SOIL TEST CROP RESPONSE STUDIES ON GINGER IN LATERITE SOILS OF KERALA

By

M. JAYALAKSHMI

THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF HORTICULTURE
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DECLARATION

I hereby declare that this thesis entitled " SOIL TEST CROP RESPONSE STUDIES ON GINGER IN LATERITE SOILS OF KERALA" is a bonafide record of work done by me during the course of research and that the thesis has not previously formed the basis for the award to me for any degree, diploma, fellowship, or other similar title, of any other university or society.

M. Jayalakshmi

Vellanikkara,
29 -09-2001

M. JAYALAKSHMI

Dr. M.A. Hassan,
Associate Professor,
Department of Soil Science and
Agricultural Chemistry,
College of Horticulture,
Kerala Agricultural University,
Vellanikkara.

CERTIFICATE

Certified that this thesis entitled "SOIL TEST CROP RESPONSE STUDIES ON GINGER IN LATERITE SOILS OF KERALA" is a record of research work done independently by **Ms. M. Jayalakshmi**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Dr. M.A. Hassan
(Chairman, Advisory Committee)

CERTIFICATE

We, the undersigned members of the Advisory committee of **Ms. M. Jayalakshmi** a candidate for the degree of Master of science in Agriculture agree that the thesis entitled "Soil Test Crop Response studies on Ginger in laterite soils of Kerala" may be submitted by Ms. M. Jayalakshmi in partial fulfillment of the requirement for the degree.

Dr. M.A. Hassan
Chairman Advisory committee
Associate Professor
Department of Soil Science and
Agricultural Chemistry
College of Horticulture
Vellanikkara

29/9/01

Dr. N.P. Chinnamma
Professor and Head
Department of Soil Science and
Agricultural Chemistry
College of Horticulture
Vellanikkara

29/9/01

Dr. P. Sureshkumar
Assistant Professor
Radio Tracer Laboratory
Department of Soil Science and
Agricultural Chemistry
College of Horticulture
Vellanikkara

29/09/2001

Dr. P.A. Valsala
Associate professor
Department of Plantation
Crops and Spices
College of Horticulture
Vellanikkara

29-09-2001

29/9/01

External Examiner

Dr. G. Selvakumar
Professor (SS&AC)
STCR Project
TNAU

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Plates

List of Abbreviations

AICRP	– All India Coordinated Research Project
ANOVA	– Analysis of variance
CD	– Critical difference
FGE	– Fertility Gradient Experiment
FYM	– Farm Yard Manure
ha	– hectare
IARI	– Indian Agricultural Research Institute
kg	– Kilogram
KAU	– Kerala Agricultural University
K	– Potassium
N	– Nitrogen
OC	– Organic Carbon
POP	– Package of Practices
RBD	– Randomized Block Design
STCR	– Soil Test Crop Response
STL	– Soil Testing Laboratory
STVs	– Soil Test Values
t	– Tonne
TNAU	– Tamil Nadu Agricultural University

INTRODUCTION

CHAPTER-1
INTRODUCTION

Fertilizers play a major role in Agriculture. There is a strong relationship between fertilizer consumption and production of crops. The increased consumption of fertilizers in the country over years, led to the spiraling of fertilizer prices and consequent increase in the production of the crops. Hence there is a need to application of fertilizers, based on the requirement of crops.

The generalized state level fertilizer prescriptions for the crops are based on fertilizer trials conducted at farmer's fields and in research stations. In these prescriptions variations in soil fertility and targeted yield are not at all considered, hence the adoption will not provide efficient and economic fertilizer use.

The formulation of fertilizer recommendation must take into account, the soil nutrient status and the crop needs. This has emphasized the use of soil test for fertilizer prescriptions.

Soil testing is a chemical method for estimating the nutrient supplying power of a soil. It involves series of steps including collection of soil samples, extraction of available nutrients, interpretation of the data and formulation of fertilizer prescriptions. Different soils differ in their capacity to supply the nutrients to crops and the crops also differ in their nutrient requirements. Hence the soil test data should be correlated with nutrient uptake by crops for making efficient fertilizer recommendation.

Soil test crop response correlation studies fulfil the above needs. In this approach required variations in soil fertility were created in one and the same field. The available nutrient status of the soil is determined in the laboratories and correlated with crop response to the applied nutrients in the field. From the data, fertilizer prescription equations are derived for the particular crop in a particular soil type. Then these equations are test verified in farmer's fields before large-scale adoption. Such soil test based fertilizer recommendation avoids the wastage or under usage of fertilizers.

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

Higher rate of fertilizer consumption can be optimized by, judicious application of organic manures. The combined use of organics and inorganics enhance the nutrient use efficiency. Hence the soil test crop response correlation studies are conducted under integrated plant nutrition system.

Ginger is an important spice crop, known in India from ancient times, used both as spice and medicine. The major ginger producing countries are India, China, Taiwan and Nigeria. Ginger is grown over 0.709 lakh ha with a production of 233 lakh tonnes during 1996-97 in India (Peter, 1998).

India exports ginger to 36 countries, which includes Bangladesh, Pakistan, Saudi Arabia, Morocco and USA. Dry ginger export was valued Rs. 20.53 crores during 1995-96. The share of ginger in total spice import was four percent.

Due to its increased demand, the soil management practices and mineral nutrition studies of ginger demands much attention. The studies on mineral nutrition of ginger are restricted. Hence the soil test crop response studies are conducted in ginger to develop an efficient prescription equation.

In Kerala 65% of land area is covered by laterite soil (KAU, 1989). Hence the study is conducted in laterite soil with inclusion of organic manure to exploit the yield potential of ginger.

The soil test crop response studies were undertaken in ginger in laterite soils of Kerala with the following objectives:

1. To establish the relationship between soil available and applied nutrients with rhizome yield of ginger through a response surface model.
2. To provide a basis for fertilizer recommendation for maximum and economic rhizome yield at varying soil test values.
3. To develop soil test based balanced fertilizer recommendation for specific yield targets of ginger.
4. To study the pattern of uptake of N, P and K under the influence of the graded doses of these nutrients.
5. To study the effect of N, P and K treatments on the yield and quality characters of ginger;
6. To evaluate the conjoint use of organic manure and fertilizer in relation to soil test values in ginger cultivation.
7. To know the influence of native elements (Na, Ca, Mg, Cu, Zn, Fe, Mn) in yield of ginger.

CHAPTER-2
REVIEW OF LITERATURE

Literature on various statistical models employed to predict yield of crops, to rationalize fertilizer prescriptions based on various approaches and the nutrient requirements of the crop ginger based on various experiments are reviewed in this chapter.

I. MODELS FOR SOIL TEST CALIBRATION, PREDICTION AND OPTIMISATION OF FERTILIZER DOSES

Applications of chemical fertilizer increase the crop yield when all other production factors are maintained at optimum level. It is necessary to quantify the functional relationship that exists between different inputs and crop yield, to know the crop yield for various fertilizer levels, and for optimization of fertilizer doses to obtain maximum yield. Hence in agriculture for marking any logical production system, statistical models are developed (Sankar, 1992). Efficient prediction models are important for prescription and optimization of fertilizer doses. Details of various statistical models for efficient fertilizer use, and rationalized prescriptions of fertilizer doses are reviewed under here.

here

I.1. Liebig's model: -

Liebig's law of minimum states that a proportional increase in yield was obtained for the addition of nutrients to soil. Accordingly the yield of crop will, increase at a constant rate, with regard to each growth factor, until some other factor is limiting. Liebig's law of minimum is applicable only to mobile nutrients like nitrate nitrogen. The linear model is represented by the function

$$Y = a + bx$$

Where

Y = yield.

a = the y intercept with no applied nutrients or soil nutrient supply.

b = coefficient for first degree.

x = fertilizer nutrient added.

I.2. Quadratic model: -

The fertilizer requirements were calculated using quadratic yield response (Heady and Ray 1971). They worked out the equation for two different economic situations and found that for achieving desired result, biological and economic variables are to be combined in a function.

The equation for quadratic model is

$$Y = a + bx + cx^2$$

Where

x = fertilizer nutrient added

The common procedure for combining soil and fertilizer variable to obtain crop response and to determine a functional relationship was suggested by Mombiela *et.al.,* (1981).

The quadratic equation modified by Anderson and Nelson (1971) is as follows

$$Y = a_1 (X+d) + a_2 (X+d)^2$$

Where

d = F (T)

d is the statistical estimate of the amount of plant available nutrient in soil

F (T) is a function of soil test values.

a_1 and a_2 - regression co efficients

Y - percentage yield.

X - nutrient added.

The square root or logarithmic function usually fits to the situation where the same high doses of nutrients when applied in different manner may result in yields equal to or higher than intermediate rates.

It is obvious from this equation, that there exists a significant linear relationship between soil test values and estimates.

I.3. Orthogonal polynomial model: -

For calibrating yield fertilizer trend, Colwell (1968) proposed orthogonal polynomial model. The polynomials accommodate different fertilizer interaction effects and are flexible and easy to compute. It is possible to fit linear, quadratic, cubic and quartic of any n^{th} order polynomial depending on its significance of variables. The form of n^{th} order polynomial is

$$Y = a_0 + a_1x + a_2x^2 + a_3x^3 \ldots\ldots\ldots + a_nx^n$$

Where

$a_0, a_1, a_2 \ldots\ldots\ldots a_n$ are polynomial co-efficients.

In colwel's orthogonal polynomial approach polynomials are calibrated for yield and fertilizer data after eliminating the trend variables which are significantly related with each other. The calibrated yield fertilizer trend orthogonal polynomial model using the data of a wheat experiment (Velayutham *et.al.,* 1978) is as follows.

$$Y = 7330M + 1553.9Ln - 306.4Qn + 175.5Lp - 142.3Qp + 430.0LK + 393.8LnLp$$

Where

Ln and Qn = linear and quadratic N trends

Lp and Qp = linear and quadratic P trends.

LnLp = Interaction of linear N and P trends.

Lk = linear k trends

The pooled model representing soil fertility and fertility trends of the same experiment conducted at 5 different locations can be given as

$$Y = 7850M + (5487 - 9211.43\ SN^{1/2} + 4920.38\ SN)\ Ln + 47.53\ Qn + (-1314 + 987.7\ SP^{1/2} - 121.18\ SP)\ Lp + (446 - 392.1\ SP^{1/2} + 62.93SP)\ Qp + (10581 - 551.42\ SK^{1/2} + 5.52\ SK)\ LK + 119.52\ Ln\ Lp.$$

Location specific regression equation can be obtained from the pooled model by using conversion constants of the trends to regressions and the location soil test values. The form of converted regression equation is

$$Y = 1171 + 58.83\ FN^{1/2} + 0.97\ FN + 38.62\ FP^{1/2} + 3.32\ FP + 35.30\ FK^{1/2} + 2.03\ FNFP$$

The fertilizer trend surface can be obtained by using the converted regression equation and the optimal fertilizer doses can easily be derived from the trend surface for each location.

I.4. Mitscherlich's model: -

Mitscherlich (1909) developed a model for expression of the growth rate

for different level of an essential immobile nutrient in the soil. Mitscherlich`s law states that "the increase in yield per unit of added nutrient is proportional to the difference between the maximum attainable and the actual yield".
Mathematically it is expressed as

$$dy / dx = C(A-Y)$$

Where

Y - yield obtained with x units of fertilizer application

A - maximum asymptotic yield, and

C - fertilizer efficiency factor

The most widely used model is of exponential type. Quadratic and square root models are also there.

I.5. Mitscherlich - Bray model: -

The various models developed by the different scientists (Spillman and long, 1924, Balmukand, 1928, Wilcox 1937, and Panse 1945), failed to give due connections to soil test values. This was realized by Bray (1948) who modified the Mitscherlich equation by introducing efficiency coefficients to soil test and applied forms of nutrients.

The mathematical expression is

$$\text{Log}\,(A - Y) = \log A - C_1 b - Cx$$

Where

A = maximum yield (100% yield) with all nutrients at adequate levels

Y = percentage yield of crops with all nutrients except the nutrient being studied.

C_1 = proportionality factor for soil nutrient

b_1 = soil test value of the nutrient for the control plot/untreated plot.

C = proportionality factor for added form of fertilizer nutrient.

X = dose of fertilizer added.

Mitscherlich`s model is applicable only to single nutrient studies and seldom used for optimization of fertilizer in multi nutrient studies. The Mitscherlich model under conditions of varying yield maximum showed that (Russell 1972),

$$\text{Log}\,(Y\,max - Y) = \log Y\,max - C\,(b\,z + x)$$

Where

b = level of soil nutrient

z = parameter directly related to the favorable condition on Y_{max}

X= level of nutrient

Mitscherlich`s model clearly states that "yield increases with addition of fertilizer up to a maximum, beyond which any additional application decreases production". This is seen in practical experience in many cases, higher doses of fertilizers give rise to an imbalance with other nutrients leading to deficiency symptoms. Though Mitscherlich-Bray model is useful, lack of standard procedures for assessing the maximum yield and the neglect of nutrient interactions limit the scope of its applicability (Ranganathan *et.al.*, 1969)

I.6. Multiple Regression model: -

The technique of multiple regression is a proper statistical tool to obtain the contribution of nutrients from the soil to yield. This approach was suggested by Ramamoorthy *et.al.*, (1967) for prescribing fertilizer doses based on soil test values to attain either maximum yield or maximum profit. This model is more realistic and practical approach based on creation of artificial fertility gradients. The significant relationship between soil tests, fertilizer dose and crop yield is established by fitting a multiple regression of the quadratic form taking linear terms of soil and fertilizer nutrients and interaction terms of soil and fertilizer nutrients (Ramamoorthy, 1974). The range in soil test values in one and the same field is created by conducting gradient experiment to minimize interference of other factors affecting crop yield

The regression equation obtained using quadratic function can be expressed as,

$$Y = A \pm -b_1SN \pm -b_2SN^2 \pm b_3SP \pm b_4SP^2 \pm b_5SK \pm b_6SK^2 \pm b_7FN \pm b_8FN^2 \pm b_9FP \pm b_{10}FP^2 \pm b_{11}FK^2 \pm b_{12}FK^2 \pm b_{13}FNSN \pm b_{14}FPSP \pm b_{15}FKSK$$

Where

Y	- crop yield (Kg/ha)
A	- Intercept
b_1 to b_{15}	- Regressions coefficients
SN, SP and SK	- soil available N, P and K (Kg/ha)
FN, FP, FK	- Fertilizer N, P and K (Kg/ha)

If the equation attain a high and significant R^2 value, and if meets the conditions like response type of N is positive, quadratic fertilizer N (FN^2) and interaction of fertilizer and soil N is (FNSN) negative, and further the terms are also significant it can be used for optimization analysis. The optimum dose of N for maximum yield is computed from the equation,

$$FN = \frac{b_7}{2b_8} - \frac{b_{13}}{2b_8} SN$$

For maximum profit it is,

$$FN = \frac{b_7}{2b_8} - \frac{b_{13}}{2b_8} \times SN - \frac{1}{2b_8} R$$

Where

FN	=	Fertilizer nitrogen
SN	=	Soil available nitrogen
R	=	Ratio of unit cost of fertilizer (one kg of fertilizer Nutrient) and value of crop (value of one kg of grain)
b_7,b_8, and b_{13}	=	Coefficients of linear, quadratic and interaction term of fertilizer

The multiple regression models are more efficient and useful for studying fertilizer responses under different levels of soil and fertilizer contribution for different crops on different soils. When compared to other models there is high percentage of yield predictability with minimum of experimental error.

In addition, the model was found to be more efficient than other models based on R^2 adequacy and also Residual Mean Square Ratio (RMSR) test.

I.7. Targeted yield model: -

Experimental proof for the fact that liebig's law of minimum operate equally well for N, P and K (Ramamoorthy, *et.al.,* (1967) forms the basis for targeted yield model, first advocated by Troug (1960) .According to this concept a linear relationship exits between the yield obtained and nutrient supplied. The linear relationship between, the yield of grain and uptake of nutrients was reported by Aggarwal and Ramamoorthy (1978) and Reddy, *et.al.,*

(1987) which explain that to obtain specific yield the nutrient must be taken up by the crop.

The targeted yield model requires the following parameters to compute the fertilizer prescription equation. (i) Nutrient requirement (NR in kg/t) (ii) percent contribution from the soil available nutrient (CS in percent) and (iii) percent contribution from applied fertilizer nutrients (CF in percent). The targeted model of N, P and K nutrients can be expressed as

$$FN = NR/CF * T - CS/CF * SN$$
$$FP = NR/CF * T - CS/CF * SP$$
$$FK = NR/CF * T - CS/CF * SK$$

The optimum fertilizer doses for varying soil test values to obtain different yield targets can be computed easily by using this model. These developed equations are test verified in farmer's field conditions before they are generalized for large-scale adoption. Sankar, *et.al.,* (1989).

The fertilizer prescription based on this concept are more precise and meaningful because of the combined use of soil and plant analysis data for computation. 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).

This model is also utilized for,

(i) Allocation of fertilizer under conditions of fertilizer credit shortage (Ramamoorthy, 1974).
(ii) Fertilizer recommendation for targeted yields in a cropping system (Ramamoorthy, 1975 and Aggarwal and Ramamoorthy, 1978)

(iii) In multiple cropping system to predict the post harvest soil test values (Velayutham and Raniperumal, 1976).

(iv) Fertilizer prescription for integrated plant nutrition system by using organic manures and chemical fertilizers (Raniperumal, et.al., 1984, and Reddy, *et.al.,* 1987).

(v) For computation of critical soil test values. (Randhawa and Velayutham, 1982).

(vi) To make efficient fertilizer prescription, if the cost of investment of fertilizer is same as that of general recommendation (Ramamoorthy, 1974).

(vii) To estimate the yield in unfertilized plot (Ramamoorthy and Bajaj 1970).

(viii) It is used to predict efficient crop rotation system from the ability of crop and crop varieties to utilize soil and fertilizer nutrients (Ramamoorthy, 1986).

(ix) To develop area wise fertilizer recommendation based on nutrient index of soil (Ramamoorthy and Pathak , 1969).

I.8. Path coefficient model: -

For calculating the estimates of direct and indirect effects of soil and fertilizer N,P and K with yield, the path coefficient model has been suggested by Sankar *et.al.,* (1985). This model is useful in optimization studies by screening of soil and fertilizer nutrients.

I.9. Linear programming model: -

This model is efficient under condition when the quadratic terms are not significant. For that linear programming has been suggested by Sankar *et.al.,* (1987) for computing the fertilizer N,P and K requirement of crops.

While choosing the fertilizer response model, one has to consider the design and layout of experiments (Sankar, 1992). The model should provide enough treatment levels for the precise estimation. Only a good statistical model will give convenient use and conservative estimates of fertilizer requirements.

II. Approaches for soil test based fertilizer recommendations: -

The economic and judicious use of fertilizers based on soil test values to increase the productivity was suggested by many scientists (Ramamoorty and Pathak 1969, Kanwar, 1971, Ramamoorthy and Velayutham 1972, 1974 and 1976, Goswami and Singh 1979, Beringer,1985 and Velayutham, *et.al.*, 1985).

Scientists to obtain a workable basis for predicting the fertilizer requirement of crops have putforth many methods and approaches. These approaches are employed with the main objective of utilizing soil and fertilizer nutrients efficiently and there by increasing the productivity and the returns of the farm. The important approaches are reviewed below.

II.1. General / blanket recommendation: -

The relationship of soils to judicious use of fertilizers was first realized in 1953. Blanket recommendations were based on the results of agronomic experiments conducted on Government farms and simple fertilizer trials on cultivators' field. Adoption of this recommendation did not provide assurance to efficient and economic fertilizer use, because it is an average recommendation for a majority of situations. The general recommendation leads to wastage of fertilizers or to under usage (Reddy, *et.al.*, 1994).

II.2. Soil test rating and fertilizer adjustments: -

Making use of services of soil testing laboratories at IARI and the results of ad hoc research projects, accurate soil testing procedures were identified and Soil Test Values were grouped into categories like low, medium and high (Muhr, *et.al.,* 1965 and Perur, *et.al.,* 1973) The medium level fertility of soil were equated to general blanket recommendation. If the soil is low fertile then the recommendation is 30-50% higher and if it is high fertile the prescription is 30-50% lower than that of general recommendation. This technique gave 11% increased yield compared to general dose (Randhawa and Velayutham, 1982).

II.3. Fertilizer recommendations for a certain percentage of yield maximum: -

Mitscherlich - Bray approach is the basis for fertilizer recommendation for a certain percentage of maximum yields. In this approach an empirical relationship is developed between percentage yield to soil and fertilizer nutrients. Based on this fertilizer recommendation were made for various percentage of maximum yield for a given soil test value. This approach is normally computed for calibrating soil tests for immobile nutrients.

The modified Mitscherlich Bray equation (Tisdale, *et.al.,* 1990) can be represented as

$$\textbf{Log (A-Y) = log A- } \mathbf{C_1 b - Cx}$$

Where

A - Maximum yield (100% yield) with all nutrients at adequate levels

Y - Percentage yield with all the nutrients except the nutrients being studied

b - Soil test value

$\mathbf{C_1}$ - Proportionality factor for soil nutrients

X - Fertilizer dose

In this approach the maximum yield A is taken as the highest yield obtained in a particular region or computed by extrapolation method as given by Ranganathan, *et.al.,* (1969) .This approach was used by different scientists in different crops such as sugarcane, cotton (Ranganathan, *et.al.,* 1969 & 1971 respectively) and sorghum (Sheet and Sonar, 1993)

Presently the Department of Agriculture, Tamilnadu, is adopting this approach for giving site and situation specific fertilizer recommendations for major crops.

This method gives fertilizer recommendation for certain percentages of theoretical yield maximum and not for the actual yields. The maximum yields computed from field experiments are different for different nutrients and it becomes difficult to decide which should be taken as actual maximum yield (Singh and Sharma, 1994). Further the use of percentage yield rather than actual yield has been criticized because of error in these computations of maximum yield on inter seasonal comparisons and there by its limitation for making fertilizer recommendation based on soil test values under field conditions (Bolland and Gilkes, 1992). They observed that maximum yields are not always indicated by well-defined yield plateau. It is seen that in the same site, with the same 'P' fertilizer and the same plant species, the relationship between yield and soil test P differed for different years. Accordingly fertilizer recommendation based on this concept is likely to be incorrect.

II.4. Critical level approach: -

This concept is based on the fact that if the soil nutrient content is below the critical level, the possibility of response is greater and vice versa. Three different techniques are adopted to find the critical limits of available nutrients viz., the graphical procedure (Cate and Nelson, 1965), mathematical procedure using two mean square discontinuous model (Cate and Nelson, 1971) and linear response plateau (LRP) model (Anderson and Nelson, 1975).

This approach helps to determine the soil test value beyond which application of fertilizer is not required, but it does not tell anything about how much fertilizer is to be applied in quantitative terms with different soil test values.

The recommendation of phosphatic fertilizer is based on critical level approach in the soil testing laboratories of Andra Pradesh (Krishnamoorthy, *et.al.,* 1963).

Critical limits of available P for various crops as reported by different workers in various soil and agro climatic situations was summarized by Tandon (1987).

But Cox (1992) from his nine years of study on different crops like corn, soybean and wheat opined that it was difficult to find a single critical value for any of these crops. It has been proved that there is a range in critical limits rather than a true single value,. which limits the use of critical level approach for soil test, based fertilizer recommendation.

II.5. Colwell's deductive approaches: -

This approach putforth by Colwell (1968) of Australia involves the conduct of multi location trials, over a larger area. The data generated are used to obtain the soil test based calibration. The fertilizer doses were adjusted in accordance with STVs and their Interactions. The location specific fertilizer recommendations were derived by using this model for different crops like wheat grown in black soil (Velayutham *et.al.,* (1978) and for rice, millets, groundnut and cotton grown in Tamilnadu (Anonymous,1982 and Mosi, *et.al.,* 1987).

The All India co-ordinated research project on soil test crop response correlation conducted multi-location trials in farmers fields based on Colwell's approach. The data from these experiments have not met with much success to obtain soil test based fertilizer calibrations in India (Velayutham, *et.al.*, 1985).

II.6. Inductive approach: -

Inductive methodology of Ramamoorthy (1968) forms the basis for fertilizer recommendations for maximum yield and profit. In this approach fertility variations are created in one and the same field. To develop a fertility gradient graded doses of fertilizers are applied and a gradient crop is raised. Differences due to other factors such as climate and management which often results in insignificant correlation, obtained from the data on multilocation trials are avoided in this model. Thus a new technique of STCR correlation studies based on fertility gradient approach has been developed by (Ramamoorthy and Velayutham 1971) in the AICRP for investigation on STCR correlation.

II.7. Fertilizer recommendation based on regression analysis approach: -

Nutrients occur in soil in various amounts, and also added through fertilizers in varying proportions. So, there will be interactions among the nutrients available in the soil and added through fertilizers. Regression analysis is used to establish a functional relationship between soil test value, fertilizer use and yield of crops. The suitability of the soil test method for the prediction of yield response is indicated by the significant value of co-efficient of determination(R^2) with high order of predictability (66%). If the predictability is more than 66% 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.

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

$$\textbf{F (maximum)} = \frac{b-d.s}{-2c}$$

$$\textbf{F (economic)} = \frac{b-d.s-r}{-2c}$$

Where

b and c = linear and quadratic regression co-efficients

s = Soil test values.

r = ratio of nutrient to produce unit quantity of yield

Ramamoorthy and Velayutham (1971) recommended multiple regression analysis for STCR work in India. Hanway (1971) suggested multiple regression for relating field response of crop with laboratory results to study the crop response principles for the system containing several uncontrollable variables.

The significant relationship between soil test values, crop yield and fertilizer dose was established by fitting a multiple regression using a quadratic response function (Ramamoorthy, 1974).

Multiple regression analysis accurately evaluate the effects of soil and fertilizer nutrients on both the plant uptake of nutrients and yield (Reddy, *et.al.,1*985). This analysis enables the study of number of factors simultaneously at a time (Ahmed, 1985)

To study the fertilizer response under varying levels of soil fertility for different crops in different soils, multiple regression models are used (Sankar, 1992).

In STCR correlation studies organic/bio fertilizer treatments were also included under integrated plant nutrition system. (Raniperumal, *et.al.,* 1984 Murugappan 1985, Sumam, 1989, Swadija, *et.al.,* 1995, TNAU, 1994, Santhi, 1995 and KAU, 1996).

Fertilizer adjustment equations for varying soil test values for maximum yield and profit per hectare have been calibrated using multiple regression model for different varieties of crops like rice (Raniperumal, *et.al.,* 1982 and 1984), sorghum (Raniperumal *et.al.,* 1982),maize (Sumam, 1988), ragi (Raniperumal, *et.al.,* 1982 and Mercy kutty, 1989) and groudnut (Raniperumal, *et.al.,* 1982) and TNAU, 1994 at Tamilnadu 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 the black soils of Maharastra (Sankar, *et.al.,* 1988).

II.8. Targeted yield approach:

This approach forms the basis for the national programme on soil test crop response correlation studies under the co-ordinated scheme of ICAR. In this approach fertilizer dose is computed considering the amount of nutrients removed per unit quantity of economic produce, initial fertility status of the soil, efficiency of nutrients supplied and present in the soil and added through fertilizer and possible nutrient interactions as well (Ramamoorthy, 1973)

It is in this context, in the 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 the targeted yield approach several studies have been conducted at TNAU Coimbatore, and useful prescription equations are derived for desired yield targets for different varieties of different crops like rice, maize, sorghum, ragi, groundnut, blackgram, soybean, sugarcane, cotton, tapioca, sunflower and chilli in different soil series (Raniperumal, *et.al.,* 1982, 1984, 1986, 1987 and 1988; TNAU, 1994, Baskaran, et. al., 1994 and Loganathan, *et.al.,* 1993).

In Kerala Swadija, *et.al.,* (1993) have worked out prescription equations for rice variety Bharathi and Cassava variety M4 (Swadija,1997). Technology verification trials conducted at farmer's fields proved the validity of the equations. The prescription equations also developed for desired yield targets of rice in lowland acid laterite soils of Kerala (KAU, 1996).

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

In Punjab targeted yield equations are developed for rice based on the farmer field trials conducted at different locations (Chand, *et.al.,* 1984).

The State Department of agriculture, Maharastra, used the targeted yield approach for giving fertilizer recommendation for field crops (Velayutham and Reddy, 1990).

The targeted yield equations have been reported by Reddy, *et.al.,* (1991) for groundnut in Bhavanisagar ,Hyderabad (redsoil), Rahuri (blacksoil) and Dholi (alluvial soil).

