SOIL TEST CROP RESPONSE STUDIES ON GROUNDNUT (*Arachis hypogaea* L.) IN LATERITE SOILS OF KERALA

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"Soil test crop response studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala"** is a bona-fide 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 of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
10.2.2005

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CERTIFICATE

Certified that this thesis, entitled **"Soil test crop response studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala"** is a record of research work done independently by **Ms. Sidha, P.S.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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We, the undersigned members of the Advisory Committee of **Ms. Sidha, P.S.** a candidate for the degree of **Master of Science in Agriculture** with major in **Soil Science and Agricultural Chemistry,** agree that the thesis entitled **"Soil test crop response studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala"** may be submitted by Ms. Sidha, P.S. in partial fulfilment of the requirements for the degree.

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ABBREVIATIONS

AICRP	-	All India Co-ordinated Research Project
ANOVA	-	Analysis of variance
CD	-	Critical difference
FGE	-	Fertility gradient experiment
ha	-	hectare
IARI	-	Indian Agricultural Research Institute
kg	-	kilogram
KAU	-	Kerala Agricultural University
K	-	Potassium
N	-	Nitrogen
OC	-	Organic carbon
P	-	Phosphorus
RBD	-	Randomized Block Design
STCR	-	Soil Test Crop Response
STVs	-	Soil Test Values
T	-	Targeted yield
t	-	tonne
TNAU	-	Tamil Nadu Agricultural University

Introduction

INTRODUCTION

Fertilizers play a major role in Agriculture. It is the key input in enhancing crop production. Presently fertilizer contributes about 50 per cent to the total increase in food grain production. Fertilizer consumption on food grain production is closely correlated. Increasing pressure of population and shrinking land resources demand for vertical expansion of agriculture where the role of fertilizers will further increase. This increased consumption of fertilizers in the country over years led to the spiraling of fertilizer prices.

The generalized state level fertilizer prescription for the crops are based on fertilizer trials conducted at farmers field and in research stations. In these prescriptions, variations in soil fertility and desired yield are not at all considered and hence their adoption will not provide an efficient and economic use of fertilizer. This situation leads to wastage of fertilizers in some cases and under usage in some others.

Scientific and economic fertilizer use must take into account the soil fertility status as well as the crop needs. This has necessitated the formulation of fertilizer dose for crops based on soil tests. Soil testing is a chemical method of estimating the nutrient supplying power of a soil and it is one of the most important tool to practice balanced fertilization. The different steps involved in soil testing are collection of soil samples, extraction and estimation of available nutrients, interpretation of soil test data and formulation of fertilizer recommendation. Different soils differ in their capacity to supply nutrients to crops and crops vary in their nutrient requirement. Hence soil test data should correlate with nutrient uptake by crops for making efficient fertilizer recommendations.

Soil test crop response correlation studies fulfill the above needs. In this approach, variations in soil fertility are created in one and the same field. The available nutrient status of the soil is determined in the laboratory and correlated with the crop response to the applied nutrients in the field. From this data, fertilizer prescription equations are derived for a particular crop in a particular soil type. Then these equations are test verified in farmers field before they are recommended for large scale adoption. Such soil test based fertilizer recommendations ensure balanced use of soil and fertilizer nutrients for sustained crop production.

Soil test crop response experiments are conducted for a crop or cropping sequence on a benchmark soil which represents a larger area in a particular region and results of the experiments can be extrapolated to areas of similar soils to avoid laborious and expensive process of conducting the soil test crop response experiment in each and every piece of land.

Organic manures play a vital role in maintaining soil fertility under tropical conditions. High soil temperature in these areas leads to rapid decomposition of organic matter which is a key component for the soil to remain productive (Dalzell *et al.*, 1987). Moreover the Indian soils are poor in organic matter and major plant nutrients. The environmental hazards caused by the irrational use of fertilizers can be mitigated to a greater extent by optimizing the fertilizer with judicious application of organics. Besides, increasing the nutrient use efficiency, the complementary use of organics and inorganics helps to sustain high yields of crops. Hence soil test crop responses are useful under integrated plant nutrient system.

Oilseed crops have been the backbone of agricultural economy of India from time immemorial. In Kerala groundnut is cultivated in 2437 ha with a total production of 1812 t (GOK, 2004). Among the seven edible annual oilseed crops cultivated in India, groundnut (*Arachis hypogaea* L.) is the most important and is well known as the "king of oilseeds" as it contributes about 60 per cent of total oilseed production in the country.

Among the different oilseed crops groundnut finds extensive use in vanaspathi ghee. Being a legume crop with root nodules, it is capable of fixing atmospheric nitrogen, thereby improving soil fertility.

Due to its increased demand, soil management practices and mineral nutrition studies of groundnut demand much attention. The studies on mineral nutrition of groundnut are limited in Kerala. Though the crop can be grown in soils of marginal fertility, proper fertilization is necessary in order to realize the full potential of groundnut. This can be achieved by fertilizer recommendation based on STCR studies carried out in these soils.

In Kerala 65 per cent of land area is covered by laterite soil (KAU, 1989). In general laterite soils are poor in organic matter, nitrogen, phosphorus and potassium contents. Hence this study was carried out in a laterite soil with the following objectives.

- To establish the relationship between soil available and applied nutrients with pod yield of groundnut through response surface model.
- To provide a basis for fertilizer recommendation for maximum and economic pod yield at varying soil test values.
- To develop soil test based balanced fertilizer recommendation for specific yield targets of groundnut.
- To evaluate the conjoint use of organic manure and fertilizer in relation to soil test values.

Review of Literature

2. REVIEW OF LITERATURE

In order to ensure balance fertilization, the fertilizer should be applied on the basis of soil test values. There is a need for balancing the nutrients that is supplied from the fertilizers and those already available from the soil in order to have an efficient and economic use of fertilizers.

2.1 FERTILIZER RECOMMENDATIONS BASED ON SOIL TEST APPROACHES

Many successful attempts have been made by scientists for making the soil test as a predictive tool for fertilizer recommendation. Literature on various approaches for soil test based fertilizer recommendation for crops and nutritional requirement of the test crop groundnut based on the fertilizer experiments are targeted yield approach (Troug, 1960), critical level approach (Cate and Nelson, 1965), inductive approach (Ramamoorthy ,1968) reviewed in this chapter. There are many different approaches and some of them are general / blanket recommendation, nutrient index approach (Parker *et al.* 1952), deductive approaches (Colwell, 1968), regression analysis approach (Hanway, 1971), DRIS (Beaufils, 1973), ten-class system (Nambiar *et al.*, 1977). The maximum yield concept has also gained importance recently. According to this concept an economically viable maximum yield research system comprises of improved varieties, increased plant population, balanced use of N, P and K fertilizers, improved fertilizer placement, use of secondary and micronutrients etc. (Portch, 1988). Recent works in maximum yield research was reported from Kerala by Meerabai *et al.* (2001) in coconut and Susan (2003) in cassava. In the present study importance is given to regression and targeted yield approaches.

2.1.1 Fertilizer Recommendation Based on Regression Analysis Approach

Nutrients occur in the soil in various amounts, either naturally or added through fertilizers. So there will be interactions among the nutrients, available in the soil and those added through fertilizers. Regression analysis is used to establish the functional relationship between soil test values, fertilizer use and yield of crops. The functional relationship between soil test values, fertilizer use and yield of crops. The relationship can be established by fitting a regression equation of quadratic form, which is expressed as

$$Y = A \pm b_1SN \pm b_2 SN^2 \pm b_3SP \pm b_4SP^2 \pm b_5SK \pm b_6SK^2 \pm b_7FN \pm b_8FN^2 \pm b_9FP \pm b_{10}FP^2 \pm b_{11}FK \pm b_{12}FK^2 \pm b_{13}FNSN \pm b_{14}FPSP \pm b_{15}FKSK$$

where

Y= Crop yield (kg ha^{-1})

A= Intercept

b_1 to b_{15} = Regression coefficients

SN, SP, SK = Soil available N, P and K nutrients (kg ha^{-1})

FN, FP, FK = Fertilizer N, P and K nutrients (kg ha^{-1})

From the regression equation, the dose of fertilizer for maximum and economic response can be computed from partial regression technique.

$$F\,(\text{maxm}) = \frac{b - d.\,S}{-2c}$$

$$F\,(\text{economic}) = \frac{b - d.\,S - R}{-2c}$$

where

b and c = linear and quadratic regression coefficients
S = soil test value
R = ratio of cost of 1 kg nutrient to 1 kg produce
d = interaction terms of nutrients

The suitability of soil test method for the prediction of yield response is indicated by the significant value of coefficient of determination (R^2) with high order of predictability. If the predictability is more than 66 per cent, the soil test values are calibrated to obtain fertilizer doses for economic and maximum yield per hectare and maximum profit per rupee spent on fertilizer.

Hanway (1971) recommended multiple regression for relating the field crop responses with laboratory results for the system which contains several uncontrollable variables. Ramamoorthy and Velayutham (1971) recommended multiple regression analysis for STCR work in India.

Multiple regression analysis accurately evaluates the effect of soil and fertilizer nutrients on both plant uptake of nutrients and the yield (Reddy *et al.*, 1985). This analysis enables the study of a number of factors simultaneously in contrast to Mitscherlich-Bray approach where only one nutrient is studied at a time (Ahmed, 1985). According to Sankar (1992), the multiple regression models are more efficient and useful for studying fertilizer response under varying levels of soil fertility for different crops in different soils.

In STCR correlation studies organic or biofertilizer treatments were also included under integrated plant nutrition system (Raniperumal *et al.*, 1984; Murugappan, 1985; Sumam, 1988; Swadija *et al.*, 1993; TNAU, 1994; Maragatham, 1995; Santhi, 1995; KAU, 1996 and Andi, 1998).

Fertilizer adjustment equations for varying soil test values for maximum yield and profit per hectare have been calibrated using multiple regression model for different variety of crops like rice (Raniperumal *et al.*, 1987), maize (Sumam, 1988), ragi (Raniperumal *et al.*, 1988 and Mercykutty, 1989) and groundnut (Raniperumal *et al.*, 1986) and TNAU (1994) at Tamil Nadu in different soil types.

Sankar *et al.* (1987) have computed the optimization of fertilizer N, P and K nutrients and prediction of yield at varying soil test values based on regression models. The soil test based fertilizer adjustment equation were calibrated only for N and P nutrients of rabi sorghum in black soils of Maharashtra (Sankar *et al.*, 1988). Reddy and Ahmed (2000) have calibrated the multiple regression equation for predicting maize yield through soil and fertilizer nutrients and their interactions. The results of the experiment showed that the fertilizer doses required for attaining a specific yield target of maize decreases with increase in soil test values and the requirement of potassic fertilizer become zero when the soil available K is at 400 and 500 kg ha^{-1} for production of 40 and 50 q ha^{-1} of maize yield.

2.1.2 Targeted Yield Approach

Fertilizer adjustments or prescription equations for targeted yield concept based on soil testing were developed for some crops of the areas with the methodology adopted by Troug (1960) and later on extended to different crops in different soils (Randhawa and Velayutham, 1982).

Targeted yield concept strikes a balance between fertilizing the crop and fertilizing the soil. The procedure provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. In the targeted yield approach, it is assumed that there is a linear relationship between grain yield and nutrient uptake for the crop.

This approach forms the basis for the national programme on STCR correlation studies under the co-ordinated scheme of ICAR. Ramamoorthy *et al.* (1967) showed that Liebig's law of minimum operates equally well for N, P and K for wheat (Sonora-64). In this approach fertilizer dose is calculated by considering the amount of nutrients removed per unit quantity of economic produce, initial fertility status of soil, efficiency of nutrients supplied and present in the soil and added through fertilizers and possible nutrient interactions. Reddy *et al.* (1987) reported that the fertilizer use efficiency was atleast 30 per cent more in targeted yield approach, based on soil test than the general recommendation as revealed by the response ratio.

The uptake of nutrients from the soil and fertilizer together should be in a ratio, which is actually needed by the specific variety of the crop. This is possible only by fertilizer application based on targeted yield model and not by any other method of fertilizer prescription (Ramamoorthy, 1993). Experiments based on this concept are being conducted in seventeen centres in the country and fertilizer adjustment equations have been developed mostly for field crops (Rao and Srivastava, 2001).

In this context, in STCR investigation judicious use of fertilizer is practiced along with the objective of targeted yield (Singh and Sharma, 1978). This approach brought up a new dimension to the value and utility of soil testing (Velayutham, 1979).

Based on targeted yield approach several studies have been conducted in TNAU, Coimbatore and useful prescription equations for achieving desired yield targets of different varieties of different crops like rice, maize, sorghum, ragi, groundnut, black gram, soybean, sugarcane, cotton, tapioca, sunflower and chilli have been formulated in different soil series (Raniperumal *et al.*, 1982, 1984, 1986, 1987 and 1988; TNAU, 1994; Baskaran *et al.*, 1994 and Loganathan *et al.*, 1995).

The AICRP on STCR conducted large number of experiments all over the country in different agro climatic regions. It revealed that the yield targets could be achieved within ± 10 per cent deviation, if the targets chosen are not unduly high. Under this scheme various scientists worked out the prescription equations for different crops varieties like rice (Ramamoorthy *et al.*, 1970, Chand *et al.*, 1984 and Raniperumal *et al.*, 1987); wheat (Sekhon *et al.*, 1976; Singh and Sharma, 1978 and Dev *et al.*, 1985); green gram (Chand *et al.*, 1986); ragi (Raniperumal *et al.*, 1986; Duraisamy *et al.*, 1989) green and groundnut (Loganathan *et al.*, 1995).

The targeted yield equations have been reported by Dhillon *et al.* (1978) and Dev *et al.* (1985) for wheat in Ludhiana and Gurdaspur, Singh and Sharma (1978) for different crops in Delhi, Dev *et al.* (1978) in rice in tropical acid brown soils, Raniperumal *et al.* (1986); Reddy and Ahmed (1999) in groundnut, Santhi *et al.* (1999) in rice-rice-pulse sequence, Tamboli and Sonar (1999) for wheat and chickpea, Maragatham (1995) for sunflower, Sharma *et al.* (1990), Suri and Verma (1999) and Verma *et al.* (2002) for maize and wheat, Ahmed *et al.* (2000) for castor. In

Maharashtra, the targeted yield approach is exclusively used by the State Department of Agriculture for giving fertilizer recommendation for field crops (Velayutham and Reddy, 1990). In Andhra Pradesh, Meena *et al.* (2001) developed fertilizer prescription equation for onion.

The targeted yield equations have been reported by Reddy *et al.* (1991) for groundnut in Bhavanisagar, Hyderabad (red soil), Rahuri (black soil) and Dholi (Alluvial soil). In Adhra pradesh, the targeted yield equation for maize was developed by Reddy and Ahmed (2000). Ray *et al.* (2000) developed the fertilizer prescription equation based on targeted yield for jute, rice and wheat in West Bengal. The targeted yield approach with integrated plant nutrient system (IPNS) is also effectively used for appropriate fertilizer recommendation with organics. Based on the level of application of organic manure, the dose of chemical fertilizers get adjusted through soil test calibration (Raniperumal *et al.*, 1984).

This model is useful for computing fertilizer doses for varying soil test values for obtaining different yield targets. The derived doses are then tested under farmer's field conditions for their reproducibility before they are generalized for large scale adoption (Sankar *et al.*, 1989). In Kerala, Swadija (1997), Jayalakshmi (2001) and Nagarajan (2003) computed the targeted yield equations under IPNS for cassava, ginger and coleus respectively. They have taken FYM as organic source.

By using targeted yield equation under IPNS the fertilizer doses were worked out for different crops like turmeric and rice (Kharif and rabi) during 2001 and for Nendran banana during 2000-2001 in laterite soils of Kerala (KAU, 2003). According to Prasad and Prasad (1993) the conjoint application of fertilizers and organic manures lead to efficient nutrient use of fertilizer and considerable saving in fertilizers. Tandon (1994) rightly pointed out that this approach also indicated the magnitude of contribution by the organic/ biological sources of plant nutrients complementing fertilizers in meeting nutrient requirement of crops.

Prescription equations involving the conjoint use of organics and inorganics have been reported by Raniperumal *et al.* (1988) and Duraiswamy *et al.* (1989) in ragi with FYM, Mercykutty (1989) in ragi with Azospirillum, Baskaran *et al.* (1994) in cassava with composted coir pith, Santhi (1995) in rice with FYM and phosphobacteria, Jha *et al.* (1997) in maize with FYM, Santhi *et al.* (2002) in onion with FYM and *Azospirillum*, Verma *et al.* (2002) in maize and wheat with FYM.

In Hisar, Singh *et al.* (2000) formulated the targeted yield equations for barley, cotton and wheat. Soil test based targeted yield equation has been developed for Bhindi, Potato and Sugarcane in Karnataka (GKVK, 2002). The targeted yield equations developed for a particular variety of crop for particular soil type can be suitably extrapolated to other variety of the same crop and the similar soils (Velayutham, 1979).

The prescription equation developed for the ragi variety Co-11 fitted well for the variety Co-12 also (Duraisamy *et al.*, 1989). Raniperumal *et al.* (1986) have found that the fertilizer prescription equations developed for the groundnut variety POL-2 holds good for the variety TMV-7. Similarly the fertilizer adjustment equation with organics developed for the rice variety Bhavani were found suitable for other varieties like Ponni, IR-20, IR-50, CO-43 and Paiyur-1 in the same soil type (Raniperumal *et al.*, 1987).

Fertilizer application based on targeted yield approach provides the assurance for the maintenance of soil fertility (Velayutham and Raniperumal, 1976). In the test verification trials with rice in vertisols, the post harvest soil analysis revealed slight reduction in $KMnO_4$-N status only, without much depletion in other nutrients (Raniperumal *et al.*, 1984). With groundnut, the post harvest soil analysis indicated a slight increase in available N and P status while the K status followed a reverse trend, when fertilizers are applied based on targeted yield approach (Raniperumal *et al.*, 1986). The test verification trials with rice on alluvium indicated that the fertility status was not altered considerably by following the prescription concept of fertilizer application (Raniperumal *et al.*, 1987).

The superiority of fertilizer recommendation based on targeted yield approach over the general/blanket dose have been indicated by several scientists. Fertilizer application based on targeted yield approach would be most economical (Ramamoorthy and Pathak, 1969). Velayutham (1979) had formulated equations which satisfy the twin objectives of high profit from fertilizer nutrients and maintenance of soil fertility. Balasundaram (1978) obtained reliable relationship with respect to phosphorus based on post harvest soil test values. Here the quantity of nutrients left after the harvest of crop could be obtained by statistical evaluation of the dependability of post harvest soil test values. Similar works with post harvest soil test values were reported by Dhawan *et al.* (1989), Maragatham and Chellamuthu (2001) and Rao and Srivastava (2002).

2.2 NUTRITIONAL REQUIREMENTS OF GROUNDNUT

2.2.1 Response to Groundnut to Nitrogen Application

Nitrogen is the major structural constituent of the plant cell and plays an important role in plant metabolism (Mahapatra *et al.*, 1985). Groundnut is a leguminous crop, which fixes atomopheric nitrogen in the root modules and reduces the demand for applied nitrogen. Groundnut may respond to N fertilizer additions though it fixes around 200-260 kg N ha^{-1} (York and Colwell, 1951 and Williams, 1979).

Nitrogen had significant influence on the number of pods per plant and number of filled pods per plant (Jadhar and Narkhende, 1980), which was because of production of more number of flowers and pegs at higher doses of nitrogen (Saradhi *et al.*, 1990). The increase in number of pods with 40-60 kg N ha^{-1} was reported by Reddy *et al.* (1984), Yakadri *et al.* (1992) and Patra *et al.* (1995). However

Chawle *et al.* (1993) reported that application of N did not influence the number of mature pods in silty clay loam soils.

Application of moderate level of N (10-30 kg N ha^{-1}) produced higher pod yield in groundnut and after that there was a decrease in pod yield (Mahakulkar *et al.*, 1992; Patel *et al.*, 1994; Kakati and Sarmah, 1995; Pant and Katiyar, 1996; Malligawad *et al.*, 2000). But increasing yield was obtained with 40 kg N ha^{-1} also (Barik *et al.*, 1994 and Bhatol *et al.*, 1994).

2.2.2 Response of groundnut to P application

Groundnut though being a legume is considered as a heavy feeder of nutrients and often gives response to applied nutrients especially P (Rajendran and Lourduraj, 1988 and Prasad *et al.*, 1996). P is also important for root formation, root growth and N fixation (Lakshmamma and Raj, 1997). The improvement in yield attributes with addition of P seems to be on account of its pivotal role in formation of roots, their proliferation and improvement in their functional activities (Samtana *et al.*, 1994). The magnitude of response to applied P depends on initial available soil P (Budhar *et al.*, 1988). Agasimani and Hosmani (1989) reported that the response of P could be obtained when the available P status in soil was less than 35 kg P_2O_5 ha^{-1}.

