorus:			
0	20.10	—	
45	19.64	-2.40	-2.40
90	14.88	-26.30	
Potash:			
0	14.10	—	
60	20.20	42.80	4.650
120	23.40	66.40	

Number of Bacteria in the Non-rhizosphere Region:

The analysis of variance table (Appendix VI) shows that the effect of nitrogen and phosphorus alone is significant The mean number of bacteria in lakhs under different treatment and the percentage increase over the respective control are given in the table VI. It is seen that the application of nitrogen increases the bacterial count up to a stage and thereafter bacterial count decreases. As the level of phosphorus is increased to 45 lb. increase in number of bacteria over the control is 4.7% whereas the application of 90 lb. decreases bacterial numbers by 0.6%. The bacterial number is reduced by 23.4% when potash is increased to the level of 120 lb. Minimum bacterial population of 13 lakhs is seen under highest levels of nitrogen, phosphorus and potash.

BACTERIAL COUNT IN THE NON-RHIZOSPHERE REGION

Table VII

Treatment	Mean number of bacteria in lakhs	Percentage increase over control	Mean response in lakhs
Nitrogen:			
0	26.10	--	
50	29.80	14.10	0.40
100	26.90	3.07	
Phosphorus:			
0	29.40	--	
45	30.80	4.70	0.10
90	29.60	0.60	
Potash:			
0	31.60	--	
60	33.33	10.40	-3.690
120	24.22	-23.40	
N_0P_0	31.50	--	
$N_{50}P_{45}$	23.60	-25.30	-3.850
$N_{100}P_{90}$	29.20	- 7.30	

Ratio of the number of bacteria in the rhizosphere to the number in non-rhizosphere.

The microbial population of the rhizosphere may be compared with the population outside the rhizosphere by using a numerical value, the R/S ratio. This ratio is the number of organisms per gram of rhizosphere soil divided by the number per gram in the non-rhizosphere region. The ratios are tabulated and given in table VIII.

T a b l e VIII

Treatment N	P	K	Number of bacteria in rhizosphere (lakhs)	Number of bacteria in non-rhizosphere (lakhs)	R/S ratio
0	0	0	10.00	40.25	0.24
0	0	60	18.25	27.00	0.66
00	0	120	28.50	19.25	1.47
0	45	0	11.00	32.00	0.34
0	45	60	12.00	22.00	0.54
0	45	120	18.50	20.50	0.90
0	90	0	12.00	45.00	0.26
0	90	60	11.25	26.00	0.42
0	90	120	12.00	21.00	0.57
50	0	0	16.00	34.00	0.47
50	0	60	24.00	31.00	0.77
50	0	120	27.00	26.00	1.03
50	45	0	14.00	32.00	0.43
50	45	60	30.00	26.00	1.15
50	45	120	18.00	27.50	0.66
50	90	0	12.00	19.00	0.63
50	90	60	26.00	46.00	0.66
50	90	120	30.00	31.50	0.96
100	0	0	20.00	30.50	0.66
100	0	60	24.50	32.00	0.75
100	0	120	28.25	26.00	1.08
100	45	0	20.00	37.00	0.54
100	45	60	21.00	33.00	0.63
100	45	120	32.00	29.00	1.10
100	90	0	12.00	16.00	0.75
100	90	60	13.00	16.75	0.81
100	90	120	16.50	13.00	1.27

Flowering:

The analysis of variance table (Appendix VII) shows that the effect of nitrogen is highly significant, the percentage of plants flowering for the three levels of nitrogen namely 0, 50 lb. and 100 lb. being 2.1, 2.8 and 0.55 respectively. The percentage of plants flowering decreases as the level of nitrogen increases. The effect of potash, even though, not satistically significant, seems to increase the percentage of plants flowering. Corresponding to 0, 60 and 120 lb. potash per acre the percentage of plants flowered are 1.2, 2.0 and 2.2. Higher levels of phosphorus also give a higher percentage of plants flowering even though there is no statistical significance. But the highest percentage of 5.5 is seen for the combined treatment of 50 lb. nitrogen, 90 lb. phosphorus and 120 lb. potash followed by 4.5 corresponding to two treatment combinations $N_{50}P_0K_{60}$ and $N_0P_{45}K_{120}$. The lowest percentage namely zero has been observed in 3 treatment combinations $N_0P_0K_0$, $N_{100}P_0K_0$ and $N_{100}P_{45}K_{120}$.

EFFECT OF DIFFERENT TREATMENTS ON FLOWERING

Table IX

Treatment	Percentage of plant flowered	Percentage increase over control	Mean response in percentage
Nitrogen:			
0	2.10	--	
50	2.80	33.30	-0.775
100	0.53	71.40	
Phosphorus:			
0	1.40	--	
45	1.90	35.71	0.335
90	2.17	55.00	
Potash:			
0	1.20	--	
60	2.00	66.60	0.500
120	2.20	83.30	

Yield:

The analysis of variance table (Appendix VIII) shows that the effect of nitrogen and potash are significant. The effect of phosphorus and the interactions are not significant. This is similar to the obsērvations on other growth characteristics. The mean yield per plot in Kilograms for different levels of nutrients is given in table No. X. The mean yield calculated on acre basis and percentage increases over the respective zero levels are given in table No. XI. The mean yield per plot for different treatments is also given in table XII.

The response due to potash is the maximum giving 30.70% increase for 60 lb. potash and 90.55% increase for 120 lb. potash over zero level.

The response to nitrogen is also significant giving 15.20% increase in yield for 50 lb. nitrogen and 38.40% increase for 100 lb. nitrogen over the zero level.

Even though the response to phosphorus is not significant there is an increase of 5% in yield for 90 lb. whereas the percentage increase for 45 lb. of phosphorus is only 1.66 over zero level. Maximum yield of 4280 Kg. per acre was obtained when highest dose of nitrogen, phosphorus and potash were applied. Mean response to nitrogen, phosphorus and potash are 235.375, 49.495 and 457.25 Kg. per acre respectively.

It is seen from table No. XII that the application of 90 lb. phosphorus in combination with higher doses of nitrogen and potash has produced significant increase in yield.

Table X

Treatment	Mean yield of turmeric in Kg. per plot	Percentage increase over zero level	Mean response Kg.per plot
Nitrogen:			
0	1.51	—	
50	1.74	15.20	0.290
100	2.09	38.40	
Phosphorus:			
0	1.73	—	
45	1.80	1.66	0.045
90	1.82	5.00	
Potash:			
0	1.27	—	
60	1.66	30.70	0.570
120	1.42	90.55	

Table XI

Treatment	Mean yield of turmeric in Kg. per acre.	Percentage increased over zero level	Mean response per acre in Kg.
Nitrogen:			
0	1163.86	—	
50	1347.42	15.26	235.375
100	1639.60	38.40	
Phosphorus:			
0	1330.04	—	
45	1396.40	1.66	49.495
90	1429.03	5.00	
Potash:			
0	978.01	—	
60	1285.42	30.60	457.23
120	1892.47	90.50	

AVERAGE YIELD IN KG. PER PLOT

Table XII

N	K	Phosphorus in lb. per acre		
		0	45	90
0	0	1.740	1.355	1.745
0	60	1.472	1.775	2.107
0	120	2.515	2.635	2.447
50	0	1.447	1.997	1.657
50	60	2.615	2.967	1.595
50	120	4.292	2.937	1.952
100	0	1.975	1.820	2.375
100	60	2.107	2.452	3.237
100	120	4.425	5.087	5.462
Mean		1.732	1.807	1.822

CD = 0.865

Ratio of rhizome to bulb:

The ratio of rhizome to bulb calculated on plot yield basis is given in table No. XIII.