Dhillon, *et.al.,* (1978) and Dev, *et.al.,* (1985),developed targeted yield equations for wheat in Ludhiana and Gurdaspur, and also by Chand *et.al.,* (1986) for greengram in Punjab, Dev, *et.al.,* (1978) for rice in tropical acid brown soils and Singh and Sharma (1978) for many crops in Delhi and Sankar, *et.al.,* (1991) for banana in vertisol of Maharastra.

Targeted yield approach is also effectively used for appropriate fertilizer recommendation with organics or biofertilizers. Based on the level of application of organic manures, the dose of chemical fertilizers adjusted through soil test calibration (Raniperumal, *et.al.,* 1984).

Prescription equations involving the conjoint use of organics and inorganics have been reported by Santhi (1995) in rice with FYM and phosphobacteria, Baskaran, *et.al.,* (1994) in Tapioca with composted coirpith, Duraisamy, *et.al.,* (1989) in ragi with FYM, Mercykutty (1989) in ragi with Azospirillum and Raniperumal, *et.al.,* (1988) in ragi with FYM.

The conjoint application of fertilizers and organic manures lead to efficient use of fertilizer and considerable saving in fertilizers (Prasad and Prasad, 1993). The magnitude of contribution by the organic and biological sources of plant nutrients complimenting fertilizers in meeting nutrient requirement of crops (Tandon, 1994).

The targeted yield equations developed for a particular variety of crops for a particular soil type can be suitably extrapolated to other varieties of the same crop and to similar soils (Velayutham *et.al.,*1978)

The prescription equations developed for the ragi var. Co .11 fitted well for the var. Co.12 also (Duraisamy, *et.al.,* 1989). Similarly the fertilizer adjustment equations with organics developed for the rice var. Bhavani were found suitable for the other varieties like IR20, IR50, Ponni, CO43 and Paiyur-1 in the same soil type (Raniperumal, *et.al.,* 1987).

The superiority of fertilizer recommendation based on targeted yield approach over the general / blanket doses have indicated by several scientists. Fertilizer application based on targeted yield approach would be the most economical (Ramamoorthy and Pathak, 1969).

II.9. Nutrient Index approach: -

This approach was developed by Parker, *et.al.,* (1951) .This method is based on the soil test values of different nutrients. According to the values soil samples are classified into low, medium and high categories. The soil nutrient Index can be calculated from the formula

$$NI = \frac{Nl + 2Nm + 3Nh}{Nl + Nm + Nh}$$

Where,

NI - Nutrient Index

Nl - Soil sample falling under low nutrient status

Nm - Soil sample falling under medium nutrient status

Nh - Soil sample falling under high nutrient status

An Index below 1.5 is termed as low, between 1.5-2.5 is medium, and above 2.5 is high. This method is useful to make recommendations only for compact areas. This is the major limitation of nutrient Index approach.

II.10. Ten-class system: -

This method was proposed by Nambiar, *et.al.,* (1977). The fertilizer prescriptions are given as percent of package of practices recommendation.

Nambiar, *et.al.,* categorized the lower fertility level to 3 classes, medium fertility level to 4 classes and higher fertility level to 3 classes. Totally the fertility status of the soil is grouped into 10 classes. For each fertility class, recommendations are given based on package of practices recommendations for each crop. This system of fertilizer prescription is followed in Kerala.

II.11. DRIS: -

The diagnosis and recommendation integrated system has been developed recently and applied to field of soil fertility with considerable success. These approach over come the limitations in using the critical level of nutrient elements in plant tissues and the nutrient ratios. The advantages of this approach are (1) Ability to make a diagnosis at any stage of crop growth. (2) List the nutrient elements in the order of limiting importance on yield. (3) To identify the order in which the nutrients are likely to limit the yield. Sumner (1979) compared the critical level approach with that of DRIS method for various crops with the same set of data and reported that the DRIS approach is able to make meaningful diagnosis because it classify the nutrient which limits the yield.

The superiority of the DRIS over critical level approach is reported for various crops such as wheat (Sumner, 1981) corn (Escano, *et.al.,* 1981) sunflower (Grave and Sumner, 1982) and sugarcane (Jones and Bowen, 1981, Meyer, 1981, Sumner, 1983 and Elwale and Gasho, 1984).

Based on DRIS approach Counce and Wells (1986) studied the midseason fertilization for rice to correct nutrient deficiency.

Ratios among nutrients were computed for different crops such as potato (Mackay, *et.al.,* 1987) soybean (Evanylo, *et.al.,* 1987) and rubber (Mercykutty *et.al.,* 1993).

II.12. Modeling: -

Modeling and its application are now a days being used in every research field and agriculture is not an exception. For any location models are applied to develop optimal fertilization strategies, by making use of the data generated from fertilizer experiments over number of years. Fertilization decision model based on soil and plant parameters, reported by Kafkafi, *et.al.,* (1978). A model could be formulated in a target oriented way, based on yield level, level of radiation, water availability, P supply, nutrient interaction etc (Wolf, *et.al.,* (1989).

III. Nutritional requirement of Ginger: -

Ginger requires heavy fertilization for higher yield. The nutrient requirement of ginger varies with the cuitivar, cropping system, management practices etc. So literature on the nutritional requirement of ginger are reviewed here under.

III.1. Response of ginger to nitrogen application: -

The nitrogen consumption of ginger was high during it's active growth and tillering stage, during which leaf contained 3% Nitrogen and application of Nitrogen at the rate of 70 kg/ha increased significantly the number of tillers in ginger. (Dasarathi, *et.al.,* 1971).

There was a progressive increase in plant height and number of tillers per plant for nitrogen application up to 90 kg/ha in ginger (Aclan and Quisumbing, 1976).

The dry matter content in ginger decreased by the application of nitrogen at levels of 56-112 kg/ha (Aiyadurai, 1966).

In ginger Samad (1953) recorded increase in yield with application of 100kg N/ha. Aiyadurai (1966) also reported increases in yield of ginger by N application.

The yield of ginger doubled when the application of N level was increased from 30 to 90 kg/ha (Aclan and Quisumbing, 1976). It was also suggested by (Sadanandan and Sasidharan, 1979).

Application of N above 50kg / ha reduced the yield of ginger significantly (Muralidharan, 1973)

The total N in ginger shoots and rhizomes increased with increasing fertilizer N application (Lee, *et.al.,* 1981). According to them , the yield of ginger shoots and rhizomes and the leaf N concentrations increased with the total amount of N applied up to the highest level studied, 336 kg N /ha.

Pillai (1973) found that higher level of nitrogen applied considerable effect on the number, length and breadth of leaves and number of tillers.

Nair (1975) found that foliar application of urea 2.0% and planofix 400 ppm increased the yield significantly.

Aiyadurai (1966) in his review of the ginger development scheme, Himachal Pradesh showed that nitrogen application from the level of 50 to 100 kg/ha had significantly increased the yield by 18 to 32 percent and improved the dry matter content of rhizome.

Muralidharan (1974) revealed that 70kg N/ha increased significantly the number of tillers and yield of rhizome

III.2. Response of ginger to fertilizer: -

The uptake of N, P and K. were found to be maximum with the highest level of fertilizer application in ginger. Highest dry ginger yield was obtained with highest fertilizer dose of 93.75, 62.5 and 162.5kg N, P and K/ha and for green ginger the doses were 112, 75, 75 kg N,P and K /ha respectively (Ancy (1992)).

Significant increase in yield was observed with the application of 60kg N, 40 kg P_2O_5 and 60 kg K_2O /ha (Lokanath and Dash, 1964). Kannan and Nair (1965) recommended 36kg N, 36kg P_2O_5 and 72kg K_2O / ha for optimum yield of ginger.

Sahu (1989) obtained highest yield of fresh ginger rhizomes with application of N, P and K at the levels of 90:60:90 kg/ha. Maximum yield of ginger was reported at the dose of 125:70:150 N, P and K kg/ha (Mohanty, *et.al.*, 1992).

In an experiment to study the effect of 3 levels each of N (50, 75 and 100 kg /ha) P_2O_5 (50, 75 and 100kg/ha) and K_2O (100, 150 and 200 kg /ha) to the yield of ginger variety Rio-do Janeiro, revealed that the application of 'N' above the dose of 50 kg /ha reduced the yield of ginger significantly. The nutrients P and K had no significant effect on the yield at the levels studied (Muralidharan, 1973).

In the fertilizer trials conducted under the technical collaboration between Kerala Agricultural Department and Indian Potash Institute during 1957- 60, showed that application of 50 kg N, 50 kg P_2O_5 and 100 kg of K_2O/ha gave the maximum yield of ginger.

Series of experiments conducted at Ambalavayal and Thodupuzha showed that application of complete fertilizer (N, P and K) was better than nitrogen, phosphorus and potassium application separately (Anonymous, 1954).

Trials conducted at Regional Research Station, Kandaghat for four years with nitrogen, phosphorus and potassium, indicated that the combination of 100 kg nitrogen, 50kg phosphrous and 50kg potassium per hectare proved best and produced a significant increase in the height of plants, yield of rhizome and number of tillers in ginger over control (Randhawa and Nandpuri, 1965).

Muralidharan, *et.al.,* (1973) reported that the height and yield of ginger increased with application of NPK @ 70:70:140 kg /ha respectively.

The highest yield was obtained in the mango ginger with application of N, P and K at the levels of 30:30: 60 kg /ha respectively (Mirudula, *et.al.,* 1999).

Groda and Prasad (1998) reported that highest yield of ginger was obtained at the fertilizer dose of 150 :75:50 N, P and K kg/ha in red sandy loam soils.

Studies on nitrogen, phosphorous and potassium content and their uptake pattern in ginger cultivars showed the greatest nitrogen contents were reported in Nadan and phosphorous content in Maran (Prasad, *et.al.,* 1997).

III.3. Response of ginger to organics: -

Sayed 1960 reported that for maximum production of ginger application of both organic and inorganic manures were essential.

A study conducted on effect of farm yard manure on growth and yield of ginger showed that rhizome yield increased with increasing rates of FYM application (Khandkar, *et.al.*, 1996).

Kannan and Nair (1965) reported that ginger require heavy manuring with 25 to 30 tons of cattle manure as basal dose.

III.4. Response of ginger to micronutrients: -

Effect of micronutrients Zn, B, Mo applied individually and in combination on ginger was studied in a field experiment conducted at Ambalavayal. The availability of DTPA extractable Zn was higher in ginger and for B and Mo was on par among the treatments (Sadanandan *et.al.*,1997) Only very few works were conducted in micronutrients studies of ginger.

MATERIALS AND METHODS

CHAPTER - 3
MATERIALS AND METHODS

The study with the aim of investigating the soil test crop response relationship of ginger in laterite soils of Kerala an investigation was undertaken at the College of Horticulture, Vellanikkara. For this study the technique of inductive methodology developed by Ramamoorthy (1968) as followed in AICRP for investigations on STCR correlation (Reddy et.al., 1985) was adopted.

The field experiments consisted of fertility gradient experiment with the crop maize STCR experiment with the crop ginger using fertilizers and organic manures. The details of the field 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 (FGE) and the STCR experiment were conducted in the farm attached to the College of Horticulture, Vellanikkara during (March – Nov) 2000.

The field is located at $10^{o}31'$N latitude and $76^{o}13'$N longitude at an altitude of 25m above mean sea level. A bulk crop of turmeric occupied the experimental area in the previous season.

3.1.2 Climate

The general weather conditions experienced by the study area are as follows (Appendix 1). The mean annual rainfall is 181.4mm. The mean maximum and minimum temperatures are 34.1 and 23.1°C respectively. The

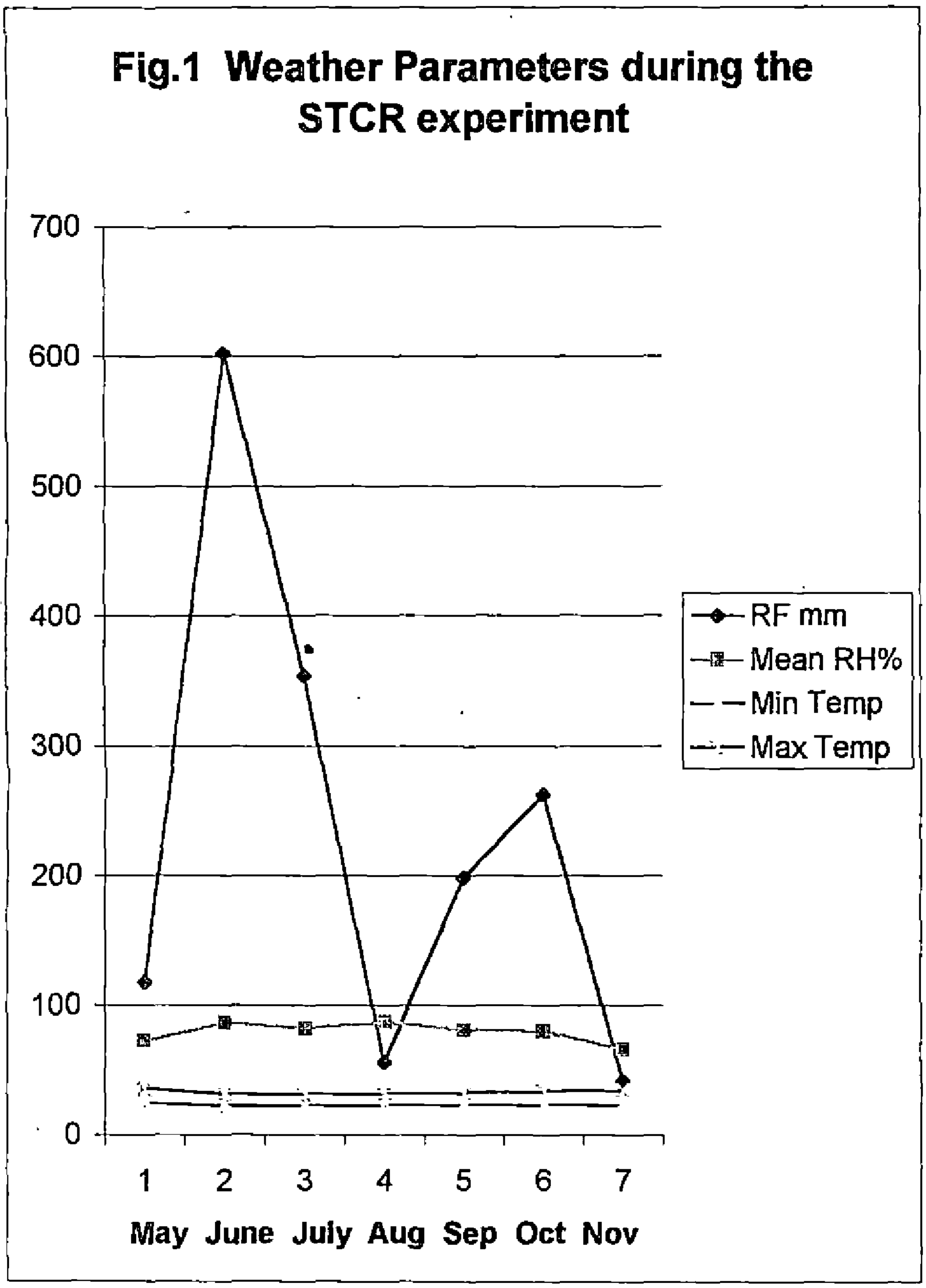


Fig.1 Weather Parameters during the STCR experiment
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
May June July Aug Sep Oct Nov
RF mm
Mean RH%
Min Temp
Max Temp

relative humidity ranges from 59 percent to 87 percent. The evaporation rate ranges from 91.8mm to 203.4mm.

During the cropping period a mean rainfall of 67.9mm (March - April) 299mm (May - Nov.) were received during the stand of gradient crop and the test crop respectively. The mean maximum and minimum temperature for the gradient crop was 37.1 and 24.3^{o}C while for the test crop it was 33 and 22.9^{o}C. The mean evaporation (mm) prevailed during the two cropping seasons were 154.7 and 112.8 respectively. The mean relative humidity was 70.5 and 79.1 percent respectively for the gradient and the test crop.

3. 1. 3 Soil type

The initial physical and chemical properties of the soil is given in Table 1.
The soil of the experimental site was laterite, which comes under the order inceptisol. The soil was sandy loam in Texture with low water holding capacity. It was acidic with a pH of 5.1 having high p fixing (82%) and low k fixing capacities (6%).

Table 1. Physical and Chemical properties of initial soil sample of the experimental site

Property	Unit	Value
Mechanical Composition		
Sand	%	48.0
Silt	%	21.6
Clay	%	33.6
Texture	-	sandy clay loam
pH	-	5.10
EC	ds m^{-1}	0.12
cation exchange capacity	mol (p^{+}) kg^{-1}	4.23

P fixing capacity	%	82
K fixing capacity	%	6
Organic carbon	%	0.49
Available N	kg/ha	238.00
Available P	kg/ha	14.86
Available K	kg/ha	82.62

3.2 Field Experiments

3.2.1 Fertility gradient experiment

The main objective of this experiment was to create variations in soil fertility in one and the same field, so as to generate the 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 and each strip into four equal plots. Totally 16 soil samples (one from each plot) were collected from 0-15cm depth and another 16 soil samples from 0-30cm depth.

3.2.3 Treatments

Graded doses of N as urea (46%N) P as super phosphate (16% P_2O_5) and K as muriate of potash (60% K_2O) were applied in four 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).

Strip I - $N_0 P_0 K_0$ - No fertilizers

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.

The quantities of N.P and K applied in four strips are given in table 2.

Table 2. Treatment Structure for FGE

Strip	Treatment	Fertilizer dose		
		N	P_2O_5	K_2O
I	$N_0 P_0 K_0$	0	0	0
II	$N½ P½ K½$	75	50	90
III	$N_1 P_1 K_1$	150	100	180
IV	$N_2P_2K_2$	300	200	360

3.2.4 Gradient Crop

A gradient crop of fodder maize (zea mays L.) variety Co.1 was raised following the usual agronomic practices (KAU 1999) except the treatments. The seeds were obtained from TNAU Coimbatore. The seeds were dibbled at a spacing of 30 x 15 cm on 2.03.2000 and the crop was harvested on 28.04.2000.

3.2.5 Observations Recorded

3.2.5.1 Green Fodder Yield

At harvest, strip wise green fodder yield was recorded leaving one border row all around in each strip and expressed in t ha^{-1}.

3.2.5.2 Dry Fodder Yield

Four plant samples (each from one plot) were collected from each strip prior to general harvest. After recording fresh weight the plant samples were dried in an oven at 60 ± $5^{O}C$ to constant dry weight. The dry fodder yield was computed strip wise from these observations.

3.2.6 Uptake of Nutrients

The sixteen composite plant samples (one from each plot) were analysed for N,P and K contents. The analytical methods adopted are represented in table 3. The uptake of nutrients was calculated using the plant dry weight and their nutrient contents. Uptakes of nutrient contents are expressed in kg/ha.

3.2.7 Soil Analysis

Soil samples were collected from two different depths [0-30cm and 0-15cm] prior to fertilizer application and after harvest. The methods of soil analysis adopted are given in table 3.

Apart from that a composite soil sample was collected from whole field and analysed for mechanical composition, water holding capacity, pH, soluble salts, cation exchange capacity, organic carbon and available N,P and K contents and P and K fixing capacities.

Table 3. Methods of soil and plant analysis

Parameter	Method	Reference
Soil Analysis		
Mechanical composition	International pipette method	Piper (1966)
Water holding capacity	Core method	Gupta and Dakshinamoorthy (1980)
pH	Potentiometry	Jackson (1973)
Electrical conductivity	Conductometry	Jackson (1973)
Cation exchange capacity	Neutral normal ammonium acetate method	Scholenberger and Dreibelbis (1930)
P fixing capacity	Equilibrium with potassium dihydrogen phosphate	Waugh and Fitts
K fixing capacity	Equilibrium with Potassium chloride	Waugh and Fitts (1966)
Organic carbon	Wet oxidation method	Walkley and Black (1934)
Available N	Alkaline permanganate method	Subbiah and Asija (1956)
Available P	Bray No.1 Extract method	Watnabe and Olsen (1965)
Available K	Neutral normal ammonium acetate method	Hanway and Heidal (1952)
Exchangeable Ca and Mg	Neutral normal ammonium acetate method using AAS	Jackson (1973)
Exchangeable Fe	DTPA Extractable method using AAS	Lindsay and Norvell (1978)

Exchangeable Cu	DTPA Extractable method using AAS	Lindsay and Norvell (1978)
Exchangeable Zn	DTPA Extractable method using AAS	Lindsay and Norvell (1978)
Exchangeable Mn	DTPA Extractable method using AAS	Lindsay and Norvell (1978)
Plant analysis		
Total N	Modified micro-Kjeldahl Jackson method	Jackson (1973)
Total P	Vanado – molybdo - phosphoric yellow colour method	Jackson (1973)
Total K	Flame photometry	Piper (1966)
Exchangeable Ca and Mg	Diacid extract using AAS	Jackson (1973)
Exchangeable Fe	Diacid extract using AAS	Jackson (1973)
Exchangeable Cu	Diacid extract using AAS	Jackson (1973)
Exchangeable Zn	Diacid extract using AAS	Jackson (1973)
Exchangeable Mn	Diacid extract using AAS	Jackson (1973)

(AAS – Atomic Absorption Spectrophotometer)

3.2.8 Statistical analysis

The data related to gradient crop experiment viz., fodder yield, nutrient uptake, crop and soil analysis after harvest were subjected to statistical analysis adopting the technique of analysis of variance (ANOVA) for Randomised Block

Design (RBD) as described by Snedecor and Cochran (1968). Critical difference is provided wherever F test is significant.

3.3 STCR Experiment

The principle methodology adopted in the STCR experiment is to establish quantitative relationship between soil test values, applied nutrients and the resultant crop yield. Hence field experiments were conducted with measured levels of fertilizer nutrients viz., N, P_2O_5 and K_2O with the test crop. This investigation was superimposed in 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 ginger and the variety used was Maran, which is a popular variety in the state. This variety yields on an average 23-25 tons of rhizome with 8-10% oleoresin. Disease free planting materials were obtained from progressive ginger growing farmers of Palakkad.

3.3.2 Treatments

Treatment structure comprises of factorial combinations of four levels of N three levels of P and 5 levels of K along with three levels of FYM. The treatment levels and doses of Nutrients applied are given in table 4.

Table 4. Treatment levels for STCR experiment

Levels	Fertilizer Dose (kg/ha)		
	N	P	K
1	0	0	0
2	50	37.5	37.5
3	100	75	75
4	200	--	150
5	--	--	300

3.3.3 Design and layout of the experiment:

Each strip was divided into 24 plots of 3 x 1.5m size. The 24 plots are allotted with 20 treatment combinations and four controls in each strip. The FYM levels were superimposed in the four strips.

Design	:	Response surface design
Treatments	:	24
Number of strips	:	4
Number of blocks	:	4
Number of plots per strip	:	24
Plot size	:	3 x 1.5m (24 plants)
Spacing	:	25cm x 25cm
System of planting	:	Raised bed System

The layout of the experiment is presented in figure 3

N ↑

Fig.3. STCR experiment (Field layout)

FYM	0	2	0	1
Strip 1	T_{1}	T_{5}	T_{11}	T_{15}
	T_{10}	T_{2}	T_{13}	T_{16}
	T_{12}	T_{6}	T_{3}	T_{19}
	T_{14}	T_{7}	T_{17}	T_{4}
	T_{18}	T_{8}	T_{20}	T_{23}
	T_{21}	T_{9}	T_{22}	T_{24}
Strip 2	T_{6}	T_{13}	T_{19}	T_{7}
	T_{21}	T_{14}	T_{16}	T_{9}
	T_{8}	T_{3}	T_{12}	T_{10}
	T_{23}	T_{18}	T_{4}	T_{11}
	T_{24}	T_{21}	T_{5}	T_{1}
	T_{20}	T_{22}	T_{15}	T_{17}
Strip 3	T_{16}	T_{10}	T_{6}	T_{5}
	T_{7}	T_{11}	T_{9}	T_{12}
	T_{3}	T_{15}	T_{8}	T_{14}
	T_{13}	T_{4}	T_{24}	T_{18}
	T_{17}	T_{20}	T_{1}	T_{22}
	T_{19}	T_{23}	T_{21}	T_{2}
Strip 4	T_{5}	T_{12}	T_{7}	T_{3}
	T_{9}	T_{16}	T_{10}	T_{6}
	T_{11}	T_{17}	T_{14}	T_{8}
	T_{4}	T_{19}	T_{18}	T_{13}
	T_{15}	T_{1}	T_{23}	T_{20}
	T_{22}	T_{24}	T_{2}	T_{21}

Treatment Structure

	N	P	K
T_{1}	0	0	0
T_{2}	0	0	0
T_{3}	0	0	0
T_{4}	0	0	0
T_{5}	0	37.5	0
T_{6}	50	0	37.5
T_{7}	50	37.5	37.5
T_{8}	0	0	75
T_{9}	0	37.5	75
T_{10}	50	0	75
T_{11}	50	37.5	75
T_{12}	100	0	75
T_{13}	100	37.5	75
T_{14}	100	75	75
T_{15}	0	0	150
T_{16}	50	37.5	150
T_{17}	100	75	150
T_{18}	200	0	150
T_{19}	200	37.5	150
T_{20}	200	75	150
T_{21}	100	37.5	300
T_{22}	100	75	300
T_{23}	200	37.5	300
T_{24}	200	75	300

FYM LEVELS

0 - Nil **1-15t/ha** **2-30t/ha**

3.3.4 Manures and Fertilizers:

The nutrient contents of organic manure and fertilizers used are presented in Table 5.

The organic manure as per treatments was applied after the raised bed formation. Full dose of P and half dose of K were applied as basal dressing. First top dressing was done at 60 days after sowing with half dose of nitrogen. The remaining dose of nitrogen and potassium were applied 120 days after sowing.

Table 5. Nutrient contents of organic manure and fertilizers used

Fertilizers / Organic manure	Nutrient content
Urea	46 % N
Super phosphate	16 % P2O5
Muriate of potash	60 % K2O
FYM	0.48% N, 0.36% P2O5 and 0.39% K2O

Management practices

Management practices were carried out as per package of practices recommendation with out treatments. In addition one drenching and spraying was done as a plant protection measure.

3.3.5 Observations recorded:

3.3.5.1. Rhizome yield:

The plants are carefully pulled out from the plot, the rhizomes were separated, cleaned and the fresh weight was recorded and expressed in t/ha.

3.3.5.2. Root and Leaf Yield:

The leaf with stem, and the roots from the rhizome were carefully separated and fresh weight, dry weight were recorded.

3.3.6. Uptake of Nutrients:

It was computed separately for leaf, root and rhizome. After harvest, pooled samples (100 g) were collected from each plot in all strips. The samples were dried uniformly in hot air oven at the temperature range of $60+5^{o}C$. 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 (0-30cm and 0-15cm) after land preparation but before fertilizer application for the test crop. The soil samples were analysed for organic carbon and available N, P and K contents adopting the analytical methods given in Table 3.

3.4 Yield of oleoresin

The oleoresin content of rhizome was estimated by the cold percolation method as mentioned in A.S.T.A (1960).

3.5 Statistical Analysis:

3.5.1 Correlation:

The nature and degree of relationship between the dependent and independent parameters was determined using the simple linear correlation (Snedecor and Cochran, 1968). The calculated values of correlation coefficient (r) were tested using student t-test with n-2 degree of freedom for their significance.

3.6 Multiple correlation and regression analysis:

The relationship between each uncontrollable variable with the controllable variable is expressed through simple correlation coefficient. But the controlled variable is not solely influenced by any one independent variable but by all of them through their direct, reciprocal and interaction relationships. So the data were subjected to multiple regression analysis.

The relationship between soil test values, applied fertilizer doses and organic manure and the resultant rhizome yield of ginger was established through multiple regression using the quadratic model. (Snedecor and Cohran 1968) as given below:

$$\mathbf{Y = A\ b_1FYM \pm b_2FYM^2 \pm b_3SN \pm b_4SN^2 \pm b_5SP \pm b_6SP^2 \pm b_7SK \pm b_8SK^2 \pm b_9FN \pm b_{10}FN^2 \pm b_{11}FP \pm b_{12}FP^2 \pm b_{13}FK \pm b_{14}FK^2 \pm b_{15}SNFN \pm b_{16}SPFP \pm b_{17}SKFK.}$$

Where

Y	=	Rhizome yield (tha^{-1})
A	=	Intercept
b_1	=	Regression coefficients (tha^{-1})

FYM = Dose of FYM applied (tha^{-1})

SN, SP, SK = Available soil N, soil P and Soil K ($kgha^{-1}$) respectively.