Application of 40-60 kg P_2O_5 ha^{-1} produced higher number of pods (Shinde *et al.*, 1981; Sagare *et al.*, 1986; Vishnumurthy and Rao, 1986; Thanzuala and Dahiphale, 1988; and Patel and Thakur, 1997a). However, application of P above 60 kg P_2O_5 ha^{-1} did or did not decrease the number of pods depending on the soil fertility status (Rao *et al.*, 1984 and Singh *et al.*, 1994). Application of moderate to high level of P fertilizers resulted in an increase in shelling percentage (Rao *et al.*, 1984; Chauhan *et al.*, 1987; Gnanamurthy and Balasubramanian, 1992)

2.2.3 Response of groundnut to K application

It is well recognized that groundnut is a heavy feeder of K and adequate supply of this nutrient is indispensable to obtain a better yield (Geethalakshmi *et al.*, 1993). But groundnut makes satisfactory growth even in K deficient soils where other crops would fail (York and Colwell, 1951).

Potassium nutrition had favourable impact on the photosynthesis and translocation of leaf reserves to developing pods (Koch and Mengal, 1977). The general trends of K fertilization showed that 40-60 kg K_2O ha^{-1} was optimum for groundnut beyond which deleterious effect was noticed (Putankar and Poathkel, 1967 and Yakadri *et al.*, 1992).

Potassium application increased all the yield contributing characters and pod yield of groundnut with an increase in K level (Loganathan and Krishnamoorthy, 1980 and Singh *et al.*, 1994) whereas absence of response to K fertilization in yield attributes and yield was also reported (Chowdary *et al.*, 1977). Increased pod yield per plant was observed with K fertilization (Eweida *et al.*, 1981 and Singh *et al.*, 1994).

Soil dressing of 80 kg K_2O ha^{-1} increased the number of pods per plants (Gopalswamy *et al.*, 1978; Nair *et al.*, 1981). Similarly, at 40 and 60 kg K_2O ha^{-1} levels, number of pods per plant and test weight of seeds increased (Ramanathan *et al.*, 1982 and Dubey *et al.*, 1986) and the maximum was attained with 50 kg K_2O ha^{-1}. The response was quadratic and also influenced the K content in seeds (Jana *et al.*, 1990).

2.2.4 Response of groundnut to combined application of N, P and K

The importance of balanced fertilizer schedule and its influence on groundnut were reported (Venkateswaralu and Nath, 1989). Subbarao (1994) reported that the response for NPK together varied from 3.0 to 9.2 kg pods ha^{-1}.

Combined application of NPK (20:40:40 N: P_2O_5: K_2O kg ha^{-1}) produced highest yield (Pradhan and Das, 1989). Yadav (1990) found that the application of N, P_2O_5 and K_2O @ 20:60:40 resulted highest yield.

Application of 50 kg N, 30 kg P_2O_5 and 30 kg K_2O resulted good yield (Reddy *et al.*, 1991). But Balasubramaniam and Palaniappan (1991) reported the application rate as 150 kg N, 50 kg K_2O produced high yield. But Application of N, P_2O_5 and K_2O @ 40:80: 30 kg ha^{-1} resulted highest pod yield in groundnut (Barik *et al.*, 1994).

Mehta *et al.* (1996) reported the positive response of integrated use of nutrients with organic fertilizer in increasing the pod yield of groundnut under moisture stress and nutrient deficiency conditions. Kumaran (2001) reported that the application of 34:17:54 kg ha^{-1} N, P_2O_5 and K_2O along with 12.5t FYM recorded higher pod yield.

Materials and Methods

3. MATERIALS AND METHODS

The research programme to investigate the soil test crop response relationship of groundnut in laterite soils of Kerala was undertaken at the College of Horticulture, Vellanikkara during 2003-2004. For this study the technique of inductive methodology developed by Ramamoorthy *et al.* (1967), followed in All India Co-ordinated Research Project (AICRP) for investigations on Soil Test Crop Response (STCR) correlation (Reddy *et al.*, 1985) was adopted.

The field experiments consisted of a fertility gradient experiment (FGE) using exhaustive crop of maize and a STCR experiment with groundnut crop using fertilizers and farm yard manure. The details of the experiments conducted, methods of analysis of soil and plant samples and the statistical methods followed are presented in this chapter.

3.1 DETAILS OF THE EXPERIMENTAL SITE

3.1.1 Location

The fertility gradient experiment and STCR experiments were conducted in the farm attached to the College of Horticulture, Vellanikkara during July 2003 February 2004.

The field was located at 10°31'N latitude and 76°13'N longitude at an altitude of 25 m above mean sea level. The area was occupied by coleus crop in the previous year.

3.1.2 Climate

The experimental area has a typical humid tropical climate with mean annual rainfall of 2222.80 mm and the mean maximum and minimum temperatures of 35.2°C and 21.9°C respectively. The relative humidity ranged from 50 per cent to 84 per cent. The evaporation rate ranged from 99.50 mm to 229.10 mm. During the cropping period a mean rainfall of 3454.60 mm (July-September) and 18.20 mm (November-February) were received for the stand of gradient crop and the test crop respectively. The mean maximum and minimum temperature for gradient crop were 30.16°C and 22.76°C, while that of test crop were 33.08°C and 22.65°C. The mean evaporation prevailed during the two cropping seasons were 117.50 mm and 196.83 mm respectively. The mean relative humidity during the growth period was 82.00 per cent and 58.75 per cent respectively for the gradient and test crop.

3.1.3 Soil type

The basic physico-chemical properties of the soil are given in Table 1. The soil type of the experimental site was laterite, which comes under the order Ultisol. The soil was sandy loam in texture. It was acidic with a pH of 5.10 having high phosphorus fixing capacity (81%) and low potassium fixing capacity (7%).

Table 1. Physico-chemical properties of soil of the experimental area

Sl.No.	Property	Value
1	Mechanical composition a) Sand (%) b) Silt (%) c) Clay (%)	 46.40 21.20 32.40
2	Texture	Sandy clay loam
3	pH	5.10
4	EC (dS m^{-1})	0.12
5	CEC [Cmol (p^{+}) kg^{-1}]	4.38
6	P fixing capacity (%)	81.00
7	K fixing capacity (%)	7.00
8	Organic carbon (%)	1.08
9	Available nitrogen (kg ha^{-1})	339.40
10	Available phosphorus (kg ha^{-1})	20.30
11	Available potassium (kg ha^{-1})	313.60

3.2 FIELD EXPERIMENTS

3.2.1 Fertility Gradient Experiment

Fertility gradient experiment was conducted to create variation in soil fertility in one and the same field, so as to obtain values for each controllable variable (fertilizer dose) at different levels of uncontrollable variable (soil fertility). It is necessary to create such variations in soil fertility to ensure better correlations between soil test values and response to fertilizers.

3.2.2 Layout of the Experiment

The selected field was divided into four equal strips (Fig.1). Four soil samples were collected from each strip both from 0-15 cm and 0-30 cm depths. These soil samples were used to study the status of major available nutrients of the experimental area before the conduct of fertility gradient experiment.

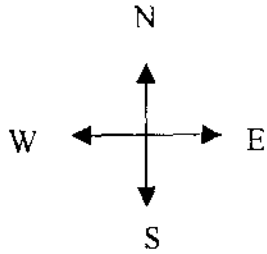
3.2.3 Treatments

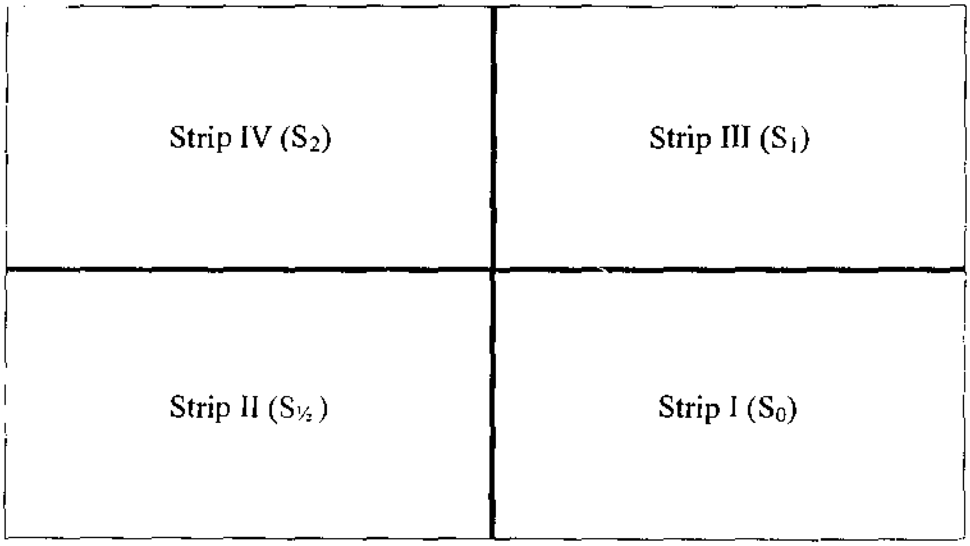
Graded doses of N as urea (46% N), P as Rajphos (18% P_2O_5) and K as muriate of potash (60% K_2O) were applied in the strips. This formed the treatments for FGE. The doses of NPK were fixed as mentioned in the instruction manual for STCR studies (Reddy *et al.*, 1985). The treatment structure was given below (Table 2).

Table 2. Treatment structure for FGE

Strip	Treatment	Fertilizer dose (kg ha^{-1})		
		N	P_2O_5	K_2O
I	$N_0P_0K_0$	0	0	0
II	$N_{½}P_{½}K_{½}$	75	50	90
III	$N_1P_1K_1$	150	100	180
IV	$N_2P_2K_2$	300	200	360

Fig. 1.Fertility gradient experiment (Field layout)





Strip I - $N_0P_0K_0$ No fertilizer

Strip II - $N_{1/2}P_{1/2}K_{1/2}$ Half the standard dose

Strip III - $N_1P_1K_1$ Standard dose

Strip IV - $N_2P_2K_2$ Double the standard dose

3.2.4 Gradient Crop

A gradient crop of maize (*Zea mays*) variety Co-1 was raised following the usual agronomic practices (KAU, 2003) except the treatments. The seeds were broadcasted on 31-7-03 and crop was harvested on 6-9-03.

3.2.5 Observations Recorded

3.2.5.1 Green Fodder Yield

At harvest strip wise fodder yield was recorded and expressed in t ha^{-1}.

3.2.5.2 Dry Fodder Yield

Plant samples (500 g wt.) were collected from each strip prior to the harvest of whole plots. After recording the fresh weight, the plant samples were dried in an oven at 70°C to constant dry weight. The dry fodder yield was computed strip wise from these observations and the green fodder yield.

3.2.6 Uptake of Nutrients

The composite plant samples (one from each strip) were analysed for the content of the major nutrients viz., N, P and K. The analytical methods adopted are represented in Table 3. The uptake of nutrients was calculated using plant dry weight and the nutrient content. Uptake of nutrients is expressed in kg ha^{-1}.

3.2.7 Soil Analysis

Soil samples were collected from two different depths (0 -15 cm and 0 -30 cm) prior to the application of fertilizers and after harvest. The methods of soil analysis adopted are given in Table 3.

Composite soil samples were also collected from whole field and analysed for mechanical composition, pH, electrical conductivity, CEC, organic carbon, available nitrogen, available phosphorus, available potassium, phosphorus fixing capacity and potassium fixing capacity.

Table 3. Methods of soil and plant analysis

Parameter	Method	Reference
Soil analysis		
Mechanical composition	International pipette method	Piper (1966)
pH	1: 2.5 soil water suspension	Jackson (1958)
Electrical conductivity	Conductometry	Jackson (1958)
Cation exchange capacity	Neutral normal ammonium acetate	Scholenberger & Dreibelbis (1930)
P fixing capacity	Equilibrium with potassium dihydrogen orthophosphate	Waugh & Fitts (1966)
K fixing capacity	Equilibrium with potassium chloride	Waugh & Fitts, (1966)
Organic carbon	Wet oxidation method	Walkley & Black (1934)
Available nitrogen	Alkaline permanganate distillation	Subbiah & Asija (1956)
Available phosphorus	Bray No.1extractant ascorbic reductant - spectrophotometry	Bray and Kurtz (1945)
Available Potassium	Neutral normal ammonium acetate method	Jackson (1958)
Plant Analysis		
Total nitrogen	Microkjeldahl digestion and distillation	Jackson (1958)
Total phosphorus	Vanado-molybdophosphoric yellow colour - spectrophotometry	Jackson (1958)
Total potassium	Flame photometer	Jackson (1958)

3.2.8 Statistical Analysis

The data obtained for the gradient crop experiment viz., fodder yield, nutrient uptake, plant and soil analysis after harvest were subjected to statistical analysis adopting the techniques of analysis of variance (ANOVA) for Randomised Block Design (RBD) as described by Snedecor and Cochran (1968). Critical difference is provided whenever F test is significant.

3.3 STCR EXPERIMENT

The principal methodology adopted in STCR experiment is to establish quantitative relationships between soil test values, applied nutrients and the resultant crop yield. Hence the experiments were conducted with measured levels of fertilizer nutrients viz., N, P_2O_5 and K_2O with the test crop. This investigation was super imposed on the four fertility gradients created as mentioned in the instructional manual for STCR experiment (Reddy *et al.*, 1985).

3.3.1 Test Crop

The test crop for the STCR experiment was groundnut and the variety used was TAG - 24.

3.3.2 Treatments

Treatment structure comprised of factorial combinations of four levels of N, three levels of P_2O_5 and five levels of K_2O along with three levels of FYM (Table 4). The treatment structure and doses of nutrients applied are given in Table 5.

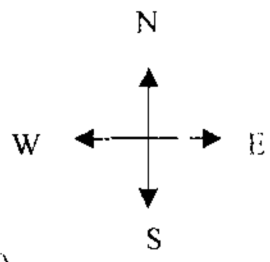
Table 4. Treatment levels of STCR experiment

Levels	Fertilizer dose (kg ha^{-1})			
	N	P_2O_5	K_2O	FYM (t ha^{-1})
1	0	0	0	0
2	5	40	37.5	2
3	10	80	75	4
4	20	-	150	-
5	-	-	300	-

Table 5. Treatment structure of STCR experiment

Treatments	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})
	N	P_2O_5	K_2O	
T_1	0	0	0	0
T_2	0	0	0	0
T_3	0	0	0	2
T_4	0	0	0	4
T_5	0	0	37.5	2
T_6	5	0	37.5	2
T_7	5	40	37.5	2
T_8	0	0	75.0	2
T_9	0	40	75.0	2
T_{10}	5	0	75.0	0
T_{11}	5	40	75.0	0
T_{12}	10	0	75.0	0
T_{13}	10	40	75.0	0
T_{14}	10	80	75.0	0
T_{15}	0	0	150.0	4
T_{16}	5	40	150.0	4
T_{17}	10	80	150.0	0
T_{18}	20	0	150.0	0
T_{19}	20	40	150.0	4
T_{20}	20	80	150.0	0
T_{21}	10	40	300.0	0
T_{22}	10	80	300.0	0
T_{23}	20	40	300.0	4
T_{24}	20	80	300.0	4

Fig. 2. STCR experiment (Field layout)



Strip IV (S2) Strip III (S1)

T_3	T_{10}	T_{17}	T_{19}	T_6	T_{22}	T_3	T_{10}	T_{17}	T_{19}	T_6	T_{22}
T_9	T_{18}	T_{23}	T_{15}	T_{16}	T_5	T_9	T_{18}	T_{23}	T_{15}	T_{16}	T_5
T_{20}	T_2	T_{21}	T_8	T_{11}	T_1	T_{20}	T_2	T_{21}	T_8	T_{11}	T_1
T_{24}	T_{14}	T_4	T_7	T_{12}	T_{13}	T_{24}	T_{14}	T_4	T_7	T_{12}	T_{13}
T_3	T_{10}	T_{17}	T_{19}	T_6	T_{22}	T_3	T_{10}	T_{17}	T_{19}	T_6	T_{22}
T_9	T_{18}	T_{23}	T_{15}	T_{16}	T_5	T_9	T_{18}	T_{23}	T_{15}	T_{16}	T_5
T_{20}	T_2	T_{21}	T_8	T_{11}	T_1	T_{20}	T_2	T_{21}	T_8	T_{11}	T_1
T_{24}	T_{14}	T_4	T_7	T_{12}	T_{13}	T_{24}	T_{14}	T_4	T_7	T_{12}	T_{13}

Strip II (S1/2) Strip I (S0)

3.3.3 Design and Layout of the Experiment

Each strip was divided into 24 plots of 2 x 1.5 m size (Fig. 2). The twenty four plots in each strip are alloted the 22 treatment combinations along with the two control treatments. The FYM levels were super imposed on the 4 strips. The layout of the experiment was presented in Fig.2.

Design	: Response surface
Treatments	: 24
No. of strips	: 4
No. of plots/strip	: 24
Total no. of plots	: 96
Plot size	: 2 x 1.5 m
Spacing	: 15 x 15 cm
System of planting	: Raised bed system

3.3.4 Manures and Fertilizers

Farmyard manure was applied in the raised beds as per treatments. Fertilizers were applied as basal doses. Lime was applied at 50 per cent flowering stage. The nutrient content of organic manure and fertilizers used are presented in Table 6.

Table 6. Nutrient contents of organic manure and fertilizers

Fertilizers / Organic manure	Nutrient content (%)
Urea	46% N
Rajphos	18% P_2O_5
Muriate of potash	60% K_2O
FYM	0.80% N, 0.40% P and 0.60% K

3.3.5 Management Practices

Management practices like racking, irrigation etc.were carried out as per Package of Practice recommendation for the different treatments. After the application of lime it was incorporated to the soil by gentle racking. Later earthing up of bed was done for proper proliferation and development of pods. In addition, soil drenching and spraying of plant protection chemicals were done whenever needed. The plots were soaked thoroughly by irrigation one day prior to harvest for easy lifting.

3.3.6 Observations Recorded

3.3.6.1 Pod and Haulm Yield

The plants were carefully pulled out from the plots and separated into pods and haulm. The fresh weights were recorded and expressed in kg ha^{-1}. The pods were air dried for 3-4 days and later separated into kernel and shells. The corresponding weights were also recorded. These samples were stored for further analysis.

3.3.6.2 Uptake of Nutrients

The uptake was computed separately for haulm and pods (shell and kernel). From the air dried and stored samples of each plot 500 g of haulm and 250 g of pods were weighed out. The samples were dried uniformly in hot air oven at a temperature of 70°C. The samples were analysed separately for the contents of N, P and K at harvest using the methods given in Table 3. The total uptake of N, P and K was computed from the nutrient contents and dry weights of plant parts and expressed as kg ha^{-1}.

3.3.7 Soil Analysis

Soil samples were collected from two different depths (0-15 and 0-30 cm) after land preparation but before fertilizer application for the test crop. These samples were analysed for organic carbon and available nutrients viz., N, P and K adopting the analytical methods given in Table 3.

3.4 FERTILIZER PRESCRIPTION FOR SPECIFIC YIELD TARGET TARGETED YIELD MODEL

In targeted yield concept fertilizer prescription equations were developed from the data on soil test values, pod yield and the nutrient uptake by groundnut. From the equations, fertilizer recommendations are made for specific yield targets of groundnut with and without FYM.