The analysis of variance table (Appendix IX) shows that the effect of nitrogen alone is significant whereas the effect of phosphorus and potash and other interactions are not significant. Nitrogen has a significant depressing effect on the ratio of rhizome to bulb. The response to the application of potash is not statistically significant but a percentage increase of 16.00% for 60 lb. potash per acre and 12.7% for 120 lb. potash per acre are seen. Both phosphorus and potash increase the ratio only up to a certain stage but higher dose of phosphorus and potash decrease the ratio.

Table XIII

Treatment	Mean ratio of rhizome to bulb	Percentage increase over control
Nitrogen:		
0	3.57	—
50	2.77	-22.40
100	2.14	-39.40
Phosphorus:		
0	2.88	—
45	2.94	2.08
90	2.92	1.40
Potash:		
0	2.75	—
60	3.24	16.00
120	3.10	12.70

Cured Produce:

The yield of cured produce for different treatments is given in table XIV.

The analysis of variance table (Appendix X) shows that the effect of potash alone is significant. The effect of nitrogen, phosphorus and all other interactions are not significant. The mean yield of cured produce estimated on plot basis is given in table XIV.

The increase in cured product is maximum for potash giving 27.20% for 60 lb. and 75.84% for 120 lb. over zero level. Even though the effect of nitrogen is not statistically significant there is an increase of 45% for 100 lb. nitrogen over zero level. The response to phosphorus is even smaller, the corresponding increase in yield being 7.14 and 8.46% for the two levels of 45 and 90 lb. per acre. Mean response to nitrogen, phosphorus and potash are 0.147, 0.032 and 0.224 Kg. per plot respectively.

Table XIV

Treatment	Mean weight of cured produce in Kg. per plot	Percentages increases over zero level.	Mean response in Kg.
Nitrogen:			
0	0.652	—	
50	0.786	20.55	0.147
100	0.947	45.24	
Phosphorus:			
0	0.756	—	
45	0.810	7.14	0.032
90	0.820	8.46	
Potash:			
0	0.592	—	
60	0.753	27.20	0.224
120	1.041	75.84	

CORRELATION AND REGRESSION STUDIES

An attempt has been made to find out the correlation and the regression equation of yield on height, nitrogen, potash and bacterial count in the rhizosphere and R/S ratio.

1. Height and yield.

The results indicate that height of plant is positively correlated to the yield. The correlation coefficient is found to be 0.63. The regression equation of yield (y) on height (x) was estimated and found as:

$$y = 0.08x + 1.35$$

2. Rhizosphere bacteria, nitrogen, potash and yield.

The results show that yield of turmeric is closely related to nitrogen, potash and rhizosphere bacteria. Hence regression equation of yield (y) on bacteria (x) in rhizosphere, nitrogen (N) and potash (K) was calculated. The equation is:

$$y = 11.2880 + 0.0073x + 0.011N + 0.037K + 0.00024N^2 + 0.00033K^2.$$

3. R/S ratio and yield:

R/S ratio denotes the ratio of the number of bacteria in rhizosphere to the number in the non-rhizosphere region. It is seen that yield of turmeric is closely correlated to R/S ratio and the correlation coefficient being 0.75. The regression equation of yield per acre on R/S ratio was calculated and found as:

$$y = 1089x + 508.2.$$

ECONOMICS OF MANURING

Cultivators are interested only in the economy of fertilizer application. Hence the results were also subjected to the analysis of their economics. Since the effects of all interactions are not significant, the main effects alone have been taken into consideration. The economics of various treatments are given in table No. XV.

ECONOMICS OF TREATMENTS

Table XV

Treat-ments.	Yield per acre in Kg.	Extra yield in Kg.	Value of extra yield Rs. nP.	Cost of fertili-zers. Rs. nP.	Profit or loss Rs. nP.
N_0	1168.86	—	..	..	..
N_{50}	1347.42	178.74	71.20	47.50	+23.70
N_{100}	1639.60	470.74	188.28	95.00	+93.28
P_0	1330.04	..	..	..	..
P_{45}	1396.41	66.37	26.54	33.75	- 7.25
P_{90}	1429.43	99.38	39.59	67.50	-27.91
K_0	978.01	..	..	..	..
K_{60}	1285.40	307.39	122.96	42.00	+80.96
K_{120}	1892.47	914.46	364.76	84.00	+280.76

It can be concluded from the above table that, among the three nutrients, potash has given the highest profit per acre. Nitrogen comes next in order. Phosphorus application has resulted in net loss.

DISCUSSION OF RESULTS

Results presented in the previous chapter are discussed in the following pages. The findings of the investigation are discussed in the following order of classification.

A. PRE-HARVEST STUDIES:

1. Germination.
2. Height of plants.
3. Number of leaves.
4. Number of suckers.
5. Bacteria in the rhizosphere.
6. Bacteria in non-rhizosphere.
7. R/S ratio.
8. Flowering.

B. POST HARVEST STUDIES:

1. Yield.
2. Ratio of rhizome to bulb.
3. Cured produce.

A. PRE-HARVEST STUDIES:

1. Germination of rhizomes.

The rhizomes of uniform size were planted on 20--6--1963 and 21--6--1963. Germination started 20 days after planting and continued up to 30th day. The data presented in table No. II show that there is no marked difference in the rate of germination under different treatments of nitrogen, phosphorus and potash.

Seeds and seed materials depend for germination and early growth on their stored food materials and not on the food materials available in the substrate in which it sprouts. Unless the substrate brings in variations in moisture, aeration and warmth, it cannot affect germination. In the present investigation since the planting was done in the month of June, the season of abundant South west monsoon, various doses of fertiliser application did not affect variably the moisture intake by turmeric. Temperature and aeration are also uniform in different treatments. Hence uniformity of germination was noticed in all treatments. This is in agreement with the findings of Swaran Singh Purewal (1957) who has reported that different fertilizers have no effect on germination of tuberous crop like colocasia.

Height of plants and number of leaves:

The data presented in table III show that the height increases at a very slow rate up to 60 days after planting and the rate of growth increases rapidly thereafter. There is no increase in height after 120 days and maximum growth is observed between 90 - 120 days. The relationship between height and yield is given in figure No. 3.

No significant difference is noticed in the number of leaves under different treatments. The data presented in table No. IV show that maximum number of leaves are produced between 90 - 120 days after planting. There is no production of leaves after 130 days.

The slow rate of increase in height up to 60 days may be attributed to the small extent of development of the root system and the dependence mainly on reserve food material in the seed rhizome. During the third and fourth month after planting, plants produce large sized leaves for the manufacture of greater amounts of food and a well developed root system for greater absorption. This results in rapid increase of height.

The slow rate of growth after 120 days indicates that the plants are advancing towards maturity and rhizome development. The food material produced by photosynthesis which was being utilised by the plants in large amounts for their growth till now, gets diverted for the rhizome formation. Thus the rate of growth ceases considerably from 120th day onwards.