FN, FP, FK = Fertilizer N, Fertilizer P_2O_5 and fertilizer K_2O ($kgha^{-1}$) respectively.

The nature of functional relationship between rhizome yield, the dependent variable and the set of independent variables, namely the STVs and applied nutrients and the significant contributors towards the changes in dependent variable was easily obtained from the multiple regression analysis. In this analysis, the partial regression coefficient b_i showed the expected changes in the dependent variable (Y_i) for unit change in the independent variable X_i where the other independent variables are held constant. The partial regression coefficients were tested by using the student's t-test with n-k-1 degrees of freedom for the statistical significance.

Fertilizer recommendation for maximum and economic yield - multiple regression model:

The data from multiple regression of rhizome yield with STVs and applied nutrients were utilized to form a quadratic response surface equation. From that simplified fertilizer adjustment equations were derived for recommending fertilizers for maximum and economic yield of ginger at varying STVs.

3.7 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, rhizome yield, and the nutrient uptake by ginger. From the equations fertilizer recommendations are made for specific yield targets of ginger with and without FYM.

3.7.1 Calculations of basic parameters:

3.7.1.1 Nutrient requirement (NR):

Nutrient requirements were calculated for each and every treatments in all the four strips in terms of N, P_2O_5 and K_2O in Kg per tonne of rhizome production by using the following formulae.

$$\text{Kg N required per tonne of rhizome production} = \frac{\text{Total uptake of N (kg/ha)}}{\text{Rhizome yield (t/ha)}}$$

$$\text{Kg } P_2O_5 \text{ required per tonne of rhizome production} = \frac{\text{Total uptake of } P_2O_5 \text{ (kg/ha)}}{\text{Rhizome yield (t/ha)}}$$

$$\text{Kg } K_2O \text{ required per tonne of rhizome production} = \frac{\text{Total uptake of } K_2O \text{ (kg/ha)}}{\text{Rhizome yield (t/ha)}}$$

3.7.1.2 Percent contribution of nutrients from soil (Cs):

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

$$\text{\% Contribution of N from soil} = \frac{\text{Total uptake of N in control plot (kg/ha)}}{\text{STV for available N in control plot}} \times 100$$

$$\text{\% Contribution of } P_2O_5 \text{ from soil} = \frac{\text{Total uptake of } P_2O_5 \text{ in control plot (kg/ha)}}{\text{STV for available } P_2O_5 \text{ in control plot}} \times 100$$

$$\%\ \text{Contribution of } K_2O \text{ from soil} = \frac{\text{Total uptake of } K_2O \text{ in control plot (kg/ha)}}{\text{STV for available } K_2O \text{ in control plot}} \times 100$$

3.7.1.3 Percent contribution of nutrients from fertilizer (CF):

The percent contribution of nutrients from fertilizer were calculated utilizing the data obtained from plots treated with fertilizers only and no FYM was applied, by using the given formulae.

$$\%\ \text{Contribution of N from fertilizer} = \frac{\text{Total uptake of N in fertilizer treated plot (kg / ha)} - \text{STV for available N in treated plot} \times \frac{\text{Average Cs}}{100}}{\text{Fertilizer N applied (kg/ha)}} \times 100$$

$$\%\ \text{Contribution of } P_2O_5 \text{ from fertilizer} = \frac{\text{Total uptake of } P_2O_5 \text{ in fertilizer treated plot (kg / ha)} - \text{STV for available } P_2O_5 \text{ in treated plot} \times \frac{\text{Average Cs}}{100}}{\text{Fertilizer } P_2O_5 \text{ applied (kg/ha)}} \times 100$$

$$\%\ \text{Contribution of } K_2O \text{ from fertilizer} = \frac{\text{Total uptake of } K_2O \text{ in fertilizer treated plot (kg / ha)} - \text{STV for available } K_2O \text{ in treated plot} \times \frac{\text{Average Cs}}{100}}{\text{Fertilizer } K_2O \text{ applied (kg/ha)}} \times 100$$

3.7.1.4 Percent contribution of nutrients from FYM (COM):

The data from FYM applied plots but treated with no fertilizers were utilized to calculate the percent contribution of nutrients from FYM by using the given formulae.

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

$$\%\text{ Contribution of } P_2O_5 \text{ from FYM} = \frac{\text{Total uptake of } P_2O_5 \text{ in FYM treated plot} - \text{STV for available } P_2O_5 \text{ in treated plot} \times \frac{\text{Average CS}}{100}}{P_2O_5 \text{ applied through FYM (kg/ha)}} \times 100$$

$$\%\text{ Contribution of } K_2O \text{ from FYM} = \frac{\text{Total uptake of } K_2O \text{ in FYM treated plot} - \text{STV for available } K_2O \text{ in treated plot} \times \frac{\text{Average CS}}{100}}{K_2O \text{ applied through FYM (kg/ha)}} \times 100$$

After computation of data utilizing the above formulas, averages were taken out to obtain NR, CS, CF and COM in terms of N, P_2O_5 and K_2O.

3.7.1.5 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:

With out FYM,

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

$$FP_2O_5 = \frac{NR}{CF/100} T - \frac{CS}{CF} \times SP \times 2.29$$

$$FK_2O = \frac{NR}{CF/100} T - \frac{CS}{CF} SK \times 1.21$$

With FYM

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

$$FP_2O_5 = \frac{NR}{CF/100} T - \frac{CS}{CF} SP \times 2.29 - \frac{COM}{CF} \times OP \times 2.29$$

$$FK_2O = \frac{NR}{CF/100} T - \frac{CS}{CF} SK \times 1.21 - \frac{COM}{CF} OK \times 1.21$$

Where,

FN	= Fertilizer N in kg/ha
FP_2O_5	= Fertilizer P_2O_5 in kg/ha.
FK_2O	= Fertilizer K_2O in kg/ha
NR	= Nutrient requirement of N or P_2O_5 on K_2O in kg/t.
CS	= % Nutrient contribution from soil.
CF	= % Nutrient contribution from fertilizer
COM	= % Nutrient contribution from FYM.
SN	= STV for available N in kg/ha.
SP	= STV for available P in kg/ha.

SK =STV for available K in kg/ha.

ON = N applied through FYM in kg/ha.

OP = P applied through FYM in kg/ha.

OK = K applied through FYM in kg/ha.

T = Yield target in t/ha.

3.8 Influence of native elements in soil:

3.8.1 Soil Analysis:

The soil samples were analyzed for the micronutrients (Na, Ca, Mg, Cu, Zn, Fe, Mn) without providing any treatments to know the influence of these elements on yield and other attributes. The analytical procedures followed are presented in Table 3.

3.8.2 Plant Analysis:

The plant samples collected for STCR study were analyzed for the micro nutrient (Na, Ca, Mg, Cu, Zn, Fe, Mn), contents without giving any treatments, following the analytical procedure given in Table 3.

3.8.3 Statistical Analysis.

3.8.3.1 Correlation:

Correlation analysis is a statistical device, which helped to analyse the covariation of two or more variables. Correlation co-efficients were obtained using the analytical data, rhizome yield and with the basic soil characters.

3.8.3.2 Correlation of soil micronutrient content with yield

The data on analysis of micronutrient contents of soil as such correlated with the yield, without including any treatments and strip levels.

3.8.3.3 Correlation of plant micro nutrient content with yield

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

3.9 Path Analysis

The correlations co-efficient of soil and plant micro nutrient contents with yield were subjected to path analysis to know the direct and indirect effects.

RESULTS

CHAPTER 4
RESULTS

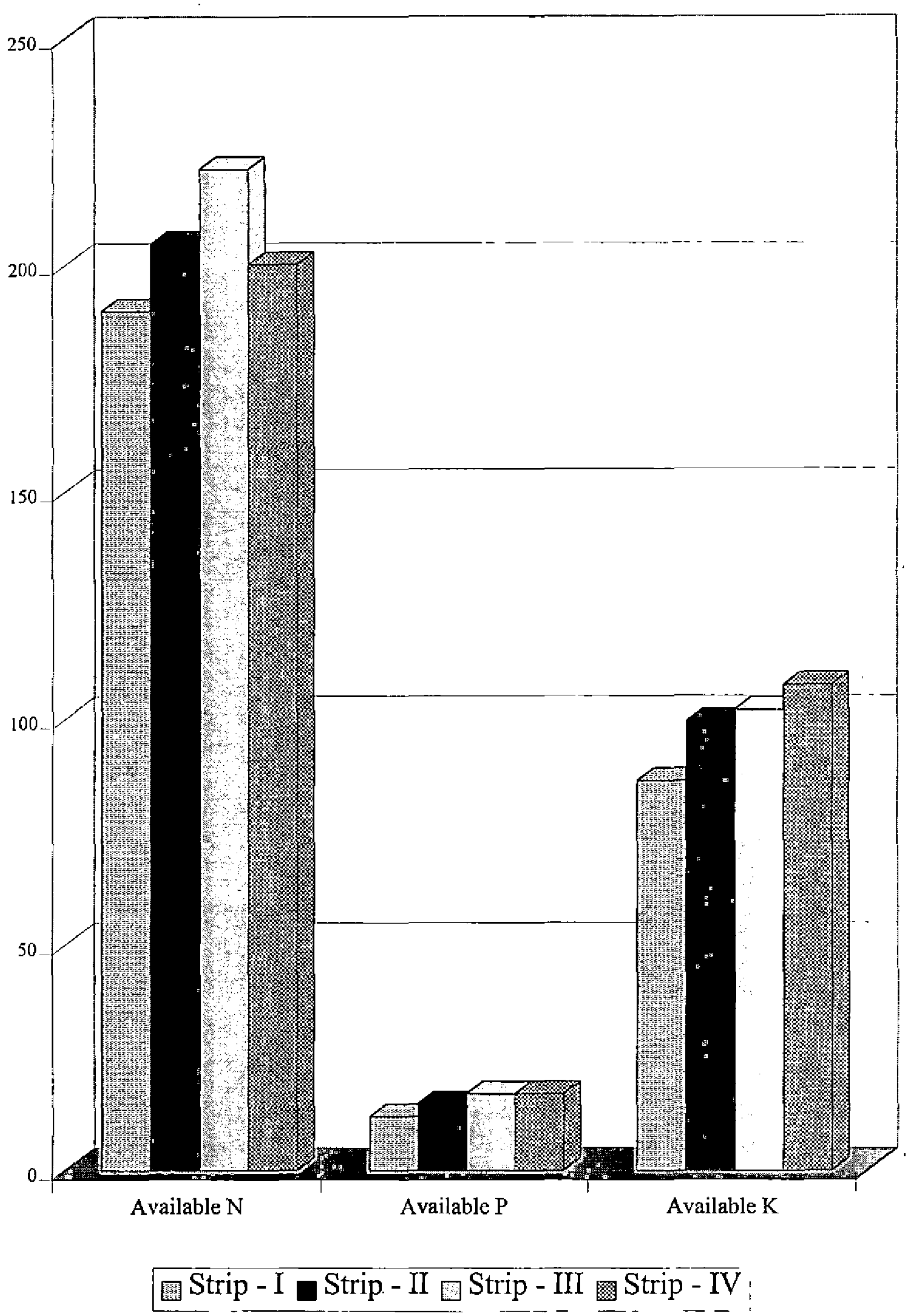
Soil testing provide fertilizer recommendation for profitable and sustainable crop production. To obtain significant correlation between soil test values and crop response to fertilizers, the soil test calibration and fertilizer recommendation must be based on local field experiments. Hence the present study was undertaken to establish soil test based balanced fertilizer prescription for ginger variety Maran in the laterite soils of Kerala. The field experiments consisted of fertility gradient and test crop experiment. The related results of the experiments are presented in this chapter.

4.1 Fertility Gradient Experiment:

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

To develop a fertility gradient, experimental area was divided into four equal strips and each strip into four equal blocks. By applying graded doses of N, P and K a deliberate attempt was made to create a gradient in soil fertility from strip 1 to strip IV. A preparatory crop of fodder maize variety Co.1 was raised. By comparing the response of the gradient crop in all the four strips and the soil test values before and after the experiment, it can be checked, whether sufficient fertility gradient has been created or not. The data were also analysed statistically to confirm the build up of fertility gradient.

Fig.4. **Soil fertility status after fertility gradient experiment**



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 contents after the harvest of fodder maize (gradient crop). The data on soil analysis are furnished in Table 6 and Fig. 4.

The soil nutrient status prior to the conduct of FGE (Table 6) ranged from 0.768 to 1.132% of organic carbon 206.0 to 233.1 kg/ha available N 12.3 to 17.9 kg/ha available P and 68.24 to 81.88 kg/ha of available K respectively.

The analysis of soil samples collected after the harvest of the fodder maize revealed that the ranges were 0.631% to 1.084% for organic carbon, and 189.8 to 221.3 kg/ha for available N 11.8 to 16.9 kg/ha for available P and 86.1 to 107.3, kg/ha for available K contents respectively.

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 increased progressively from strip I to strip IV (Table 7) with increase in the nutrient levels of N, P and K applied. (Fig. 5 & 6)

The nutrient uptake is calculated from the nutrient content of maize and dry fodder yield. The statistical analysis of the data showed that fodder yield and nutrient uptake by the gradient crop differed significantly in the strips.

4.2 STCR Experiment:

After the creation of fertility gradient by applying graded doses of fertilizers the STCR experiment was conducted in the same field by raising the test crop of ginger var. Maran. For STCR experiment each strip was divided

Fig.5 **Yield of fodder maize after fertility gradient experiment**

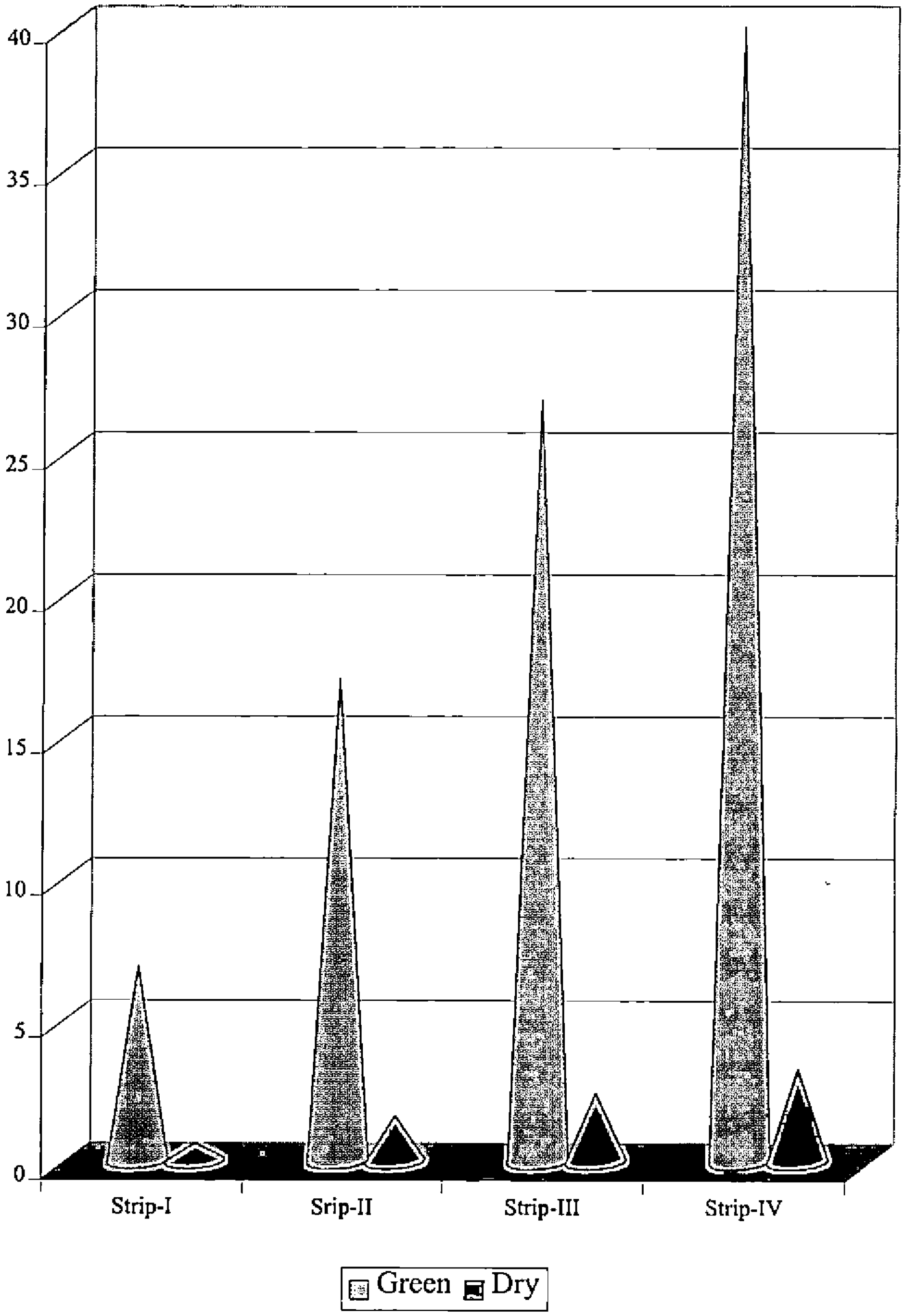
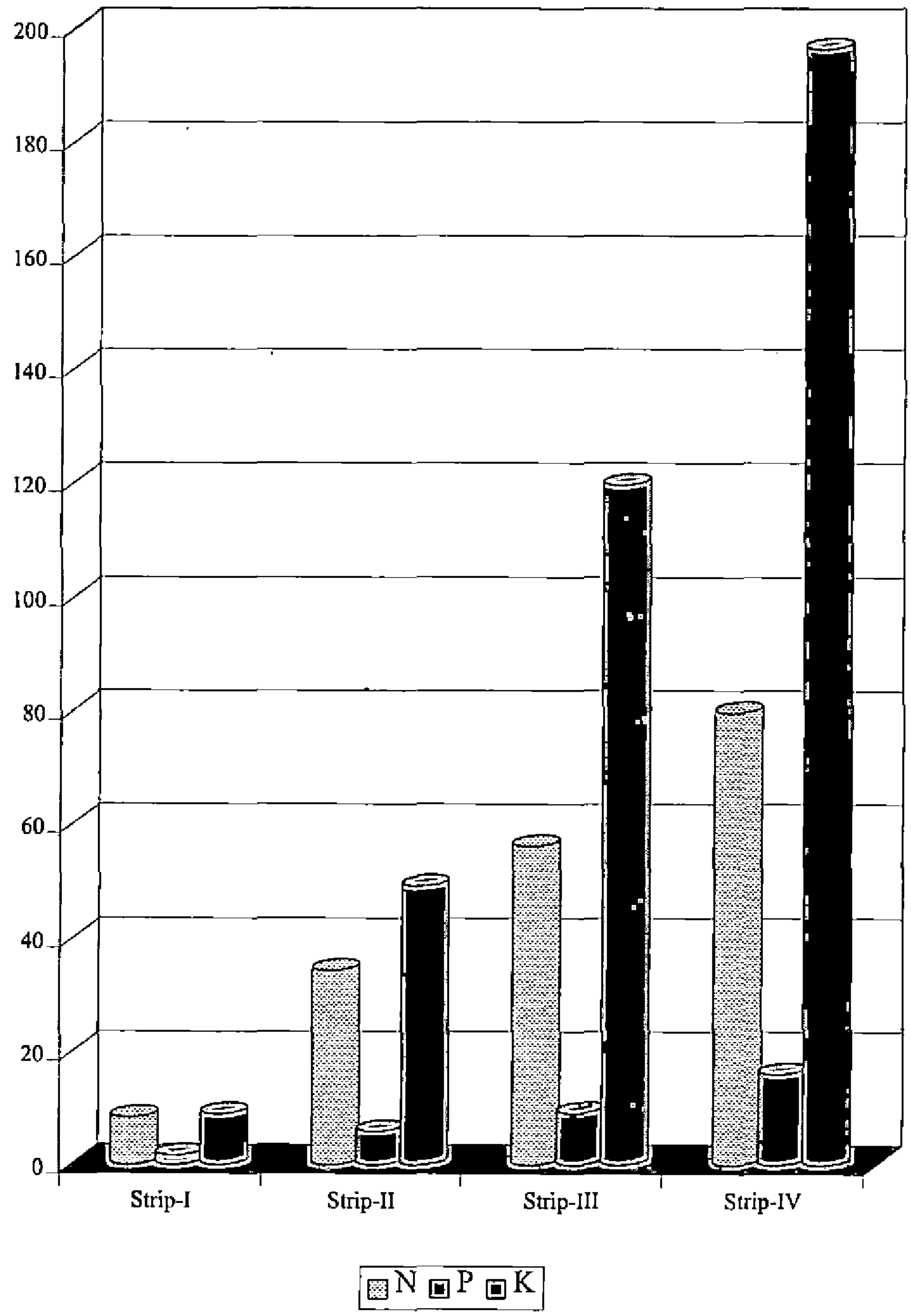


Fig. 6. **Uptake of fodder maize after fertility gradient experiment**



into 24 plots of equal size. The relationship between soil fertility, applied nutrients and the resultant crop yield was evaluated under uniform environmental conditions, and management practices.

Judicious combinations of organic and inorganic sources of nutrients were used to obtain economy in fertilizer use and enhanced nutrient use efficiency. In the test crop experiment, three levels of FYM was maintained as a treatment along with inorganic fertilizer treatments. The organic manure was applied across the strips in four blocks (Reddy, *et.al.,* 1985).

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 strip IV.

Each strip contained two control plots, those plots that received no FYM or fertilizer for ginger. The remaining plots (22 per strip) received either FYM or fertilizer or a combination of both organics and inorganics.

4.2.1 Pre-planting soil analysis

Soil samples were collected prior to application of fertilizers and sowing of ginger to estimate the contribution of nutrients from the soil. The soil samples were analysed for organic carbon and available N, P and K and the data are given in Table 8 to 11. In each strip the mean values of soil nutrient content is calculated and furnished in Table 12 and Fig. 7

Organic carbon content in the soil varied from 0.563 to 0.65, 0.69 to 0.84, 0.82 to 0.92 and 0.91 to 1.07% in strip I, II, III and IV respectively. (Table 8) and the corresponding mean values were 0.61, 0.77, 0.89 and 0.98% (Table - 12).

Soil available N registered a range in values from 176.4 to 199.8, 193.8 to 211.3, 218.7 to 238.0 and 200.0 to 228.9, kg/ha in strip I, II, III and IV with mean values of 188.5, 205.1, 226.4 and 213.6 (Table - 12).

Available P status (Table 10) ranged from 11.68 to 13.99, 14.68 to 16.31, 15.98 to 16.99 and 16.66 to 17.22 in strip I, II, III and IV respectively. The average mean values in the respective strips (Table 12) were 12.90, 15.63, 16.49 and 16.95, kg/ha.

Available K (Table 11) ranged from 86.38 to 93.69, 93.92 to 101.21, 100.2 to 106.7 and 103.8 to 119.1 in Strip I, Strip II, Strip III and Strip IV respectively. The average K contents in strip I to IV (Table 12) were 90.04, 97.9, 103.5 and 112.1 kg/ha respectively.

Table 8. Organic carbon (%) in soil prior to STCR experiment

T.No.	N	P	K	FYM	Strip 1	FYM	Strip2	FYM	Strip 3	FYM	Strip 4
1	0	0	0	0	0.64	1	0.78	0	0.89	2	0.97
2	0	0	0	2	0.61	0	0.70	1	0.90	0	0.93
3	0	0	0	0	0.60	2	0.73	0	0.86	1	0.95
4	0	0	0	1	0.58	0	0.71	2	0.90	0	1.01
5	0	0	1	2	0.59	0	0.69	1	0.91	0	1.07
6	1	0	1	2	0.63	0	0.81	0	0.91	1	0.97
7	1	1	1	2	0.64	1	0.73	0	0.89	0	0.93
8	0	0	2	2	0.65	0	0.83	0	0.87	1	0.92
9	0	1	2	2	0.63	1	0.80	0	0.90	0	0.91
10	1	0	2	0	0.58	1	0.73	2	0.89	0	0.92
11	1	1	2	0	0.57	1	0.83	2	0.91	0	0.98
12	2	0	2	0	0.62	0	0.84	1	0.86	2	0.93
13	2	2	2	0	0.59	2	0.81	0	0.88	1	1.01
14	2	2	2	0	0.62	2	0.70	1	0.91	0	0.94
15	0	0	3	1	0.64	0	0.78	2	0.92	0	1.05
16	1	0	3	1	0.62	0	0.80	0	0.83	2	1.07
17	2	1	3	0	0.59	1	0.81	0	0.89	2	1.03
18	3	0	3	0	0.60	0	0.77	1	0.86	0	0.94
19	3	0	3	1	0.59	0	0.81	0	0.90	2	0.94
20	3	0	3	0	0.56	0	0.73	2	0.88	1	1.03
21	2	2	4	0	0.62	2	0.77	0	0.91	1	0.99
22	2	2	4	0	0.63	2	0.81	1	0.82	0	0.94
23	3	0	4	1	0.61	0	0.80	2	0.90	0	1.03
24	3	0	4	1	0.60	0	0.81	0	0.92	2	0.97

Table 9. Available N (kg/ha) in soil prior to STCR experiment

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	189.9	1	199.8	0	228.0	2	200.0
2	0	0	0	2	193.2	0	200.2	1	223.0	0	201.0
3	0	0	0	0	199.8	2	211.1	0	224.8	1	202.8
4	0	0	0	1	176.4	0	202.8	2	221.3	0	208.6
5	0	0	1	2	188.6	0	204.6	1	233.8	0	204.8
6	1	0	1	2	183.4	0	208.3	0	231.6	1	210.3
7	1	1	1	2	188.7	1	210.1	0	222.6	0	211.8
8	0	0	2	2	178.9	0	199.8	0	218.7	1	201.3
9	0	1	2	2	186.8	1	201.1	0	232.8	0	208.5
10	1	0	2	0	189.9	1	203.4	2	218.9	0	209.6
11	1	1	2	0	193.1	1	201.8	2	222.3	0	212.3
12	2	0	2	0	190.0	0	209.3	1	218.7	2	218.4
13	2	1	2	0	188.8	2	210.1	0	224.8	1	219.6
14	2	2	2	0	187.6	2	208.1	1	228.1	0	213.8
15	0	0	3	1	182.3	0	207.8	2	229.3	0	221.3
16	1	1	3	1	183.1	0	210.1	0	231.6	2	218.1
17	2	2	3	0	194.3	1	211.3	0	234.8	2	221.6
18	3	0	3	0	192.1	0	208.9	1	218.8	0	228.9
19	3	1	3	1	198.1	0	199.3	0	225.6	2	226.3
20	3	2	3	0	191.2	0	198.4	2	236.8	1	221.3
21	2	1	4	0	190.0	2	193.8	0	228.9	1	218.9
22	2	2	4	0	188.0	2	202.6	1	218.8	0	217.3
23	3	1	4	15	189.3	2	208.9	2	222.4	0	210.0
24	3	2	4	15	188.7	2	210.3	0	238.0	2	220.9

Table 10. Available P (kg/ha) in soil prior to STCR experiment

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	11.83	1	14.68	0	16.87	2	16.90
2	0	0	0	2	12.10	0	14.90	1	16.99	0	16.88
3	0	0	0	0	12.23	2	15.10	0	16.66	1	16.90
4	0	0	0	1	11.90	0	14.72	2	16.89	0	16.73
5	0	0	1	2	13.12	0	14.78	1	16.77	0	17.01
6	1	0	1	2	13.23	0	15.31	0	16.82	1	17.22
7	1	1	1	2	11.99	1	15.92	0	16.63	0	17.03
8	0	0	2	2	12.86	0	14.93	0	16.58	1	17.08
9	0	1	2	2	11.93	1	15.38	0	16.43	0	17.14
10	1	0	2	0	12.68	1	15.99	2	16.32	0	17.18
11	1	1	2	0	13.01	1	16.01	2	16.88	0	16.93
12	2	0	2	0	13.36	0	16.31	1	16.34	2	16.66
13	2	1	2	0	13.58	2	15.38	0	16.10	1	16.84
14	2	2	2	0	12.69	2	15.99	1	16.28	0	16.92
15	0	0	3	1	11.68	0	15.76	2	16.38	0	16.94
16	1	1	3	1	13.99	0	16.03	0	16.66	2	16.98
17	2	2	3	0	11.89	1	16.11	0	16.78	2	16.73
18	3	0	3	0	12.90	0	16.22	1	16.91	0	16.89
19	3	1	3	1	13.33	0	15.98	0	16.18	2	16.99
20	3	2	3	0	13.90	0	15.87	2	16.12	1	16.93
21	2	1	4	0	13.89	2	15.66	0	15.99	1	17.07
22	2	2	4	0	13.94	2	15.99	1	15.98	0	17.02
23	3	1	4	15	13.88	0	16.21	2	16.01	0	16.91
24	3	2	4	15	13.67	0	16.11	0	16.12	2	17.00