3.4.1 Calculations of Basic Parameters

3.4.1.1 Nutrient Requirement (NR)

Nutrient requirement were calculated for each and every treatment in all the four strips in terms of N, P and K in kg per tonne of pods production by using the following formulae.

$$\text{Kg N required per tonne of pod production} = \frac{\text{Total uptake of N (kg ha}^{-1}\text{)}}{\text{Pod yield (t ha}^{-1}\text{)}}$$

$$\text{Kg P required per tonne of pod production} = \frac{\text{Total uptake of P (kg ha}^{-1}\text{)}}{\text{Pod yield (t ha}^{-1}\text{)}}$$

$$\text{Kg K required per tonne of pod production} = \frac{\text{Total uptake of K (kg ha}^{-1}\text{)}}{\text{Pod yield (t ha}^{-1}\text{)}}$$

3.4.1.2 Per cent Contribution of Nutrients from Soil (CS)

The nutrient contributions from the soil were calculated utilizing the data from absolute control plots.

$$\text{Per cent contribution of N from soil} = \frac{\text{Total uptake of N in control plot (kg ha}^{-1}\text{)}}{\text{STV for available N in control plot (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Per cent contribution of P from soil} = \frac{\text{Total uptake of P in control plot (kg ha}^{-1}\text{)}}{\text{STV for available P in control plot (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Per cent contribution of K from soil} = \frac{\text{Total uptake of Kin control plot (kg ha}^{-1}\text{)}}{\text{STV for available K in control plot (kg ha}^{-1}\text{)}} \times 100$$

3.4.1.3 Per cent Contribution of Nutrients from Fertilizer (CF)

The per cent contribution of nutrients from fertilizer was calculated utilizing the data obtained from plots treated with fertilizers only without any FYM application.

$$\text{Contribution of N from fertilizer} = \frac{\text{Total uptake of N in fertilizer treated plots (kg ha}^{-1}\text{)} - \left[\text{STV for available N in treated plots (kg ha}^{-1}\text{)} \times \frac{\text{Average CS}}{100}\right]}{\text{N applied through fertilizer (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Contribution of P from fertilizer} = \frac{\text{Total uptake of P in fertilizer treated plots (kg ha}^{-1}\text{)} - \left[\text{STV for available P in treated plots (kg ha}^{-1}\text{)} \times \frac{\text{Average CS}}{100}\right]}{\text{P applied through fertilizer (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Contribution of K from fertilizer} = \frac{\text{Total uptake of K in fertilizer treated plots (kg ha}^{-1}\text{)} - \left[\text{STV for available K in treated plots (kg ha}^{-1}\text{)} \times \frac{\text{Average CS}}{100}\right]}{\text{K applied through fertilizer (kg ha}^{-1}\text{)}} \times 100$$

3.4.1.4 Per cent Contribution of Nutrients from FYM (COM)

The data from the plots where FYM was applied without any fertilizer application were utilized to calculate the per cent contribution of nutrients from FYM by using the given formulae.

$$\text{Contribution of N from FYM (\%)} = \frac{\text{Total uptake of N in FYM treated plots} - \left(\text{STV for available N in treated plots} \times \frac{\text{Average CS}}{100}\right)}{\text{N applied through FYM (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Contribution of P from FYM (\%)} = \frac{\text{Total uptake of P in FYM treated plots} - \left(\text{STV for available P in treated plots} \times \frac{\text{Average CS}}{100}\right)}{\text{P applied through FYM (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Contribution of K from FYM (\%)} = \frac{\text{Total uptake of K in FYM treated plots} - \left(\text{STV for available K in treated plots} \times \frac{\text{Average CS}}{100}\right)}{\text{K applied through FYM (kg ha}^{-1}\text{)}} \times 100$$

After computation of data utilizing the above formulae for each plot, average were taken out to obtain NR, CS, CF, COM in terms of N, P and K.

3.4.2 Targeted Yield Equation

The basic parameters calculated were substituted into targeted yield equations for prescribing fertilizers dose for any yield target, based on soil tests as given below.

Without FYM

$$FN = \frac{NR}{CF/100} T - \frac{CS}{CF} SN$$

$$F P_2O_5 = \left(\frac{NR}{CF/100} T - \frac{CS}{CF} SP \right) x\ 2.29$$

$$F K_2O = \left(\frac{NR}{CF/100} T - \frac{CS}{CF} SK \right) x\ 1.21$$

With FYM

$$FN = \left(\frac{NR}{CF/100} T \right) - \left(\frac{CS}{CF} SN \right) - \left(\frac{COM}{CF} \right) x\ ON$$

$$F P_2O_5 = \left(\frac{NR}{CF/100} T \right) - \left(\frac{CS}{CF} SP \right) x\ 2.29 - \left(\frac{COM\ x\ OP}{CF} \right) x\ 2.29$$

$$F K_2O = \left(\frac{NR}{CF/100} T \right) - \left(\frac{CS}{CF} SK \right) x\ 1.21 - \left(\frac{COM\ x\ OK}{CF} \right) x\ 1.21$$

Where

FN = Fertilizer N in kg ha^{-1}

F P_2O_5 = Fertilizer P_2O_5 in kg ha^{-1}

F K_2O = Fertilizer K_2O in kg ha^{-1}

NR = Nutrient requirement of N or P_2O_5 or K_2O in kg t^{-1}

CS = % Nutrient contribution from soil

CF = % Nutrient contribution from fertilizer

COM = % Nutrient contribution from FYM

SN = STV for available N in kg ha^{-1}

SP = STV for available P in kg ha^{-1}

SK = STV for available K in kg ha^{-1}

ON = N applied through FYM in kg ha^{-1}

OP = P applied through FYM in kg ha^{-1}

OK = K applied through FYM in kg ha^{-1}

T = Yield target in t ha^{-1}

3.5 MULTIPLE REGRESSION ANALYSIS

This approach was suggested by Ramamoorthy *et al.* (1967) for prescribing fertilizer doses based on soil test values to attain maximum yield or maximum profit. In this approach a significant relationship is established between soil test values, fertilizer doses and crop yield by fitting a multiple regression of the quadratic form taking linear terms of soil and fertilizer nutrients. The regression equation obtained using the quadratic function can be expressed as,

$$Y = A \pm b_1SN \pm b_2 SN^2 \pm b_3SP \pm b_4SP^2 \pm b_5SK \pm b_6SK^2 \pm b_7FN \pm b_8FN^2 \pm b_9FP \pm b_{10}FP^2 \pm b_{11}FK \pm b_{12}FK^2 \pm b_{13}FNSN \pm b_{14}FPSP \pm b_{15}FKSK$$

where

Y= Crop yield (kg ha^{-1})

A= Intercept

b_1 to b_{15} = Regression coefficients

SN, SP, SK = Soil available nutrients (kg ha^{-1})

FN, FP, FK = Fertilizer nutrients (kg ha^{-1})

3.6 STATISTICAL ANALYSIS

3.6.1 Correlation

Correlation is a statistical device, which helps to analyse two or more variables. Correlation co-efficients were obtained using the analytical data, pod yield and basic soil characters.

3.6.1.1 Correlation of Nutrient Uptake with Yield

The data on analysis of nutrient uptake is correlated with the yield, without considering any treatments and strip levels.

3.6.1.2 Correlation of Nutrient Uptake and Yield with Available and Applied Nutrients

The data on analysis of available and applied nutrients of soil is correlated with the nutrient uptake and yield.

3.6.1.3 Correlation of Major Plant Nutrient Content with Yield

The data on analysis of major plant nutrient contents of all treatments as such correlated with yield to know the influence of these elements on yield.

3.6.2 Path Analysis

The path co-efficient analysis is simply a standardized partial regression co-efficient which splits the correlation co-efficient into the measure of direct and indirect effects. It measures the direct and indirect contribution of independent (soil available nutrients) on dependent variable (yield). The path co-efficient analysis is carried out using the estimates of correlation co-efficient of available soil nutrient with yield. This was done both before the conduct of STCR experiment as well as after the harvest of the test crop.

Results

4. RESULTS

Fertilizer recommendation for profitable and sustained crop production can be done based on soil testing. To obtain significant correlation between soil test values and crop response to fertilizers, the soil test calibration and fertilizer recommendation must be based on local field experiments. Hence the present study was undertaken to establish soil test based balanced fertilizer prescription for groundnut var. TAG-24 in the laterite soils of Kerala. The field experiments consisted of Fertility Gradient Experiment (FGE) and test crop experiment (STCR experiment). The results of the experiments are presented in this chapter.

4.1 FERTILITY GRADIENT EXPERIMENT

The yield of a crop is assumed to be a function of soil fertility and applied fertilizers at constant levels of other factors affecting yield. In this study, all the needed variation in soil fertility was created in one and the same field in order to ensure homogenity in soil studied, management practices adopted and climatic conditions prevailing.

The experimental area was divided into four equal strips and each strip into four blocks for developing a fertility gradient among the strips. A deliberate attempt was made to create a gradient in soil fertility from strip I to IV by applying graded doses of N, P and K (Table 2). An exhaustive crop of fodder maize variety Co-1 was raised in all the strips. The general field view of the gradient crop experiment was shown in Plate1. The soil test values before and after the experiment was computed for checking the response of the gradient crop in all the four strips to know whether sufficient fertility gradient has been created or not. The field view of gradient crop experiment in strips I, II, III and IV were shown in Plates 2, 3, 4 and 5. The data were also analysed statistically to confirm the build up of fertility gradient.

Plate 1. General view of gradient crop experiment

Plate 2. General view of gradient crop maize in Strip I ($N_0P_0K_0$)

Plate 3. General view of gradient crop maize in Strip II ($N_{1/2}P_{1/2}K_{1/2}$)

Plate 4. General view of gradient crop maize in Strip III ($N_1P_1K_1$)

Plate 5. General view of gradient crop maize in Strip IV ($N_2P_2K_2$)

4.1.1 Soil fertility status before and after FGE

The soil fertility gradient created from strip I to IV was confirmed by assessing the soil nutrient content after the harvest of fodder maize (gradient crop). The data on soil analysis before and after the fertility gradient experiment were furnished in Tables 7 and 8.

The soil nutrient status prior to the conduct of FGE (Table 7) ranged from 1.00 to 1.12 per cent of organic carbon, 384.75 to 395.38 kg ha^{-1} available N, 13.00 to 14.10 kg ha^{-1} available P and 317.30 to 321.00 kg ha^{-1} available K for 15 cm depth. The values for 30 cm depth ranged from 0.99 to 1.13 per cent of organic carbon, 385.10 to 393.10 kg ha^{-1} available N, 13.10 to 14.00 kg ha^{-1} available P and 318.00 to 321.00 kg ha^{-1} available K.

The analysis of soil samples collected after the harvest of the fodder maize revealed that the ranges were 0.99 to 1.11 per cent of organic carbon, 317.80 to 382.00 kg ha^{-1} available N, 13.24 to 27.50 kg ha^{-1} available P and 340.90 to 418.45 kg ha^{-1} available K for 15 cm depth in strips I, II, III and IV (Table 8). The values for 30 cm depth ranged from 0.97 to 1.10 per cent or organic carbon, 318.30 to 380.70 kg ha^{-1} available N, 13.37 to 27.35 kg ha^{-1} available P and 341.10 to 418.50 kg ha^{-1} available K for strips I, II, III, IV respectively (Table 8).

4.1.2 Yield and Uptake of Nutrients by Gradient Crop

The green and dry fodder yield of the gradient crop (fodder maize) as well as the nutrient uptake was computed strip wise. The results on yield and uptake of nutrients by fodder maize were furnished in Table 9. The maximum green and dry fodder yields were observed in strip IV (S_2) which were 22.92 and 4.76 t ha^{-1} respectively, whereas the minimum were recorded in strip I (S_0) with values 6.58 and 1.30 t ha^{-1} respectively.

Table 7. Soil fertility status before FGE at 0 -15 and 0 -30 cm depth

Strip	Fertilizer dose (kg ha^{-1})			15 cm depth				30 cm depth			
	N	P_2O_5	K_2O	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
I	0	0	0	1.00	384.75	13.00	317.30	0.99	385.10	13.10	318.00
II	75	50	90	1.09	389.80	13.16	320.00	1.09	388.50	13.12	320.80
III	150	100	180	1.10	390.10	13.20	318.80	1.10	389.60	13.18	319.60
IV	300	200	360	1.12	395.38	14.10	321.00	1.13	393.10	14.00	321.00
Mean				1.08	389.76	13.37	319.30	1.08	388.83	13.35	319.85

Table 8. Soil fertility status after FGE at 0 -15 and 0 -30 cm depth

Strip	Fertilizer dose (kg ha^{-1})			15 cm depth				30 cm depth			
	N	P_2O_5	K_2O	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	OC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
I	0	0	0	0.99	317.80	13.24	340.90	0.97	318.30	13.37	341.10
II	75	50	90	1.07	340.80	19.32	368.20	1.10	342.40	20.10	367.70
III	150	100	180	1.08	382.00	24.50	398.15	1.08	380.70	24.00	400.00
IV	300	200	360	1.11	376.60	27.50	418.45	1.07	377.20	27.35	418.50
Mean				1.06	354.30	21.03	381.25	1.06	354.65	21.21	381.83
CD (P < 0.05%)				0.043	2.677	0.172	0.795	0.034	2.178	0.255	1.035

Table 9. Effect of graded doses of N, P and K on fodder yield and nutrient uptake

Strip	Fertilizer dose (kg ha^{-1})			Fodder yield (t ha^{-1})		Nutrient uptake (kg ha^{-1})		
	N	P_2O_5	K_2O	Green	Dry	N	P	K
I	0	0	0	6.58	1.30	33.80	5.88	38.35
II	75	50	90	13.35	2.69	61.87	10.22	123.74
III	150	100	180	18.82	3.86	84.92	16.06	200.33
IV	300	200	360	22.92	4.76	95.20	21.23	264.66
CD (P<0.05%)				3.25	0.68	14.90	2.02	18.80

The nutrient uptake is calculated from the nutrient content of maize and dry fodder yield. The highest nutrient uptake of N, P and K were obtained for strip IV (S_2), with values 95.20, 21.23 and 264.66 kg ha^{-1} respectively (Table 9). The statistical analysis of the data showed that the strips differed significantly in fodder yield and nutrient uptake by gradient crop which lend support to the creation of fertility gradient.

4.2 STCR EXPERIMENT

After the creation of fertility gradient the STCR experiment was conducted in the same field by raising the test crop, groundnut var. TAG-24. Each strip was divided into 24 plots of equal size (2 x 1.5 m). The general field view of STCR experiment was shown in Plate 6 and that of strips I, II, III and IV were shown in Plates 7,8,9 and10. The real relationship between soil fertility, applied nutrients and the resultant crop yield was evaluated in the same soil type under uniform environmental conditions and management practices.

Use of judicious combinations of organic and inorganic sources of nutrients are important for effecting economy in fertilizer use and enhancing nutrient use efficiency. Hence in the present STCR experiment three levels of FYM was also maintained as a treatment along with inorganic fertilizer treatments (Table 4). The organic manure was applied across the strips in four blocks (Reddy *et al.*, 1985).

Plate 6. General field view of STCR experiment

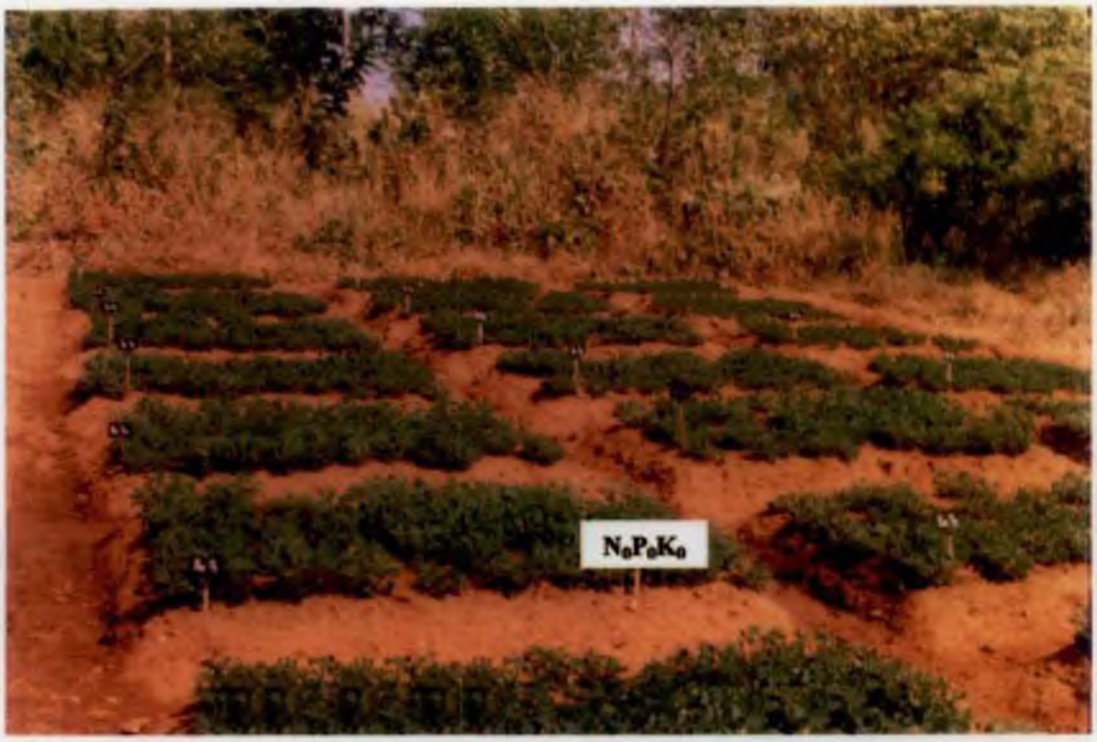


Plate 7. General view of test crop groundnut in Strip I ($N_0P_0K_0$)

Plate 8. General view of test crop groundnut in Strip II ($N_{1/2}P_{1/2}K_{1/2}$)

Plate 9. General view of test crop groundnut in Strip III ($N_1P_1K_1$)

Plate 10. General view of test crop groundnut in Strip IV ($N_2P_2K_2$)

The treatment structure was in such a way that each strip as well as each FYM blocks received all the treatment combinations. The gradient in soil fertility was from strip I to IV. Each strip contained two control plots, those plots which received no FYM or fertilizer for groundnut. The treated plots refer to those plots (22 per strip) which received either FYM or fertilizers alone or a combination of both treatments.

4.2.1 Pre planting Soil Analysis

Analysis of soil samples collected prior to the application of fertilizers was done for estimating the contribution of nutrients from the soil. The soil samples were analysed for pH, EC, organic carbon, available N, P and K and the data were given in Tables 10, 11, 12, 13, 14 and 15. The mean values of soil nutrient content before STCR the experiment were given in Table 16.

The pH varied from 4.80 to 5.30, 4.90 to 5.30, 5.00 to 5.30 and 4.90 to 5.20 in strips I, II, III and IV respectively. EC recorded range of values from 0.11 to 0.16, 0.10 to 0.14, 0.10 to 0.13 and 0.10 to 0.14 dS m^{-1} for strips I, II, III and IV. Organic carbon content in the soil varied from 0.8 to 1.10, 0.97 to 1.19, 0.84 to 1.22 and 0.85 to 1.23 per cent in strips II III IV and I respectively (Table 12). Available N status ranged from 264.40 to 398.93, 272.20 to 400.20, 291.06 to 453.34 and 288.23 to 448.80 kg ha^{-1} in strips I, II, III and IV respectively (Table 13). The soil available P registered a range in values from 10.65 to 18.92, 11.02 to 30.71, 19.29 to 29.21 and 20.94 to 36 kg ha^{-1} in strips I, II, III and IV (Table 14). Available K ranged from 246.40 to 448.00, 246.40 to 470.40, 358.50 to 483.71 and 313.60 to 470.40 kg ha^{-1} in strips I, II, III and IV respectively (Table 15).

Considering the STVs of all plots, the soil fertility status ranged from 0.8 to 1.23 per cent of organic carbon, 264.40 to 453.34 kg ha^{-1} available N, 10.65 to 36.00 kg ha^{-1}available P and 246.40 to 483.71 kg ha^{-1}available K respectively (Tables 12, 13, 14 and 15). From the data it is obvious that necessary gradient in soil fertility was created in the field for conducting the STCR experiment.