The percentages of increase in height over the respective control in different treatments are given in table No.III. The response to potash is greatest giving 15.1% increase for 60 lb. and 38.5% for 120 lb. over the control of zero level. The mean response to potash is 6.365 cm.

The response to nitrogen is also significant giving 10.20% increase in height for 50 lb. nitrogen and 22.80% for 100 lb. nitrogen over zero level. The response to phosphorus is not significant but an increase of 4% for 90 lb. phosphorus is noticed. The maximum height of

53.37 cm. was noticed when higher dose of nitrogen, phosphorus and potash was applied.

Measurements made under the item height and number of leaves relate only to the elaboration of the leaf tissue, because, turmeric is a plant which has its stem portion under ground. The shoot portion above ground constitutes only the leaf sheath and lamina. Seed rhizome planted sends out roots into the soil and leaves above the ground. In the early stages, the nitrogen absorbed by the roots might have been mainly utilized for tissue building of the bulk portion of the underground stem rather than leaf tissue above the ground. But after 90 days, nitrogen nutrition with a more elaborate root system seems to be diverted for a more increased rate of development of the aerial portion. Results of experiments conducted on rhizomatous crops like ginger at Ambalawayal in 1955-56 also had the same trend obtained in the present investigation on turmeric.

Number of suckers:

The rhizomes of turmeric are named variably according to the order of development. The first formed are the primary mothers (rounds) followed by secondary mothers and primary fingers. The primary fingers in course of time give rise to fingers of second and sometimes third order. The suckers are developed from secondary mothers and in later stage from the primary fingers. Hence number of suckers will give an indication of the number of secondary mothers, consequently the yield.

The data presented in table No. V show that the effect of nitrogen and potash alone are significant. Plants in control plots and those under phosphorus treatment did not produce any suckers. Maximum sucker count was seen in plants receiving balanced fertilizers. The number of sprouts increases as the number of secondary mothers and primary fingers increase . Hence number of sprouts may be considered as an indication of development of underground rhizome.

Maximum number of suckers per plant, namely 4, was produced by plants receiving highest dose of nitrogen, phosphorus and potash. This treatment also produced maximum yield of 4230 Kg. per acre. The plots that received no manures and those receiving phosphorus alone produced minimum yield. Application of complete fertilizers produced more yield and suckers. Hence it may be stated that the number of suckers is closely related to yield.

<u>Bacteria in rhizosphere, non-rhizosphere and R/S ratio:</u>

An active and thriving microbial population is necessary for good growth of crop plants. While releasing major nutrients such as nitrogen, phosphorus and potash in available form from decaying plant materials, microorganisms utilise a part of it for their growth. The life cycle of higher plants and the life cycle of microorganisms are mutually dependent. The data presented in table Nos. VI, VII, VIII and figures 4 A and B brought out the following findings.

In $N_0P_0K_0$ treatment, the rhizosphere count is 10 lakhs whereas in the region away from the rhizosphere the count is 40.25 lakhs. This reduction in the bacterial count may be due to the effect of turmeric root excretions and also due to the specific nutritional requirements of the soil bacteria. In the rhizosphere region, the crop's requirement for nutrients upset the balance. This may also be one of the causes for reduction of bacterial numbers. The minimum count of 10 lakhs is seen in the rhizosphere of turmeric receiving no manures.

The count in rhizosphere and their respective non-rhizosphere control for treatments $N_{50}P_0K_0$, $N_{100}P_0K_0$ are 16.00, 20.00 lakhs and 34.00 and 30.50 lakhs respectively. An increase of 4 lakhs in the rhizosphere and a reduction of 3.50 lakhs in the non-rhizosphere are noticed when the dose of nitrogen is doubled.

The count in the rhizosphere and control for treatments $N_0P_{45}K_0$ and $N_0P_{90}K_0$ are 11.00, 12.00 and 12.00 and 32.00, 45.00 lakhs respectively showing that there is no appreciable increase in rhizosphere count with the increase of phosphorus. The effect of phosphorus on yield is also negligible.

The count in the rhizosphere and their respective control for treatments $N_0P_0K_{60}$ and $N_0P_0K_{120}$ are 18.25, 28.50 lakhs and 27.00, 19.25 lakhs respectively. This clearly shows that there is an appreciable increase of 10.25 lakhs in the count of rhizosphere and a significant reduction of 7.75 lakhs in the region away from the root when the dose of potash is doubled.

The count for $N_0P_{45}K_{60}$ and $N_0P_{90}K_{120}$ in the rhizosphere and non rhizosphere are 12.00, 12.00 and 22.00, 21.00 lakhs respectively showing that there is no considerable change in the count due to variation of fertilizer dose either in the rhizosphere or in the non-rhizosphere region. This shows that the effect of phosphorus plus potash on bacterial numbers in the absence of nitrogen is very little.

The count for the treatments $N_{50}P_{45}K_{60}$ and $N_{100}P_{90}K_{120}$ are 30.00, 16.5 and 26.00, 13.00 lakhs respectively in rhizosphere and non-rhizosphere. This shows that the application of complete fertilizer has significant effect on rhizosphere and non-rhizosphere count.

The reduction in count due to the application of 100 lb. nitrogen as Ammonium sulphate may be explained as follows:-

Higher concentration of soluble nitrogen in the non-rhizosphere region evidently results in an osmotic concentration of the soil solution unfavourable for the multiplication of bacteria whereas in the rhizosphere region, due to the depletion of nutrients by the plant, the osmotic concentration of the soil solute is constantly reduced resulting in better moisture conditions favouring a higher rate of multiplication of bacteria.

Various doses of phosphorus have not produced any effect on rhizosphere count. In the non-rhizosphere region in the plots receiving higher dose of phosphorus the bacterial count is higher than in rhizosphere region in the same plots. Therefore the indication seems to be that the intake of phosphorus by plant brings about a situation where small quantities of phosphorus alone are available for bacterial growth in the rhizosphere. This effect together with the influence of turmeric may be responsible for the small number of bacteria in the rhizosphere.

The increase in the rhizosphere count and decrease in the region away from the rhizosphere due to the application of potash can be explained as follows. The combination of the exudates of roots of turmeric with potash applied to the soil might have reduced the bacteriostatic or even the bactericidal property of such exudates and thereby might have produced a more neutral medium for the growth of bacteria in the rhizosphere. The absorption of nutrients by the plant might also have produced a better osmotic condition for more rapid multiplication.

Balanced application of nitrogen, phosphorus and potash alone will give a more or less equal count in rhizosphere and non-rhizosphere region. It is conspicuous that an increase in the dose of nitrogen and potash keep the count of bacteria in rhizosphere and the non-rhizosphere in equilibrium. The equilibrium in bacterial numbers in the two regions of turmeric crop is also seen associated with higher yields. So it may be concluded that a complete fertilizer application is the best for turmeric in the type of soil in which investigation was carried out. When nitrogen and potash are increased the rhizosphere effect becomes positive and the corresponding yield is higher. It is also seen that the yield of turmeric is directly correlated to R/S ratio and the correlation coefficient being 0.75. Maximum yield of 5.462 Kg. per plot was obtained when the R/S ratio reached 1.27. This shows that the yield of turmeric can be increased by increasing the dose of nitrogen and potash in NPK combination which will offer higher R/S ratio. Spot application at the base of each plant of farm yard manure or compost, which contain abundant number of bacteria, may also increase microbial population in the rhizosphere. Hence a higher R/S ratio may be artificially provided probably influencing yield positively. Hence application of farm yard manure, compost and green leaves in the rhizosphere region of turmeric may help to get higher yields.