Table 11. Available K (kg/ha) in soil prior to STCR experiment

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	86.38	1	94.68	0	100.3	2	107.2
2	0	0	0	2	88.99	0	95.99	1	100.8	0	108.9
3	0	0	0	0	87.33	2	96.88	0	101.3	1	108.7
4	0	0	0	1	89.34	0	93.99	2	102.6	0	111.3
5	0	0	1	2	90.01	0	95.83	1	101.8	0	111.4
6	1	0	1	2	87.39	0	96.01	0	102.6	1	109.8
7	1	1	1	2	91.21	1	94.68	0	103.1	0	107.6
8	0	0	2	2	92.38	0	94.99	0	104.3	1	106.7
9	0	1	2	2	89.01	1	97.80	0	104.8	0	107.1
10	1	0	2	0	93.46	1	99.31	2	103.9	0	107.9
11	1	1	2	0	91.38	1	99.80	2	102.6	0	107.2
12	2	0	2	0	92.44	0	101.21	1	105.6	2	103.8
13	2	1	2	0	87.20	2	100.81	0	106.0	1	109.7
14	2	2	2	0	89.38	2	93.92	1	105.9	0	110.2
15	0	0	3	1	89.44	0	97.91	2	101.8	0	116.3
16	1	1	3	1	88.38	0	98.31	0	104.3	2	117.8
17	2	2	3	0	87.39	1	98.90	0	105.7	2	117.9
18	3	0	3	0	89.14	2	98.91	1	106.3	0	118.3
19	3	1	3	1	89.88	0	99.61	0	103.8	2	116.8
20	3	2	3	0	91.16	0	100.60	2	103.2	1	119.1
21	2	1	4	0	92.68	2	100.23	0	103.9	1	117.3
22	2	2	4	0	93.69	2	99.91	1	106.7	0	118.3
23	3	1	4	15	91.68	0	100.80	2	101.8	0	117.9
24	3	2	4	15	90.91	0	98.88	0	100.2	2	112.8

Fig. 7. **Soil nutrient content prior to STCR experiment**

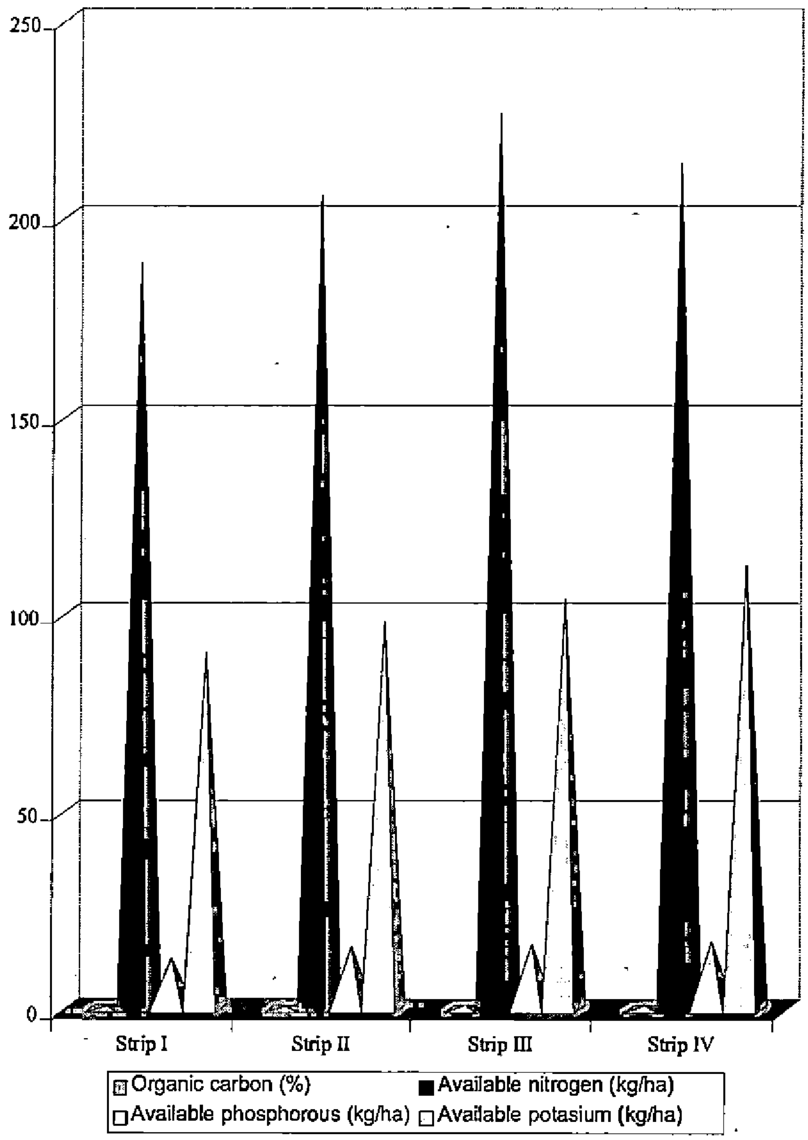


Table 12: Strip wise mean values of soil nutrient content prior to STCR experiment:

Particulars	Mean vlaues of strips			
	I	II	III	IV
Organic carbon (%)	0.61	0.77	0.89	0.98
Available nitrogen (kg/ha)	188.5	205.1	226.4	213.6
Available phosphorous (kg/ha)	12.9	15.63	16.49	16.95
Available potasium (kg/ha)	90.04	97.9	103.5	112.1

Considering the STV of all plots of the whole field (Table 8 to 11) it could be seen that soil fertility status ranged from 0.563 to 1.068% of organic carbon, and 176.4 to 228.9 kg/ha, 11.83 to 17.22 and 86.38 to 119.1 kg/ha of available N, P and K respectively. From the data it is obvious that the necessary gradient in soil fertility was created in the field for conducting the STCR experiment.

4.2.2 Yield of Ginger:

The strip wise mean values of rhizome yield are presented in Table 13 and Fig. 8.The data on rhizome yield of ginger, recorded in the experiment is given in Table-14

As evident from the data on rhizome yield, the control plots in all the strips registered much lower yield (8307 to 10720 kg/ha) than the treated plots (13,337 to 17,978 kg/ha) in the respective strips.

The average rhizome yield in control plots ranged from strip 1 to strip IV was 8307, 9937, 11757 and 10720 kg/ha.

Table 13: Strip wise mean yield of ginger

Rhizhome yield kg/ha	Mean values of strips			
	I	II	III	IV
Control plots	8307	9937	11757	10720
Treated plots	13337	13893	17978	16682
All pots	12918	13563	17460	16185

The average rhizome yield in treated plots were in the range of 13,337, 17,978kg/ha and the respective mean values from strip I to strip IV were 13,337, 13,893, 17,978 and 16,682 kg/ha respectively.

Table 14. Rhizome yield of ginger (kg/ha) as influenced by treatments

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	9667	1	9517	0	11580	2	17487
2	0	0	0	2	8160	0	10590	1	11867	0	10570
3	0	0	0	0	9822	2	10357	0	11933	1	13777
4	0	0	0	1	8453	0	11850	2	13223	0	10870
5	0	0	1	2	18737	0	11837	1	19240	0	13877
6	1	0	1	2	18213	0	9200	0	15721	1	13940
7	1	1	1	2	17260	1	17027	0	14520	0	18410
8	0	0	2	2	17160	0	13467	0	22717	1	18733
9	0	1	2	2	17123	1	13597	0	14053	0	12053
10	1	0	2	0	6297	1	14820	2	22866	0	19850
11	1	1	2	0	12870	1	15633	2	14143	0	9840
12	2	0	2	0	11030	0	15280	1	19240	2	18550
13	2	1	2	0	17213	2	13910	0	14260	1	16933
14	2	2	2	0	9873	2	14463	1	22380	0	15053
15	0	0	3	1	16163	0	15137	2	12960	0	11807
16	1	1	3	1	15393	0	11593	0	17910	2	14787
17	2	2	3	0	11517	1	19623	0	19030	2	27260
18	3	0	3	0	6837	2	18567	1	19860	0	20140
19	3	1	3	1	21967	0	15180	0	21963	2	19877
20	3	2	3	0	7003	0	11037	2	18467	1	17800
21	2	1	4	0	7850	2	16160	0	20450	1	15993
22	2	2	4	0	8567	2	18073	1	18227	0	14107
23	3	1	4	1	17000	0	9177	2	20447	0	18330
24	3	2	4	1	15853	0	9417	0	21977	2	18393

Fig. Yield of Ginger as influenced by available and applied nutrients

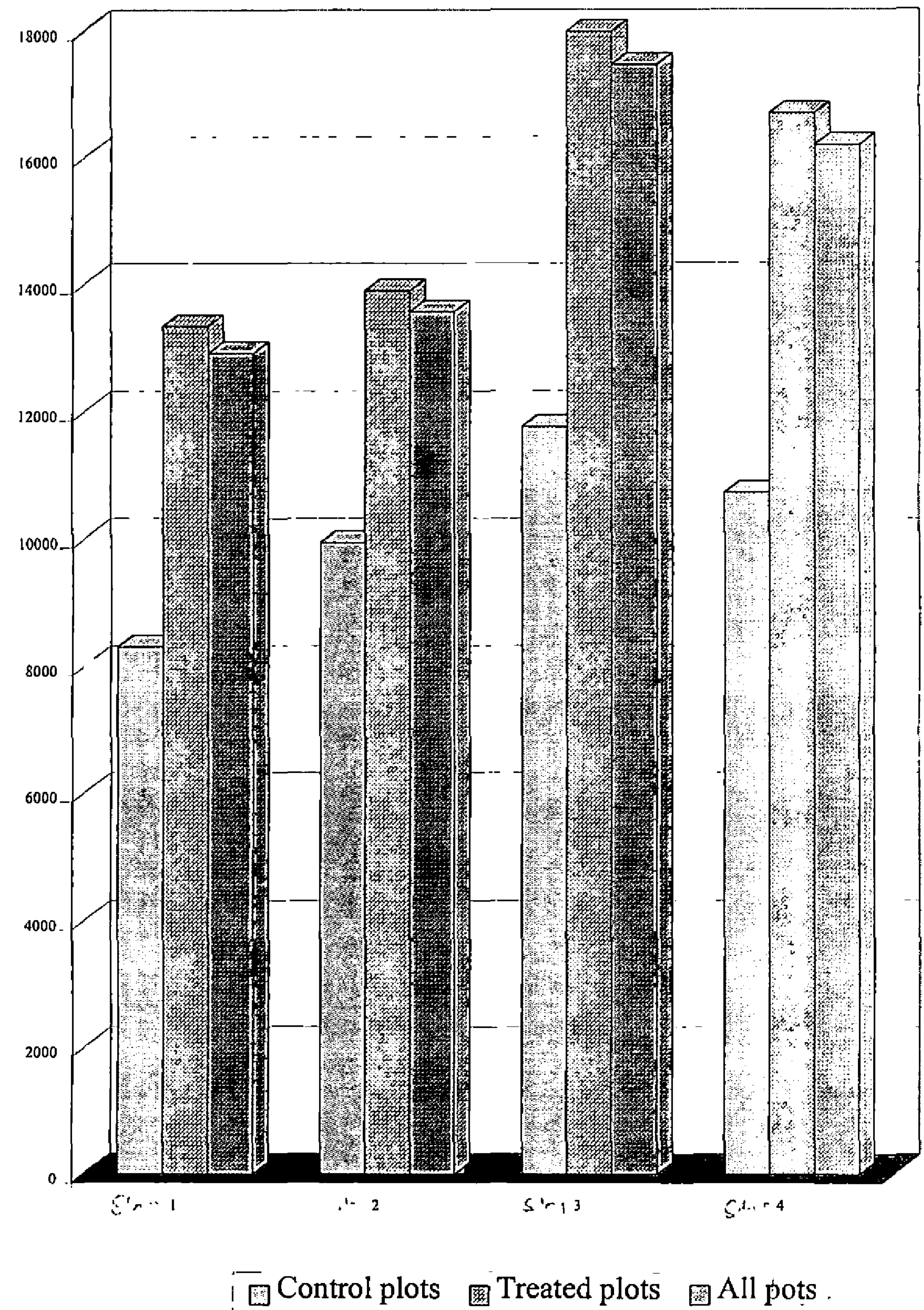


Table 15. Maximum and minimum Rhizome yield obtained due to treatments

Particulars	Strip	Soil test values (kg/ha)			Fertilizer doses (kg/ha)			FYM t/ha	Rhizome Yield (kg/ha)
		N	P	K	N	P_2O_5	K_2O		
Maximum yield	4	151.9	28.9	145.6	100	75	150	30	27260
Minimum yield	1	186.7	20.1	101.6	50	0	75	15	6297

The average rhizome yield in all the plots ranged from 12918 kg/ha to 17460 kg/ha and the respective mean values of 12918, 13563, 17460,and 16185 kg/ha were recorded in strip 1 to strip IV respectively

Among the treated plots, the highest rhizome yield of 27,260 kg/ha was obtained from strip IV which received 30 t/ha of FYM and 100:75:150 kg/ha of N, P_2O_5 and K_2O as fertilizers, when the STVs were 151.9, 28.9 and 145.6 kg/ha of available N, P and K respectively (Table 15).

The lowest rhizome yield of 6297 kg/ha was registered with strip 1 by the application of 50: 0: 75kg/ha^{-1} of N, P_2O_5 and K_2O respectively which received 15 t/ha of FYM and the STVs were 186.7, 20.1 and 101.6 kg/ha of available N, P and K respectively (Table15).

4.2.3 Soil analysis after STCR Experiment:

Soil samples were collected after the harvest of ginger from all the treatments and analysed for organic carbon and available N, P and K. The data are given in Table 16 to 19.

Organic carbon content in the soil varied from 0.25 to 1.47, 0.31 to 1.30, 0.21 to 1.46 and 0.20 to 1.24 in strip I, II, III and IV respectively. (Table 16) and the corresponding mean values were 0.86, 0.84, 0.90 and 0.79 respectively

Soil available N varied from 101.8 to 247.8, 101.5 to 233.9, 119.4 to 285.5 and 108.9 to 252.3 kg/ha in strip I, II, III and IV respectively (Table 17) and the respective mean values were 155.0,146.9,188.0, and 174.9kg/ha

Available P status (Table 18) ranged from 8.2 to30.9, 11.3 to 41.8, 20.1 to 43.7 and 17 to 46.5 kg/hg in strip I, II, III and IV respectively and the corresponding mean values were 19.0,23.9,30.3,and 29.2kg/ha respectively.

Available K (Table 19) varied from 101.6 to 235.2, 112 to 235.2, 112.0 to 201.6 and 112 to 224 kg/ha in strip I, II, III and IV respectively and the respective mean values were 154.6,146.4,162.8,and 151.3kg/ha respectively.

Table 16. Organic carbon (%) after STCR experiment

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	0.67	1	0.31	0	1.15	2	1.00
2	0	0	0	2	1.22	0	0.84	1	1.46	0	0.39
3	0	0	0	0	0.68	2	1.15	0	1.11	1	0.89
4	0	0	0	1	1.00	0	1.30	2	1.46	0	0.62
5	0	0	1	2	0.65	0	0.52	1	0.93	0	1.09
6	1	0	1	2	1.08	0	0.91	0	0.44	1	1.01
7	1	1	1	2	1.17	1	1.19	0	0.17	0	0.37
8	0	0	2	2	0.32	0	0.55	0	1.22	1	0.75
9	0	1	2	2	0.83	1	0.94	0	0.93	0	1.00
10	1	0	2	0	0.92	1	0.87	2	1.16	0	0.96
11	1	1	2	0	1.03	1	1.09	2	0.83	0	0.73
12	2	0	2	0	1.07	0	1.09	1	1.40	2	0.54
13	2	1	2	0	0.65	2	1.09	0	1.18	1	0.80
14	2	2	2	0	0.72	2	0.99	1	0.70	0	1.03
15	0	0	3	1	1.20	0	0.88	2	0.87	0	0.85
16	1	1	3	1	0.50	0	1.05	0	0.70	2	1.24
17	2	2	3	0	0.50	1	0.48	0	1.08	2	0.75
18	3	0	3	0	0.25	2	0.70	1	0.76	0	1.06
19	3	1	3	1	0.58	0	0.96	0	1.12	2	1.06
20	3	2	3	0	1.22	0	0.41	2	1.11	1	0.20
21	2	1	4	0	1.47	2	1.16	0	0.41	1	1.16
22	2	2	4	0	0.78	2	0.12	1	0.21	0	0.58
23	3	1	4	15	1.00	0	0.78	2	0.45	0	0.39
24	3	2	4	15	1.17	0	0.79	0	0.79	2	0.55

Table 17. Available N (kg/ha) in soil after STCR experiment

T.No.	N	P	K	FYM	Strips	FYM	Strip2	FYM	Strip 3	FYM	Strip 4
1	0	0	0	0	135.8	1	113.7	0	234.1	2	203.6
2	0	0	0	2	247.8	0	170.2	1	219.9	0	180.2
3	0	0	0	0	139.1	2	233.9	0	225.4	1	180.6
4	0	0	0	1	203.6	0	174.5	2	196.9	0	229.8
5	0	0	1	2	132.3	0	112.4	1	188.3	0	220.9
6	1	0	1	2	220.5	0	145.3	0	188.6	1	206.5
7	1	1	1	2	237.6	1	112.4	0	134.2	0	174.5
8	0	0	2	2	116.5	0	112.4	0	248.4	1	151.9
9	0	1	2	2	169.6	1	191.4	0	188.4	0	203.6
10	1	0	2	0	186.7	1	116.3	2	166.9	0	195.4
11	1	1	2	0	210.3	1	221.9	2	198.4	0	139.0
12	2	0	2	0	117.2	0	171.9	1	285.5	2	108.9
13	2	1	2	0	132.3	2	130.9	0	139.8	1	163.5
14	2	2	2	0	106.0	2	101.5	1	142.7	0	209.3
15	0	0	3	1	244.3	0	179.2	2	176.9	0	172.0
16	1	1	3	1	101.8	0	112.8	0	142.7	2	252.3
17	2	2	3	0	101.8	1	197.3	0	219.7	2	151.9
18	3	0	3	0	110.9	2	142.7	1	154.1	0	215.0
19	3	1	3	1	118.7	0	124.4	0	228.2	2	215.0
20	3	2	3	0	117.8	0	160.1	2	225.4	1	140.1
21	2	1	4	0	228.7	2	137.0	0	182.9	1	135.2
22	2	2	4	0	109.4	2	114.1	1	147.0	0	117.5
23	3	1	4	15	113.6	0	128.0	2	119.4	0	118.2
24	3	2	4	15	117.6	0	121.0	0	159.8	2	111.8

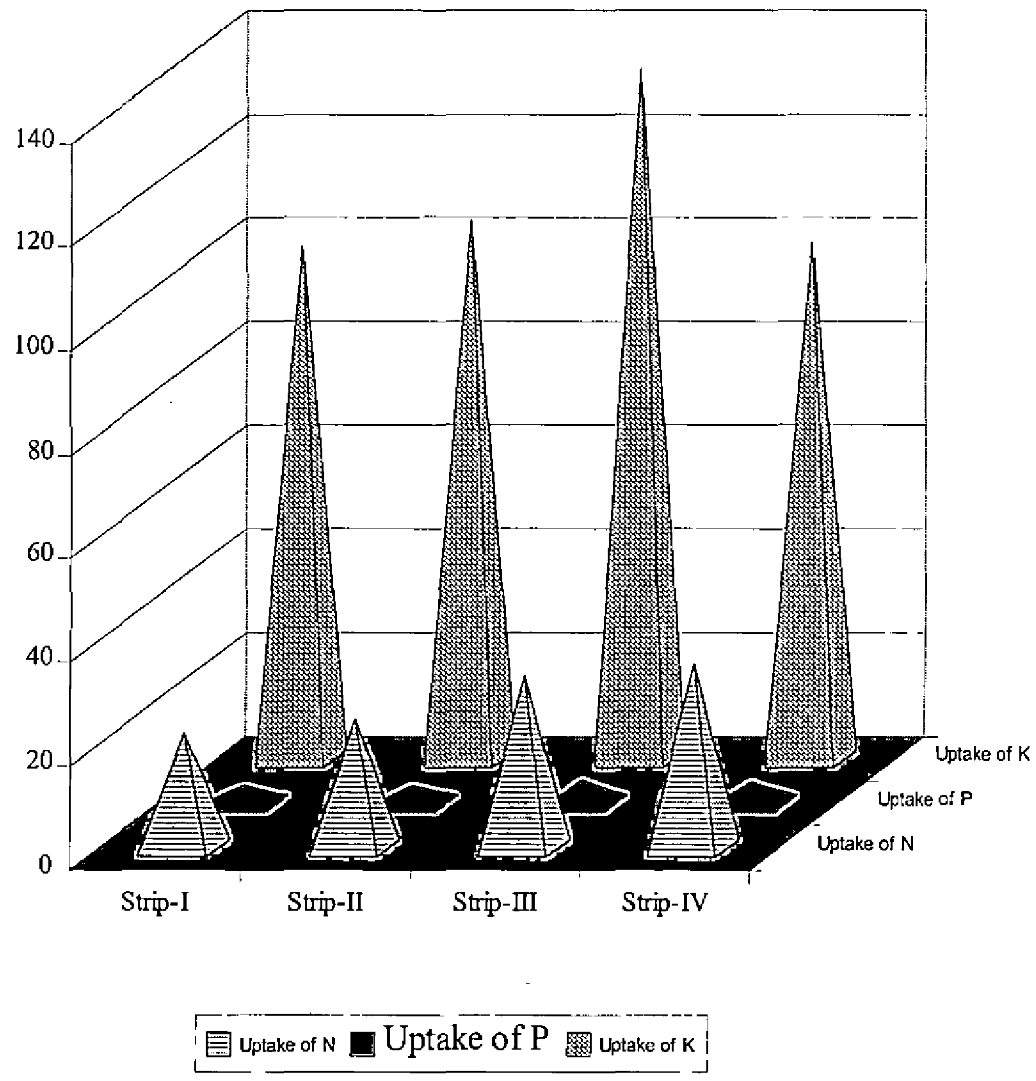
Table 18. Available P (Kg/ha) in soil after STCR experiment

T.No.	N	P	K	FYM	Strips	FYM	Strip2	FYM	Strip 3	FYM	Strip 4
1	0	0	0	0	13.5	1	33.2	0	31.5	2	38.3
2	0	0	0	2	22.5	0	11.3	1	32.1	0	36.4
3	0	0	0	0	15.4	2	30.3	0	23.7	1	26.6
4	0	0	0	1	30.9	0	17.2	2	39.0	0	23.8
5	0	0	1	2	29.7	0	19.9	1	34.0	0	31.1
6	1	0	1	2	35.4	0	25.7	0	20.1	1	20.5
7	1	1	1	2	28.1	1	25.6	0	26.6	0	34.8
8	0	0	2	2	27.0	0	41.8	0	29.7	1	13.9
9	0	1	2	2	18.8	1	25.4	0	26.6	0	17.0
10	1	0	2	0	20.1	1	26.8	2	32.2	0	21.5
11	1	1	2	0	13.9	1	31.5	2	39.4	0	24.4
12	2	0	2	0	19.0	0	13.9	1	28.3	2	20.3
13	2	1	2	0	13.3	2	30.0	0	29.2	1	30.3
14	2	2	2	0	8.2	2	31.2	1	37.0	0	35.7
15	0	0	3	1	21.1	0	36.0	2	43.7	0	30.5
16	1	1	3	1	21.5	0	23.1	0	25.4	2	36.7
17	2	2	3	0	11.9	1	13.4	0	21.7	2	28.9
18	3	0	3	0	15.1	2	18.5	1	31.9	0	27.4
19	3	1	3	1	12.5	0	28.9	0	29.5	2	46.5
20	3	2	3	0	14.7	0	12.5	2	29.9	1	26.8
21	2	1	4	0	9.2	2	25.2	0	34.8	1	39.5
22	2	2	4	0	22.1	2	24.2	1	33.0	0	33.2
23	3	1	4	15	22.3	0	13.5	2	25.1	0	25.0
24	3	2	4	15	10.0	0	15.4	0	22.8	2	32.8

Table 19. Available K (kg/ha) in soil after STCR experiment

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip 3	FYM	Strip 4
1	0	0	0	0	134.4	1	112.4	0	190.4	2	123.2
2	0	0	0	2	112.0	0	122.4	1	179.2	0	201.6
3	0	0	0	0	100.8	2	123.2	0	201.6	1	134.4
4	0	0	0	1	190.4	0	100.8	2	190.4	0	179.2
5	0	0	1	2	168.0	0	130.4	1	145.6	0	156.8
6	1	0	1	2	208.8	0	126.8	0	134.4	1	160.4
7	1	1	1	2	206.0	1	168.0	0	112.8	0	123.2
8	0	0	2	2	201.6	0	139.2	0	179.2	1	112.0
9	0	1	2	2	156.0	1	160.4	0	156.8	0	134.4
10	1	0	2	0	101.6	1	112.0	2	145.6	0	112.0
11	1	1	2	0	145.6	1	168.0	2	201.6	0	116.8
12	2	0	2	0	134.4	0	168.0	1	156.8	2	145.6
13	2	1	2	0	134.4	2	156.8	0	134.4	1	159.2
14	2	2	2	0	145.6	2	146.4	1	168.0	0	159.2
15	0	0	3	1	156.8	0	134.4	2	166.4	0	123.2
16	1	1	3	1	179.2	0	134.4	0	190.4	2	145.6
17	2	2	3	0	145.6	1	212.8	0	201.6	2	145.6
18	3	0	3	0	116.8	2	185.2	1	112.0	0	156.8
19	3	1	3	1	179.2	0	145.6	0	156.8	2	134.4
20	3	2	3	0	112.0	0	136.4	2	123.2	1	224.0
21	2	1	4	0	235.2	2	235.2	0	145.6	1	123.2
22	2	2	4	0	124.6	2	124.8	1	134.4	0	168.0
23	3	1	4	15	155.2	0	157.6	2	201.6	0	89.6
24	3	2	4	15	165.3	0	112.8	0	179.2	2	201.6

Fig. 9. **Uptake of N, P and K by ginger as influenced byavailable and applied nutrients**



4.2.4 Nutrient uptake by ginger:

The nutrient uptake of ginger was calculated separately for rhizome, root and leaf, for all the treatments. Total nutrient uptake by ginger (rhizome uptake + leaf uptake + root uptake) is represented in Table 20 to 22 and Fig. 9. The mean values in each strip are given in Table 23 and Fig. 10.

Uptake of N, P and K ranged from 11.9 to 60.1, 1.3 to 9.0 and 39.30 to 221.9 kg/ha N, P and K in strip I, II, III and IV respectively (Table 20 to 22). The highest uptake was registered by K followed by N and P.

In the control plots (Table 23) uptake of N registered mean values of 14.7, 16.0, 18.9 and 26.6 kg/ha in strip I, II, III and IV respectively. The mean P uptake of in strip 1 to IV were 2.1,1.5, 3.1 and 3.5, kg/ha. Uptake of K recorded means values of 61.1,65.2, 105.1 and 82.4 kg/ha in strips I to IV.

In general the mean values of N uptake in strip I, II, III and IV were 24.1, 24.9, 33.0 and 34.0 kg/ha respectively.