Table 10. pH of soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	5.10	5.00	5.10	4.90
T_2	5.00	4.90	5.00	5.00
T_3	4.90	5.30	5.10	5.20
T_4	5.10	5.00	5.00	5.10
T_5	5.20	5.10	5.20	5.00
T_6	5.00	5.20	5.00	5.10
T_7	4.80	5.00	5.10	5.10
T_8	4.90	4.90	5.30	5.20
T_9	5.10	4.90	5.00	5.00
T_{10}	5.00	5.00	5.20	5.10
T_{11}	5.20	4.90	5.20	5.20
T_{12}	5.00	5.10	5.00	5.00
T_{13}	5.10	5.00	5.00	4.90
T_{14}	4.90	5.20	5.10	5.10
T_{15}	5.00	4.90	5.20	4.90
T_{16}	5.30	5.20	5.10	5.00
T_{17}	5.00	5.00	5.30	5.10
T_{18}	5.10	5.10	5.00	5.00
T_{19}	5.20	5.10	5.20	5.10
T_{20}	5.30	5.20	5.10	5.10
T_{21}	5.00	5.10	5.00	5.20
T_{22}	5.20	5.00	5.20	5.00
T_{23}	5.00	5.20	5.10	5.00
T_{24}	5.10	5.00	5.00	5.20
Mean	5.06	5.05	5.10	5.06

Table 11. EC (dS m^{-1}) of soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	0.12	0.10	0.12	0.12
T_2	0.11	0.11	0.11	0.10
T_3	0.13	0.11	0.10	0.11
T_4	0.12	0.12	0.10	0.12
T_5	0.13	0.10	0.12	0.13
T_6	0.11	0.13	0.13	0.10
T_7	0.12	0.12	0.10	0.11
T_8	0.14	0.11	0.11	0.12
T_9	0.16	0.14	0.10	0.12
T_{10}	0.15	0.10	0.12	0.13
T_{11}	0.14	0.10	0.12	0.13
T_{12}	0.13	0.12	0.11	0.12
T_{13}	0.11	0.13	0.10	0.11
T_{14}	0.14	0.11	0.13	0.10
T_{15}	0.13	0.14	0.12	0.13
T_{16}	0.12	0.12	0.12	0.14
T_{17}	0.12	0.14	0.10	0.14
T_{18}	0.11	0.13	0.10	0.12
T_{19}	0.12	0.12	0.11	0.10
T_{20}	0.13	0.11	0.11	0.12
T_{21}	0.10	0.10	0.12	0.13
T_{22}	0.10	0.13	0.13	0.12
T_{23}	0.12	0.13	0.13	0.11
T_{24}	0.11	0.12	0.12	0.10

Table 12. Organic carbon content (%) of soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	0.80	0.97	1.01	0.88
T_2	0.82	1.12	1.10	1.03
T_3	0.85	1.13	1.11	0.85
T_4	0.96	1.03	1.22	0.96
T_5	1.00	1.19	1.05	1.14
T_6	1.04	1.13	1.09	1.22
T_7	1.06	1.14	0.84	1.06
T_8	0.88	1.14	0.98	0.88
T_9	0.96	1.05	1.12	0.96
T_{10}	0.90	1.16	1.08	1.09
T_{11}	0.88	1.05	0.87	1.10
T_{12}	1.00	1.12	1.16	1.06
T_{13}	0.95	1.07	1.17	1.13
T_{14}	1.00	1.12	1.14	1.17
T_{15}	1.10	1.06	1.17	1.11
T_{16}	0.87	1.05	1.10	1.15
T_{17}	1.10	1.03	1.16	1.19
T_{18}	0.94	1.07	0.98	1.23
T_{19}	1.09	1.14	1.13	1.09
T_{20}	1.04	1.05	1.05	1.14
T_{21}	0.97	1.01	1.02	1.10
T_{22}	0.89	1.17	1.17	1.19
T_{23}	0.93	1.09	1.20	1.17
T_{24}	1.00	1.05	1.18	1.11
Mean	0.96	1.10	1.04	1.08

Table 13. Available N content (kg ha^{-1}) in soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	267.00	274.81	296.60	293.83
T_2	264.40	272.20	293.83	288.23
T_3	272.20	277.50	291.06	293.83
T_4	264.40	285.31	304.91	307.69
T_5	269.60	287.98	310.46	299.38
T_6	274.80	387.02	406.24	346.70
T_7	318.54	342.82	397.68	366.92
T_8	326.40	295.83	304.91	310.46
T_9	285.31	298.45	313.24	302.14
T_{10}	326.40	315.31	394.39	402.69
T_{11}	322.88	377.49	341.52	405.60
T_{12}	305.30	400.20	387.80	418.52
T_{13}	295.20	376.19	391.56	403.87
T_{14}	299.53	390.41	410.95	413.90
T_{15}	285.31	303.68	335.41	321.55
T_{16}	320.35	382.26	409.76	428.50
T_{17}	348.00	378.80	422.42	390.64
T_{18}	287.00	301.07	433.34	436.00
T_{19}	334.21	306.30	405.31	415.47
T_{20}	345.60	322.10	424.30	391.63
T_{21}	357.90	327.25	435.99	395.40
T_{22}	398.93	340.50	450.89	445.00
T_{23}	365.80	375.91	453.34	438.89
T_{24}	375.57	390.00	440.30	448.80
Mean	312.95	333.73	377.35	373.57

Table 14. Available P content (kg ha^{-1}) in soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	17.50	13.59	20.56	21.86
T_2	16.90	13.96	20.92	24.10
T_3	15.43	11.02	22.22	24.80
T_4	15.01	12.10	25.53	22.22
T_5	18.92	16.16	21.86	28.50
T_6	12.86	15.98	24.43	30.10
T_7	13.78	17.08	23.51	29.02
T_8	13.04	15.43	27.74	25.31
T_9	12.31	13.04	19.65	22.78
T_{10}	11.39	14.51	25.72	28.29
T_{11}	16.35	16.53	22.59	35.82
T_{12}	15.80	15.80	22.78	30.49
T_{13}	13.22	22.22	23.69	28.65
T_{14}	13.22	19.29	26.82	25.31
T_{15}	12.67	16.53	20.94	29.02
T_{16}	12.86	15.01	24.43	28.02
T_{17}	12.67	25.71	19.29	22.56
T_{18}	11.76	30.71	25.31	36.00
T_{19}	14.69	20.02	26.63	33.98
T_{20}	14.14	13.96	22.96	21.86
T_{21}	12.12	19.29	29.21	24.43
T_{22}	10.65	21.67	27.55	30.67
T_{23}	14.14	21.86	25.31	20.94
T_{24}	11.02	17.27	25.90	23.80
Mean	13.85	17.45	23.98	27.03

Table 15. Available K content (kg ha^{-1}) in soil prior to STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	322.30	360.20	420.50	448.00
T_2	320.00	380.80	418.00	447.60
T_3	336.00	425.60	448.00	380.80
T_4	336.50	448.00	450.60	400.00
T_5	313.60	358.40	483.71	403.20
T_6	336.00	268.80	425.30	448.00
T_7	291.20	358.40	440.20	470.40
T_8	380.80	336.00	418.40	470.40
T_9	291.20	358.40	448.00	448.00
T_{10}	246.40	403.20	438.80	425.60
T_{11}	291.20	380.80	420.20	403.20
T_{12}	291.20	268.80	387.70	448.00
T_{13}	403.20	246.40	365.30	470.40
T_{14}	380.80	358.40	367.60	470.40
T_{15}	313.60	380.80	359.20	425.60
T_{16}	358.40	291.20	361.60	403.20
T_{17}	358.40	336.00	358.50	336.00
T_{18}	362.30	403.20	363.10	313.60
T_{19}	375.20	470.40	377.60	403.20
T_{20}	365.50	425.60	380.00	425.60
T_{21}	448.00	355.50	372.60	425.60
T_{22}	380.80	350.20	367.60	403.20
T_{23}	377.30	344.60	364.50	380.80
T_{24}	336.00	403.20	365.10	440.00
Mean	312.95	333.73	377.35	373.57

The mean values of organic carbon were 0.96, 1.10, 1.04 and 1.08 per cent respectively for strips I, II, III and IV. Available N registered mean values of 312.95, 333.73, 377.35 and 373.57 kg ha^{-1} for strips I, II, III and IV respectively. The mean values of available P were 13.85, 17.45, 23.98 and 27.03 respectively for strips I, II, III and IV and that of K were 342.33, 363.04, 400.08 and 420.45 kg ha^{-1} (Table 16).

Table 16. Strip wise mean values of soil nutrient content before STCR experiment

Particulars	Strips			
	I	II	III	IV
Organic carbon (%)	0.96	1.10	1.04	1.08
Available N (kg ha^{-1})	312.95	333.73	377.35	373.57
Available P (kg ha^{-1})	13.85	17.45	23.98	27.03
Available K (kg ha^{-1})	342.33	363.04	400.08	420.45

4.2.2 Yield of groundnut

The data on pod yield as influenced by treatments were recorded in the Table17. As evident from the data the control plots in all the strips registered much lower yield (1680 to 1945.50 kg ha^{-1}) than the treated plots (1756.40 to 2372.30 kg$h\bar{a}^{1}$) (Table 17). The strip wise mean values of pod yields and shelling percentage were given in Tables 18 and 19.

In the treated plots, the pod yield varied from 1756.40 to 2285.00, 1810.00 to 2240.40, 2000.80 to 2372.30 and 1955.80 to 2370.40 kg ha^{-1} in strips I, II, III and IV respectively (Table 17). The mean pod yields from treated plots were 1995.30, 2076.62, 2208.52 and 2163.38 kg ha^{-1} (Table 18). Considering all plots in each strip, the average pod yield recorded were 1969.32, 2048.60, 2181.25 and 2141.88 kg ha^{-1} (Table 18). The average shelling percentage of contról plot recorded range of values 62.10, 64.35, 58.94 and 60.05 per cent for strips I, II, III and IV (Table 19). In treated plots the values were 63.06, 65.23, 62.50 and 62.89 per cent respectively for strips I, II, III and IV (Table 19). Considering all plots in each strip, the average shelling

Table 17. Pod yield of groundnut (kg ha^{-1}) as influenced by available and applied nutrients

Treatments	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Strip I	Strip II	Strip III	Strip IV
	N	P	K					
T_1	0	0	0	0	1680.00	1738.00	1937.00	1900.40
T_2	0	0	0	0	1687.00	1742.70	1945.50	1910.00
T_3	0	0	0	2	1795.50	1810.00	2065.40	1955.80
T_4	0	0	0	4	1800.10	1838.70	2100.00	1980.30
T_5	0	0	37.5	2	1990.00	2000.50	2095.40	2068.30
T_6	5	0	37.5	2	1840.80	2015.70	2100.70	2144.80
T_7	5	40	37.5	2	1756.40	2032.50	2184.50	2200.00
T_8	0	0	75	2	1948.00	2065.00	2252.30	2287.90
T_9	0	40	75	2	1958.80	2038.00	2282.80	2258.40
T_{10}	5	0	75	0	2035.60	2046.00	2062.00	2100.50
T_{11}	5	40	75	0	2100.20	2100.50	2145.60	2273.60
T_{12}	10	0	75	0	2178.60	2175.00	2076.00	2354.10
T_{13}	10	40	75	0	2210.00	2193.60	2100.40	2370.40
T_{14}	10	80	75	0	2245.80	2045.30	2010.80	2268.00
T_{15}	0	0	150	4	2285.00	2100.00	2200.00	2266.80
T_{16}	5	40	150	4	2112.60	2200.50	2372.30	2264.50
T_{17}	10	80	150	0	2182.80	2240.40	2247.30	2310.40
T_{18}	20	0	150	0	1817.50	2180.80	2284.50	2317.10
T_{19}	20	40	150	4	1955.90	2100.30	2276.40	2255.70
T_{20}	20	80	150	0	1812.30	2040.30	2000.80	2248.20
T_{21}	10	40	300	0	1771.70	2095.20	2188.70	2125.80
T_{22}	10	80	300	0	1848.50	2140.00	2280.00	2140.00
T_{23}	20	40	300	4	2140.50	2112.30	2256.00	2100.80
T_{24}	20	80	300	4	2110.00	2115.00	2120.50	2188.00

percentage recorded were 62.98, 65.16, 62.20 and 62.65 per cent for strips I, II, III and IV respectively (Table 19).

Table 18. Strip wise mean yield of groundnut

Pod yield (kg ha^{-1})	Strips			
	I	II	III	IV
Control plots	1683.50	1740.35	1941.25	1905.40
Treated plots	1995.30	2076.62	2208.52	2163.38
All plots	1969.32	2048.60	2181.25	2141.88

Table 19. Strip wise mean shelling percentage of groundnut

Shelling percentage	Strips			
	I	II	III	IV
Control plots	62.10	64.35	58.94	60.05
Treated plots	63.06	65.23	62.50	62.89
All plots	62.98	65.16	62.20	62.65

In the control plots, the maximum pod yield of 1945.50 kg ha^{-1} was recorded in strip III with STVs of 293.83, 20.92, and 418.00 kg ha^{-1} available N, P and K respectively (Table 20). The minimum yield of 1680.00 kg ha^{-1} was obtained from strip I with STVs of 267.00, 17.50, and 322.30 kg ha^{-1} available N, P and K respectively (Table 20).

Among the treated plots, the highest pod yield of 2372.30kg ha^{-1} was obtained from strip III (T_{16}) which received 4 t ha^{-1} FYM and 5:40:150 kg ha^{-1} of N, P_2O_5 and K_2O as fertilizers, where the STVs were 409.76, 24.43, 361.60 kg ha^{-1} of available N, P and K respectively. The minimum yield of 1756.40 kg ha^{-1} was obtained from strip I (T_7) with STVs of 318.54, 13.78, and 291.20 kg ha^{-1} available N, P and K respectively (Table 20).

4.2.3 Nutrient uptake by Groundnut

The nutrient uptake of groundnut was calculated separately for the different parts like haulm, shell and kernel for all the treatments. The total nutrient

Table 20. Maximum and minimum pod yield of groundnut due to treatments

Particulars	Strip	Soil test values (kg ha^{-1})			Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Pod yield (kg ha^{-1})
		N	P	K	N	P	K		
Control plots									
Maximum yield	III	293.83	20.92	418.00	0	0	0	0	1945.50
Minimum yield	I	267.00	17.50	322.30	0	0	0	0	1680.00
Treated plots									
Maximum yield	III	409.76	24.43	361.60	5	40	150	4	2372.30
Minimum yield	I	318.54	13.78	291.20	5	40	37.50	2	1756.40

uptake of N, P and K by groundnut (haulm + shell + kernel) is represented in Table 21 to 23. Uptake of N, P and K ranged from 66.42 to 129.42, 5.48 to12.44 and 29.87 to 64.47 kg ha^{-1} in strips I, II, III and IV respectively (Tables 21, 22 and 23). The mean values in each strip are given in Table 24.

In the control plots uptake of N registered mean values of 69.78, 75.75, 81.13 and 91.52 kg ha^{-1} in strips I, II, III and IV respectively .The mean uptake of P were 5.62, 6.82, 8.16 and 9.14 kg ha^{-1} and that of K were 30.09, 35.85, 43.79 and 46.85 kg ha^{-1} for strips I, II, III and IV respectively (Table 24).

In general the mean values of uptake of N were 93.27, 101.23, 107.36 and 112.20 kg ha^{-1} in strips I, II, III and IV respectively. The average P uptake were 7.15, 8.22, 9.84 and 11.38 kg ha^{-1} in strip I, II, III and IV respectively. The mean values of K uptake were 37.52, 47.57, 54.35 and 57.14 kg ha^{-1} in strips I, II, III and IV respectively (Table 24).

4.2.4 Post Harvest Soil Analysis

Soil samples were collected after the harvest of groundnut from all the plots (96) and analysed for pH, EC, organic carbon, available N, P and K. The data were given in Tables 25, 26, 27, 28, 29 and 30 respectively.

The pH of the soil varied from 5.00 to 5.50, 5.10 to 5.50, 5.00 to 5.40 and 5.10 to 5.50 for strips I, II, III and IV respectively. The EC varied from 0.10 to 0.15, 0.11 to 0.15, 0.10 to 0.14 and 0.10 to 0.13 for strips I, II, III and IV respectively. The organic carbon content in the soil varied from 0.53 to 0.79, 0.64 to 0.9, 0.86 to 0.95 and 0.92 to 1.19 per cent in strips I, II, III and IV respectively (Table 27). The available N content ranged from 250.21 to 368.65, 270.51 to 390.66, 280.20 to 431.30 and 281.10 to 425.20 kg ha^{-1} respectively for strips I, II, III and IV (Table 28). The available P content varied from 5.31 to 15.88, 7.33 to 16.63, 8.22 to 22.02 and 9.13 to 18.80 kg ha^{-1} respectively in strip I, II, III and IV (Table 29). The available K content

Table 21. Uptake of N (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Uptake of N (kg ha^{-1})			
	N	P	K		Strip I	Strip II	Strip III	Strip IV
T_1	0	0	0	0	75.86	66.42	80.31	90.91
T_2	0	0	0	0	75.64	73.14	81.95	92.13
T_3	0	0	0	2	75.20	90.59	92.83	96.81
T_4	0	0	0	4	70.47	80.57	98.03	115.40
T_5	0	0	37.5	2	83.38	88.98	94.25	95.005
T_6	5	0	37.5	2	93.89	83.13	109.51	107.84
T_7	5	40	37.5	2	80.26	107.98	101.09	104.75
T_8	0	0	75	2	96.33	107.00	117.44	113.84
T_9	0	40	75	2	88.07	107.85	121.89	109.17
T_{10}	5	0	75	0	86.46	98.96	103.97	109.66
T_{11}	5	40	75	0	108.02	113.82	97.47	104.802
T_{12}	10	0	75	0	113.06	99.22	114.46	123.40
T_{13}	10	40	75	0	112.13	91.21	119.74	123.46
T_{14}	10	80	75	0	115.30	89.88	96.17	119.12
T_{15}	0	0	150	4	111.14	103.63	113.74	129.42
T_{16}	5	40	150	4	107.40	106.85	127.45	126.44
T_{17}	10	80	150	0	99.87	114.44	112.12	109.88
T_{18}	20	0	150	0	93.00	123.44	109.35	126.11
T_{19}	20	40	150	4	82.74	112.59	117.18	112.27
T_{20}	20	80	150	0	91.79	111.94	101.55	124.11
T_{21}	10	40	300	0	101.08	115.205	102.97	115.21
T_{22}	10	80	300	0	89.20	108.67	125.90	114.17
T_{23}	20	40	300	4	110.11	109.14	122.53	117.17
T_{24}	20	80	300	4	90.01	113.03	114.54	111.63

Table 22. Uptake of P (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Uptake of P (kg ha^{-1})			
	N	P	K		Strip I	Strip II	Strip III	Strip IV
T_1	0	0	0	0	5.48	6.82	8.10	9.20
T_2	0	0	0	0	5.75	6.82	8.22	9.08
T_3	0	0	0	2	6.37	7.01	8.92	9.52
T_4	0	0	0	4	6.23	7.29	9.26	9.74
T_5	0	0	37.5	2	6.60	7.75	8.77	9.67
T_6	5	0	37.5	2	6.40	7.94	9.20	10.21
T_7	5	40	37.5	2	6.64	7.74	9.73	10.63
T_8	0	0	75	2	6.83	7.83	10.10	13.95
T_9	0	40	75	2	6.76	8.06	10.05	10.37
T_{10}	5	0	75	0	7.20	8.16	8.99	9.75
T_{11}	5	40	75	0	7.55	8.56	9.68	10.10
T_{12}	10	0	75	0	7.54	8.40	9.44	10.90
T_{13}	10	40	75	0	7.67	8.76	9.15	12.25
T_{14}	10	80	75	0	7.73	8.16	9.41	12.40
T_{15}	0	0	150	4	9.20	8.62	10.15	12.00
T_{16}	5	40	150	4	8.25	8.79	10.55	10.55
T_{17}	10	80	150	0	7.78	9.14	9.94	11.15
T_{18}	20	0	150	0	6.78	9.22	9.56	11.04
T_{19}	20	40	150	4	7.25	8.61	10.38	11.33
T_{20}	20	80	150	0	7.34	8.84	10.42	12.44
T_{21}	10	40	300	0	6.80	8.83	12.38	12.31
T_{22}	10	80	300	0	7.14	8.09	10.38	12.40
T_{23}	20	40	300	4	8.25	8.87	11.32	12.00
T_{24}	20	80	300	4	8.00	8.94	11.00	11.98

Table 23. Uptake of K (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Uptake of K (kg ha^{-1})			
	N	P	K		Strip I	Strip II	Strip III	Strip IV
T_1	0	0	0	0	29.87	35.90	42.96	46.41
T_2	0	0	0	0	30.30	35.80	44.61	47.28
T_3	0	0	0	2	33.78	39.00	48.64	49.95
T_4	0	0	0	4	35.30	40.07	49.56	51.51
T_5	0	0	37.5	2	35.10	42.87	46.62	49.45
T_6	5	0	37.5	2	32.89	44.28	54.32	55.50
T_7	5	40	37.5	2	36.38	46.87	58.17	58.21
T_8	0	0	75	2	36.30	47.15	57.42	56.35
T_9	0	40	75	2	35.92	48.56	55.78	54.80
T_{10}	5	0	75	0	38.14	49.20	51.44	57.63
T_{11}	5	40	75	0	39.71	47.08	56.31	55.55
T_{12}	10	0	75	0	40.31	49.34	52.76	59.11
T_{13}	10	40	75	0	38.61	50.46	48.27	61.92
T_{14}	10	80	75	0	39.57	47.25	54.80	62.42
T_{15}	0	0	150	4	40.87	52.49	57.69	62.76
T_{16}	5	40	150	4	40.60	50.10	63.21	64.47
T_{17}	10	80	150	0	41.48	52.73	58.84	58.67
T_{18}	20	0	150	0	38.14	54.37	60.06	61.45
T_{19}	20	40	150	4	38.75	54.54	57.05	60.24
T_{20}	20	80	150	0	39.35	52.67	56.54	59.58
T_{21}	10	40	300	0	37.30	52.33	55.65	57.18
T_{22}	10	80	300	0	38.11	48.49	58.31	60.02
T_{23}	20	40	300	4	42.46	49.58	56.74	59.64
T_{24}	20	80	300	4	41.40	50.73	58.54	60.95