Katznelson (1946) reported that fertilizer application might induce changes in the rhizosphere microflora.

Voldendrop (1962) reported that the joint action of lime, potash and magnesium had a beneficial influence on the maintenance of the number of bacteria in the soil. The finding of this investigation is in agreement with the finding of the experiment conducted in Orissa in 1955 that bacteria respond to nitrogen and phosphorus while the effect of potash is depressive.

Flowering of turmeric.

Turmeric does not flower generally in South India. This investigation shows that high level of nitrogen retards flowering, but high levels of phosphorus and potash induce it. Plants in control plots do not flower. It is seen that an optimum level of nitrogen is required for the development of the primordia of inflorescence. The optimum level of nitrogen is found to be 36.5 lb. and nitrogen above and below this level reduces flowering. Phosphorus and potash increase the percentage of flowering as their levels are increased. By raising the level of phosphorus and potash in combination with 36.5 lb. nitrogen, the percentage of plants flowered has been observed to increase. This finding is in agreement with that of Jasper and Smith (1961) who showed maximum flower production in Chrysanthemum can be increased by higher doses of phosphorus and potash in combination with an optimum level of nitrogen.

B. <u>POST HARVEST STUDIES</u>:

<u>Yield of Rhizome, Cured produce and Ratio of Rhizome to Bulb</u>.

Yield of turmeric due to different treatments and yield calculated on acre basis are presented in tables X and XI. Average yield of rhizome per plot is given in table XII. The effect of different treatments on rhizome-bulb ratio and curing percentage are presented in tables XIII and XIV. The relationship between yield and major nutrients is also given in figure No. 3.

Application of nitrogen at the rate of 50 lb. per acre produced 1347.42 Kg. which is 15.2% more than that of zero level. When the dose of nitrogen doubled the increase in yield is 38.4% over the control. The nitrogen content of the soil is 0.04% which is below the optimum and hence application of nitrogen has significant effect on the yield.

50 lb. nitrogen alone gives lower height and yield averages than plots receiving $N_0P_0K_0$. The introduction of additional nitrogen induces probably the multiplication of soil microorganisms resulting in greater competition for nutrients with the plant. When the condition is made more balanced by the application of 60 lb. potash, the soil substrate conditions become more suitable for the plant as evidenced by the increase in yield and height of the plant. This influence becomes more sustained and very conspicuous when the dose of potash is doubled to 120 lb. Therefore it becomes apparent that in the soil

substrate where the microbial activity is increased by greater application of nitrogen, a corresponding increase in the potash levels becomes more and more beneficial to turmeric plant.

Application of highest dose of nitrogen namely 100 lb. in the absence of phosphorus and in combination with varying doses of potash does not show marked increases in height or yield as compared to the application of 50 lb. nitrogen and varying doses of potash. This shows that the doses of potash applied without phosphorus do not induce corresponding vigour in the growth of plants.

Russel (1961) reports that the effect of nitrogen on root and tubers will be perceptible only on long duration crops. But in short duration crops the effect of nitrogen is only on the top. Since turmeric is a long duration crop, the effect of nitrogen, seen both on the top and the rhizome, is in agreement with the above observation.

According to Ashby (1948) the effect of nitrogen in herbaceous plants is rapid increase of leaf production. Higher doses of nitrogen which enhances reduction of cell thickness make plant more susceptible to the attack of insect pests and diseases. The occurence of stemborer, <u>Dichocrosis Punctiferalis</u> in plots receiving the higher dose of nitrogen in the combinations $N_{100}P_0K_{60}$, $N_{100}P_0K_0$, $N_{50}P_0K_0$, $N_{100}P_{45}K_0$ confirms the above statement that nitrogen induces the attacks of insects.

The response of turmeric to nitrogen is in agreement with the findings of Turmeric Research Station, Orissa and those of Paul and Fernando (1944)

The effect of phosphorus on yield is not statistically significant. The difference in yield due to the application of 45 and 90 lb. phosphorus is only 32.63 lb. per acre. This shows that turmeric needs only little phosphorus and hence application of high doses of phosphorus is not economical.

When the plots receive phosphorus at the rate of 45 lb. per acre, its influence on height and yield in combination with varying doses of nitrogen and potash are as follows. Phosphorus in the presence of increasing doses of potash and total absence of nitrogen gives progressive response in height and yield. This may be explained as being due the balancing of nutrient status of substrate by the beneficial influence of phosphorus on nonsymbiotic nitrogen fixation in the soil resulting in addition of nitrogen to the soil and consequent balancing of the nutritional status, even though no nitrogen was added originally to the soil.

Keeping the level of phosphorus and nitrogen at 45 and 50 lb. respectively, addition of potash at 60 and 120 lb. gives marked increase in height almost similar for these two levels. Even though increases in height occur, the indication is that increasing levels of potash in combination with a constant minimum dose of nitrogen and phosphorus is not beneficial in increasing yields. Therefore the higher dose of potash inducing better vigour and growth in height can have commensurate influence on rhizome development only when the higher dose of nitrogen is present. Keeping phosphorus at 45 lb. level, increased application of nitrogen and potash at 100 and 120 lb. levels has shown marked increase in height and weight of rhizomes.

The higher yields and height of the plant is traceable to the beneficial influence of phosphorus for the better development of root system resulting in proper utilization of the higher nutrient status available in the soil due to the greater doses applied. Increasing phosphorus to the higher level of 90 lb. resulted in better growth of the above ground stem and some more growth in underground rhizome.

But phosphorus has not shown any significant effect on yield, curing percentage and rhizome bulb ratio. In the early stages turmeric requires phosphorus for root development as any other crop. But in the later stages the development of the rhizome is a function primarily of the storage of carbohydrates. At this stage the translocation and accumulation of carbohydrates is mainly related to potash rather than phosphorus. Hence the limited response to phosphorus seen in this investigation is similar to this characteristic noted generally in tuberous crops.

Among the major nutrients potash has the greatest effect on yield. Application of 60 and 120 lb. potash produced 1235.42 Kg. and 1892.47 Kg. per acre which are respectively 30.70% and 90.50% over zero level. This shows that the application of 120 lb. potash almost doubled the yield.

Experiments conducted on rhizomatous crops show that the growth of the underground storage organ is highly correlated with the amount of potash applied to the soil. Jansen and Berthelomew (1930) reported that there is progressive accumulation of carbohydrate when the level of potash is increased. Available potash content of the soil where the investigation was carried out is 0.0009% which is very low. Therefore the application of potash is very essential for increasing the yield of turmeric. In this investigation application of potash almost doubled the yield. This finding is in agreement with those of Paul and Fernando (1944) and Rao (1949).

It is seen that nitrogen and potash are required in large quantities for the production of good yield. Application of nitrogen increases the leaf area which help in greater carbon assimilation. The products of photosynthesis have to be translocated to the underground storage organs for which sufficient quantity of potash is necessary. When potash is deficient, translocation of food materials takes place at a slow rate resulting in poor development of rhizome. Therefore application of both nitrogen and potash is essential for better yields.