Table 20. Uptake of N (kg/ha) as influenced by treatments

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	14.8	1	11.9	0	16.4	2	34.4
2	0	0	0	2	23.3	0	13.8	1	27.9	0	24.4
3	0	0	0	0	14.5	2	20.1	0	21.3	1	35.2
4	0	0	0	1	13.5	0	19.8	2	33.3	0	28.8
5	0	0	1	2	24.3	0	17.9	1	22.5	0	28.9
6	1	0	1	2	34.5	0	26.3	0	30.3	1	38.8
7	1	1	1	2	49.4	1	28.8	0	35.3	0	34.8
8	0	0	2	2	24.2	0	28.8	0	30.6	1	36.0
9	0	1	2	2	20.8	1	21.5	0	34.0	0	24.7
10	1	0	2	0	20.8	1	28.8	2	25.1	0	37.2
11	1	1	2	0	34.5	1	44.3	2	60.1	0	55.4
12	2	0	2	0	26.9	0	28	1	51.8	2	52.6
13	2	1	2	0	24.3	2	24.4	0	26.9	1	27.1
14	2	2	2	0	18.7	2	20.8	1	49.6	0	22.9
15	0	0	3	1	19.7	0	28.0	2	27.8	0	18.5
16	1	1	3	1	18.8	0	21.8	0	29.4	2	33.3
17	2	2	3	0	21.6	1	30.0	0	43.2	2	48.8
18	3	0	3	0	26.2	2	27.2	1	40.7	0	34.2
19	3	1	3	1	30.1	0	23.3	0	35.7	2	48.1
20	2	2	3	0	28.7	0	26.4	2	30.1	1	48.4
21	2	1	4	0	28.0	2	33.5	0	45.4	1	32.1
22	2	2	4	0	15.3	2	16.9	1	15.9	0	27.1
23	3	1	4	1	27.8	0	27.8	2	26.1	0	18.3
24	3	2	4	1	18.1	0	28.1	0	31.7	2	26.2

Table 21. Uptake of P (kg/ha) as influenced by treatments

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	2.5	1	2.2	0	2.3	2	8.5
2	0	0	0	2	5.4	0	1.5	1	4.8	0	3.4
3	0	0	0	0	1.6	2	1.7	0	3.9	1	4.8
4	0	0	0	1	1.7	0	1.4	2	6.5	0	3.5
5	0	0	0	2	4.6	0	1.8	1	4.1	0	3.1
6	1	0	1	2	6.1	0	2.0	0	3.0	1	4.7
7	1	1	1	2	9.0	1	2.4	0	2.5	0	4.6
8	0	0	1	2	7.5	0	2.1	0	4.6	1	4.2
9	0	1	2	2	4.0	1	3.3	0	3.1	0	2.7
10	1	0	2	0	1.5	1	2.8	2	5.1	0	5.3
11	1	1	2	0	2.6	1	2.6	2	5.6	0	2.7
12	2	0	2	0	2.6	0	2.2	1	6.8	2	5.0
13	2	1	2	0	3.9	2	2.8	0	5.2	1	3.8
14	2	2	2	0	2.4	2	2.5	1	6.6	0	3.2
15	0	0	3	1	4.8	0	4.2	2	4.1	0	2.7
16	1	1	3	1	3.0	0	2.0	0	3.4	2	4.1
17	2	2	3	0	2.0	1	5.0	0	4.8	2	6.2
18	3	0	3	0	1.6	2	5.3	1	3.7	0	3.8
19	3	1	3	1	5.0	0	3.2	0	5.7	2	4.9
20	3	2	3	0	2.4	0	2.8	2	6.1	1	3.8
21	2	1	4	0	2.5	2	2.8	0	5.7	1	5.0
22	2	2	4	0	1.6	2	3.2	1	4.0	0	4.2
23	3	1	4	1	3.5	0	1.3	2	7.2	0	4.2
24	3	2	4	1	2.0	0	1.9	0	6.8	2	5.0

Table 22. Uptake of K (kg/ha) as influenced by treatments

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	59.4	1	79.7	0	69.9	2	217.2
2	0	0	0	2	118.4	0	80.7	1	97.3	0	62.7
3	0	0	0	0	62.7	2	89.0	0	140.2	1	91.1
4	0	0	0	1	40.4	0	49.6	2	118.0	0	102.0
5	0	0	1	2	145.8	0	63.0	1	156.1	0	77.3
6	1	0	1	2	131.3	0	62.3	0	107.4	1	77.9
7	1	1	1	2	157.5	1	96.2	0	64.2	0	97.5
8	0	0	2	2	127.6	0	69.1	0	105.5	1	86.7
9	0	1	2	2	112.0	1	81.9	0	77.7	0	60.3
10	1	0	2	0	39.3	1	92.5	2	146.4	0	107.0
11	1	1	2	0	89.8	1	83.7	2	143.4	0	44.6
12	2	0	2	0	88.9	0	88.8	1	117.0	2	130.2
13	2	1	2	0	185.7	2	93.8	0	91.2	1	73.0
14	2	2	2	0	84.9	2	67.2	1	126.6	0	68.2
15	0	0	3	1	146.3	0	42.3	2	83.3	0	66.4
16	1	1	3	1	130.1	0	117.4	0	163.6	2	80.5
17	2	2	3	0	62.0	1	183.9	0	151.8	2	127.4
18	3	0	3	0	54.4	2	91.5	1	121.8	0	146.6
19	3	1	3	1	173.8	0	71.1	0	168.8	2	163.1
20	3	2	3	0	58.4	0	103.6	2	197.3	1	112.3
21	2	1	4	0	105.5	2	104.5	0	214.7	1	100;6
22	2	2	4	0	45.7	2	73.5	1	104.1	0	80.8
23	3	1	4	1	89.5	0	61.8	2	221.9	0	137.6
24	3	2	4	1	58.5	0	58.6	0	202.0	2	131.3

Fig. 10. Uptake of N,P,K by ginger after STCR experiment

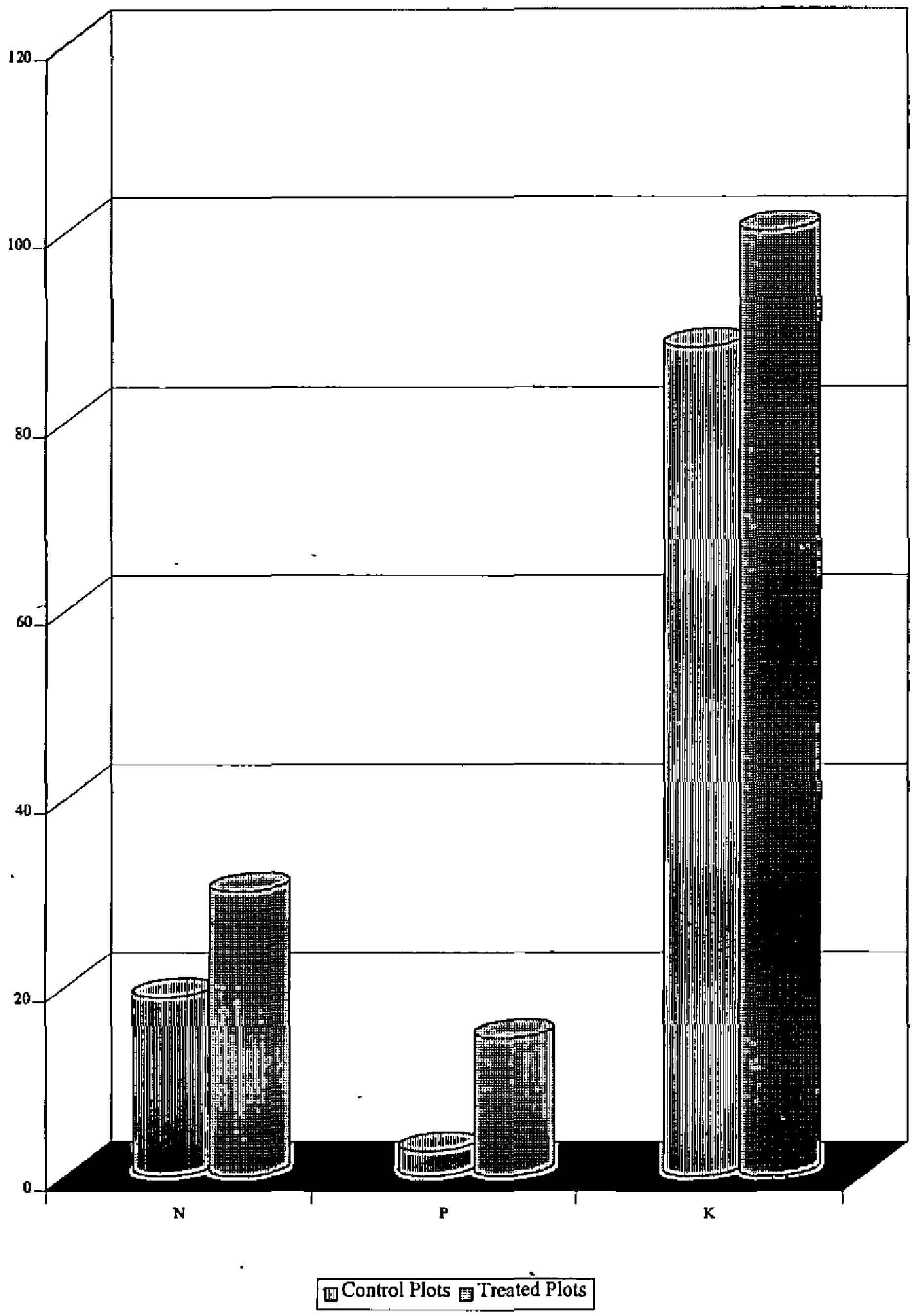


Table 23. Strip wise mean uptake of N, P and K (kg/ha) at harvest

Particulars	Mean values of strips			
	I	II	III	IV
Control Plots				
Uptake of N	14.7	16	18.9	26.6
Uptake of P	2.1	1.5	3.1	3.5
Uptake of K	61.1	65.2	105.1	82.4
Treated Plots				
Uptake of N	25.0	25.7	34.3	34.
Uptake of P	3.6	2.7	5	4.4
Uptake of K	102.	85.3	135.5	103.5
All Plots				
Uptake of N	24.1	24.9	33	34.0
Uptake of P	3.5	2.6	4.8	4.3
Uptake of K	98.7	83.6	132.9	101.3

The average P uptake were 3.5, 2.6, 4.8 and 4.3 in strips I to IV. The mean values of K uptake were 98.7, 83.6, 132.9 and 101.8 kg/ha in strip I to IV respectively. In general it was observed that the uptake of K was the highest followed by N and P.

The data on uptake of nutrients showed that the increased availability of nutrients from strip I to strip IV.

4.3 Content of Oleoresin

Content of Oleoresin as extracted by cold percolation was represented in Table 24.

Table 24. Content of Oleoresin

T.No.	N	P	K	FYM	Strip1	FYM	Strip2	FYM	Strip3	FYM	Strip4
1	0	0	0	0	9.8	1	9.6	0	9.3	2	10.4
2	0	0	0	2	10.2	0	9.0	1	9.7	0	9.1
3	0	0	0	0	9.7	2	10.1	0	9.2	1	9.6
4	0	0	0	1	9.9	0	9.1	2	10.3	0	9.2
5	0	0	1	2	10.3	0	9.2	1	9.7	0	9.1
6	1	0	1	2	10.2	0	9.2	0	9.2	1	9.9
7	1	1	1	2	10.1	1	9.9	0	9.2	0	9.2
8	0	0	2	2	10.0	0	9.2	0	9.4	1	9.8
9	0	1	2	2	10.1	1	9.9	0	9.1	0	9.6
10	1	0	2	0	9.3	1	9.8	2	10.1	0	9.3
11	1	1	2	0	9.4	1	9.8	2	10.2	0	9.2
12	2	0	2	0	9.2	0	9.0	1	9.7	2	10.3
13	2	1	2	0	9.1	2	10.2	0	9.3	1	9.3
14	2	2	2	0	9.6	2	10.2	1	9.9	0	9.1
15	0	0	3	1	9.9	0	9.1	2	10.3	0	9.2
16	1	1	3	1	10.0	0	9.3	0	9.0	2	10.3
17	2	2	3	0	9.0	1	9.7	0	9.2	2	10.4
18	3	0	3	0	9.1	2	10.2	1	9.9	0	9.1
19	3	1	3	1	9.9	0	9.0	0	9.0	2	10.1
20	3	2	3	0	9.2	0	9.3	2	10.3	1	9.9
21	2	1	4	0	9.2	2	10.1	0	9.0	1	10.0
22	2	2	4	0	9.3	2	10.0	1	9.7	0	9.0
23	3	1	4	1	9.9	0	9.1	2	10.2	0	9.2
24	3	2	4	1	9.8	0	9.1	0	9.1	2	10.2

4.4 Soil test calibration

The purpose of soil test crop response studies in essence is calibration of STVs for fertilizer recommendation. The main objectives of crop response models are

i. Computation of fertilizer nutrients for maximum and economic yields at varying STVs.

ii. To workout fertilizer requirements 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.

4.4.1. Multiple regression models for prescription of fertilizer doses at varying soil test values

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.

A wide variation in both rhizome yield and uptake of nutrients was observed in the present study due to application of FYM and N, P and K. fertilizers. The data obtained from the experiment fitted into a quadratic response model, by using the theory of regression.

The model includes linear, quadratic and interaction terms of soil and fertilizer nutrients. The multiple regression model developed at IARI (Ramamoorthy, 1974) formed the basis for this calibration. This model predicts

Table 25 Multiple regression equations for ginger

Particulars	Multiple regression equations	R^2 value
All plots		
with 15 variables		
SN as available N	Y = -507.91 - 1.419SN - 0.947SP + 1.299SK + 153FN + 79.8 FP + 206.01 FK + 0.32SN^2 - 0.16SP^2 - 0.45SK^2 - 0.018 FN^2 - 0.004 FP^2 - 0.0037 FK^2 - 0.28 SNFN - 0.87SPFP - 0.21 SKFK.	**0.740****
SN as OC	Y = -81.643 - 642.3OC - 0.586SP - 0.1403SK + 642.3FN + 189.1FP +197FK + 292.72OC^2 - 1.630SP^2 - 0.563SK^2 - 0.001FN^2 - 0.0012FP^2+ 0.0004FK^2 – 518.4OCFN - 898.3SPFP - 206.0 SKFK.	**0.731****
With 17 variables		
SN as available N	Y = 857.69 + 0.435FYM + 0.0747FYM^2 - 0.181SN - 0.265SP + 0 .170SK + 44.4FN + 87.9FP + 207.6FK + 0.0426FN^2 - 0.009FP^2 - 0.0665FK^2 - 0.0005SNFN – 0.0017SPFP - 0.002SKFK.	**0.700***
SN as OC	Y = 77.56 + 0.6577FYM + 1.260FYM^2 - 367.16 OC - 0.187SP - 0.163SK + 0.071FN + 0.117FP + 0.203FK - 275.4OC^2 - 0.082SP^2 - 0.68SK^2 - 0.191FN^2 - 0.019FP^2 – 0.04FK^2 – 0.50OCN + 0.63SPFP - 0.74SKFK.	**0.698***

**-Significant at 1% level
* - Significant at 5% level

the type of response for each nutrient for different crops (Singh and Sharma, 1978).

For each nutrient there are eight types of responses are possible, based on + or - sign for each of the three regression co-efficients such as the co-efficient for the linear, quadratic and interaction terms of the nutrient (Ramamoorthy, 1973: Ramamoorthy *et.al.*, 1974 : Velayutham *et.al.*, 1989 and Sankar, *et.al.*, 1987).

Among the different types of responses for working out fertilizer doses at varying soil test values, the response type of +, -, - signs respectively for co-efficients of linear, quadratic and interaction terms of the nutrient was considered to be the normal type.

Multiple regression models were calibrated by utilizing the plot wise data on soil test values, applied organic manure and inorganic fertilizers and the resultant rhizome yield of ginger.

The categories of multiple regression models are

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

(2) As above with organic carbon % as a measure of soil N.

(3) Model developed with 17 variables consisted of all the 15 variables of model (i) along with linear and quadratic terms of FYM.

(4) As above with organic carbon % as a measure of soil N.

From the regression equation developed fertilizer doses were computed by differentiation and for that regression equation should have high R^2 value (>0.66). Higher R^2 value is necessary to explain the variation in yield by applied and available nutrients.

The nutrient for which the fertilizer dose to be developed should have the normal (+ - -) type of response behavior. As already mentioned the (+ - -) are the signs the coefficients of linear and quadratic terms of the applied nutrient and the interaction term between the applied and soil available nutrient. The co-efficients should be significant at least at 5% level.

Among the models calibrated (Table-25), the one with 15 variables calibrated utilizing the data from all plots and available N as a measure of soil N had the highest predictability (74%). Hence the data from these equation was utilized to develop prescription equation for N and P.

The model with 17 variables comprising of linear, quadratic and interaction terms of soil available and fertilizer N, P and K nutrients calibrated with available N, including the linear and quadratic terms of FYM variable had 70% predictability which was significant also. Among the three fertilizer nutrients, only FN and FP showed the normal or (+,-,-) type of response.

The soil test based fertilizer adjustment equation for differentiating the regression equation partially with respect to FN derived recommending N dose

FN = 153 - 0.28SN

This is an adjustment equation of the Fertilizer N in terms of the Soil Test N.

Similar multiple regression models calibrated with organic carbon as a measure of available N in the soil had also significant and higher coefficient of predictability (73%). In this model also, FN and FP had (+, -, -) type of response behavior.

The fertilizer adjustment equation derived by differentiating the regression equation with respect to FN

$$FN = 312.94 - 518.4OC$$

It is seen from the regression equation the term FP also have the normal (+--) type of response. Differentiating the regression equation partially with respect to FP the prescription equation was derived as given below.

$$FP = 79.8 - 0.94\ SP$$

The behavior of applied K was found to produces responses other than normal. Hence the optimization of fertilizer doses was done only for N and P.

4.5 Correlation Studies:

Simple correlation's co-efficient were worked out between nutrient uptake and yield of ginger and are presented in Table. 26.

Table 26. Correlation coefficients between nutrient uptake at harvest and yield of ginger

	Uptake of N	Uptake of P	Uptake of K
Uptake of N			
Uptake of P	0.546**		
Uptake of K	0.398**	0.722**	
Rhyzhome yield	0.524**	0.790**	0.715**

** Significant at 1% level.

Rhizome yield was positively correlated with uptake of N, P and K and the inter correlation's between uptake of N, P and K were also significant.

4.6 Nutrient uptake and yield with available and applied nutrients:

Uptake of nutrients showed positive correlation's with available and applied N, P and K as evident from Table - 27.

Table 27. Correlation co-efficient of yield and nutrient uptake with available and applied nutrients

	Yield	N Uptake	P Uptake	K Uptake
Organic carbon	0.200**	0.208**	0.316**	0.167**
Available N	0.237**	0.302**	0.313**	0.198**
Available P	0.400**	0.192**	0.482**	0.390**
Available K	202**	0.104	0.160**	0.208*
Fertilizer N	0.176**	0.208*	0.184*	0.239*
Fertilizer P2O5	0.196**	0.187*	0.123*	0.109*
Fertilizer K2O	0.109*	0.121*	0.133*	0.166*
FYM	0.198	0.114*	0.59	0.48

** - Significant at 1% level

* - Significant at 5% level.

From the data it is evident that higher correlation was observed between nutrient uptake and available nutrients than between nutrient uptake and applied nutrients.

Rhizome yield was positively correlated with organic carbon and available N, P and K contents in the soil and applied N, P and K.

4.7 Correlation's of plant major nutrient contents with yield

Higher positive correlations were obtained from yield with major nutrients. The correlation coefficients are represented in Table 28.

Table 28. Correlation's of Plant major nutrient contents with yield

	N	P	K
Yield	0.784**	0.601**	0.934**
N	1.000	0.581**	0.728**
P	0.581**	1.000	0.633**
K	0.728**	0.633**	1.000

**-Significant at 1% level

4.8 Response of ginger to applied nutrients

4.8.1. Farm yard manure:

The data obtained from plots, which received FYM alone with different levels, is given in Table 29 and Fig. 11. In each strip two absolute control plots were maintained in that neither FYM nor fertilizer was applied.

From the data it is obvious that higher yield were obtained from plots which received FYM alone.

The response to FYM application was worked out and presented in Table 29. It is seen that the response of FYM was high at F2 level (30t/ha) than at F1 level and from absolute control plots. The average response at F1 level (15t/ha) was 44kg of Rhizome per tonne of FYM while at F2 level it was 76kg per tonne of FYM.

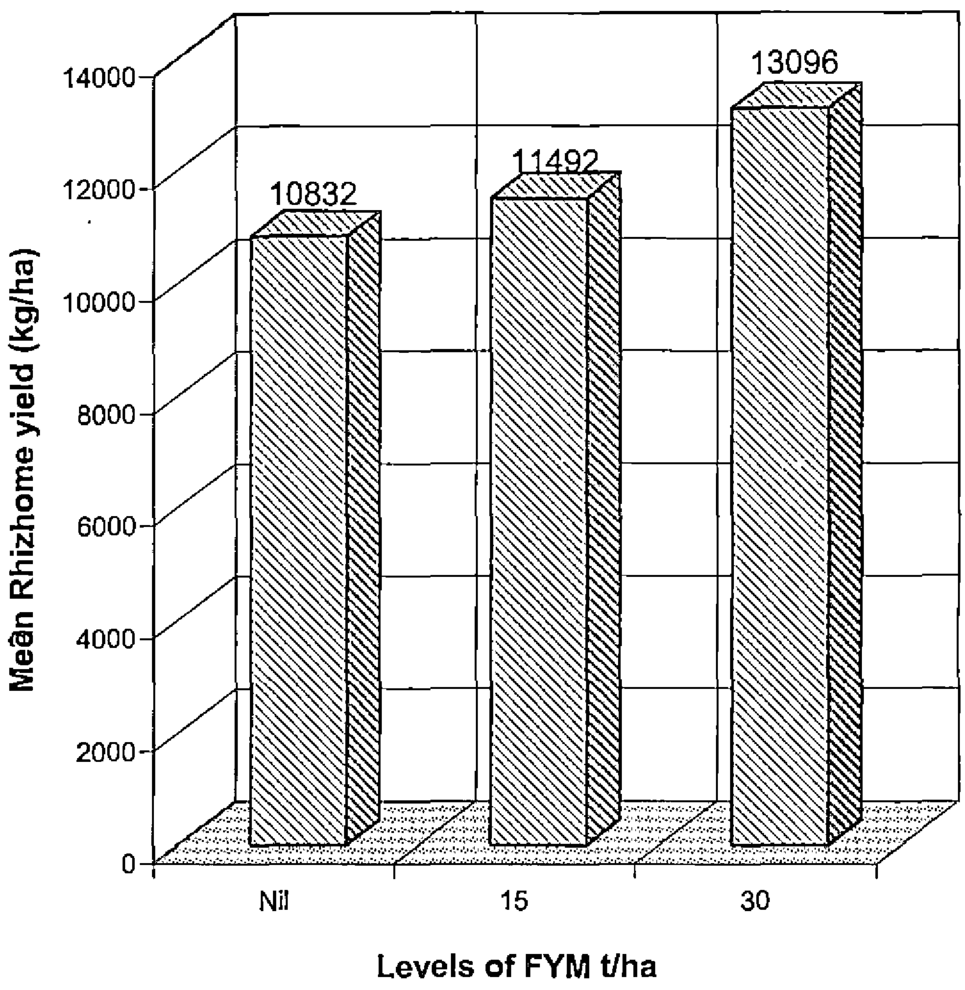
Table 29. Mean Response of ginger to FYM

Levels of FYM t/ha	Rhizome yield (kg/ha)				
	Strip 1	Strip 2	Strip 3	Strip 4	Mean
Nil	8160	9517	11.580	10.570	10171.75
Nil	8453	10357	11.867	10870	11491.75
15	9667	10590	11933	13777	11491.75
30	9822	11850	13223	17487	13095.50
CD to compare of with F1 & F2 CD to compare F1 & F2					2.385 1.095

Table 30. Response of rhizome yield to FYM.

Levels of FYM t/ha	Mean response Rhizome yield t/ha	Response per tonne of FYM
15	0.66	44
30	2.26	76

Fig-II Response of Ginger to FYM



4.9 Optimization of fertilizer doses for different yield targets - targeted yield model:

In the normal range of soil nutrient status and fertilizer application, there is a linear relationship between yield of crop and uptake of a nutrient. To obtain economic produce (yield) a definite amount of nutrient should be taken up by the crop. If the amount of nutrient required is known for a given yield, the fertilizer needed can be calculated taking in to account the efficiencies of contribution of nutrients from the soil and fertilizer. The basic parameters needed for a given soil type in an agro-climatic condition are,

(i) Nutrient requirement (NR) per unit of produces (economic part)

(ii) Percent contribution of nutrients from the soil (CS).

(iii) Percent contribution of nutrients from the fertilizer (CF).

The above values were calculated using the formulae represented in Chapter-3 and are presented in Table 31 and fig. 12.

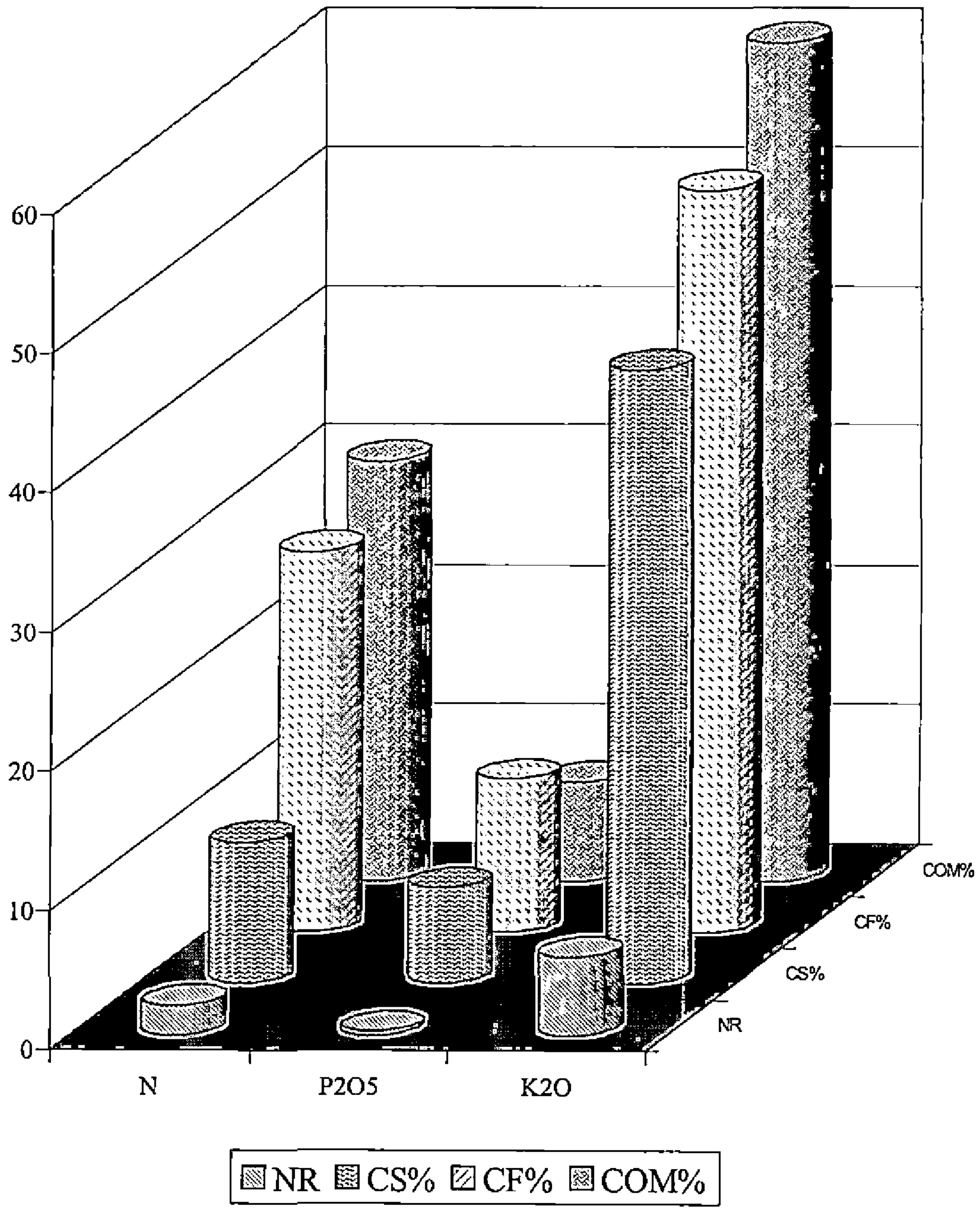
Table 31. Basic data required for computing targeted yield equations

Nutrients	NR kg/t	CS%	CF%	COM %
N	2.1	10.1	27.3	30
P_2O_5	0.3	6.9	10.9	7
K_2O	5.6	44	53.	60

4.9.1 Nutrient requirement

The computed values showed that ginger var. Maran required 2.1 kg N, 0.3 kg P_2O_5 and 5.6-kg K_2O/ha to produce one tonne of rhizome. The data revealed that ginger require more amounts N and K compared to P.