Table 24. Strip wise mean uptake of N, P and K (kg ha^{-1}) at harvest

Particulars	Mean uptake of nutrients (kg ha^{-1})			
Control plots	Strip I	Strip II	Strip III	Strip IV
N	69.78	75.75	81.13	91.52
P	5.62	6.82	8.16	9.14
K	30.09	35.85	43.79	46.85
Treated plots				
N	95.41	103.55	109.74	114.08
P	7.29	8.35	9.78	10.74
K	38.20	48.64	55.301	58.07
All plots				
N	93.27	101.23	107.36	112.2
P	7.15	8.22	9.84	11.38
K	37.52	47.57	54.35	57.14

Table 25. pH of soil after STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	5.30	5.20	5.00	5.10
T_2	5.10	5.10	5.10	5.20
T_3	5.20	5.50	5.20	5.30
T_4	5.20	5.30	5.00	5.30
T_5	5.40	5.30	5.30	5.20
T_6	5.20	5.40	5.10	5.20
T_7	5.10	5.30	5.20	5.30
T_8	5.00	5.20	5.30	5.30
T_9	5.30	5.10	5.10	5.20
T_{10}	5.20	5.30	5.00	5.20
T_{11}	5.40	5.20	5.30	5.40
T_{12}	5.40	5.30	5.20	5.20
T_{13}	5.50	5.40	5.20	5.10
T_{14}	5.20	5.40	5.30	5.20
T_{15}	5.30	5.20	5.10	5.20
T_{16}	5.50	5.50	5.20	5.20
T_{17}	5.10	5.20	5.40	5.50
T_{18}	5.30	5.30	5.40	5.30
T_{19}	5.40	5.40	5.30	5.30
T_{20}	5.50	5.30	5.30	5.30
T_{21}	5.20	5.20	5.20	5.40
T_{22}	5.40	5.10	5.40	5.30
T_{23}	5.30	5.30	5.30	5.40
T_{24}	5.30	5.20	5.20	5.50
Mean	5.28	5.28	5.21	5.27

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Table 26. EC (dS m^{-1}) of soil after STCR experiment

Treatment	Strip I	Strip II	Strip III	Strip IV
T_1	0.12	0.11	0.10	0.12
T_2	0.11	0.12	0.12	0.11
T_3	0.13	0.13	0.11	0.12
T_4	0.12	0.11	0.11	0.13
T_5	0.10	0.10	0.10	0.13
T_6	0.14	0.14	0.12	0. 11
T_7	0.14	0.14	0.12	0.12
T_8	0.11	0.12	0.12	0.10
T_9	0.10	0.13	0.11	0.11
T_{10}	0.12	0.12	0.10	0.12
T_{11}	0.13	0.11	0.11	0.11
T_{12}	0.14	0.13	0.12	0.13
T_{13}	0.13	0.14	0.10	0.12
T_{14}	0.12	0.12	0.12	0.12
T_{15}	0.15	0.15	0.13	0.12
T_{16}	0.10	0.15	0.14	0.13
T_{17}	0.12	0.14	0.12	0.13
T_{18}	0.14	0.14	0.12	0.10
T_{19}	0.13	0.15	0.13	0.12
T_{20}	0.14	0.13	0.13	0.13
T_{21}	0.13	0.12	0.13	0.13
T_{22}	0.13	0.14	0.14	0.12
T_{23}	0.14	0.13	0.12	0.12
T_{24}	0.14	0.14	0.13	0.11

Table 27. Organic carbon content (%) in soil after STCR experiment

Treatments	Strip I	Strip II	Strip III	Strip IV
T_1	0.53	0.68	0.86	0.92
T_2	0.60	0.64	0.87	0.95
T_3	0.77	0.77	0.91	1.03
T_4	0.79	0.84	0.89	1.08
T_5	0.70	0.79	0.91	1.00
T_6	0.71	0.74	0.90	1.12
T_7	0.68	0.84	0.93	1.18
T_8	0.70	0.79	0.92	0.99
T_9	0.70	0.83	0.95	1.13
T_{10}	0.68	0.75	0.89	0.98
T_{11}	0.67	0.79	0.90	1.12
T_{12}	0.58	0.77	0.91	1.00
T_{13}	0.59	0.81	0.90	1.15
T_{14}	0.69	0.86	0.93	1.16
T_{15}	0.73	0.90	0.88	1.09
T_{16}	0.70	0.81	0.86	0.99
T_{17}	0.77	0.85	0.92	1.00
T_{18}	0.72	0.82	0.92	1.12
T_{19}	0.74	0.85	0.94	1.10
T_{20}	0.70	0.88	0.95	1.18
T_{21}	0.73	0.76	0.93	0.99
T_{22}	0.72	0.86	0.91	1.19
T_{23}	0.71	0.83	0.94	1.15
T_{24}	0.74	0.88	0.95	1.12
Mean	0.69	0.81	0.91	1.07

Table 28. Available N content (kg ha^{-1}) in soil after STCR experiment

Treatments	Strip I	Strip II	Strip III	Strip IV
T_1	253.51	271.33	288.20	281.10
T_2	250.22	270.51	280.22	285.30
T_3	266.31	280.00	285.55	297.20
T_4	260.55	278.65	308.60	310.22
T_5	250.21	272.93	294.56	304.45
T_6	268.90	368.84	390.54	338.55
T_7	275.63	355.20	288.95	359.00
T_8	310.69	300.10	310.55	293.10
T_9	292.35	273.42	297.41	305.31
T_{10}	321.98	310.50	381.60	390.30
T_{11}	327.55	381.35	352.20	410.41
T_{12}	310.12	390.66	371.45	398.51
T_{13}	288.80	381.23	398.66	412.25
T_{14}	301.70	388.00	390.12	422.20
T_{15}	282.50	310.22	341.50	315.50
T_{16}	316.30	379.00	410.50	425.20
T_{17}	340.70	381.50	418.10	411.33
T_{18}	300.55	290.33	409.63	420.90
T_{19}	337.54	310.87	382.33	422.60
T_{20}	329.78	325.10	400.30	389.00
T_{21}	340.22	320.20	394.65	400.21
T_{22}	368.65	334.00	425.51	413.10
T_{23}	355.20	366.62	431.30	410.92
T_{24}	348.77	387.21	426.77	400.20
Mean	304.12	330.20	362.24	366.76

Table 29. Available P content (kg ha^{-1}) in soil after STCR experiment

Treatments	Strip I	Strip II	Strip III	Strip IV
T_1	7.12	12.00	12.61	11.78
T_2	8.04	11.30	11.30	12.00
T_3	7.76	12.79	15.81	14.31
T_4	12.97	14.20	22.02	18.82
T_5	8.86	10.05	20.83	16.20
T_6	5.31	8.86	11.42	10.23
T_7	8.86	11.10	21.20	18.80
T_8	7.95	10.60	12.42	12.35
T_9	7.97	12.36	10.87	13.52
T_{10}	8.48	7.33	11.69	18.00
T_{11}	12.42	14.31	13.52	10.93
T_{12}	10.05	8.04	8.22	9.13
T_{13}	12.88	12.06	11.60	10.78
T_{14}	13.90	15.72	10.20	16.81
T_{15}	11.53	11.53	15.62	18.82
T_{16}	12.67	12.67	13.16	13.10
T_{17}	15.88	14.81	12.69	16.54
T_{18}	10.88	11.28	11.30	12.52
T_{19}	13.10	13.10	15.31	10.80
T_{20}	15.30	14.81	8.84	9.13
T_{21}	14.50	11.88	20.74	14.53
T_{22}	14.10	16.63	17.33	18.27
T_{23}	11.38	14.62	19.64	17.50
T_{24}	13.60	13.60	15.68	13.50
Mean	11.07	12.32	14.34	14.10

Table 30. Available K (kg ha^{-1}) in soil after STCR experiment

Treatments	Strip I	Strip II	Strip III	Strip IV
T_1	256.00	292.10	300.50	362.60
T_2	250.10	291.10	298.80	399.70
T_3	268.00	295.50	310.50	410.40
T_4	272.10	283.80	315.10	392.70
T_5	310.80	275.70	298.70	420.60
T_6	236.30	300.56	342.10	388.90
T_7	310.70	295.20	331.00	376.30
T_8	283.40	320.00	318.50	400.50
T_9	305.70	288.00	320.11	433.40
T_{10}	300.10	250.12	312.00	410.00
T_{11}	310.70	288.60	342.20	370.20
T_{12}	230.30	284.22	380.10	344.00
T_{13}	220.30	330.00	375.00	370.30
T_{14}	256.40	318.40	388.60	330.00
T_{15}	300.50	294.00	361.30	298.40
T_{16}	248.00	385.10	358.40	270.00
T_{17}	260.40	369.33	280.20	262.80
T_{18}	250.10	295.10	271.00	255.10
T_{19}	235.80	289.33	342.70	320.54
T_{20}	242.00	316.84	351.80	373.30
T_{21}	260.00	332.10	360.00	354.50
T_{22}	270.20	324.56	342.20	322.40
T_{23}	288.80	368.00	350.50	344.00
T_{24}	297.00	381.12	370.10	330.80
Mean	269.35	319.66	330.08	359.61

recorded range of values from 220.30 to 310.80, 250.12 to 385.10, 271.00 to 388.60 and 255.10 to 433.40 kg ha^{-1} for strips I, II, III and IV (Table 30).

The mean values of organic carbon content were 0.69, 0.81, 0.91 and 1.07 per cent for strips I, II, III and IV respectively. The available N registered mean values of 304.12, 330.22, 362.24, 366.76 kg ha^{-1} for strips I, II, III and IV respectively. The mean values of P were 11.07, 12.32,14.34, 14.10 kg ha^{-1} and that of K were 269.35, 319.66, 330.08, 359.61 kg ha^{-1} (Table 31).

Table 31. Strip wise mean values of soil nutrient content after STCR experiment

Particulars	Strips			
	I	II	III	IV
Organic carbon (%)	0.69	0.81	0.91	1.07
Available N (kg ha^{-1})	304.12	330.22	362.24	366.76
Available P (kg ha^{-1})	11.07	12.32	14.34	14.10
Available K (kg ha^{-1})	269.35	319.66	330.08	359.61

4.2.5 Correlation Studies

4.2.5.1 Nutrient Uptake and Yield

Simple correlation coefficients were worked out between nutrient uptake and yield of groundnut and is presented in Table 32.

Table 32.Correlation coefficient of yield and nutrient uptake

Particulars	Pod yield	Uptake of N	Uptake of P	Uptake of K
Uptake of N	0.818*	-	0.732*	0.758*
Uptake of P	0.788*	0.732*	-	0.924*
Uptake of K	0.744*	0.758*	0.924*	-

- Significant at 1%

The uptake of N, P and K was positively correlated with the yield and is highly significant. The inter correlations between uptake of N, P and K were also significant.

4.2.5.2 Nutrient Uptake and Yield with Available and Applied Nutrients

Correlation coefficients of nutrient uptake and yield with soil available and applied nutrients are presented in Table 33. All the available nutrients showed a highly significant positive correlation with nutrient uptake. Among the applied nutrients inorganic fertilizers showed a positive significant correlation with N and K uptake than P.

4.2.5.3 Yield with Major Nutrient Content in Plant

Higher positive correlations existed between yield and major plant nutrient contents. The correlation coefficients are furnished in Table 34.

4.2.6 Path Coefficient Analysis

The path coefficient analysis was worked out to study the direct and indirect effect of the soil on pod yield.

4.2.6.1 Path Coefficient Analysis of Soil Nutrients with Pod yield before STCR Experiment

Path analysis was carried out by using the significant correlation coefficient of three characters namely soil available N, P and K with pod yield. Abstract of the results are given in Table 35 and Fig. 3. From the table it was evident that SN has direct positive effect on yield followed by SP.

Table 35. Path coefficient of soil available nutrients with pod yield before STCR experiment

Particulars	SN	SP	SK	OC
SN	**0.2857**	0.1395	-0.0023	0.1357
SP	0.1472	**0.2706**	-0.0238	0.1735
SK	0.0105	0.1036	**-0.0622**	0.1108
OC	0.1475	0.1786	-0.0262	**0.2629**

R = 0.5490

Table 33. Correlation coefficient between nutrient uptake and yield with available and applied nutrients

Particulars	Nutrient uptake			Yield
	N	P	K	
Organic carbon	0.541*	0.774*	0.798*	0.536*
Available N	0.545*	0.599*	0.687*	0.559*
Available P	0.512*	0.775*	0.780*	0.568*
Available K	0.262**	0.453*	0.411*	0.163
Fertilizer N	0.382*	0.220**	0.307*	0.281**
Fertilizer P_2O_5	0.304*	0.211**	0.264**	0.282**
Fertilizer K_2O	0.465*	0.279**	0.326*	0.329*
FYM	0.104	0.115	0.091	0.108

* Significant at 1%

** Significant at 5%

Table 34. Correlation coefficient between plant nutrient content with yield

Particulars	Haulm			Shell			Kernel		
	N	P	K	N	P	K	N	P	K
Yield	0.519*	0.528*	0.568*	0.376*	0.511*	0.616*	0.396*	0.607*	0.132
Haulm N	1.000	0.809*	0.829*	0.262*	0.715*	0.753*	0.111	0.824*	0.149
Haulm P	0.809*	1.000	0.907*	0.389*	0.848*	0.656*	0.114	0.789*	0.129
Haulm K	0.829*	0.907*	1.000	0.339*	0.852*	0.633*	0.098	0.846*	0.063
Shell N	0.262**	0.389*	0.339*	1.000	0.366*	0.284*	0.170	0.324*	0.139
Shell P	0.715*	0.848*	0.852*	0.366*	1.000	0.532*	0.109	0.734*	0.114
Shell K	0.753*	0.656*	0.633*	0.284*	0.532*	1.000	0.283*	0.763*	0.305*
Kernel N	0.111	0.114	0.098	0.170*	0.109	0.283*	1.000	0.153	0.170
Kernel P	0.824*	0.789*	0.846*	0.324*	0.734*	0.763*	0.153	1.000	0.173
Kernel K	0.149	0.129	0.063	0.139	0.114	0.305*	0.170	0.173	0.162

* - Significant at 1% level

** - Significant at 5% level

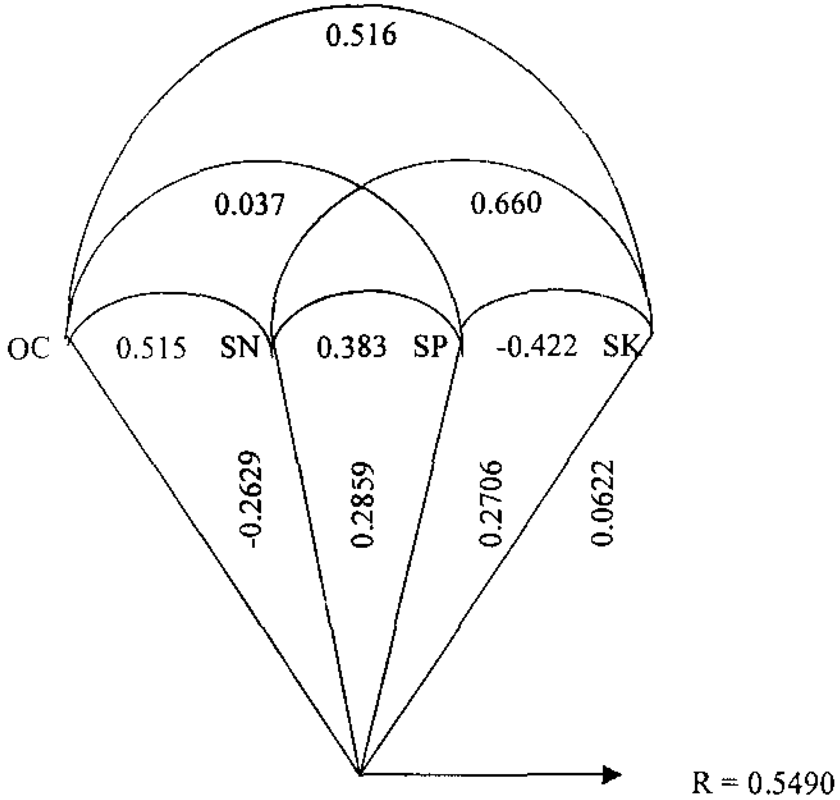

Fig. 3. Path diagram for major soil nutrients with pod yield of groundnut before STCR experiment

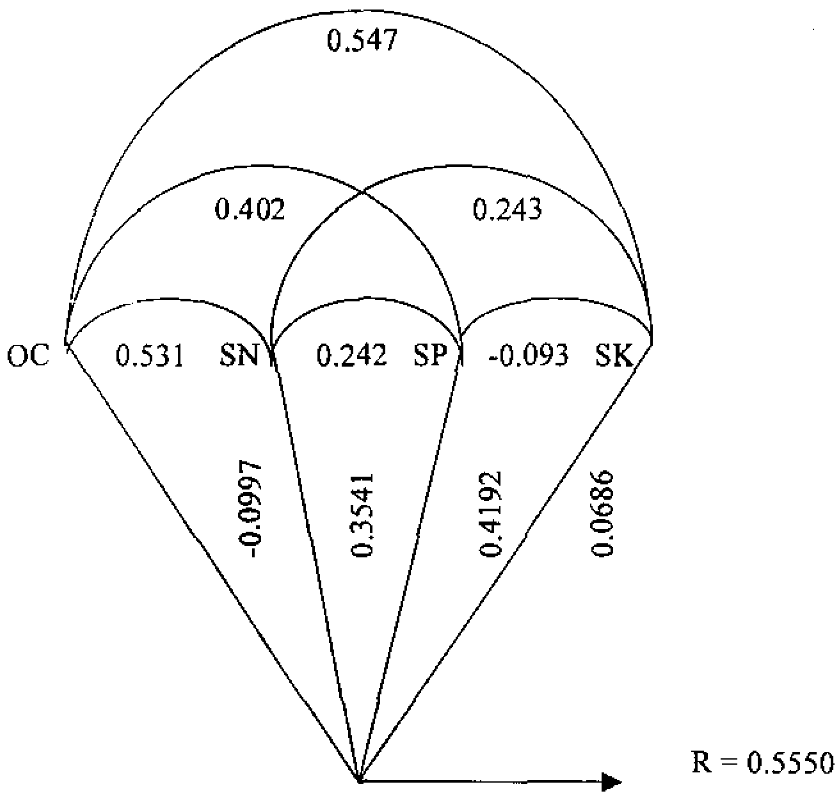

Fig. 4. Path diagram for major soil nutrients with pod yield of groundnut after STCR experiment

4.2.6.2 Path Coefficient Analysis of Soil Nutrients with Pod Yield after STCR Experiment

Path analysis was carried out by using the significant correlation coefficient of three characters namely soil available N, P and K after STCR experiment with pod yield. Abstract of the results are given in Table 36 and Fig. 4. The data from the table showed that SP is directly correlated with yield, which has got a value of 0.4192 followed by SN with a value of 0.3541.

Table 36. Path coefficient of soil available nutrients with pod yield after STCR experiment

Particulars	SN	SP	SK	OC
SN	**0.3541**	0.2225	-0.0276	0.0546
SP	0.1879	**0.4192**	-0.0166	0.0242
SK	0.1423	0.1013	**-0.0686**	0.0232
OC	0.1938	0.1019	-0.0159	**0.0997**

R = 0.5550

4.2.7 Response of Groundnut to Applied Nutrients

4.2.7.1 Response of Groundnut to FYM

The data on the pod yield of groundnut from application of FYM alone at different levels were given in Table 37. In each strip two absolute control plots were maintained in which neither FYM nor fertilizer was applied. The effect of FYM on pod yield was understood by comparing the yields of FYM applied plots (F_1, F_2) with that of absolute control (F_0). From the Table 37 it was evident that higher yields were obtained from plots that received the FYM alone compared to absolute controls.

Table 37. Effect of FYM on pod yield of groundnut

Levels of FYM (t ha^{-1})	Pod yield (kg ha^{-1})				
	Strip I	Strip II	Strip III	Strip IV	Mean
F_0 - Nil	1680.00	1738.00	1937.00	1900.40	1813.75
F_0 - Nil	1687.00	1742.70	1945.00	1910.40	1821.28
F_1 - 2	1795.50	1810.00	2065.00	1955.80	1906.58
F_2 - 4	1800.10	1838.70	2100.00	1980.30	1929.78

The response to FYM application was worked out and given in Table 38. From the table, it could be seen that the response in terms pod yield was more at F_1 level (89.06) than F_2 (112.26). The average response at F_1 level was 44.53 kg of pod per ton of FYM while at F_2 level, it was 28.07 kg pod per ton of FYM.