For better absorption of nutrients from the soil, a well developed root system is required. For the production of maximum yield application of nitrogen, phosphorus and potash is necessary. Highest yield of 4250 Kg. per acre was produced under the treatment $N_{100}P_{90}K_{120}$ followed by 3920 Kg. under $N_{100}P_{45}K_{120}$. A fertilizer mixture having the ratio 2 : 1 : 4 to supply 80 lb. nitrogen is found to be the optimum for turmeric.

The ratio of rhizome to bulb presented in table No. XIII shows that nitrogen has a significant depressing effect on the ratio. The increase of ratio due to potash application is not statistically significant but percentage increase of 16.00 is seen for 60 lb. potash. The depressing effect of nitrogen can be explained as follows: In turmeric bulb is formed first and development of rhizome from the bulb taken place about four months after planting when the vegetative growth reaches the final phase. Application of nitrogen in early stages is almost utilised for the development of the bulb. Application of higher dose of nitrogen in early stage reduces the rhizome bulb ratio by the improportionate development of bulb. Hence it is probable that the application of part of total nitrogen in later stage i.e. during the development of rhizomes may result in greater development rhizomes. Consequently greater rhizome bulb ratio. Therefore split application of nitrogen is desirable for increasing the ratio.

Nitrogen and phosphorus have no significant effect on curing percentage of turmeric, even though 100 lb. nitrogen and 90 lb. phosphorus increase curing percentage by 45.25 and 8.46 respectively over zero levels. The increase in cured product is maximum for potash giving 27.20% for 60 lb. and 75.84% for 120 lb.

Sugawara (1939) reported that carbohydrate accumulation was increased in underground storage organs by heavy application of potash and was lowered by potash starvation. Potash is essential for the increase of dry matter content of storage organs and hence curing percentage is related to potash absorption. The mean response to nitrogen, phosphorus and potash are 0.147, 0.032 and 0.224 Kg. per plot respectively.

From this investigation it is seen that the application of complete fertilizer is necessary for economic production of turmeric. Hence an attempt was made to determine the optimum level of nutrients. Application of 82.5 lb. nitrogen, 43.25 lb. phosphorus and 160.50 lb. potash is found to be the optimum under the conditions obtaining in Vellayani, where the investigation was carried out.

SUMMARY AND CONCLUSIONS

An experiment was conducted with the object of studying the effect of different levels of nitrogen (0, 50 and 100 lb.), phosphorus (0, 45 and 90 lb.) and potash (0, 60 and 120 lb.) alone and in various combinations on germination, height, number of leaves, yield and curing percentage of turmeric. The lay out was 3^3 factorial experiment with two replications having 27 treatments each. Nitrogen, phosphorus and potash were tried in the form of Ammonium sulphate, super phosphate and muriate of potash.

The results of the experiment show that a fertilizer mixture of 2 : 1 : 4 ratio to supply 80 lb. nitrogen per acre is the optimum dose under Vellayani condition, where the investigation was carried out. Application of nitrogen in split doses extending up to four months after planting is found to be effective in increasing rhizome and reducing bulb.

Since bactericidal property of turmeric is well known, the effect of fertilizers on bacterial population in both rhizosphere and non-rhizosphere region was also studied, in addition to the studies of various morphological characters of turmeric. It is seen that nitrogen and potash increase bacteria, in the rhizosphere region and reduce it in non-rhizosphere region. A positive rhisosphere effect is necessary for better yield and this suggests the application of organic materials like farm yard manure, compost and green manure. This substantiates the present practice of applying large quantity of farm yard manure and green manures to crops like turmeric and ginger by farmers. It is also noted that potash has a depressing effect on bacterial population in laterite soils whereas medium doses of nitrogen and phosphorus help in the proliferation of bacteria.

Regression equations of yield on height, nitrogen potash and rhizosphere bacteria were worked out. Height of plant and R/S ratio were correlated with yield and correlation coefficients were found to be 0.65 and 0.75 respectively.

CONCLUSIONS

1. Germination:

Nitrogen, phosphorus and potash have no effect on the germination of rhizomes.

2. Height of plant:

(a) Nitrogen and potash have significant effect on height of plants. The effect of phosphorus is very little.

(b) Maximum height was seen in plants receiving highest dose of nitrogen, phosphorus and potash.

(c) Rate of increases in plant height was found to be greatest between 90th and 120th days after planting.

3. Number of leaves:

(a) Fertilizer application has no effect on the number of leaves at various stages of growth.

(b) Greatest number of leaves is produced between 3 - 4 months after planting. There is no leaf production after 150 days of planting.

4. Number of suckers:

(a) Nitrogen and potash increase the number of suckers. Phosphorus has no effect on the production of suckers.

(b) Number of suckers may be taken as indication of yield.

5. Bacteria in the rhizosphere:

(a) Roots of turmeric excrete some substance which has inhibitory action on bacterial number in the root zone.

(b) Bacteria in the rhizosphere respond to nitrogen and potash whereas phosphorus has a depressing effect on bacteria in the root zone.

(c) Bacteria in rhizosphere increase only up to a level by the application of nitrogen.

(d) Application of higher dose of phosphorus namely 90 lb. per acre reduces bacteria in the rhizosphere.

6. Bacteria in non-rhizosphere region:

(a) Bacteria in the non-rhizosphere respond to nitrogen and phosphorus, but potash has a highly significant depressing effect on it.

(b) Application of higher doses of nitrogen and phosphorus is not conducive to the multiplication of bacteria.

7. Ratio of rhizosphere to non-rhizosphere bacteria (R/S ratio)

(a) R/S ratio is positively correlated to the yield and correlation coefficient is found to be 0.75.

(b) Positive rhizosphere effect is necessary for better yields and this can be achieved by increasing the dose of nitrogen and potash in N P K combination which will increase bacteria in rhizosphere and reduce it in non-rhizosphere.

(c) It is suggested that positive rhizosphere effect can be brought about by application of farm yard manure, compost green leaves, etc., in the root zone.

(d) The effect of phosphorus and potash on bacteria in the absence of nitrogen is very little both in rhizosphere and non-rhizosphere.

8. Flowering:

(a) Application of high dose of nitrogen reduces flowering but nitrogen applied in conjunction with phosphorus and potash increases flowering.

(b) Application of nitrogen at 36.5 lb. is found to be optimum. Nitrogen above and below this level supresses flowering. By raising the levels of phosphorus and potash in combination with 36.5 lb. nitrogen, percentage of plants flowering can be increased.

9. Yield of turmeric:

(a) Application of nitrogen and potash increased yield significantly over control. Application of 120 lb. potash alone per acre almost doubled the yield.

(b) The effect of phosphorus is seen only in the presence of nitrogen and potash.

(c) Application of complete fertilizer is better than individual fertilizers. Maximum yield of 4280 Kg. per acre was obtained under 100 lb. nitrogen, 90 lb. phosphorus and 120 lb. potash followed by 3920 Kg. in 100 lb. nitrogen, 45 lb. phosphorus and 120 lb. potash treatment.

(c) Application of 87.5 lb. nitrogen, 43.25 lb. phosphorus and 160.50 lb. potash is the optimum level required for the crop. Hence a fertilizer mixture of 2 : 1 : [illegible] ratio to supply 80 lb. nitrogen can be recommended.