Fig. 12. **Nutrient requirement and efficiency of nutrient contribution from soil, fertilizers and FYM for ginger var. Maran in laterite soil**



4.9.2 Soil and fertilizer efficiencies:

Soil and fertilizer efficiencies were worked out using the formulae given under 3.5. The soil efficiencies were 10.1%, 6.9% and 44% N, P_2O_5 and K_2O respectively. (Table 30) and the fertilizer efficiencies were 27.3%, 10.9% and 53.2% N, P_2O_5 and K_2O respectively.

It was evident from the data that contribution fertilizer was so high compared to contribution from soil.

4.9.3 Organic manure efficiency:

The organic manure efficiency COM for N, P and K nutrients were computed using the formulae given under 3.5 to 1.4.

The computed value for organic manure efficiency was 30%, 7% and 60%.

4.9.4 Fertilizer prescription for targeted yield of ginger:

The fertilizer prescription equations were developed for N, P_2O_5 and K_2O, by substituting the corresponding NR, CS, CF and COM values in targeted yield equations.

The prescription equation for ginger without FYM can be represented as,

FN = 7.8T - 0.37 SN

FP = 2.8T - 0.64 SP

FK = 10.6T - 0.835 SK

Where,

FN, FP, FK - Fertilizer N, P_2O_5, and K_2O respectively in Kg/ha.

T - Target of rhizome yield in t/ha.

SN, SP, SK - Soil available N, P and K in kg/ha respectively.

By using the data on percent contribution of organic manure to rhizome yield, the prescription equations are developed, considering the farmyard manure.

With FYM, the equations are as given below:

FN = 7.8T - 0.37SN - 1.11 ON

FP = 2.8T - 0.64 SP - 0.7 OP

FK = 10.6T - 0.835 SK - 1.13 OK.

Where

ON, OP and OK are quantities of N, P and K supplied through organic manure in kg/ha.

In Kerala, fertilizer prescription equations developed for rice (Swadija et.al., 1993) and Cassava (Swadija, 1995) Ready reckoners can be prepared for prescribing fertilizer doses based on these targeted yield equations, either as inorganic alone or in combination with organics.

It is helpful for the farmer in giving fertilizer prescription based on the availability of organic source and financial background.

4.10 Influence of native elements in soil

The data on analysis of soil and plant micro nutrient contents are presented in appendix 2 to 21.

4.10.1 Correlation co-efficients of root, leaf, rhizome micronutrient contents with yield.

Correlation coefficients are significant only for leaf magnesium and rhizome iron and manganese content with yield. The co-efficients are represented in table 32.

Table 32. Correlation coefficients of plant micro nutrient contents with yield

	Leaf Mg	Rhizome Fe	Rhizome Mn
Yield	0.497**	-0.325**	0.384**
Leaf Mg	1.000	-0.214**	0.337**
Rhizome Fe	0.214**	1.000	0.200**
Rhizome Mn	0.337**	0.200**	1.000

**- Significant at 1% level

*-Significant at 5% level

4.10.2 Correlation coefficients of soil micronutrient content with yield

Soil micronutrient contents at two different depths was correlated with yield separately and presented in table 33 and table 34.

Table 33. Correlation coefficients of soil micronutrient content (30cm depth) with yield

	Ca	Mg	Zn	Fe	MN
Yield	0.219*	0.243**	-0.233**	-0.265**	0.122*
Ca	1.000	0.684**	-0.201**	-0.247*	0.961**
Mg	0.684**	1.000	-0.101**	-0.229*	0.181*
Zn	-0.201*	-096*	1.000	0.215*	-0.109*
Fe	-0.247	-0.229*	0.215*	1.000	0.046*
MN	0.961**	0.181*	-0.109*	-0.040*	1.000

**- Significant at 1% level

*-Significant at 5% level

Table 34. Correlation coefficients of soil micronutrient content (15cm depth) with yield

	Ca	Mg	Zn	Fe	Mn
Yield	0.239**	0.296*	-0.770**	-0.830**	-0.930*
Ca	1.000	0.739*	-0.910*	-0.940**	-0.720*
Mg	0.739**	1.000	0.630**	-0.101*	-0.162*
Zn	-0.910*	0.630**	1.000	0.260*	0.181**
Fe	-0.940*	-0.101*	0.260**	1.000	0.090*
Mn	-0.930*	-0.720**	-0.162**	0.181*	1.000

**- Significant at 1% level

*-Significant at 5% level

4.11. Path Analysis

The correlation coefficients of soil and plant micronutrient with yield were subjected to path coefficient analysis to know the direct and indirect effects of these nutrients with yield. The path diagrams (Fig. 13 to 25) clearly represents the influence of yield by the native elements present in soil and also the mutual interactions between different elements.

DISCUSSION

CHAPTER - 5
DISCUSSION

The highest crop yield per unit area can be achieved through efficient and economic use of fertilizers apart from the use of high yielding varieties of crops. The availability of applied nutrients is affected by various physical, chemical and biological properties of soil. Hence there is a need to develop fertilizer prescriptions for crops based on soil types (Goswami, 1986).

Fertilizer recommendations are based on inherent capacity of soil to supply nutrients, crop uptake and the amount of nutrients supplied through fertilizers. According to Ramamoorthy, 1993 the real balance for maximum yield is "not that between the applied nutrients but that after taking into account the relative availability from soil and fertilizer.

In the present scenario, soil test based fertilizer recommendations are much more relevant, which provide fertilizer prescription for targeted yield of crops. It is laborious and time consuming to develop prescription equations for crops in each piece of land. So experiments are conducted in a soil type which is representative of the type of soil present in larger area of a particular region and the results of the experiments are extrapolated to similar soils of other areas.

In the present investigation the prescription equations for ginger is developed in the laterite soils. The experiment was conducted at the farm attached to the College of Horticulture, Vellanikkara. The study included the fertility gradient experiment by raising the gradient crop maize variety Co.1 and soil test crop response experiment with the test crop of ginger variety Maran. It also included the evaluation of yield response of ginger with soil test values, development of prescription equations for ginger to obtain targeted yield and the interactive influence of various native elements with the yield of ginger. The important findings of the experimental results are discussed in this chapter.

Plate No. 1 General view of gradient crop maize in Strip 1 (N_0 P_0 K_0)

Plate No. 2 General view of gradient crop maize in Strip 2 ($N_{½}$ $P_{½}$ $K_{½}$)


$N_0 P_0 K_0$


$N_{1/2} P_{1/2} K_{1/2}$

Plate No. 3 General view of gradient crop maize in Strip 3 (N_1 P_1 K_1)

Plate No. 4 General view of gradient crop maize in Strip 4 (N_2 P_2 K_2)


N1 P1 K1


N2 P2 K2

5.1 Fertility Gradient experiment (FGE)

The main aim of the experiment was to create variation in soil fertility with in the experimental area. This was done by employing the "Inductive field plot methodology" (Ramamoorthy, 1968)

The variations in soil fertility were created by dividing the whole field into four equal strips and by applying graded dose of fertilizers in each strip as furnished in Table 35.

Table 35. Treatment levels for FGE

Strips	Fertilizer dose (kg/ha)		
	N	P_2O_5	K_2O
I	0	0	0
II	75	50	90
III	150	100	180
IV	300	200	360

The crop maize is used as the gradient crop due to its absorbent nature. The creation of fertility gradient was confirmed with the nutrient uptake by the gradient crop of maize from strip I to strip IV and the comparison of soil test data before and after the FGE.

5.1.1 Soil fertility status before the FGE

In each strip four soil samples were collected before the conduct of FGE. The soil samples were analyzed following the internationally accepted analytical methods contents of organic carbon, N, P and K.

Plate No.5 General field view of STCR experiment


PROGRAMME FOR M.Sc (Ag) THESIS WORK
DEPT. OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY
Name of the student
TOPIC : SOIL TEST CROP RESPONSE
CORRELATION STUDIES ON GINGER
IN THE LATERITE SOILS OF KERALA
Crop : GINGER
Variety : Maran
Design : Responce surface. Design
No. of treatments : 24
No. of strips : 4
Treatment structure
Date of planting

The organic carbon and available N were in the range of 0.768 to 1.132% and 206.0 to 233.1 kg/ha respectively. But there was a slight decrease in available N content in strip IV. This may be due to increased mineralization and uptake of nutrients, in strip IV by the maize crop.

In the case of available P and K contents there was a progressive increase of 11.87 to 16.91 kg/ha of P and 86.11 to 107.25 kg/ha of K in strip I to strip IV.

The data on analysis of soil samples before the FGE also showed the variations in soil fertility in different strips. This may be due to used of same piece of land, for conducting the STCR experiment in the previous season.

5.1.2 Soil fertility status after fertility gradient experiment

Four soil samples were collected in each strip, after the harvest of fodder maize and analyzed for organic carbon and available N, P and K.

Table.36 Strip wise mean values of soil nutrient content after FGE

Strips	Organic carbon %	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
I	0.631	189.8	11.87	86.11
II	0.82	204.6	14.63	99.2
III	0.923	221.3	16.87	101.81
IV	1.084	200.1	16.91	107.3

The data on the analysis of samples after FGE revealed that there was increase in contents of organic carbon, available phosphorous, available potassium from strip I to strip IV. But in the case of N content, it increased from strip I to strip III and decreased in strip IV. This may be due to the increased uptake of N and high fertilizer use efficiency in strip IV.

Plate No.6 General view of test crop ginger in Strip 1 (N_0 P_0 K_0)


NoPoKo

5.2 STCR experiment for the crop ginger

To emphasize the use of soil test for fertilizer recommendation, ICAR started the All India Co-orientated Soil Test Crop Response Correlation Project during the fourth five-year plan in the year 1967-1968

In Soil Test Crop Response correlation studies each plot is considered as an experimental plot in which all the variable factors influencing the crop yield are assessed. In this experiment each strip will be divided into 24 plots of equal size before treatment allocation, soil samples are collected from individual plots of all strips and analyzed for organic carbon and available N, P and K. The Treatment structure consisted of four control plots and 20 treated plots in each strip. After the treatment allocation, the crop ginger was raised following the usual agronomic practices.

5.2.1 Pre planting soil analysis

The soil samples collected before the fertilizer application was analyzed for organic carbon and available N, P and K. Organic carbon content in the soil varied from 0.563 to 0.644, 0.69 to 0.84, 0.82 to 0.92 and 0.91 to 1.07% in strip I, II, III and IV respectively. (Table 8) and the corresponding mean values were 0.609, 0.774, 0.888 and 0.977% (Table - 12).

Soil available N registered a range in values from 176.4 to 199.8, 193.8 to 211.3, 218.8 to 238.0 and 200.0 to 228.9, kg/ha in strip I, II, III and IV (Table 9) with mean values of 188.5, 205.1, 226.4 and 213.6 (Table - 12).

Available P status (Table 10) ranged from 11.68 to 13.99, 14.68 to 16.31, 15.98 to 16.99 and 16.66 to 17.22 in strip I, II, III and IV respectively. The average mean values in the respective strips (Table 12) were 12.90, 15.63, 16.49 and 16.95, kg/ha.

Plate No.7 General view of test crop ginger in Strip 2 ($N_{½}$ $P_{½}$ $K_{½}$)

average mean values in the respective strips (Table 12) were 12.90, 15.63, 16.49 and 16.95, kg/ha.

Available K (Table 11) ranged from 86.38 to 93.69, 93.92 to 101.21, 100.2 to 106.7 and 103.8 to 119.1 in Strip I, Strip II, Strip III and Strip IV respectively. The average mean K contents in strip I to IV (Table 12) were 90.04, 97.9, 103.5 and 112.1 kg/ha respectively.

Table.37 Strip wise mean values of soil nutrient content before STCR experiment

Strips	Organic carbon %	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
I	0.61	188.6	12.90	90.0
II	0.77	205.1	15.63	97.9
III	0.89	226.4	16.49	103.5
IV	0.98	213.6	16.95	112.1

The organic carbon content was found to increase from strip I to strip IV (i.e.) from low fertile soil to high fertile soil, which showed the creation of fertility gradient in the strips.

But in the case of available N content it was increased from strip I to strip III and showed slight decrease in strip IV, which may be due to increased uptake of N in strip IV by maize crop.

While in the case of P and K contents there were gradual increase from strip I to IV. The data regarding the pre planting soil nutrient contents also proved the creation of fertility gradient in the field.

5.2.2 Yield of Ginger

At the time of harvest the crop was separated into leaf, root and rhizome. The yields of the plant parts were recorded separately for all the treatments. The rhizome yield is presented in table 12 which showed that the yield obtained in control plots were lower than that obtained from treated plots.

Table.38 Strip wise mean rhizome yield of ginger

Strips	Rhizome yield (kg/ha)		
	Control plots	Treated plots	All plots
I	8307	13337	12918
II	9937	13893	13563
II	11757	17978	17460
IV	10720	16682	16185

Considering the strip wise yield it increased from strip I to strip III and decreased in strip IV. It indicated the 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.

The highest rhizome yield of 27,260 kg/ha was obtained from strip IV in the treatment level of 100:75:150 kg/ha of N, P_2O_5 and K_2O along with 30 t/ha of FYM. This indicated that the package of practice recommendations may not be sufficient to get higher yields.

The lowest rhizome yield of 6297 kg/ha was obtained in the treatment level of 50:0:75 kg/ha of N, P_2O_5 and K_2O along with 15 t/ha of FYM. This low

Plate No. 9 General view of test crop ginger in Strip 4 (N_2 P_2 K_2)


N2P2K2
T24

5.2.3 Soil analysis after STCR experiment

After the harvest of the test crop ginger, the soil samples were collected from all plots in each strip and analyzed for organic carbon and available N, P and K.

Table.39 Strip wise mean soil test values after STCR experiment

Strips	Organic carbon %	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
I	0.86	155.0	19.0	154.6
II	0.84	146.9	23.9	146.4
III	0.90	188.0	30.3	162.8
IV	0.79	174.9	29.2	151.3

A wide variation in soil nutrient content was observed from the data on soil analysis after the test crop experiment. This proved the differences in the uptake of different nutrients and consequent influence on yield of ginger.

5.2.4 Uptake of Ginger

The uptake of nutrients ranged from (Table 20 to 22) 11.9 to 60.1, 1.3 to 9.0 and 39.3 to 221.9 kg/ha of N,P, and K respectively from strip I to Strip IV respectively.

Considering the uptake of nutrients the N uptake increased gradually from strip I to strip IV. But in the case of P and K a slight decrease in uptake was observed in strip IV. The Strip wise mean uptake of ginger recorded in control plots and treated plots were presented in table 40 and 41

Table. 40 Strip wise mean rhizome yield (kg/ha) in control plots

Strips	Uptake of N	Uptake of P	Uptake of K
I	14.7	2.1	61.1
II	16	1.5	65.2
III	18.9	3.1	105.1
IV	26.6	3.5	82.4

Table. 41 Strip wise mean rhizome yield (kg/ha) in treated plots

Strips	Uptake of N	Uptake of P	Uptake of K
I	25.0	3.6	102.0
II	25.7	2.7	85.3
III	34.3	5.0	135.5
IV	34.0	4.4	103.5

Compared to control plots, the uptake of nutrient was high in treated plots. This showed the increased rate of absorption of nutrients in the treated plots, which is reflected in the yield.

5.2.5 Yield of Oleoresin

It is obvious from the data that the oleoresin content was not at all influenced by any treatments. However the higher oleoresin contents were recorded in the treatment receiving with 30 t/ha of FYM. This indicated higher levels of FYM might have some influence on oleoresin content in ginger.

5.3 Soil test calibration - multiple regression model

Utilizing the plot wise data on soil test values, applied organic manure and inorganic fertilizers and the resultant rhizome yield of ginger multiple regression models were developed.

Higher R^2 value is (>66%) important to explain the variation in yield by available and applied nutrients. Among the different models developed (Table 25) the one with 15 variables calibrated utilizing the data from all plots and available N as a measure of soil N had the highest predictability (74%).

The model with 17 variables comprising of linear quadratic and interaction terms of soil available and fertilizer N, P and K nutrients calibrated with available N as a measure of soil N including the linear and quadratic terms of FYM variable also had good predictability (70%).

In the multiple regression equation only OC, FN and FP had showed normal (+, -, -) type of response for linear, quadratic and interaction terms. Hence the optimization of fertilizer doses were done only for OC, N and P. The general and economic fertilizer calibrations were found to exist mostly for N and P under all the regression models used (Sankar, 1992).

From the regression equations soil test based fertilizer adjustment equation for recommending N and P dose was derived by partial differentiation.

The fertilizer prescription equation for N in terms of SN and OC can be given as:

$$\mathbf{FN = 153 - 0.28\ SN}$$

$$\mathbf{FN = 312.9 - 518.4\ OC}$$

FP = 79.8 – 0.94 SP

By using the above equations ready reckoners can be made for different soil test values of OC, N, and P.

Table 42 Ready reckoner for fertilizer N based on soil test value of N

Soil test N	Fertilizer N to be applied (kg/ha)
140	113.8
160	108.2
180	102.6
200	97.0
220	91.4
240	85.8
260	80.2

Table 43 Ready reckoner for fertilizer N based on soil test value of OC

Organic carbon	Fertilizer N to be applied (kg/ha)
0.3	157.4
0.4	105.5
0.5	53.7

Table 44 Ready reckoner for fertilizer P based on soil test value of P

Soil test P	Fertilizer P_2O_5 to be applied (kg/ha)
10	70.4
15	65.7
20	61.0
25	56.3
30	51.6
35	46.9
40	42.2

Similar fertilizer adjustment equations of crop yield with soil and applied nutrients have been developed by different workers for different crops in different soils (Singh and Sharma, 1978, Randhawa and Velayutham, 1982 Swadija, 1995, Raniperumal et.al., 1982 and 1984 and Velayutham, et.al., 1985).

5.4 Correlation Studies

5.4.1 Correlation of nutrient uptake with yield.

Correlations were worked out with nutrient uptake and rhizome yield and it was observed that the uptake of nutrients showed positive correlation with yield. Higher positive correlation was obtained from uptake of P (0.790**) followed by K (0.715**) and N (0.524**). This showed that increase in P uptake might contribute to higher yield.

5.4.2 Correlation of Nutrient Uptake with available and applied nutrients

Correlation coefficients were worked out between soil available and applied nutrients with yield. Correlation coefficients of available nutrients with yield are given in table.45

Table 45 Correlation co-efficient of yield and nutrient uptake with available nutrients

	Yield	N Uptake	P Uptake	K Uptake
Organic carbon	0.200**	0.208**	0.316**	0.167**
Available N	0.237**	0.302**	0.313**	0.198**
Available P	0.400**	0.192**	0.482**	0.390**
Available K	0.202**	0.104*	0.160**	0.208*

** Significant at 1% level

* Significant at 5 % level

The applied nutrients also showed positive correlation with yield. Correlation coefficients of applied nutrients can be given as:

Table 46 Correlation co-efficient of yield and nutrient uptake with applied nutrients

	Yield	N Uptake	P Uptake	K Uptake
Fertilizer N	0.176**	0.208*	0.184*	0.239*
Fertilizer P_2O_5	0.196**	0.187*	0.123*	0.109*
Fertilizer K_2O	0.109*	0.121*	0.133*	0.166*
FYM	0.198	0.114*	0.59	0.48

**-Significant at 1% level

*-Significant at 5 % level

Higher correlations were obtained in the case of available soil nutrients N, P and K. It indicated the effect of contribution of native soil nutrients from the soil. The yield was positively correlated with all the available and applied nutrients.

5.4.3 Correlation of plant major nutrient content with yield

Higher positive correlations were obtained with major plant nutrients and yield of ginger and it revealed the importance of major plant nutrients on rhizome yield of ginger.

5.5 Response of ginger to FYM

Response of ginger to different levels of FYM given in the table.

Table 47 Response of ginger to FYM

Strips	Rhizome yield (kg/ha)		
	Control plots	FYM (15t/ha)	FYM (30t/ha)
I	8307	9667	9822
II	9937	10590	11850
III	11724	11933	13223
IV	10720	13777	17487

It is evident from the data that the organic manure application is necessary for ginger. The higher yield levels were observed for the treatments receiving FYM. As the organic matter content in the laterite soil is low, FYM application is inevitable to get higher yields.

5.6 Optimization of fertilizer doses for different yield targets

5.6.1 Nutrient requirement of Ginger

Nutrient requirement is one of the parameters for working out targeted yield equations.

In the present study the ginger var. Maran required 2.1 kg N, 0.3 kg P_2O_5 and 5.6kg K_2O ha^{-1} to produce one tonne of rhizome. As already mentioned in the literature, ginger require heavy supply of nutrients for higher yields. This is the reason for increased nutrient requirements in the present study.

5.6.2 Soil and fertilizer efficiencies

The knowledge on the contribution of nutrients from soil and fertilizers is very important to develop the prescription equations.

The data (Table 31) indicated that 10.1% of N, 6.9% of P_2O_5 and 44% of K_2O were contributed from soil and 27.3%, 10.9% P_2O_5 and 53.2% K_2O respectively were obtained from fertilizers.

It was evident from the data that CF values were higher than CS values. It could be attributed by most easily available nutrient from fertilizers.

5.6.3 Organic manure efficiency

FYM contributed 30%N, 7% P_2O_5 and 60% K_2O to rhizome yield of ginger. Lesser loss of nutrients from organic manure might have influenced for increased efficiency than from soil and fertilizer efficiencies.

5.6.4 Fertilizer prescription for targeted yield of ginger

The fertilizer prescriptions developed based on the targeted yield equations are more quantitative, precise and meaningful because the combined use of soil and plant analyses are involved in it. Marschner (1986) and Koshino (1994) have emphasized the need for combined use of soil and plant analysis for prescription of fertilizers for crops.

The combined use of organic manure and fertilizers will lead to a considerable saving in fertilizers as evident from the targeted yield equations with FYM. This was confirmed by the findings of Duraisamy *et.al.*, (1989), Prasad and Prasad (1993) and Santhi (1995). The organic manure enhances soil health by improving physical, chemical and biological properties of the soil and there by the use efficiency of the nutrients will be enhanced.

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

Table 48. kg N required for different yield targets

Soil available N (kg/ha)	Fertilizer to be applied (kg/ha)		
	15t/ha	20t/ha	25t/ha
140	65	104	143
160	58	97	135
180	50	89	128
200	43	82	121
220	36	75	114
240	28	67	106
260	21	60	99

Table 49 kg P_2O_5 required for different yield targets

Soil available P (kg/ha)	Fertilizer (P_2O_5) to be applied (kg/ha)		
	15t/ha	20t/ha	25t/ha
10	36	50	64
15	32	46	60
20	29	43	57
25	26	40	54
30	23	37	51
35	20	34	48
40	16	30	44

Table 50 kg K_20 required for different yield targets

Soil available K (kg/ha)	Fertilizer (K_20) to be applied (kg/ha)		
	15t/ha	20t/ha	25t/ha
50	117	170	223
75	96	149	202
100	75	128	181
125	54	107	160
150	33	86	139
175	12	65	118

Among the various methods of formulating fertilizer recommendation, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope to achieve if good agronomy is followed in raising the crop (Velayutham, 1979).

5.7 Influence of native elements in soil

5.7.1 Correlation coefficients of plant micronutrient content with yield of ginger.

Among the different elements analyzed (Ca, Mg, Cu, Zn, Fe, Mn,) in leaf ,root and rhizome, only the leaf Mg, rhizome Fe and Mn showed significance (Table 32). Higher positive correlations were obtained between leaf Mg and rhizome Mn content with yield. The rhizome Fe content showed negative correlation.

5.7.2 Correlation coefficients of soil micronutrient content with yield of ginger.

The data on analysis of soil micronutrient content at two different depths (0-15 cm and 0-30cm) were correlated with yield to know the influence of micronutrient contents on the yield of ginger.

Higher positive correlations were obtained between Ca and Mg content with yield of ginger. Generally the laterite soils are chareterised by low Ca and Mg content, that may be sufficient for the crop ginger. The other native microelements showed negative correlation (Table 33- 34). Further to know the direct and indirect effect of nutrients with yield the data was subjected to path analysis.

5.7.1 Path analysis

Path Analysis was carried out utilizing the data, which had significant correlation with the yield of ginger. The correlation co-efficient was derived with micro nutrient contents of soil and plant as independent variables and yield of rhizome as the dependent variable.

Among the different nutrients analyzed only Ca, Mg, Zn, Fe and Mn showed significant correlations. The path analysis of soil micronutrient content (15-cm depth) with yield can be presented as:

Table 51 Path analysis of soil micronutrient content (15 cm depth) with yield

	Ca	Mg	Zn	Fe	Mn	r Value
Ca	**0.221***	0.157*	-0.043*	-0.044	-0.052*	0.239*
Mg	0.100*	**0.225***	0.060*	-0.036*	-0.052	0.296*
Zn	0.231*	0.269*	**-0.58***	-0.38*	-0.31*	-0.77*
Fe	0.253*	0.221*	-0.552*	**-0.410***	-0.34*	-0.83*
Mn	0.163*	0.123*	-0.32*	-0.334*	**-0.562****	-0.93*

**-Significant at 1% level

*- Significant at 5 % level

From the table it is obvious that Ca and Mg showed direct positive effect. The interaction effects between the micronutrients presented as path diagrams.The path analysis was carried out for soil micro nutrient content (30-cm depth) with yield of ginger.