Table 38. Response of groundnut to FYM

Levels of FYM	Quantity of FYM applied (t ha^{-1})	Mean response pod yield (kg ha^{-1})	Response per tonne of FYM (kg)
F_1	2	89.06	44.53
F_2	4	112.26	28.07

4.2.8 Soil Test Calibration Studies

The purpose of soil test crop response studies in essence is calibration of STVs for fertilizer recommendation. So the soil test based crop response models were calibrated with the following objectives.

1. Optimization of fertilizer nutrients for maximum and economic yield at varying STVs.
2. Optimization of fertilizer nutrients for specific yield targets at varying STVs.

The calibration of soil test data would be more useful for the farmer to obtain site specific fertilizer dose for the crops to get maximum and economic yield.

Balanced use of soil and fertilizer nutrients can be achieved through soil test based fertilizer recommendation.

4.2.8.1 Multiple Regression Models for Prescription of Fertilizer Doses at Varying STVs

In soil test crop response correlation studies yield is computed as a function of soil and fertilizer nutrients keeping all other factors at an optimum level. In the present study the relationship of yield with available and applied nutrients was estimated as a quadratic response using the statistical package.

The regression model includes linear, quadratic and interaction terms of soil and fertilizer nutrients. The multiple regression model developed at IARI (Ramamoorthy and Velayutham, 1974) formed the basis for this calibration. This model predicts the type of response for each nutrient for different crops (Singh and Sharma, 1978).

Theoretically, eight types of responses for a nutrient are possible depending upon + or - sign for each of the three regression coefficients, viz., the coefficient for the linear, quadratic and interaction terms of nutrient (Ramamoorthy, 1973; Velayutham *et al.*, 1985 and Sankar *et al.*, 1987). Among the eight types, the one with +, -, - signs respectively for the coefficients of linear quadratic and interaction terms of nutrient was considered to be the normal type for working out optima of a fertilizer nutrient at varying STVs. So it is necessary to consider the actual form of response existing in the nutrients for better use of soil available nutrients.

Using the plot wise data on STVs, applied FYM and N, P and K fertilizers, and the resultant pod yield models of the following categories were calibrated.

a) Model developed with 15 variables comprising of 3 linear and 3 quadratic terms of soil nutrients (SN, SP and SK), 3 linear and 3 quadratic terms of fertilizer nutrients (FN, FP and FK) and 3 interaction terms of soil and fertilizer nutrients with available N (kg ha^{-1}) as a measure of soil N, utilizing the data from all the plots.

b) As above with organic carbon per cent (OC) as a measure of soil N.

c) Model with 17 variables consisting of all the 15 variables of model (a) along with linear and quadratic terms of FYM and available N as a measure of soil N.

d) As above with OC (%) as a measure of soil N.

From the regression equation developed fertilizer doses were computed by differentiation and for that the regression equation should have higher per cent of variance explained. The different regression models were presented in Table 39.

Among the models calibrated, the one with 15 variables utilizing the data from all plots and available N as a measure of soil N had the highest predictability (75.69 %) followed by the same model but using OC as a measure of available N with 74.30 per cent predictability (Table 39). In both these models among the three fertilizer nutrients only P and K showed the normal or (+, -, -) type of response (Table 39). For N the response type was (-, -, +) in both the models.

Here the model with highest predictability (75.69%) was selected for formulating the equation. Differentiating the regression equation partially with respect to FP and FK, the soil test based fertilizer adjustment equation for recommending P and K dose was derived as

$$FP = 32.47 - 0.709\ SP$$

$$FK = 321.36 - 0.429\ SK$$

FP and FK derived from the above equation is the optimum dose of fertilizer P (kg ha^{-1}) and fertilizer K (kg ha^{-1}) for maximum pod yield (kg ha^{-1}) for groundnut at a given soil test value for available P and K (kg ha^{-1}). This equation implied that the yield increased as long as the conditions in the equation given below are satisfied.

$$FP \leq 32.47 - 0.709\ SP$$

$$FK \leq 321.36 - 0.429\ SK$$

At higher levels of fertilizer P and K above this level, the pod yield will be decreased. In other words, fertilizer P has to be applied to the soil upto the level of 45.8 kg ha^{-1} and fertilizer K 749.10 kg ha^{-1}.

Table 39. Regression models

Particulars	Multiple regression equation	Variance (%)	R^2
With 15 variables SN as available N	$Y= 2937.224 -3.70739SN+ 0.004229SN^2 +28.35825SP- 0.390455SP^2-5.51788SK+ 0.009148SK^2 + 0.009148SK^2-18.1294FN- 0.795986FN^2 + 6.178069FP- 0.095121FP^2 + 9.830541FK- 0.015295FK^2 + 0.086944FNSN - 0.134866FPSP- 0.013122FKSK$	75.69	0.870
SN as OC	$Y= 2099.622 - 301.4055OC - 32.7898OC^2 + 21.8684SP- 0.262760SP^2 - 5.43882SK+ 0.008455SK^2 - 2.30435FN - 0.282761FN^2 + 4.834628FP - 0.072391FP^2 + 8.369590FK - 0.012349FK^2 + 3.620302FNOC - 0.088414FPSP$	74.30	0.862
With 17 variables SN as available N	$Y=3091.128 - 4.98299SN+ 0.005622SN^2 + 29.22676SP - 0.385797SP^2 - 5.285995SK+ 0.0088SK^2 - 6.50268FN - 1.37673FN^2 + 4.406830FP - 0.02888FP^2 + 9.537842FK - 0.015267FK^2 + 0.092638FNSN - 0.152842FPSP - 0.012616FKSK + 0.039143FYM - 0.000005FYM^2$	78.15	0.884
SN as OC	$Y= 2018.953 + 318.5656OC - 84.0930OC2 + 22.82033SP - 0.265226SP2 - 5.07783SK + 0.007993SK^2 + 4.13558FN - 0.660480FN^2 + 3.014144 FP - 0.014007FP^2 + 8.10048FK - 0.012263FK^2 + 5.657801OCFN - 0.094717FPSP - 0.010982FKSK + 0.028401FYM - 0.000003FYM^2$	75.86	0.871

For economic yield the above equations become

FP = 32.47 - 0.709 SP-R

FK = 321.36 - 0.429 SK-R

where R is the ratio of cost of one kg of fertilizer P and fertilizer K respectively to kg of groundnut pod. For calculating the fertilizer P requirements for economic yield, the existing cost of one kg of fertilizer P (Rs. 16.22), fertilizer K (Rs.7.77) and price of one kg of groundnut pod (Rs.10) were taken into account. The fertilizer P and K derived from the above equations is the optimum dose of fertilizers (kg ha^{-1}) for maximum profit per ha at a given STV for available P and K. By using the above equations ready reckoners were prepared (Tables 40 and 41).

The results furnished in the Table 40 clearly indicate and that for a range of 5 to 25 kg ha^{-1} available soil P the fertilizer requirement reduced from 28.93 to 14.75 kg ha^{-1} for maximum yield and from 27.31 to 9.58 kg ha^{-1} for economic yield.

The data from the Table 40 denotes that for a range of 50 to 250 kg ha^{-1} available soil K, the fertilizer requirement reduced from 299.9 to 214.10 for maximum yield and from 299.82 to 213.32 kg ha^{-1} for economic yield.

In models with 17 variables comprising of linear and quadratic terms of FYM variable had good predictability of 78.15 per cent. In this model also the FP and FK followed the normal or (+, -, -) type of response. For FN the response was (-, -, +). Hence optimization of FP and FK was done. The above model with available N as a measure of OC also follows the same trend and it has got a predictability of 75.98 per cent. So model with 78.14 per cent predictability was chosen for the optimization of equations.

By differentiating the regression equation partially with respect to FP and FK, the soil test based fertilizer adjustment equation for recommending phosphorus and potassium fertilizers were derived as

FP = 76.27 - 2.645 SP

FK = 312.37 - 0.413 SK

Table 40. Fertilizer P and K requirement for maximum and economic pod yield at varying levels of available P and K in soil using model with 15 variables

Available P (kg ha^{-1})	Fertilizer P (kg ha^{-1})		Available K (kg ha^{-1})	Fertilizer K (kg ha^{-1})	
	For maximum yield	For economic yield		For maximum yield	For economic yield
5	28.93	27.31	50	299.90	299.82
10	25.38	23.76	100	278.00	277.90
15	21.84	20.22	150	257.00	256.20
20	18.29	16.67	200	235.60	234.80
25	14.75	13.13	250	214.10	213.32

The FP and FK derived from the above equations is the optimum dose of fertilizer P and K (kg ha^{-1}) for maximum pod yield (kg ha^{-1}) for groundnut at a given soil test value (kg ha^{-1}). The above equations implied that the yield increased as long as the condition in the equations below is satisfied.

$FP \leq 76.27 - 2.645\ SP$

$FK \leq 312.37 - 0.413\ SK$

At higher levels of FP and FK above this level, the pod yield will decrease. In other words the fertilizer P has to be applied to the soil upto the level of 28.84 kg ha^{-1} available P and 756.34 kg ha^{-1} available K.

For economic yield the above equations become

$FP = 76.27 - 2.645\ SP\text{-}R$

$FK = 312.37 - 0.413\ SK\text{-}R$

where R is the ratio of cost of 1 kg fertilizer nutrient (P or K) to cost of 1 kg pod. For calculating the fertilizer P requirements for economic yield, the existing cost of one kg of fertilizer P (Rs.16.22), fertilizer K (Rs.7.77) and price of one kg of groundnut pod (Rs.10) were taken into account. The fertilizer P and K derived from the above equations give the optimum doses of fertilizer P and K (kg ha^{-1}) for maximum profit per ha at a given STV. By using the above equations ready reckoners were prepared (Table 41).

The results from the Table 41 denotes that for a range of 5.00 to 25.00 kg ha^{-1} available soil P the fertilizer requirement reduced from 63.05 to 10.15 kg ha^{-1} for maximum yield and from 61.43 to 8.53 kg ha^{-1} for economic yield.

The data from the Table 4.34 indicates that for a range of 50.00 to 250.00 kg ha^{-1} available soil K, the fertilizer requirement reduced from 291.72 to 209.12 for maximum yield and 290.90 to 208.34 for economic yield.

4.2.8.2 Optimisation of Fertilizer Doses for Different Yield Targets - Targeted Yield Model

The relationship between the yield of a crop and uptake of a nutrient will usually be linear in the normal range of soil nutrient status and fertilizer application. To obtain economic produce (yield) a definite amount of nutrient should be taken up

Table 41. Fertilizer P and K requirement for maximum and economic pod yield at varying levels of available P and K in soil using model with 17 variables

Available P (kg ha^{-1})	Fertilizer P (kg ha^{-1})		Available K (kg ha^{-1})	Fertilizer K (kg ha^{-1})	
	For maximum yield	For economic yield		For maximum yield	For economic yield
5	63.05	61.43	50	291.72	290.90
10	49.85	48.23	100	271.07	270.29
15	36.60	34.98	150	250.42	249.64
20	23.37	21.75	200	229.77	228.99
25	10.15	8.53	250	209.12	208.34

by the crop. Once this requirement is known for a given yield, the fertilizer required can be estimated taking into account the efficiencies of contribution of nutrients from the soil and fertilizer. The basic parameters needed for a given soil type to estimate optimum fertilizer dose for a yield target in an agroclimatic condition are

1) Nutrient requirement (NR) per unit of produce (economic part)
2) Per cent contribution of nutrients from the soil (CS)
3) Per cent contribution of nutrients from the fertilizer (CF).

The above values are calculated using the formula represented in Chapter 3.4.1 and were presented in Table 42.

Table 42. Basic data required for computing targeted yield equations

Nutrients	NR (kg t^{-1})	CS (%)	CF (%)	COM (%)
N	49.46	28.11	45.61	71.20
P	4.25	7.70	11.18	9.13
K	19.52	6.88	27.33	41.86

4.2.8.2.1 Nutrient Requirement of Groundnut

The computed values showed that groundnut variety. TAG-24 required 49.46 kg N, 4.25 kg P and 19.52 kg K ha^{-1} to produce one tonne of pod (Table 42).

4.2.8.2.2 Soil and Fertilizer Efficiencies

Soil and fertilizer efficiencies were worked out using the formulae given under chapter 3.4.1.2 and 3.4.1.3. The soil efficiencies were 28.11, 7.70 and 6.88 per cent of N, P and K respectively and the fertilizer efficiencies were 45.61, 11.18 and 27.33 per cent N, P and K respectively (Table 42). It was observed that the contribution from fertilizer was higher than that from soil.

4.2.8.2.3 Organic Manure Efficiency

The organic manure efficiency, COM for N, P and K were computed using the formula given under the chapter 3.4.1.4. The computed values for organic manure efficiency were 71.2, 9.13 and 41.86 per cent for N, P_2O_5 and K_2O respectively (Table 42).

4.2.8.2.4 Fertilizer Prescription for Targeted Yield of Groundnut

The fertilizer prescription equations were developed for N, P and K by substituting corresponding NR, CS, CF and COM values in targeted yield equations.

Fertilizer prescription equations for groundnut without FYM can be represented as

FN = 108.44 T - 0.616 SN

FP = 38.01 T - 1.577 SP

FK = 71.43 T - 0.305 SK

Where

FN, FP and FK are fertilizer N, P and K in kg ha^{-1} respectively

SN, SP, SK are soil available N, P and K in kg ha^{-1} respectively.

T - Target of pod yield in t ha^{-1}

With FYM, the equations were as given below:

FN = 108.44 T - 0.616 SN - 1.59 ON

FP = 38.01 T - 1.577 SP - 1.87 OP

FK = 71.43 T- 0.305 SK - 1.853 OK

where ON, OP and OK are quantities of N, P and K in kg ha^{-1} supplied through organic manure. In Kerala similar fertilizer prescription equations for specific yield targets have been developed for rice (Swadija *et al.*, 1993), cassava (Swadija, 1997), ginger (Jayalakshmi, 2001) and coleus (Nagarajan, 2003).

The fertilizer recommendations based on the above equations are more quantitative, precise and meaningful because the combined use of soil and plant analyses is involved in it. Based on targeted yield equations, ready reckoners were prepared for recommending fertilizer dose for specific yield targets of groundnut at varying STVs (Table 43, 44 and 45).

Table 43. Quantity of fertilizer nitrogen required for different yield targets of groundnut

Soil available N (kg ha^{-1})	Fertilizer to be applied (kg ha^{-1})				
	1 t ha^{-1}	1.5 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
100	16.80	101.06	155.28	209.50	263.72
150	16.00	70.26	124.48	178.70	232.92
200	-	39.46	93.68	147.90	202.12
250	-	8.66	62.88	117.10	171.32
300	-	-	32.08	86.30	140.52

Table 44. Quantity of fertilizer phosphorus required for different yield targets of groundnut

Soil available P (kg ha^{-1})	Fertilizer to be applied (kg ha^{-1})				
	1 t ha^{-1}	1.5 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
8	25.39	44.40	63.40	82.41	101.41
11	20.66	39.67	58.67	77.68	96.68
15	14.36	33.37	52.37	71.38	90.38
18	9.62	28.63	47.63	66.64	85.64
20	6.47	25.48	44.48	63.49	82.49

Table 45. Quantity of fertilizer potassium required for different yield targets of groundnut

Soil available K (kg ha^{-1})	Fertilizer to be applied (kg ha^{-1})				
	1 t ha^{-1}	1.5 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
150	25.68	61.40	97.11	132.83	168.54
200	10.43	46.15	81.86	117.58	153.23
250	-	30.90	66.61	102.33	138.04
300	-	15.65	51.36	87.08	122.79
350	-	0.4-0	36.11	71.83	107.54

Discussion

5. DISCUSSION

5.1 FERTILITY GRADIENT EXPERIMENT

5.1.1 Soil Fertility Status before and after FGE

The soil fertility gradient created from strip I to IV was confirmed by assessing the soil nutrient status prior to the conduct of FGE and just after the harvest of the gradient crop (fodder maize). The data on soil analysis was furnished in Table 8. The statistical analysis of the data showed that needed gradient has been created after FGE (Table 8). The data on the analysis of the soil samples after FGE revealed that the organic carbon content of the soil slightly declined in all the strips (Table 8). This may be due to the tendency of the soil to maintain a constant C: N ratio.

From the Table 8, it was evident that there was a decline in the status of available N after the FGE at both depths. Generally the N content of the soil increased from strip I to III and thereafter a decline was noted. This may be due to increased uptake of N by fodder maize and high rate of mineralization at the high doses of fertilizer application.

While considering the available P after FGE, the P status of the soil increased in all the strips than the initial contents which may be due to the heavier dose of P application. There was an increase in available P in strip I after FGE even without any application of P. This might be due to the fact that maize roots forage P from deeper layers and concentrate it in the surface soil.

The available K content after FGE increased from strip I to IV (Table 8). This might be due to the application of heavier doses of K over and above the K fixing capacity to the soil. During the experimental period the rainfall received was only 3454.00 mm. Hence the chances of leaching loss was less and applied K might have been retained in available form in the soil. The fertility gradient, after FGE was illustrated in Fig. 5. From the figure it was seen that there was creation of gradient in N and P. The fertility gradient was steep for K compared to P. The creation of such fertility gradient has been already reported (Jayalakshmi, 2001 and Nagarajan, 2003).

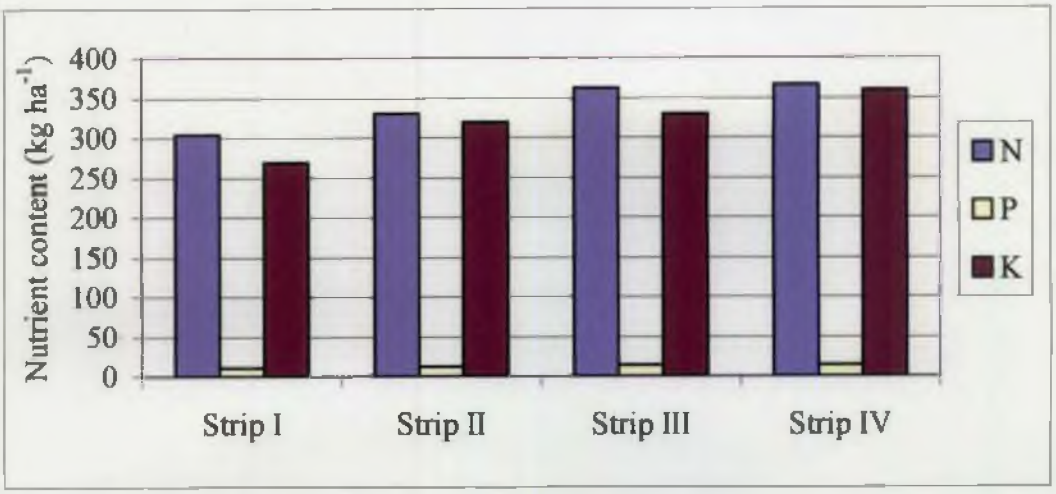

Fig. 5. Nutrient status of soil after fertility grading experiment

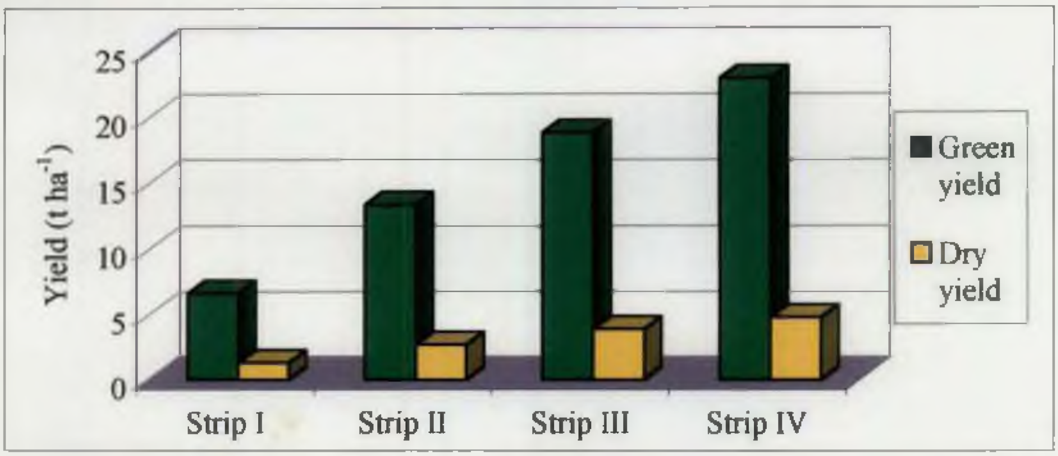

Fig. 6. Yield of fodder maize as influenced by treatments

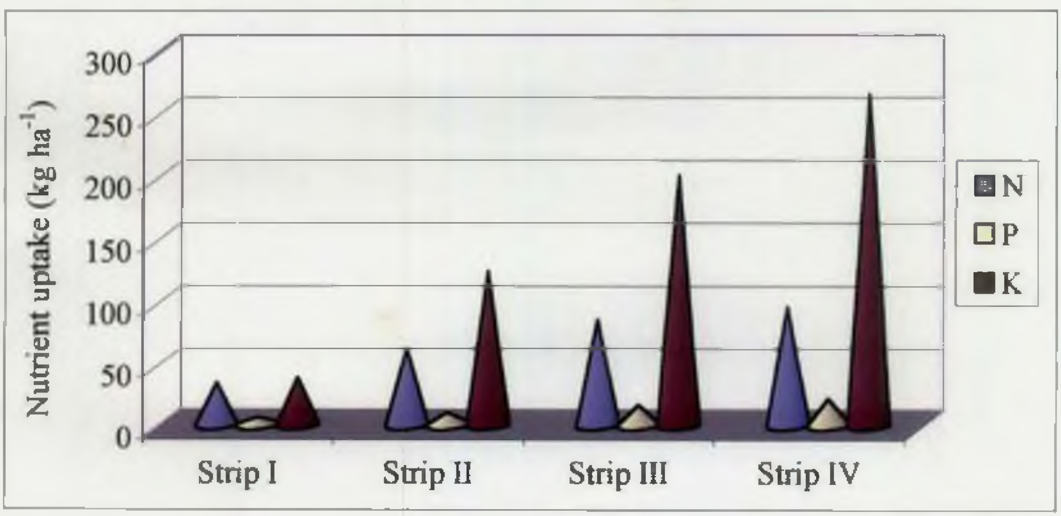

Fig. 7. Uptake of nutrients by fodder maize

The results of analysis of variance also confirmed that significant variation in soil fertility has been created in all the strips for all the nutrients.