10. Ratio of rhizome to bulb:

(a) Nitrogen has a depressing effect on rhizome to bulb ratio whereas phosphorus and potash increase the ratio.

(b) Application of a part of total nitrogen at the time of development of rhizome may increase the size and quantity of rhizome. Hence split application of nitrogen can be recommended for increasing the ratio of rhizome to bulb.

11. Curing percentage:

Potash alone has significant effect on curing percentage.

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APPENDICES

APPENDIX I

(Analysis of Variance)

Germination percentage

Source	SS	Df	Variance	F ratio	Inference
Total	102.24	53	—	—	
Block	1.23	1	1.23	1.41	
N	2.30	2	1.15	0.39	
P	1.90	2	0.95	0.32	Treatment are not significant
K	1.82	2	0.91	0.32	
NP	3.80	4	0.95	0.32	
NK	3.40	4	0.87	0.30	
PK	4.01	4	1.002	0.34	
NPK	8.10	8	1.010	0.34	
Error	75.58	26	2.90	—	

APPENDIX II

(Analysis of Variance)

(Hight of the Plant in 150th day)

Source	SS	Df	Variance	F ratio	Inference
Total	3277.2	53	—		
Block	56.80	1	56.8	1.96	
N	447.9	2	223.95	7.7	Significant at 5% level
P	40.9	2	20.45	0.68	
K	1488.8	2	744.3	25.6	Significant at 5% level
NP	14.1	4	7.05	0.24	
NK	34.8	4	17.4	0.57	
PK	54.1	4	27.05	0.93	
NPK	37.4	8	18.7	0.62	
Error	1102.00	26	29.01		

APPENDIX III

(Analysis of Variance)

(No. of leaves on 150th day)

Source	SS	Df	Variance	F ratio	Inference
Total	121.86	53	-		
Block	4.62	1	4.62	0.802	Not significant
N	13.60	2	6.80	1.18	
P	10.20	2	5.10	0.92	
K	12.42	2	6.21	1.08	
NP	15.20	4	3.80	0.66	
NK	12.50	4	3.12	0.57	
PK	11.64	4	2.91	0.503	
NPK	13.42	8	1.68	0.29	
Error	150.12	26	5.76	--	

APPENDIX IV

(Analysis of Variance)

Suckers

Source	SS	Df	Variance	F ratio	Inference
Total	63.889	53			
Block	0.017	1	0.017	0.014	
N	18.219	2	9.109	8.100	Significant at 5% level
P	0.438	2	0.219	0.180	
K	13.300	2	6.650	5.900	Significant
NP	1.175	4	0.293	0.210	
NK	0.019	4	0.004	0.001	
PK	0.182	4	0.045	0.031	
NPK	0.348	8	0.043	0.030	
Error	30.202	26	1.120		

APPENDIX V

(Analysis of Variance)

<u>Bacteria in the rhizosphere</u>

Source	SS	Df	Variance	F ratio	Inference
Total	692.22	26	--		
N	131.18	2	65.59	5.60	Significant at 5% level
P	93.18	2	46.59	3.90	
K	216.00	2	108.00	9.10	Significant at 5% level
NP	72.00	4	18.00	1.50	
NK	60.72	4	15.18	1.2	
PK	25.62	4	6.40	0.54	
Error	94.24	8	11.78		

APPENDIX VI

(Analysis of Variance)

<u>Bacteria in non-rhizosphere</u>

Source	SS	Df	Variance	F ratio	Inference
Total	634.26	26	--		
N	31.24	2	15.62	1.5	
P	450.40	2	22.70	2.2	
K	5.64	2	2.82	0.28	
NP	280.34	4	70.08	7.008	Significant at 5% level
NK	80.70	4	20.16	2.016	
PK	110.30	4	27.60	2.76	
Error	80.64	8	10.08		

APPENDIX VII

(Analysis of Variance)

Percentage of plants flowered)

Source	SS	Df	Variance	F ratio	Inference
Total	254.15	53	---		
Block	7.41	1	7.41	1.90	
N	96.93	2	31.46	8.05	Significant at 5% level.
P	5.59	2	2.795	0.71	
K	9.92	2	4.96	1.26	
NP	4.72	4	1.18	0.31	
NK	16.03	4	4.00	1.02	
PK	6.26	4	1.56	0.39	
NPK	5.48	8	0.68	0.17	
Error	101.81	26	3.91		

APPENDIX VIII

(Analysis of Variance)

Yield of Turmeric.

Source	SS	Df	Variance	F ratio	Inference
Total	25.6060	53	---		
Block	0.7957	1	0.795	4.372	
N	2.9960	2	1.498	8.233	Significant at 5% level
P	0.0843	2	0.042	0.231	
K	12.3123	2	6.156	33.000	Significant at 5% level
NP	1.0310	4	0.257	1.410	
NK	0.5187	4	0.129	0.712	
PK	1.1720	4	0.293	1.610	
NPK	1.5971	8	0.199	1.090	
Error	5.0975	26	0.182		

APPENDIX IX

(Analysis of Variance)

Ratio rhizome to bulb.

Source	SS	Df	Variance	F Ratio	Inference
Total	15.070	26	—		
N	9.197	2	4.598	7.30	Significant at 5% level.
P	0.046	2	0.023	0.03	
K	0.547	2	0.273	0.44	
NP	0.168	4	0.042	0.06	
NK	0.022	4	0.005	0.008	
P	0.049	4	0.012	0.02	
Error	5.070	8	0.633		

APPENDIX X

(Analysis of Variance)

Curing percentage of turmeric.

Source	SS	Df	Variance	F Ratio	Inference
Total	2.265	26	—		
N	0.390	2	0.195	2.600	
P	0.020	2	0.010	0.013	
[illegible]	0.930	2	0.465	6.200	Significant at 5% level
NP	0.090	4	0.022	0.300	
NK	0.110	4	0.027	0.360	
PK	0.020	4	0.005	0.060	
Error	0.605	8	0.075		

PLAN OF LAYOUT OF THE EXPERIMENT.

12 METRES. (width) — 25 METRES (length)

$n_1p_0k_1$	$n_2p_1k_0$	$n_0p_1k_0$
$n_0p_1k_2$	$n_0p_2k_2$	$n_1p_2k_2$
$n_1p_2k_0$	$n_1p_1k_1$	$n_2p_2k_0$
$n_0p_0k_0$	$n_1p_0k_0$	$n_1p_0k_2$
$n_2p_0k_0$	$n_0p_0k_2$	$n_0p_2k_1$
$n_1p_1k_2$	$n_2p_2k_1$	$n_2p_0k_2$
$n_0p_1k_1$	$n_0p_0k_1$	$n_2p_1k_2$
$n_1p_2k_1$	$n_2p_0k_1$	$n_2p_2k_2$
$n_0p_2k_0$	$n_2p_1k_1$	$n_1p_1k_0$

REPN. I.