Fig.13. Path diagram showing direct and indirect effect of soil Ca content (15 cm depth) on rhizome yield of ginger

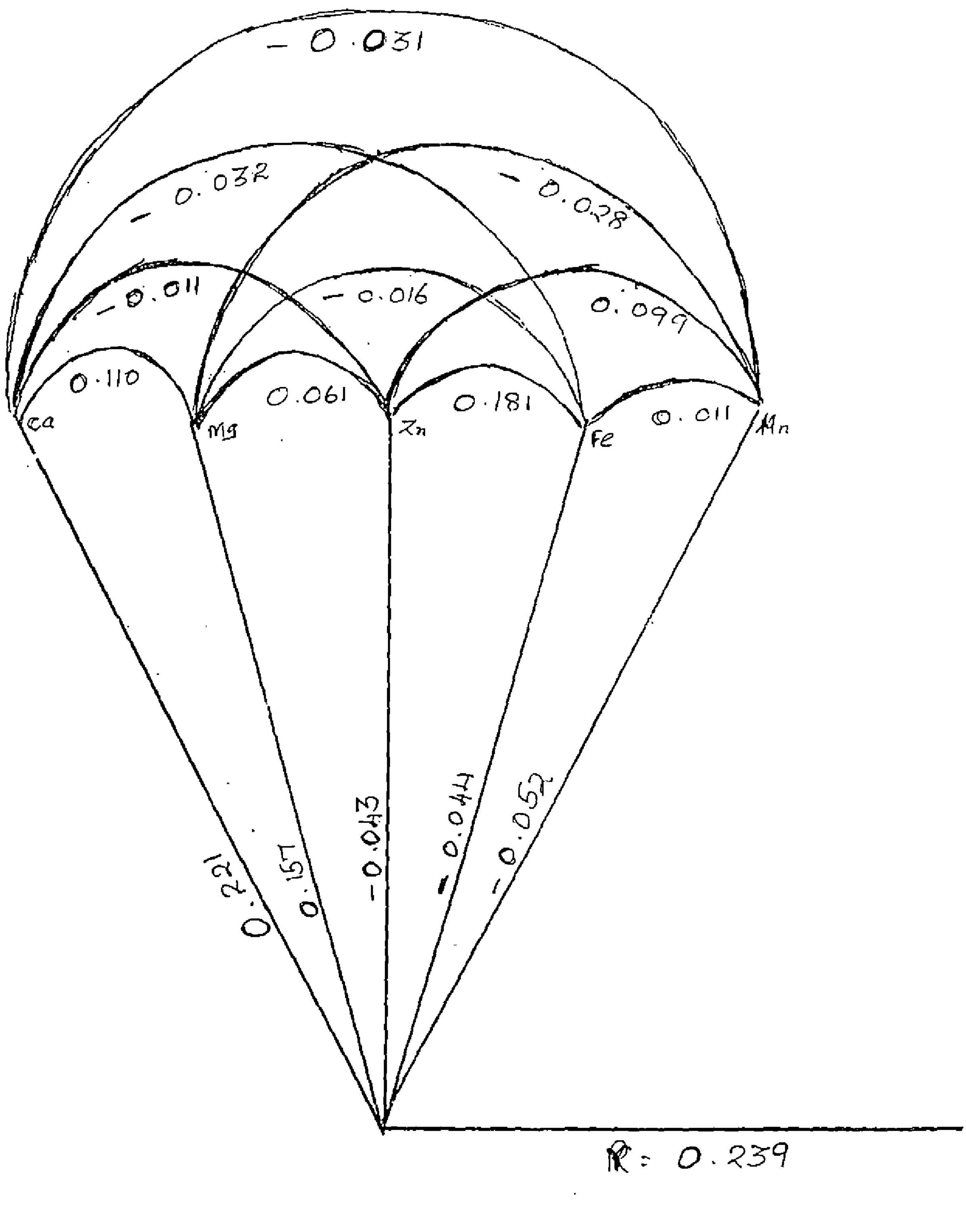


Fig.14. Path diagram showing direct and indirect effect of soil Mg content (15 cm depth) on rhizome yield of ginger

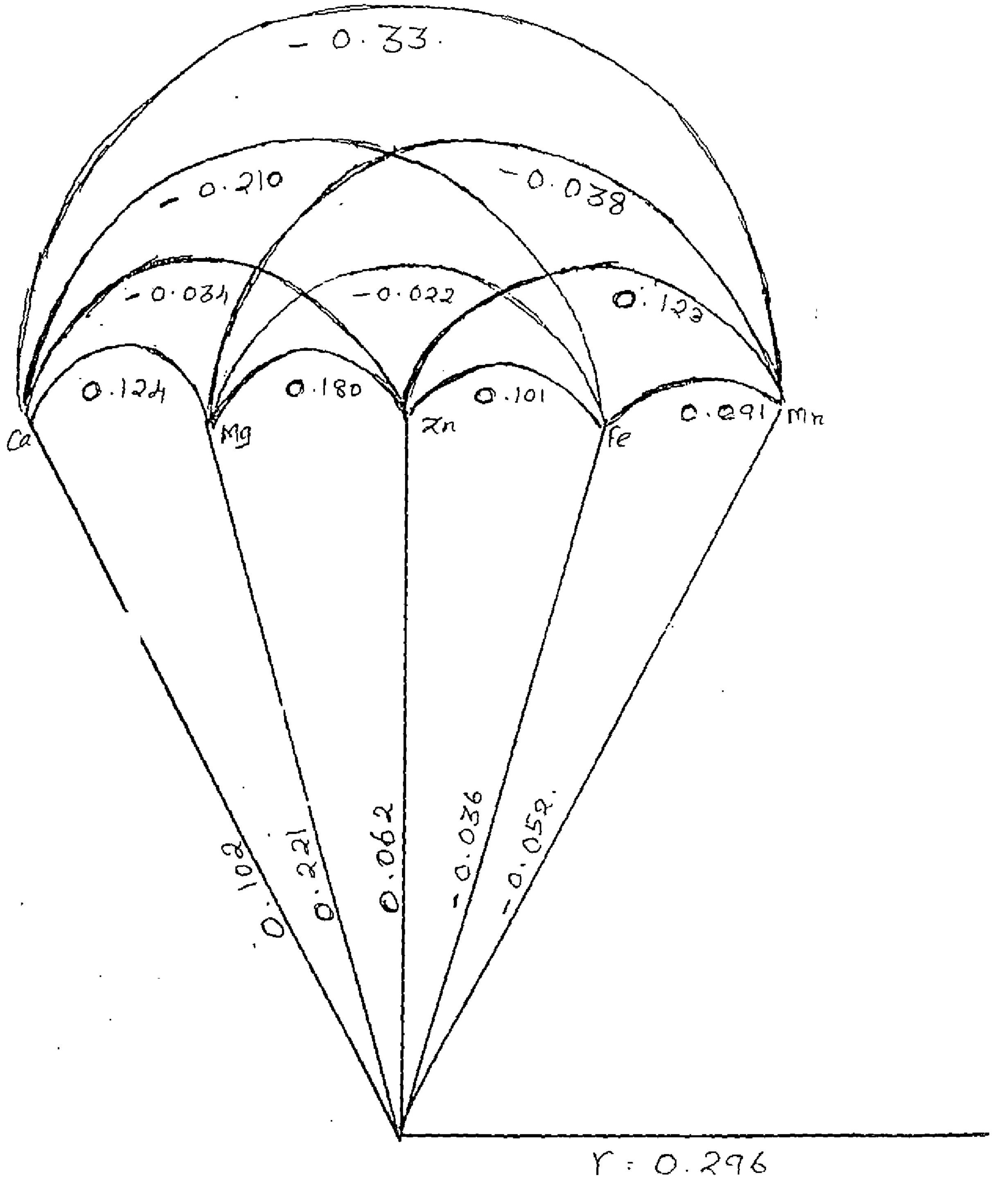


Fig.15. Path diagram showing direct and indirect effect of soil Fe content (15 cm depth) on rhizome yield of ginger

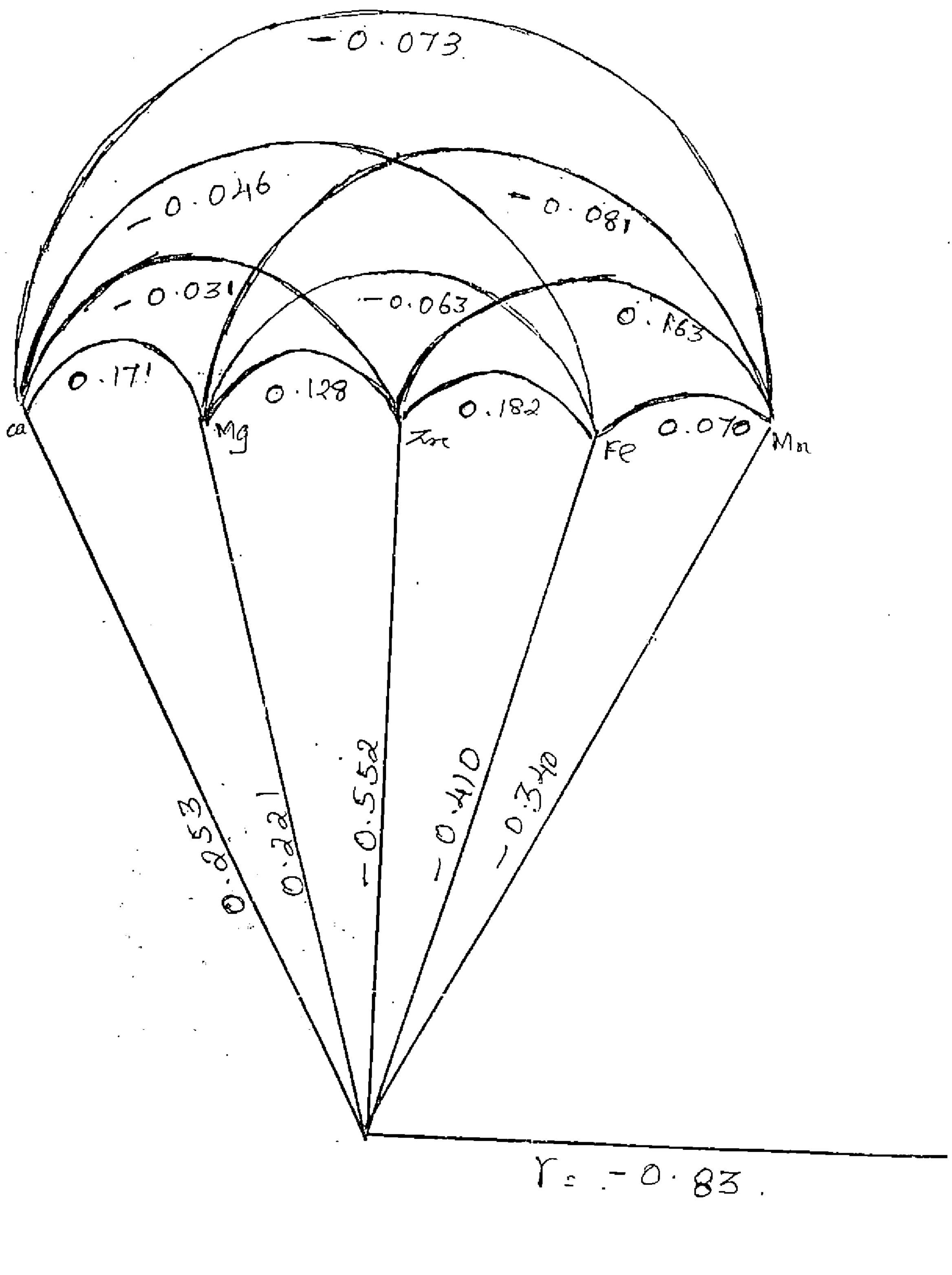


Fig.16. Path diagram showing direct and indirect effect of soil Zn content (15 cm depth) on rhizome yield of ginger

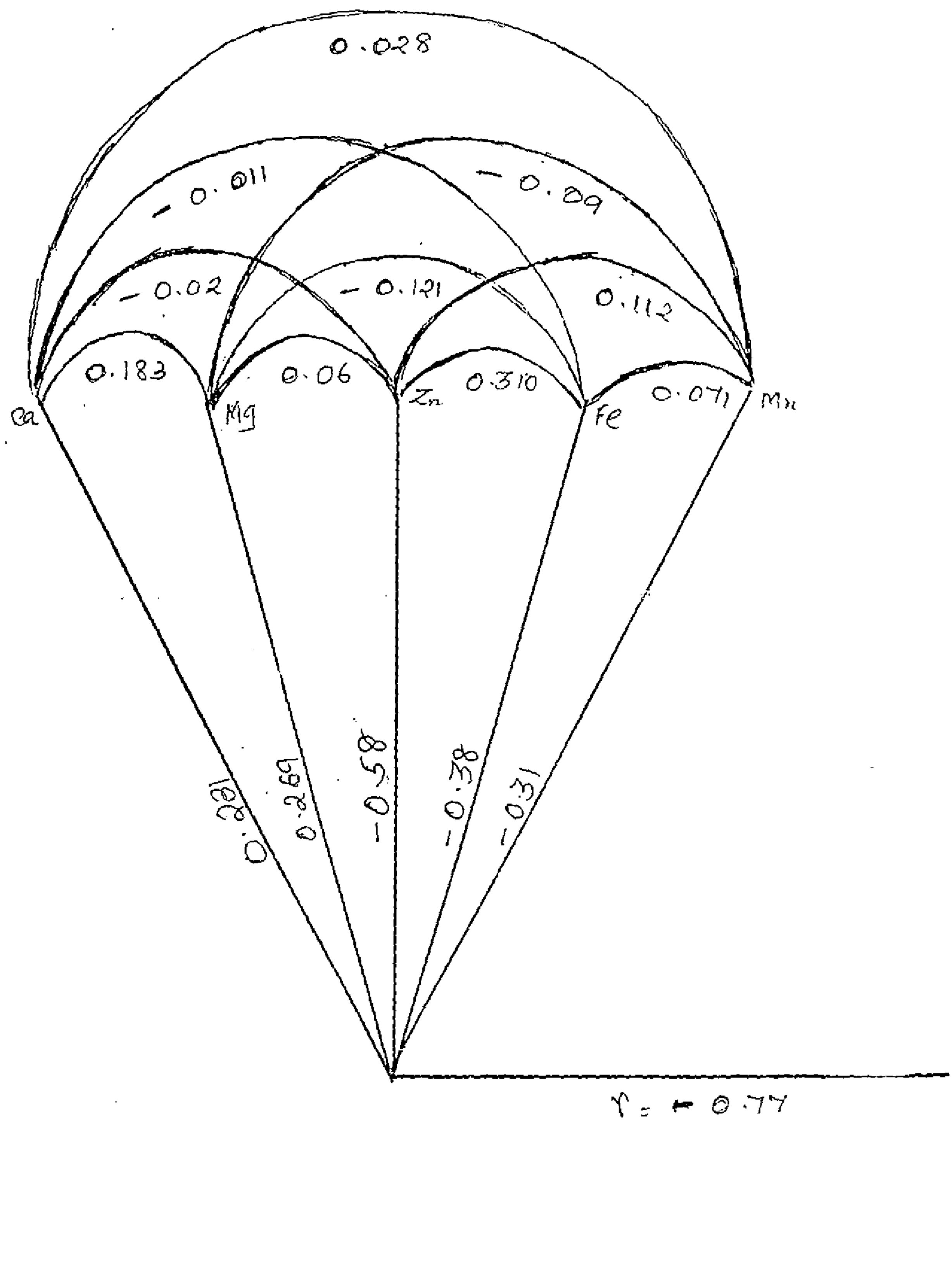


Fig.17 Path diagram showing direct and indirect effect of soil Mn content (15 cm depth) on rhizome yield of ginger

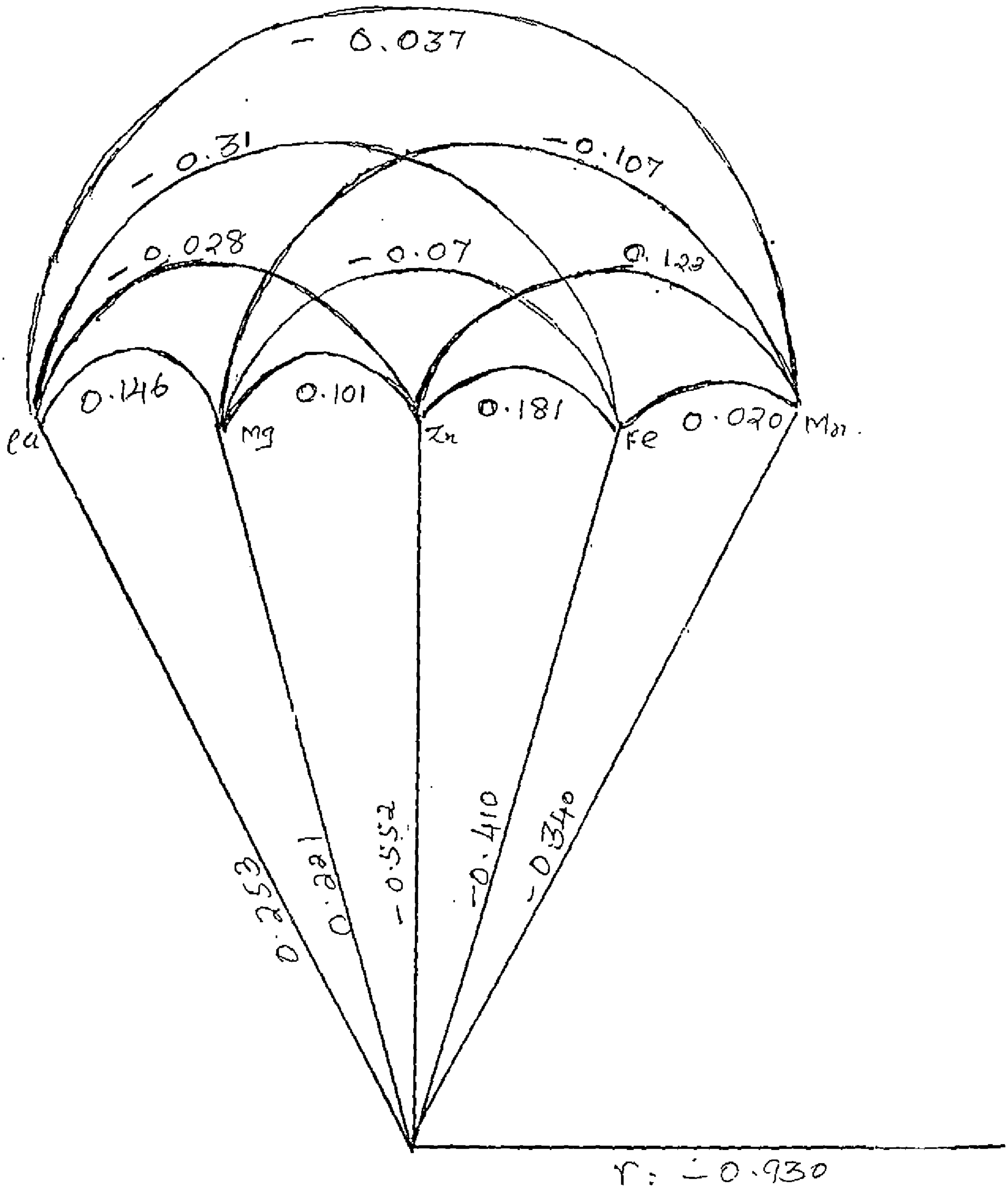


Table 52 path co-efficient of soil micronutrient content (30-cm depth) with yield

	Ca	Mg	Zn	Fe	Mn	r Value
Ca	**0.201***	0.167*	-0.053	-0.044*	-0.052*	0.219**
Mg	0.112*	**0.241***	-0.095*	-0.066	-0.072*	0.243**
Zn	0.051*	0.069*	**-0.193**	-0.07*	-0.09*	-0.233*
Fe	0.057**	0.063	-0.203	**-0.082***	-0.10*	-0.265**
Mn	0.021*	0.023*	-0.103	-0.041	**-0.023***	-0.122**

**-Significant at 1% level

*-Significant at 5 % level

From the data it is obvious that Ca and Mg showed direct positive effect and the other elements namely Zn, Fe and Mn showed indirect negative effects. The same trend was seen in path co-efficients of soil micronutrient contents at 15 cm depth.

The data on path analysis indicated that the yield may increase due to the presence of Ca and Mg extracted from the soil. The interaction effects between the different nutrients are presented as path diagrams. (fig. 18-22)

Considering the correlation co-efficents of plant micronutrient content with yield, only the leaf Mg, rhizome Fe and Mn contents showed significance. Hence the path analysis was carried out only for the above nutrients.

Fig.18 Path diagram showing direct and indirect effect of soil Ca content (30 cm depth) on rhizome yield of ginger

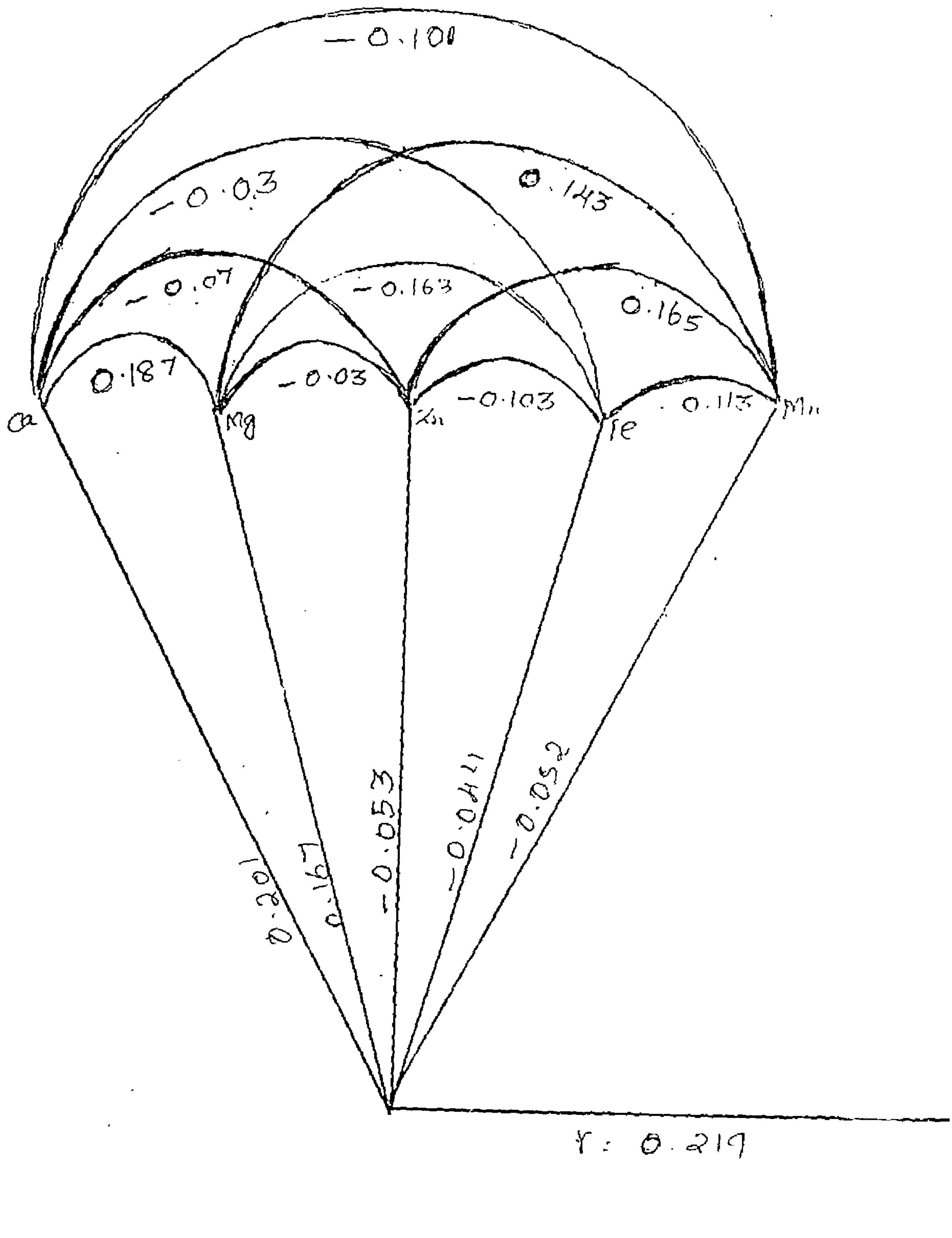


Fig.19. Path diagram showing direct and indirect effect of soil Mg content (30 cm depth) on rhizome yield of ginger

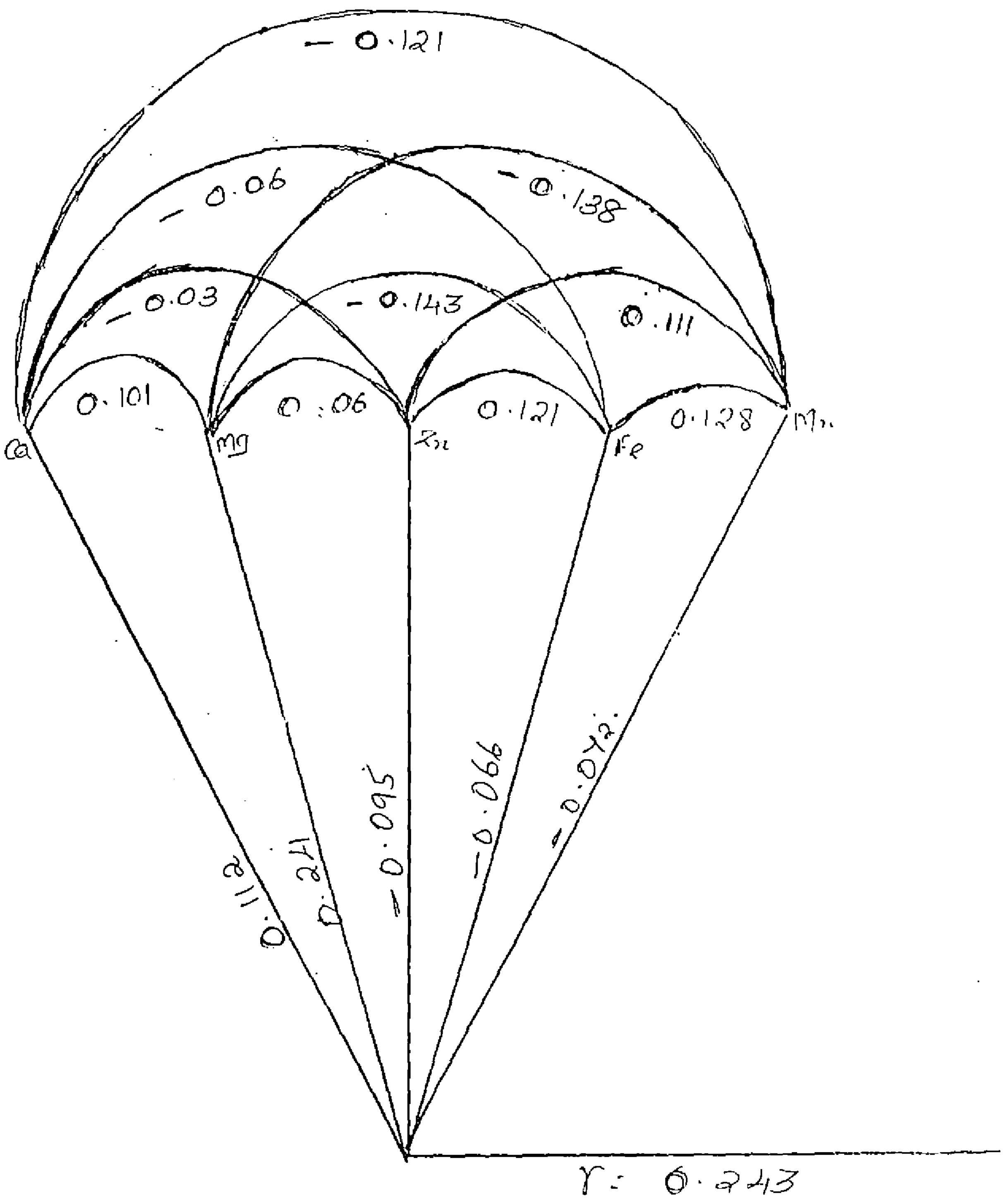


Fig.21. Path diagram showing direct and indirect effect of soil Zn content (30 cm depth) on rhizome yield of ginger

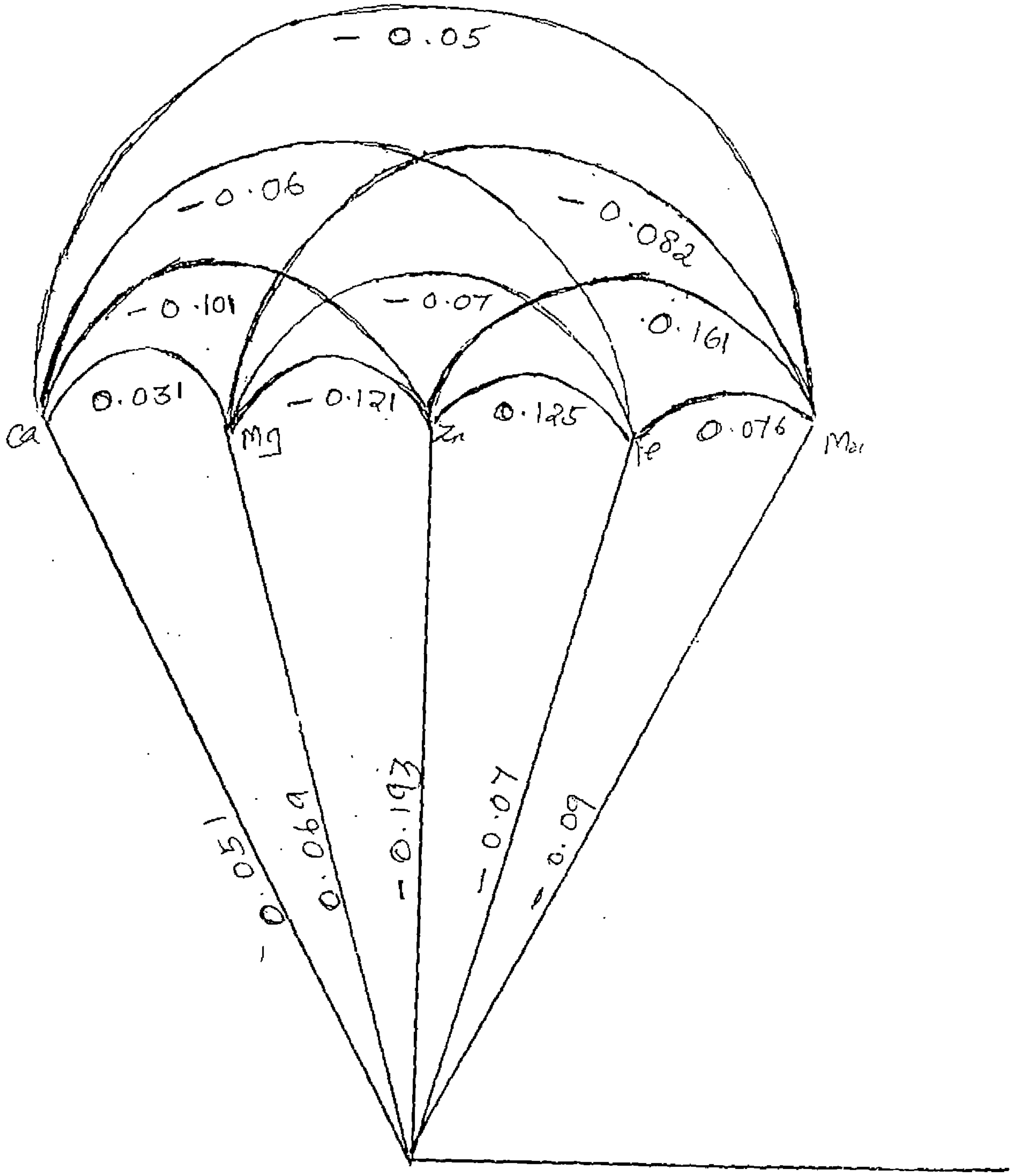


Fig.22. Path diagram showing direct and indirect effect of soil Mn content (30 cm depth) on rhizome yield of ginger