5.1.2 Yield and Uptake of Nutrients by Gradient Crop

As evident from Table 9 the green and dry fodder yields increased progressively from strip I to IV in accordance with the gradient in fertilizer application (Fig. 6). Among the three nutrients the uptake of potassium was found to be steep (Fig. 7). Crop yield is a function of soil fertility under optimal levels of other production factors. Thus the buildup of a gradient in soil fertility is reflected in the crop response data (Fig. 5 and 6).

5.2 STCR EXPERIMENT

5.2.1 Pre-planting Soil Analysis

The results furnished in Tables 12, 13, 14 and 15 showed that necessary gradient in soil fertility was created in the field for conducting the STCR experiment.

5.2.2 Yield of Groundnut

As evident from the data, the control plots in all the strips registered much lower yields than treated plots (Table 17 and Fig. 8). This might be due to the fact that the control plots depend upon only the soil available nutrients in the absence of applied nutrients.

Considering the strip wise yield, the pod yield increased progressively from strip I to III and decreased in strip IV. It showed a differential response of nutrients to yield in different fertility levels. In low to medium fertile soil the response was high and consequently the yield was also high. In high fertile soil (strip IV) the response was low and it was reflected in the yield also. This may be due to the operation of law of diminishing returns. Similar results were also obtained by Swadija (1997), Jayalakshmi (2001) and Nagarajan (2003). In high fertility level (strip IV), a good amount of photosynthates might have been diverted for increased top growth resulting in reduced pod yield.

5.2.3 Nutrient Uptake by Groundnut

The total nutrient uptake of N, P and K by groundnut was calculated separately and presented in the Table 24 and Fig. 9. Among the three nutrients highest uptake was registered by N followed by K and P (Table 24). Application of P and K increased N uptake (Kulkarni *et al*., 1986). Increased K uptake was due to higher doses of fertilizer K.

In general the uptake of nutrients increased from strip I to IV which could be attributed to the increased availability of nutrients from the soil due to fertility gradient created from strip I to IV.

5.2.4 Post Harvest Soil Analysis

From the data furnished in Table 31, it was observed that the organic carbon content decreased. But in the case of N, the depletion was less, and it was observed that on an average the depletion of available N from the soil was 8 kg due to groundnut cropping (Table 31). Being a legume crop, groundnut can fix atmospheric N in the root nodules. Groundnut could fix atmospheric N to the extend of 200 to 260 kg ha^{-1} (Williams, 1979). This might be the reason for low depletion of soil N.

Compared to preplanting soil analysis (Table 16), there was a decline in the available P after STCR experiment (Table 31). This is due to the uptake of P by groundnut. Being a oil seed crop rich in protein and oil, groundnut needed relatively more P (Rajendran and Lourduraj, 1998).

There was a greater depletion of K from the soil after STCR experiment (Table 31 and Fig. 10). Groundnut is a heavy feeder of K and absorbs K excessively. Potassium nutrition had favourable impact on photosynthesis and translocation of leaf reserves to developing pods (Koch and Mengal, 1977). During the growth period of test crop irrigation was given at frequent intervals. Hence there were chances of leaching loss of K.

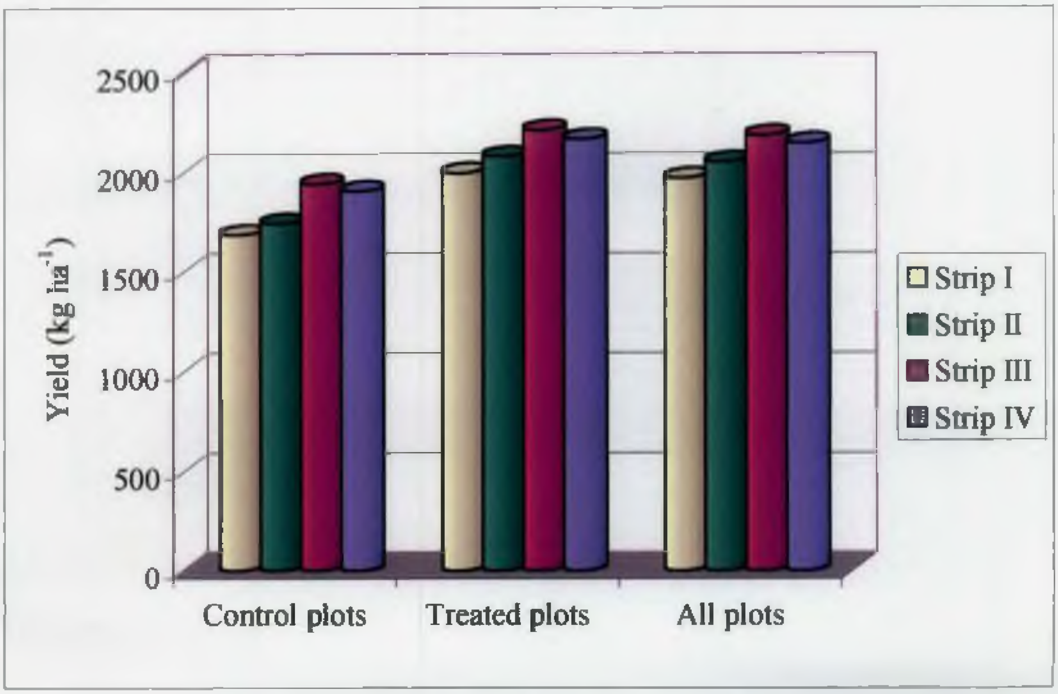

Fig. 8. Pod yield of groundnut influenced by treatments

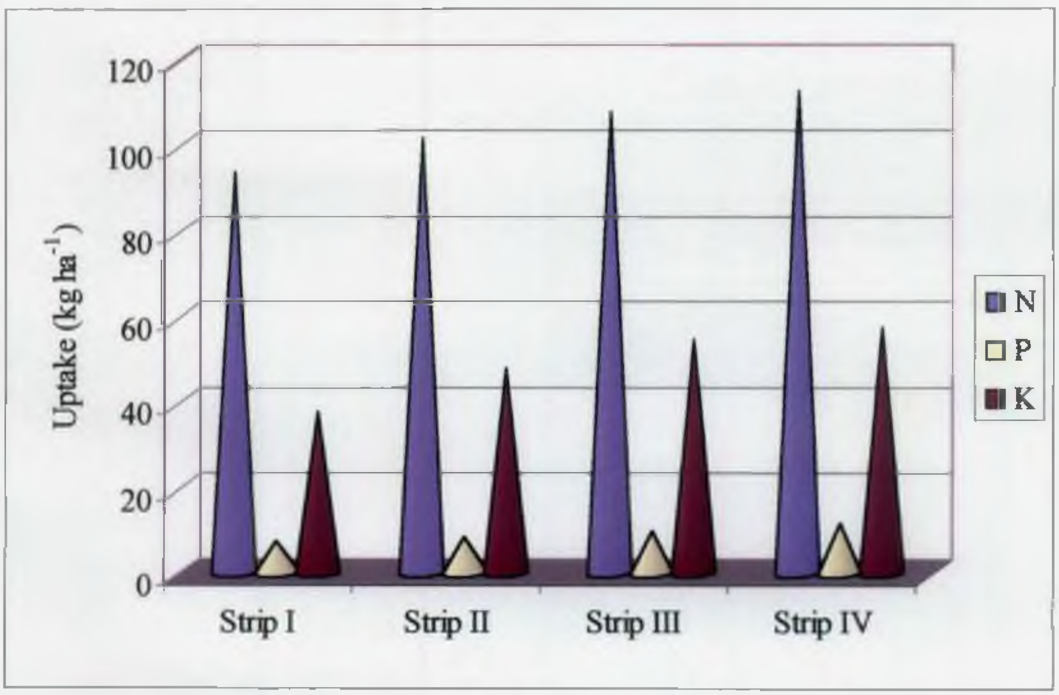

Fig. 9. Nutrient uptake of groundnut as influenced by treatment

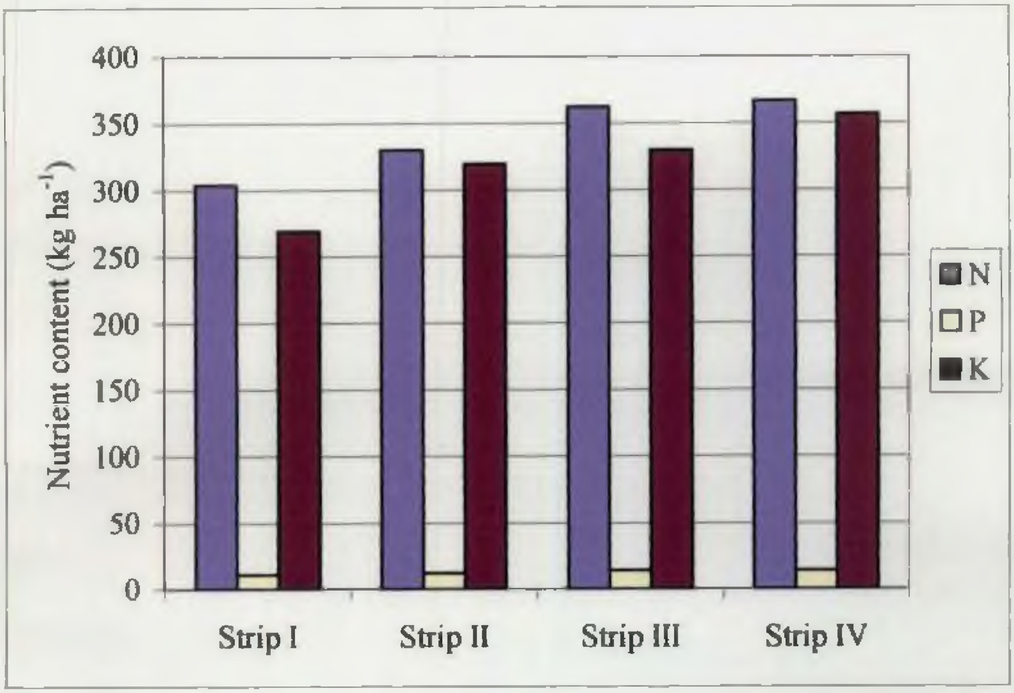

Fig. 10. Nutrient status of soil after STCR experiment

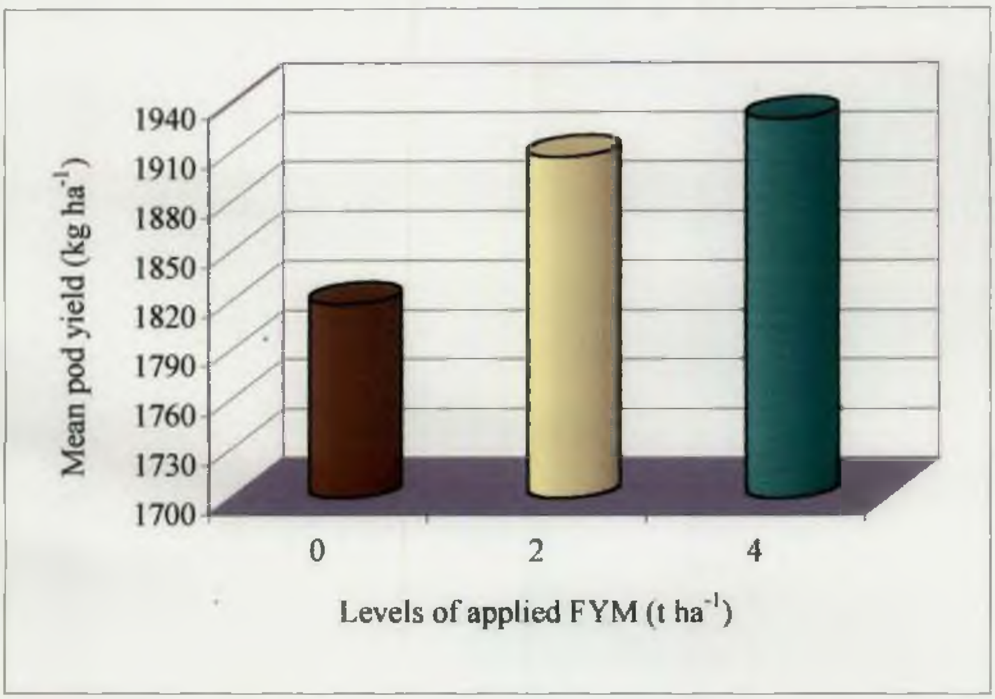

Fig. 11. Response of groundnut to applied FYM

5.2.5 Correlation Studies

5.2.5.1 Nutrient uptake and Yield

Pod yield was positively correlated with uptake of nutrients. This corroborates with the findings Boopathi (2003). Among the three nutrients, uptake of N was found to be high compared to P and K (Table 32). The combined application of chemical fertilizers along with FYM has always stimulated the uptake of N (Anandswarup *et al.*, 1998) and partially because of stimulated microbial flourish and improved root growth due to congenial soil physical condition created by addition of FYM (Golakiya, 1988). From the Table 32, it is evident that after N, uptake of P had a pronounced influence on the yield. This is because being an oil seed crop rich in protein, groundnut need relatively more P (Rajendran and Lourduraj, 1988). Yield was possitively correlated with P uptake (Sagare *et. al* 1986). The increase in the uptake of nutrients by groundnut crop appears to be due to cumulative effect of increased yield of pod and haulm. Similar results were reported by Chawale *et al.* (1993), Trivedi *et al.* (1995) and Ramesh *et al.* (1997). There was an increased uptake of P. This was due to the presence of soluble $CaPO_4$ which enhanced the uptake of phosphorus by groundnut. This was in conformity with the findings of Bheemia and Ananthanarayana (1984). Compared to N and P, the uptake of K was low. This may be due to some antagonistic effect of other nutrients especially Ca. Calcium was applied to groundnut crop as lime at 50 per cent flowering stage. This could have lead to reduced uptake of K by competitive inhibition of applied Ca (Singh and Agarwal, 1976).

5.2.5.2 Nutrient uptake and Yield with Available and Applied Nutrients

The correlation between nutrient uptake and soil available nutrients was high because the pre planting soil fertility status was little higher (Table 33). This might be due to the fact that as availability increased the uptake also increased resulting in increase yield. As per the usual agronomic practices, liming was done in the field. From the Table 33 it was found that available N is highly correlated with uptake. This was due to the synergistic effect between Ca and N due to higher nitrification in limed soil. Similar findings were reported by Soundararajan *et al.*

(1984). It was reported that Ca has a synergistic effect on the uptake of P (Tisdale *et al.*, 1993). This also may be a reason for increase in yield. With the applied nutrients, the uptake was found to be increased. A stimulated growth under the application of fertilizers might have resulted in better proliferation of root systems and increase uptake of nutrients which in turn resulted an increase in yield. Generally the application of P and K fertilizer improved N uptake with or without FYM (Kulkarni, 1986., Balasubramaniyan,1997 and Patel and Thakur, 1997b).

The uptake of K was found to be low with application of fertilizer P compared to that of available P. This can be substantiated from the results of Patel and Patel (1988).

Higher positive correlations were obtained for yield with N, P and K content of haulm, shell and kernel. This is because of N is the major structural constituent of plant cell and plays an important role in plant metabolism (Mahapatra *et al.*, 1985). K is important for photosynthesis and translocation of leaf reserves to developing pods (Koch and Mengal, 1977).

All the applied nutrients showed a significant positive correlation with yield. Among the three available nutrients P was found to be highly correlated with yield (Table 33). From the table it is evident that available potassium has no correlation with yield, this is because of the fact that potassium is susceptible to leaching loss and may not be available to the crop.

5.2.6 Path Coefficient Analysis

5.2.6.1 Path Coefficient Analysis of Soil Nutrients with Yield

The analysis was conducted with pod yield and nutrient content like OC, soil available N, P and K before and after the STCR experiment. The soil N exhibited a high positive direct effect on yield followed by P. This indicated that the higher available N content in soil directly influenced the yield. The higher values of correlation coefficient also supported the results (Table 35 and 36). The results also showed that the contribution of N from soil was higher when it was worked out for targeted yield equation (Table 42).

5.2.7 Response of Groundnut to FYM

The data obtained from plots which received FYM alone at different levels with no fertilizer was given in Table 37 and Fig 11. The data indicated that higher yields were obtained from the plots which received FYM alone. This is because of the fact that presence of nutrients like N, P and K in FYM and improvement in physico-chemical properties of soil might have resulted in higher yield in FYM treated plots.

5.3 SOIL TEST CALIBRATION STUDIES

The calibration of soil test values would be more useful for the farmer to obtain site specific fertilizer prescription for the crops to get maximum and economic yield. The balanced use of soil and fertilizer nutrients can be achieved through soil test based fertilizer recommendation.

5.3.1 Optimization of Fertilizer based on Multiple Regression Analysis

By utilizing the soil test values, quantity of inorganic fertilizers and resultant pod yield of groundnut, multiple regression models were developed. As the percent of variance increased, the precision of the equation also increased. Higher percentage variance explained is important to explain the variation in yield by available and applied nutrients. Among the different models developed one with 15 variables comprising of linear, quadratic and interaction terms of soil available and fertilizer N, P and K nutrients including the linear and quadratic terms of FYM variable had got high per cent of variance explained (75.69%) (Table 39).

In the above model with 15 variables, only P and K had showed the normal (+, -, -) type of response to linear, quadratic and interaction terms. Hence the optimization of fertilizer dose was done only for P and K. From the regression equation, soil test based fertilizer adjustment equation for recommending P and K dose was derived by partial differentiation.

The fertilizer prescription equation for P and K can be given as

FP = 32.47 – 0.709 SP-R

FK = 321.36 - 0.429 SK-R

By using the above equation, ready reckoners were made for different STVs of P and K (Table 40) for getting maximum and economic yield. For getting the economic yield we have to subtract the R value (ratio of cost of per kg fertilizer nutrient to cost of 1 kg pod). In the present study we considered the cost of 1 kg fertilizer phosphorus as Rs.16.22 and that of fertilizer potassium as Rs.7.77 and 1 kg pod as Rs. 10.00.

Equations were also made with 17 variables. This model got 78.14 per cent variance explained, which was also good. Here also only P and K followed the normal (+, -, -) response type. Hence equations were made for P and K by partial differentiation of the regression equation.

The fertilizer prescription equations for P and K for maximum yield are given below:

FP = 76.27 – 2.645 SP

FK = 312.37 - 0.413 SK

For economic yield the equation will be as given below

FP = 76.27 - 2.645 SP-R

FK = 312.37 - 0.413 SK-R

where R is the ratio of the cost of one kg of fertilizer nutrient to cost of 1 kg pod yield. The existing price of 1 kg fertilizer phosphorus (Rs.16.22) and 1 kg fertilizer potassium (Rs.7.77) and price of 1 kg pod (Rs.10) were taken into account. By using the above equations, ready reckoners were developed (Table 41).