12 METRES. (width) — 25 METRES. (length)

$n_2p_1k_0$	$n_0p_2k_0$	$n_2p_2k_0$
$n_2p_0k_0$	$n_0p_1k_2$	$n_2p_1k_2$
$n_1p_2k_0$	$n_2p_0k_1$	$n_1p_0k_1$
$n_0p_0k_2$	$n_1p_2k_1$	$n_0p_1k_1$
$n_2p_1k_1$	$n_1p_1k_0$	$n_0p_2k_0$
$n_1p_1k_2$	$n_1p_0k_0$	$n_0p_0k_0$
$n_1p_2k_2$	$n_0p_1k_0$	$n_1p_1k_1$
$n_0p_2k_2$	$n_2p_0k_2$	$n_2p_2k_2$
$n_1p_0k_2$	$n_0p_0k_1$	$n_2p_2k_1$

REPN. II.

Fig 1

RELATIONSHIP OF YIELD ON LEVELS OF NITROGEN FOR VARYING LEVELS OF POTASH

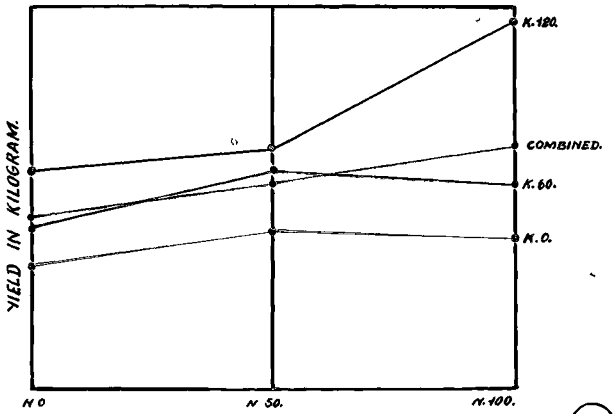

Fig 2

RELATIONSHIP BETWEEN YIELD OF TURMERIC AND HEIGHT OF PLANT

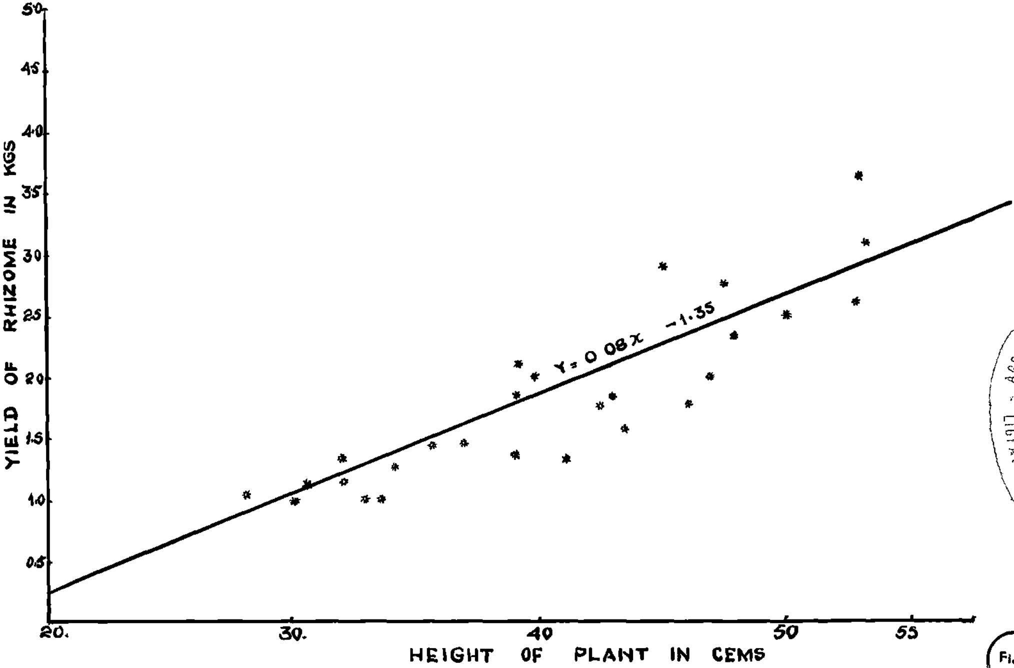

Fig 3

DIAGRAM SHOWING THE BACTERIAL COUNT UNDER DIFFERENT TREATMENTS IN RHIZOSPHERE AND ITS CONTROL

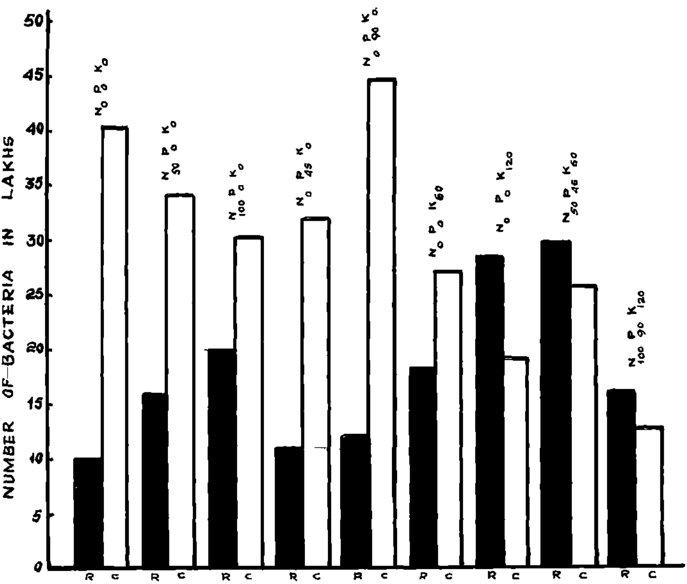

Fig 4 A

DIAGRAM SHOWING THE BACTERIAL COUNT UNDER DIFFERENT TREATMENTS IN RHIZOSPHERE AND ITS CONTROL

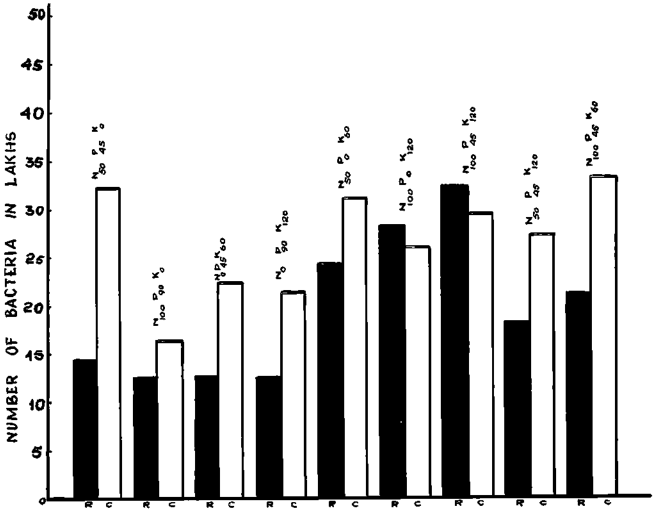

Fig 4 B

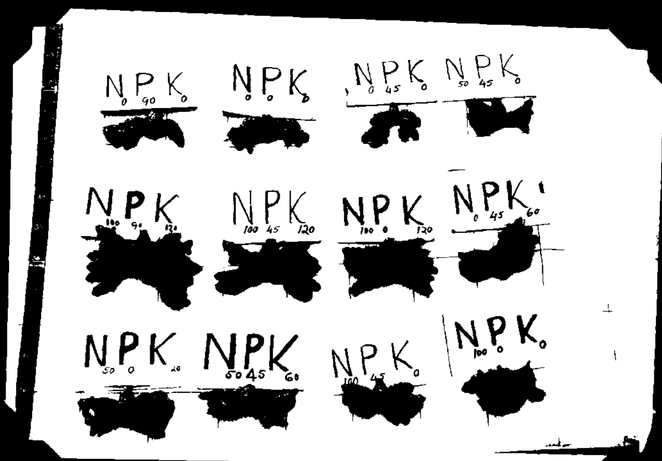

Plate I
Turmeric Rhizomes
(Under different treatments)

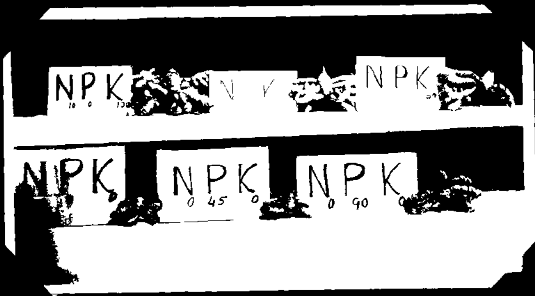

Plate II
Turmeric Rhizomes
(Under phosphorus treatments)

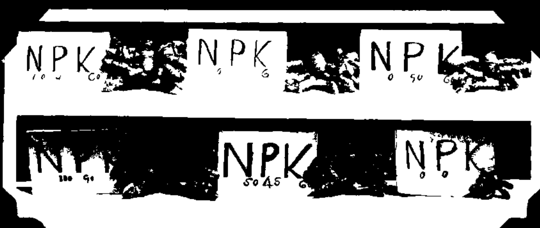

Plate III
Turmeric rhizomes
(Under complete fertilizer application and control)

Plate IV
Turmeric Plants
(Control)

Plate V
Turmeric Plants
(Under 100 lb. Nitrogen)

Plate VI
Turmeric Plants
(120 lb. K_2O)

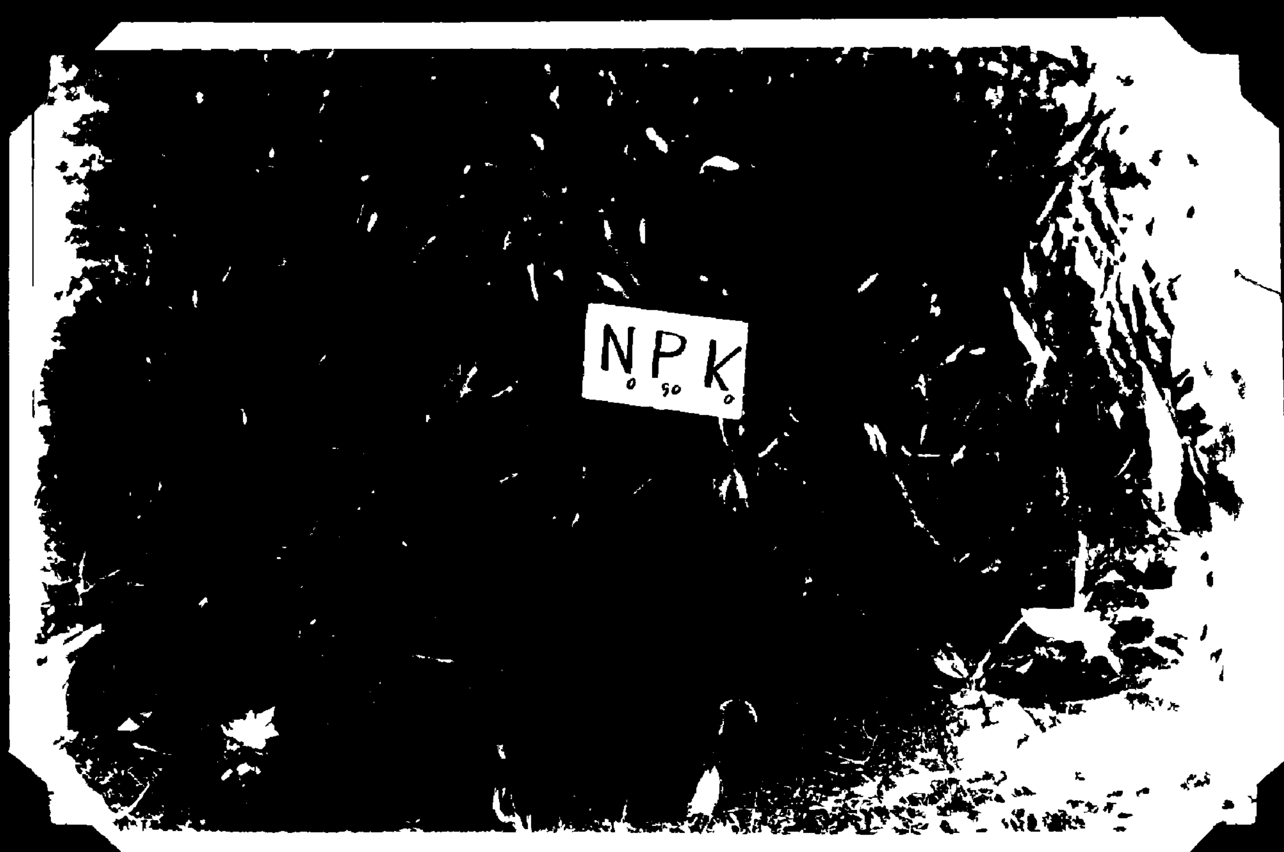

PLATE VII

(90 lb. P_2O_5)

Plate VIII
Turmeric Plants
(Under 90 lb.P_2O_5+120 lb. K_2O)

Plate IX
Turmeric Plants
(Plant under 90 lb.N+45 lb.P_2O_5
+60 lb.K_2O

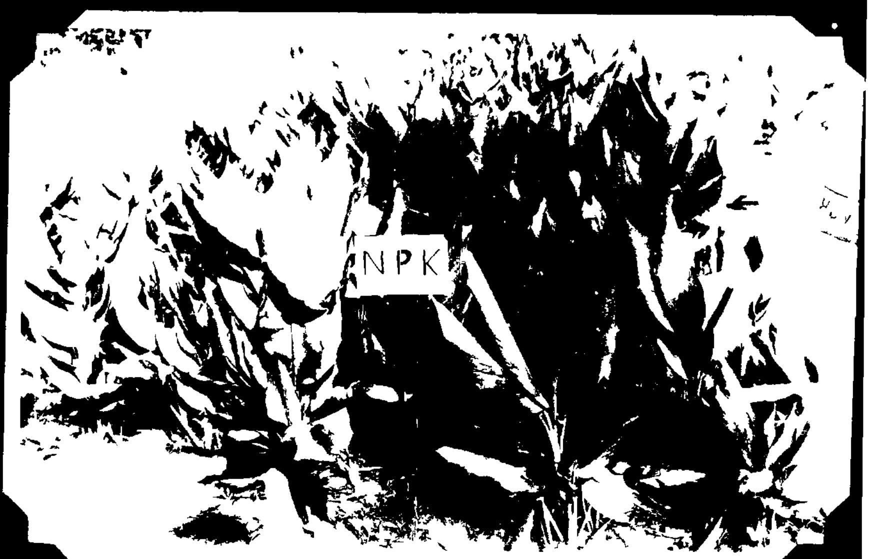

Plate XI
Turmeric Plants
(Under 100 lb.N+90lb.P_2O_5+120 lb.K_2O