5.3.2 Optimization of Fertilizer Doses for Specific Yield Targets

The optimum use of fertilizers mainly depends on the inherent capacity of the soil to supply the native nutrient, the efficiency of applied nutrients and the crop yield (Randhawa and Velayutham, 1982; Velayutham *et al.*, 1985). The concept of fertilizer prescription for specific yield target (Troug, 1960 and Ramamoorthy *et al.*, 1967) not only embraces the above aspects but also ensures both high yields and the maintenance of soil fertility to support a sustained crop production. The theoretical basis involved in this concept of predicting fertilizer needs for crop is well explained under section (4.2.7.2).

The basic parameters used for optimising the fertilizer doses are nutrient requirement (NR), soil efficiency (CS), fertilizer efficiency (CF) and organic manure efficiency (COM) (Ramamoorthy and Velayutham, 1971). The nutrient requirement values indicated that groundnut requires 49.46, 4.25 and 19.52 kg ha^{-1} N, P and K respectively, to produce one tonne of pods (Table 42 and Fig. 12). These results revealed that compared to N and K, P requirement was low for groundnut. This corroborates the findings of Kasap *et al.* (1999).

In the present investigation, the soil and fertilizer efficiencies were determined by whole field method developed in the All India Coordinated Research Project on STCR correlation studies (Ramamoorthy *et al.*, 1967). The data from the Table 42 and Fig 13 showed the fertilizer efficiencies of 45.61, 11.18 and 27.33 per cent in the case of N, P and K respectively, which were higher than the soil efficiencies of 28.11, 7.70 and 6.88 per cent (Table 42 and Fig.14.). The results revealed the need for the application of more amount of N, P and K fertilizer for groundnut crop. In tropical soil there is high rate of volatilization loss of N in gaseous form (Balasundaram, 1978). More over the high temperature in tropical region might have augmented the decomposition of organic matter and volatalization loss of N (Dalzell *et al.*, 1987). The P fixing capacity of sandy loam soil was very high. Hence the available P in the soil decreased. Compared to other nutrients, K is highly susceptable to leaching loss. In the field supplemented irrigation was done. This might have enhanced the leaching of nutrients leading to low contribution of nutrients from the soil.

Contribution of nutrients from organic manure showed that N supply (71.20%) was higher than K (41.86%) followed by P (9.13%) (Table 42). This data

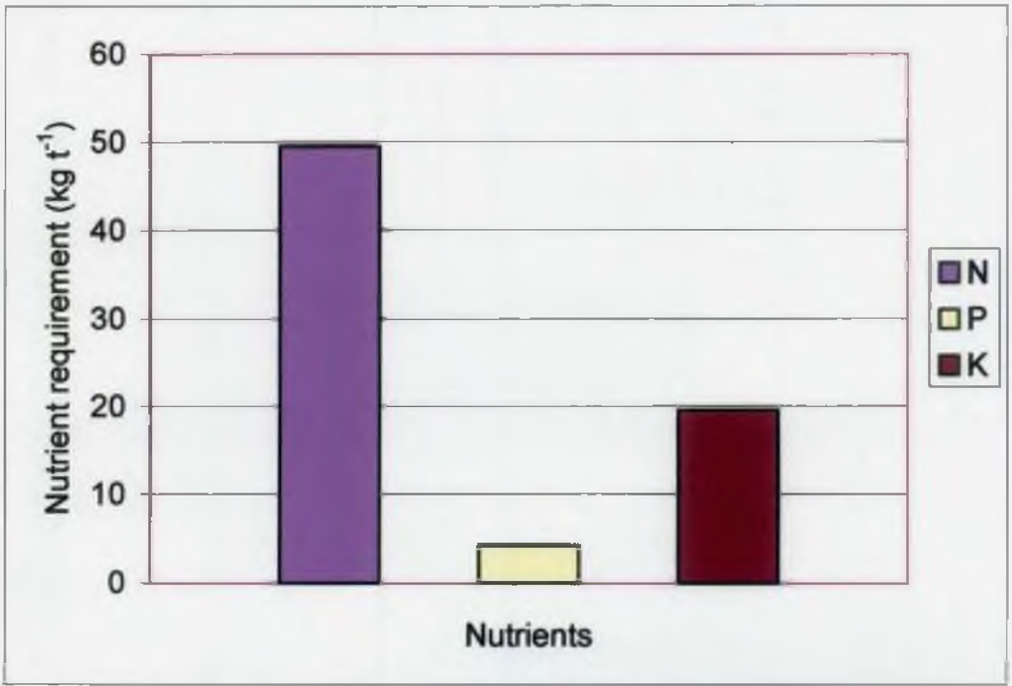

Fig. 12. Nutrient requirement of groundnut

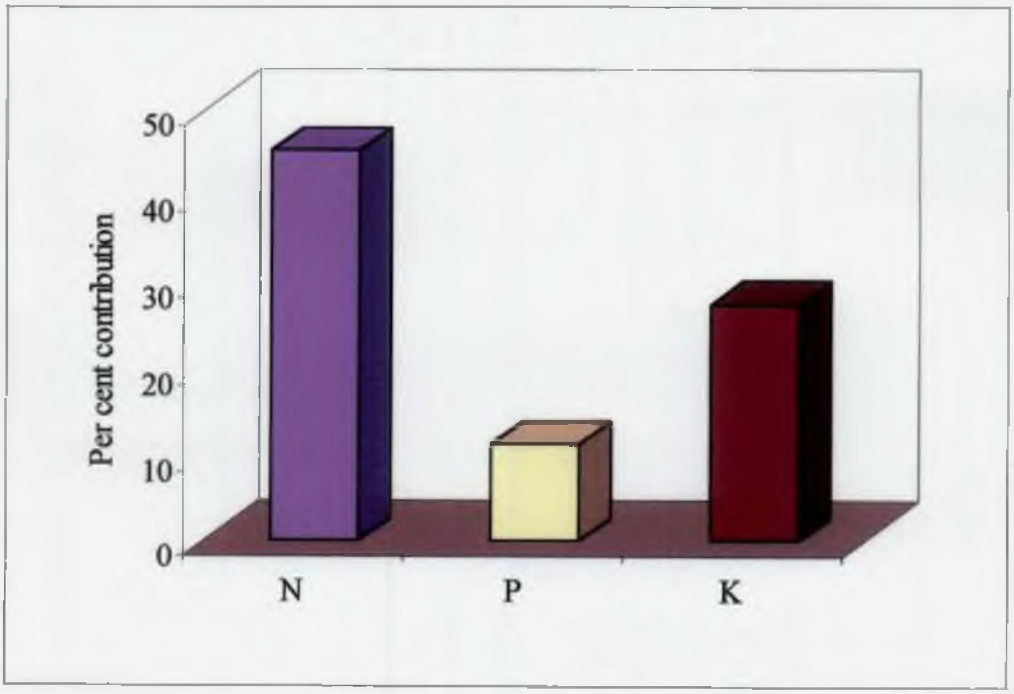

Fig. 13. Contribution of nutrients (%) from fertilizer

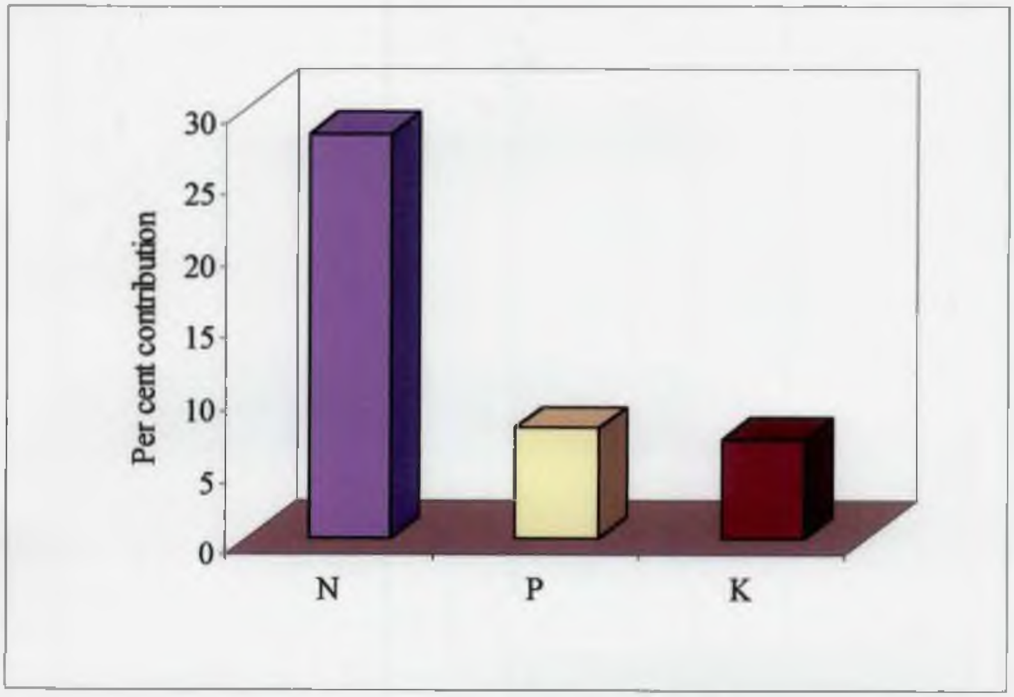

Fig. 14. Contribution of nutrients (%) from soil

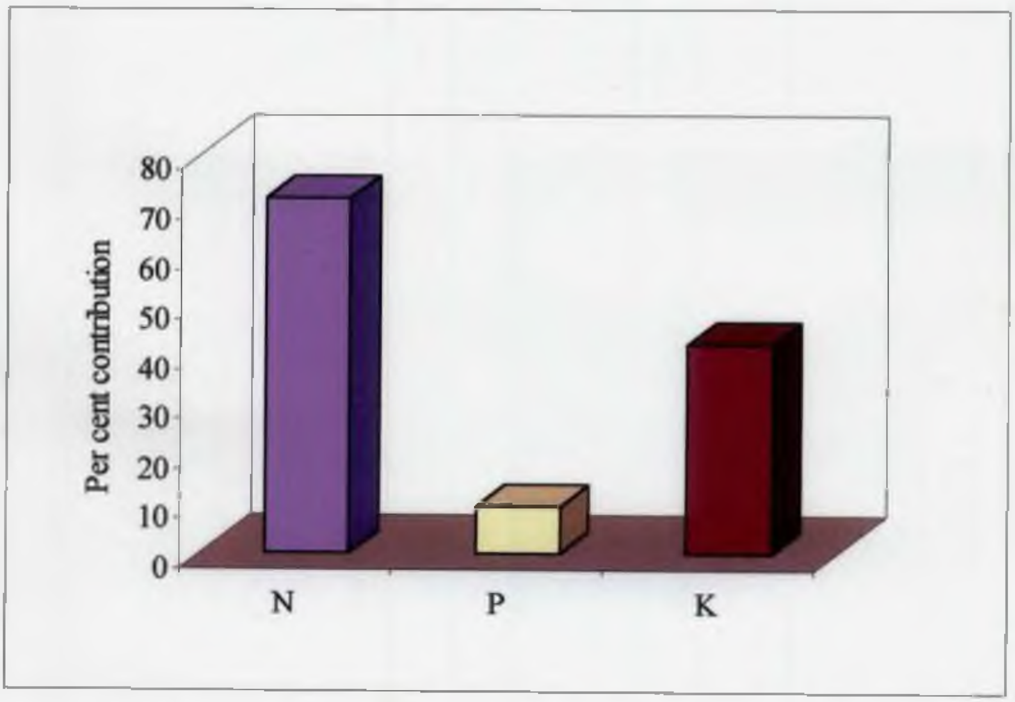

Fig. 15. Contribution of nutrients (%) from Organic manure

revealed that response of groundnut to FYM was considerable especially with respect to N (Fig. 15).

5.3.3 Fertilizer Prescription for Targeted Yield of Groundnut

The parameters mentioned earlier viz., NR, CS, CF and COM were used for computing the prescription equations of N, P_2O_5 and K_2O for groundnut crop. The fertilizer prescription developed based on the targeted yield concept is more quantitative, precise and meaningful because both soil and plant analysis are involved for deriving the equation.

The combined use of organic manure and fertilizers will lead to a considerable saving in fertilizers as is evident from targeted yield equations with FYM. This was confirmed by the findings of Prasad and Prasad (1993) and Santhi (1995), Swadija (1997), Jayalakshmi (2001) and Nagarajan (2003). The presence of nutrients like N, P and K in FYM and the improvement in physico-chemical properties of soil enhanced the use efficiency of the nutrients.

Based on targeted yield equations, ready reckoners can be prepared for recommending fertilizer dose either as inorganic alone or in combination with organics for specific yield targets of groundnut at varying STVs.

The ready reckoner values show that, increase in the soil test values corresponds to decrease in the fertilizer doses for N, P and K. From the ready reckoner, we can find out the fertilizer doses based on site specific soil test values (Table 43, 44 and 45). For example, if the STV for K is 400 kg ha^{-1}, we can produce upto 1.5 t pod ha^{-1} without adding potash fertilizers. Thus fertilizer recommendation based on this approach is meaningful, precise and more quantitative, resulting in reduction in cost of fertilizer for farmers.

Summary

6. SUMMARY

Fertilizer application is one of the most efficient means of increasing agricultural profitability. Without the prior knowledge of soil fertility status and nutrient requirements of crops, application of fertilizers by the farmers might result into adverse effect on soil as well as on crops both in terms of nutrient deficiency and toxicity either by inadequate use or over use. So the emphasis on soil test based fertilization has become much more relevant in the present scenario of high fertilizer costs and yield maximisation programmes.

Investigation entitled 'Soil test crop response studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala' was conducted during 2003-2004 in the farm associated with College of Horticulture, Vellanikkara.

The field experiment consist of a FGE and STCR experiment using fertilizers and organic manure. The FGE was conducted during July-September 2003 in the farm attached to College of Horticulture. The objective of this experiment was to create a fertility gradient by applying graded doses of N, P and K fertilizer and raising exhaustive crop, fodder maize variety Co-1 in one and the same field. The soil nutrient status before and after the experiment were analysed for both FGE and STCR. The soil nutrient status, fodder yield and nutrient uptake by the gradient crop showed an increasing trends by strip I to IV.

The STCR experiment was conducted during November 2003 to February 2004 with test crop groundnut variety TAG-24. The treatment structure consisted of four levels of nitrogen (0, 5, 10 and 20 kg ha^{-1}), three levels of phosphorus (0, 40 and 80 kg ha^{-1}) and five levels of potassium (0, 37.5, 75, 150 and 300 kg ha^{-1}) along with three levels of FYM (0, 2 and 4 t ha^{-1}). The results of the experiment are summarised below:

The pod yield increased from strip I to III (1969.32, 2048.60 and 2181.25 kg ha^{-1}) and showed a decline in strip IV (2141.88 kg ha^{-1}), which has got higher fertility level. Among the treated plots the maximum yield was obtained in strip III with fertilizer doses of 5, 40 and 150 kg ha^{-1} N, P and K along with four tonnes FYM and having soil test values 409.76, 24.43 and 361.60 kg ha^{-1} N, P and K. The minimum yield was recorded in strip I with fertilizer doses of 5, 40 and 37.50 along with two tonnes FYM with STVs values of 318.54, 13.78 and 291.20 kg ha^{-1} N, P and K

Uptake of N, P and K increased the gradually from strip I to IV. The strip wise mean uptake of nutrients were recorded as 93.27, 101.23, 107.36 and 112.20 kg ha^{-1} N, 7.15, 8.22, 9.84 and 11.38 kg ha^{-1} P and 37.52, 47.57, 54.35 and 57.14 kg ha^{-1} K in strip I, II, III and IV respectively. The uptake of N was maximum followed by K and P.

Optimization of fertilizer doses for different yield targets were worked out for groundnut by using the basic data like nutrient requirement (NR), soil efficiency (CS), fertilizer efficiency (CF) and organic manure efficiency (COM). The nutrient requirements for groundnut variety TAG-24 were estimated as 49.46, 4.25 and 19.52 kg ha^{-1} N, P and K respectively to produce one tonne of pod.

The contribution from soil were worked out as 28.11, 7.70 and 6.88 per cent N, P and K respectively for groundnut variety TAG-24 in laterite soil. In the laterite soil, contribution of nutrients from the fertilizers for groundnut were calculated as 45.61, 11.18 and 27.33 per cent N, P and K. The percentage contribution of nutrients from FYM were estimated as 71.20, 9.13 and 41.86 per cent.

The fertilizer prescription equations for specific yield targets of groundnut variety TAG-24 in laterite soil were derived as follows:

$$FN = 108.44\ T - 0.616\ SN$$

$$FP = 38.01\ T - 1.577\ SP$$

$$FK = 71.43\ T - 0.305\ SK$$

where FN, FP and FK = Fertilizer N, P_2O_5 and K_2O in kg ha^{-1}

T = Target yield in t ha^{-1}

SN, SP and SK = Soil available N, P and K kg ha^{-1}

With FYM the above equations become

$$FN = 108.44\ T - 0.616\ SN - 1.59\ ON$$

$$FP = 38.01\ T - 1.577\ SP - 1.87\ OP$$

$$FK = 71.43\ T - 0.305\ SK - 1.853\ OK$$

ON, OP and OK = Quantities of N, P and K supplied through organic manure in kg ha^{-1}

Multiple regression models were calibrated with 15 variables and 17 variables using SN as available N along with linear and quadratic interaction of FYM. The model with 15 variables has got predictability of 75.69 per cent and with 17 variables the predictability was 78.15 per cent. Among the three nutrients P and K followed the normal (+, -, -) type response. So the equations were developed for these two nutrients for models with 15 and 17 variables. The equations are given below:

With 15 variables

$$FP = 32.47 - 0.709\ SP$$

$$FK = 321.36 - 0.429\ SK$$

With 17 variables

$$FP = 76.27 - 2.645\ SP$$

$$FK = 312.37 - 0.413\ SK$$

Simple correlation coefficient were worked out for nutrient uptake and soil available and applied nutrient with yield. All the available nutrients showed the positive correlation than applied once. Uptake of nutrients also highly correlated with yield.

The study is useful to adopt the fertilizer doses between specific objective and available resources of groundnut farmer of the state.

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SOIL TEST CROP RESPONSE STUDIES ON GROUNDNUT (*Arachis hypogaea* L.) IN LATERITE SOILS OF KERALA

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ABSTRACT OF THE THESIS

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ABSTRACT

The investigation entitled "STCR studies on groundnut (*Arachis hypogaea* L.) in laterite soils of Kerala" was conducted during 2003-2004 in the farm attached to College of Horticulture, Vellanikkara.

Objectives of the study were to develop soil test based balanced fertilizer recommendation for specific yield targets to groundnut in laterite soils of Kerala, and to develop a basis for fertilizer recommendation for maximum and economic pod yield at varying STVs.

The experiment consisted of FGE and STCR experiment. The aim of FGE was to create desired gradient in soil fertility in one and the same field by applying graded doses of N, P and K fertilizers and raising an exhaustive crop, fodder maize Co-1. After development of fertility gradient, the STCR experiment was conducted in the same field with the test crop groundnut variety TAG-24. The soil nutrient status before and after the experiment were analysed for both FGE and STCR.

The nutrient requirements of groundnut variety TAG-24 were estimated as 49.46, 4.25 and 19.52 kg ha^{-1} N, P and K respectively to produce one tonne of pod. The soil efficiencies were worked out as 28.11, 7.70, 6.88 per cent for N, P and K respectively for groundnut in laterite soil. The contribution of nutrients from fertilizers were estimated as 45.61, 11.18 and 27.33 per cent for N, P and K respectively and the contribution from organic manure were 49.46, 4.25 and 19.52 per cent N, P and K respectively to produce one tonne of pod.

Fertilizer prescription equations for specific yield targets of groundnut variety TAG-24 were derived by using the above basic data and the equations were as follows:

Without FYM

$$FN = 108.44\ T - 0.616\ SN$$
$$FP = 38.01\ T - 1.577\ SP$$
$$FK = 71.43\ T - 0.305\ SK$$

With FYM

$$FN = 108.44\ T - 0.616\ SN - 1.59\ OM$$

$$FP = 38.01\ T - 1.577\ SP - 1.87\ OP$$

$$FK = 71.43\ T - 0.305\ SK - 1.85\ OK$$

Multiple regression models were calibrated with yield as dependent variable and soil available and applied nutrients as independent variables. Among the three nutrients, P and K showed normal type (+, -, -) of response in both models with 15 and 17 variables. So equations were calibrated for these two nutrients. The equations were as follows:

With 15 variables

$$FP = 32.47 - 0.709\ SP$$

$$FK = 321.36 - 0.429\ SK$$

With 17 variables

$$FP = 76.27 - 2.645\ SP$$

$$FK = 312.37 - 0.413\ SK$$

Simple correlation coefficient was worked out for nutrient uptake with yield, nutrient uptake and yield with available and applied nutrients and major plant nutrient content with yield.

The study is useful to adjust fertilizer doses based on the specific objective and available resources of groundnut farmers of the state.