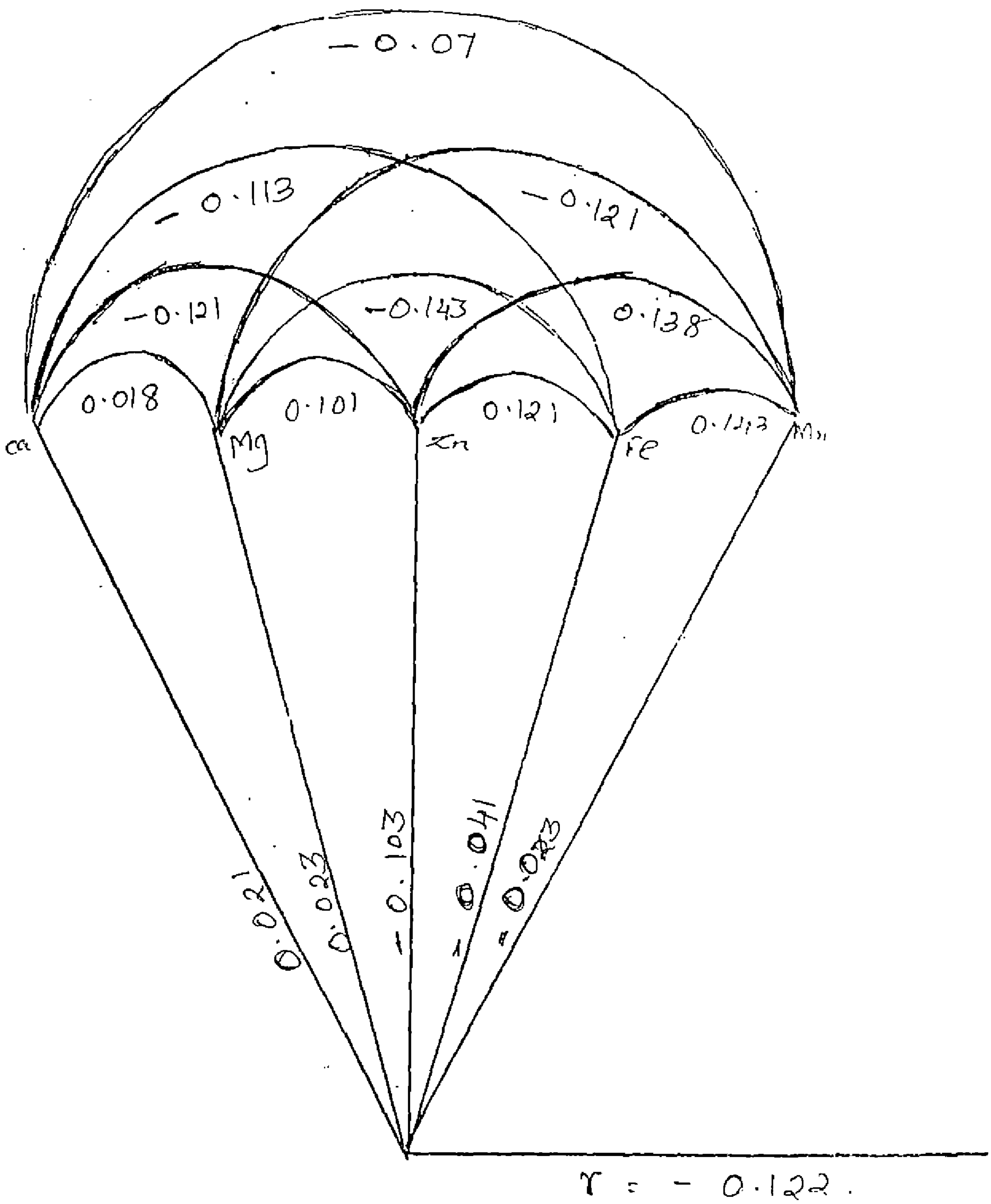


Table 53 Path Co-efficients of plant micronutient content with yield

	Leaf Mg	Rhizome Fe	Rhizome Mn	r Value
Leaf Mg	**0.382***	-0.049*	0.164*	0.497**
Rhizome Fe	0.071*	**-0.291**	0.092	-0.325**
Rhizome Mn	0.273*	-0.121*	**0.234**	-0.384**

**-Significant at 1% level

*-Significant at 5 % level

It is evident that leaf Mg and rhizome Mn contents had positive effect on yield. Interaction effects between the different nutrients are given as path diagrams (fig. 23-25).

The soil Ca and Mg showed a direct positive effect on rhizome yield. The most important role of Ca. is to maintain the integrity of structure and it enhances the absorption of P and K (Erdei and Zoldos, 1977). Magnesium also had a similar function to that of Ca, which in addition is a constituent of chlorophyll and important for photosynthesis. Magnesium either alone or in combination with Ca. appreciably improved crop growth (Padmaja and Varghese, 1966). The soil Zn., Fe. and Mn. showed negative effect on yield. Singh (1987) reported that application of Zn alone or in combination with N did not show any effect on yield. The interactive influence of Zn. Mn and Fe might have led to the negative response on the yield of ginger.

Mensovorae *et. al.,* (1985) found that excess Fe reduced the yield by tilting the balance between Ca and K. Sahu (1968) found an inverse relationship between Mn and Fe. the present study conforms the previous reports mentioned.

Fig.23 Path diagram showing direct and indirect effect of leaf Mg content on rhizome yield of ginger

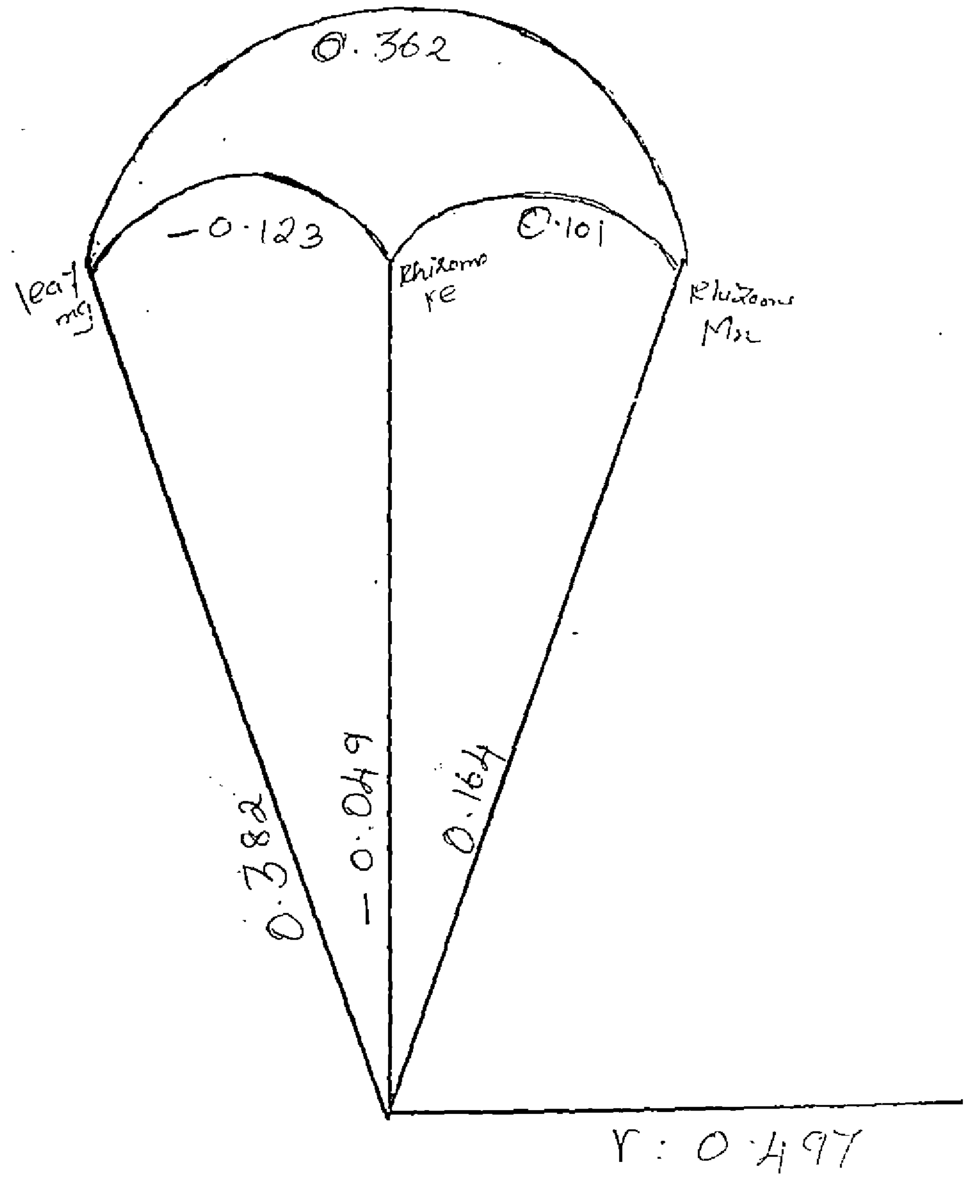


Fig.24. Path diagram showing direct and indirect effect of rhizome Fe content on rhizome yield of ginger

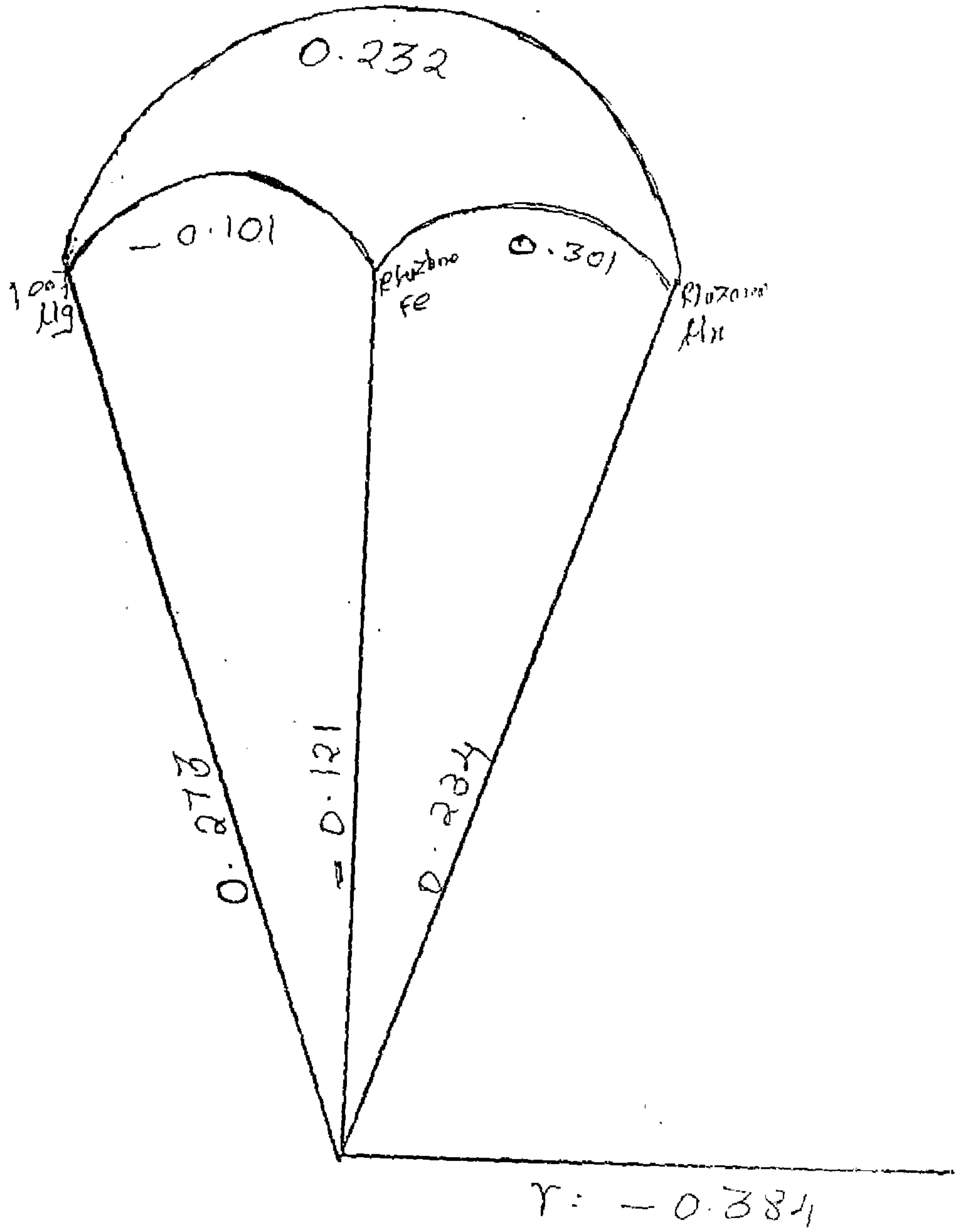
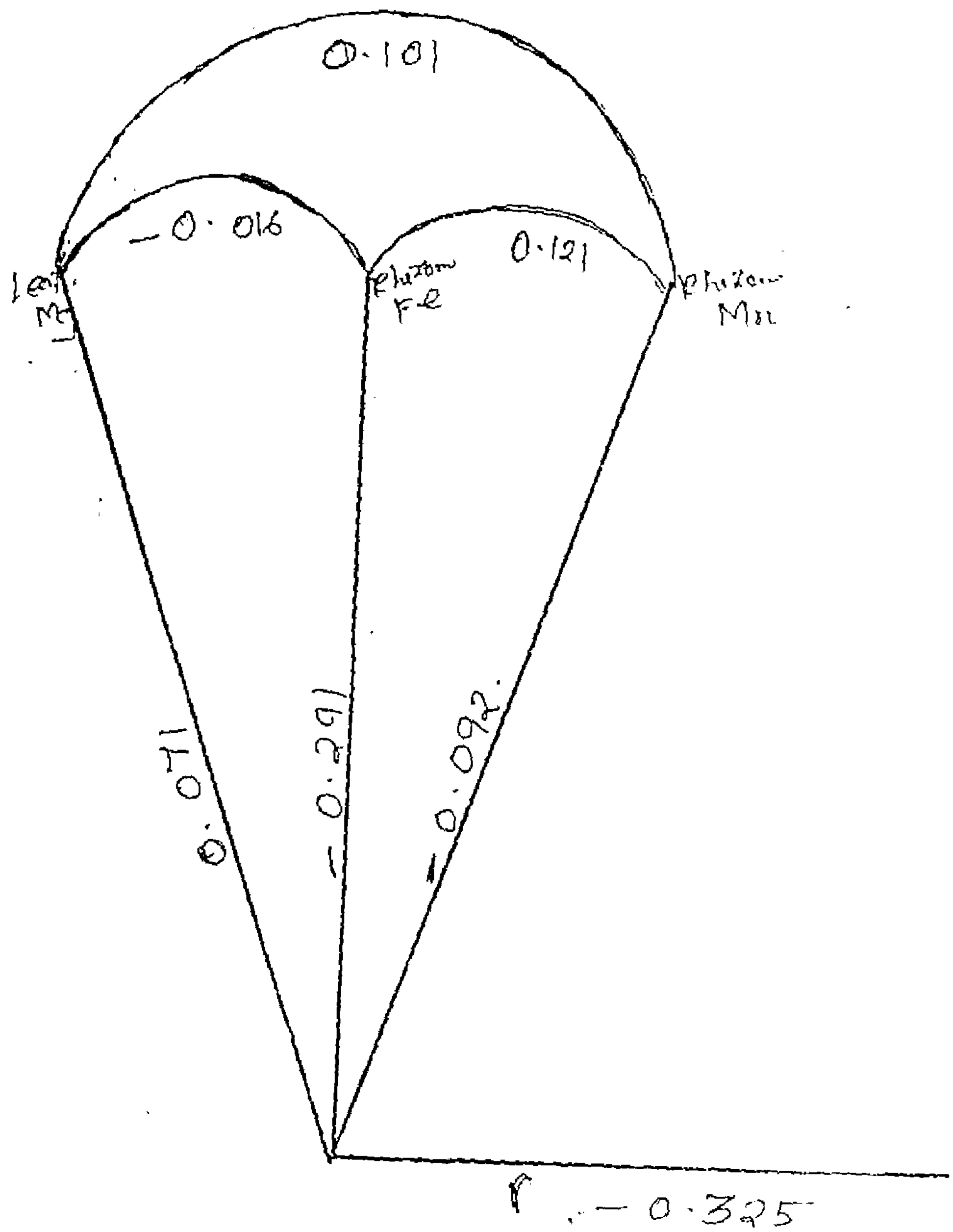


Fig.25. Path diagram showing direct and indirect effect of rhizome Mn content on rhizome yield of ginger



The inclusion of micro nutrient studies in this investigation throw some light on the defects of the prescription equations developed based on STCR technology. The STCR correlation studies do not take in to account the influence of native microelements, nutrient ratios, climatic factors etc. Hence earnest efforts must be made on a massive scale by the scientists so as to incorporate the missing links in the STCR package so as to develop a sound fertilizer recommendation programme for the various crops.

Future line of research

1. Technology verification trials may be conducted in the laterite soil in different agro-climatic zones of Kerala
2. STCR studies may be conducted with high yielding varieties of ginger under integrated nutrient supply system that too in a cropping sequence.
3. The post harvest soil fertility changes can be computed based on which fertilizer dose for the next crop in the cropping sequence can be worked without further soil tests.
4. The research may be extended to the soil test crop response correlation on important soil types and crops in the region and providing a means for better interpretation of soil test data.

SUMMARY

CHAPTER-6

SUMMARY

To establish soil test based balanced fertilizer prescription, for ginger Variety Maran an investigation was carried out at the college of Horticulture, Vellanikkara. The field study consisted of fertility gradient experiment, and STCR experiment using fertilizers and organic manure. The technique of inductive methodology developed by Ramamoorthy (1968) as followed in AICRP on STCR correlation studies was adopted for this investigation.

The fertility gradient experiment was conducted during March- April 2000 in the farm attached to the college. The fertility gradient was created by applying graded doses of N, P and K fertilizers and raising fodder maize Variety Co.1 in one and the same field.

The fodder yield, soil nutrient status and nutrient uptake by the gradient crop showed an increasing trend from strip I to strip IV. It proved the development of fertility gradient in the field.

The STCR experiment was conducted during May –Nov 2000 in the same field, with the crop ginger after the harvest of the gradient crop. The treatment structure consisted of four levels of N (0, 50, 100, 200). Three levels of P (0, 37.5, 75 kg P_2O_5 /ha) and five levels of K (0, 37.5, 75, 150, 300 Kg K_2O/ha) along with three levels of FYM (0, 15 and 30 t/ha) fitted in a response surface design.

The results of the experiment are summarized as follows:

The rhizome yield was increased from strip I to strip III (12,918, 13,563, 17460) and showed reduction in strip IV 16,185 which is Higher fertility level.

Uptake of N increased gradually from 22.1, 24.9, 33.0 and 35.2 kg/ha in strip I to strip IV respectively. But in the case of **P** & K it increased from strip I to III and showed slight reduction in strip IV.

Average P uptake values were 3.5, 2.6, 4.8 and 4.3 kg/ha in strip I to IV. The mean values of K uptake in strip I to IV were 98.70, 83.6, 132.9 and 101.8 kg/ha respectively.

Simple correlation co-efficients were established between available and applied nutrients with yield. Available nutrients showed higher positive correlation than that of applied nutrients.

Multiple regression models calibrated with yield as dependent variable and STVs for available N, P and K and applied nutrients as independent variables had 74% predictability. Among the three nutrients OC, N and P showed the normal or (+,-,-) type of response and hence optimization of only fertilizer **N** and P was done.

The fertilizer adjustment equation for varying levels of soil available N for maximum rhizome (tha^{-1}) of ginger in laterite soil was derived as **FN = 153 - 0.28SN** where FN is fertilizer N (kg ha^{-1}) SN is available N (kg ha^{-1}) in soil.

For varying organic carbon % (OC) and phosphorous in the soil, the fertilizer adjustment equation for N becomes **FN = 312.94 - 518.4OC** and **FP = 79.8 - 0.94 SP** for maximum rhizome yield where FP is fertilizer P2O5 (kg ha^{-1}) SP is available P (kg ha^{-1}) in soil

The behaviour of applied K was found to produce responses other than 'normal' and hence optimization could not be done for fertilizer K at varying soil test values.

The nutrient requirements of Ginger Variety Maran were estimated to be 2.1, 0.3 and 5.6 kg N, P_2O_5 and K_2O respectively to produce one tonne of rhizome.

The soil efficiencies were worked out as 10.1, 6.9 and 44 % N, P_2O_5 and K_2O respectively for ginger in laterite soil.

In the laterite soil, the efficiencies of contribution of nutrients from the fertilizer for ginger were calculated as 27.3, 10.9 and 53.2 N, P_2O_5 and K_2O respectively.

The percent contribution of nutrients from FYM for ginger in laterite soil were calculated as 30, 7 and 60 % N, P_2O_5, and K_2O respectively.

The fertilizer prescription equations for specific yield targets of ginger Variety Maran in laterite soil were derived as follows:

Without FYM

FN =7.8T - 0.37 SN

FP = 2.8T - 0.64 SP

FK = 10.6T - 0.835 K

With FYM

FN = 7.8T - 0.37SN - 1.11 ON

FP = 2.8T - 0.64 SP - 0.7 OP

FK = 10.6T - 0.835 SK - 1.13 OK.

Where,

FN, FP, FK - Fertilizer N, P_2O_5, and K_2O respectively in Kg/ha.

T - Target of rhizome yield in t/ha.

SN, SP, SK - Soil available N, P and K in kg/ha respectively.

ON, OP, OK - Quantities of N, P, K supplied through organic manure kg/ha

The study has revealed the superiority of fertilizer application over the semi quantitative approach followed in the soil testing laboratories and the generalized package of practices recommendation followed in the state for the crop. The fertilizer dose can be adjusted based on the specific objective and available resources of the farmer.

To know the influence of native elements on yield, without providing any treatments, the soil and plant samples were analyzed for micronutrient contents. In soil Ca, Mg and Mn showed positive correlations, Zn, Fe showed negative correlations in two different soil depth with yield.

In plant only leaf magnesium and rhizome manganese showed positive correlation and rhizome iron showed negative correlation. Further path analysis was carried out with significant correlation coefficients of different native elements to know the nutrient interactions.

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APPENDICES

APPENDIX 1 WEATHER DATA DURING THE YEAR 2000

Months	Temp Max °C	Temp Min °C	RH% morning	RH% evening	Mean RH%	RF (mm)	Rainy Days	Evaporation (mm)
January	35.2	23.2	76	43	60	0	0	203.4
February	35.6	22.8	85	52	67	4.6	1	147.4
March	38.0	23.9	87	46	67	0	0	180.9
April	36.2	24.6	89	59	74	67.9	3	128.4
May	35.5	24.4	88	56	72	117.2	8	152.2
June	32.0	22.8	94	77	86	602	21	111.8
July	31.2	21.9	93	70	82	354	15	104.3
August	31.8	22.6	94	79	87	51.8	19	95.9
September	32.6	23.0	91	70	81	198.1	10	101.1
October	33.4	22.7	91	68	80	262.2	10	101.1
November	34.4	23.1	77	54	66	41.3	5	123.4
December	33.2	22.0	70	48	59	11.2	2	161.5

APPENDIX 2

Strip 1 Soil micro nutrient contents (ppm) 0-30cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	22	49.1	21.1	42.2	0.9	65	71
2	20	52.8	24.6	12.4	0.1	85	55
3	20	43.1	19.2	12.6	0.2	90	68
4	21	41.7	19.5	26.6	1.0	55	110
5	21	61.8	32.0	36.7	2.5	190	90
6	21	68.9	33.0	33.8	0.7	75	96
7	28	50.7	25.6	27.3	1.3	115	105
8	25	42.1	21.7	13.8	1.0	90	81
9	24	41.4	22.8	19.8	1.1	110	100
10	20	55.4	28.9	19.6	1.8	110	102
11	17	49.8	18.1	19.4	1.3	151	90
12	19	41.4	18.3	14.2	3.2	170	150
13	22	42	16.3	13.3	5.2	175	145
14	19	49.6	22.1	20.9	5.6	175	148
15	19	44.3	18.2	20.6	0.9	140	140
16	19	39.7	18.5	26.6	1.3	160	142
17	20	31.1	12.7	47.5	1.0	155	90
18	18	35.9	13.5	14.5	1.0	165	100
19	22	33.8	14.6	33.4	0.9	170	180
20	17	32.3	10.9	54.9	1.1	125	90
21	19	39.2	17.2	56.6	0.7	170	120
22	22	28.3	11.3	60.4	0.8	175	120
23	19	33.3	12.7	14	4.4	180	140
24	19	47.1	15.2	18.2	0.7	155	90

APPENDIX 3

Strip 1 Soil micro nutrient contents (ppm) 0-15cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	22	52.1	25.1	40.5	1.4	150	115
2	20	55.4	26.5	47.7	1.3	155	115
3	19	44.2	19.6	48.2	1.5	125	120
4	28	54.4	260	45.6	0.4	50	70
5	24	60.1	29.6	19.3	0.8	85	65
6	22	70.5	33.5	24.5	1.1	95	60
7	29	69.5	33.6	21.6	0.8	80	75
8	19	53.7	18.7	16.3	0.6	70	37
9	21	61.9	16.8	12.6	0.3	75	49
10	21	71	23.8	15.8	0.3	50	28
11	16	44.3	12.4	12.2	0.2	55	25
12	22	45.8	15.6	16.2	0.5	60	50
13	24	48.6	12.6	10.6	0.6	65	62
14	24	45.6	130	17.3	0.7	65	67
15	22	52.6	17.2	14.8	0.5	50	30
16	21	51.4	15.1	33.5	1.5	155	140
17	17	42.7	11.8	37	1.3	150	135
18	22	29.3	18.8	27.7	1.5	170	140
19	22	39.3	130	44.9	0.6	165	145
20	20	24.8	16.5	32.6	1.5	135	155
21	20	43.3	14.2	38	1.6	160	115
22	22	33.4	11.1	17.2	2.4	170	145
23	20	36.1	11.2	21	0.8	100	90
24	25	50.2	13.7	20.9	0.8	125	105

APPENDIX 4

Strip 2 Soil micro nutrient contents (ppm) 0-30cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	20	62.1	22.2	22.1	1	155	173
2	20	58	18.3	25.3	1.1	155	105
3	21	61.6	21.7	21.8	0.8	150	178
4	19	57.9	18.0	21.2	0.2	190	180
5	27	68.4	18.2	8.0	0.4	65	150
6	31	51	16.4	7.5	0.1	70	150
7	22	54.7	18.4	16.2	0.2	70	150
8	22	61.9	22.6	5.1	0.6	60	125
9	21	49.6	16.0	11.9	0.7	85	140
10	17	45.5	15.0	8.5	1	55	115
11	19	54.8	16.8	9.1	0.5	85	105
12	18	57.8	18.2	7.7	0.8	75	125
13	21	51.1	25.6	14.3	1.2	90	130
14	19	53.4	20.4	18.6	1.8	130	115
15	18	57.8	18.2	11.8	1.3	145	100
16	36	41.5	13.6	14.6	1.0	150	115
17	21	55.1	7.2	7.1	1.1	90	100
18	19	56.2	6.5	4.3	1.1	60	105
19	18	44.2	10.9	19.5	1.3	155	135
20	17	21.2	15.4	8.3	1.7	130	115
21	21	42.6	29.8	8.9	2.1	70	100
22	24	42.5	12.9	15.1	2.8	135	140
23	19	41.63	7.8	11.2	1.8	145	130
24	20	43.28	15.8	32.3	2.3	155	150

APPENDIX 5

Strip 2 Soil micro nutrient contents (ppm) 0-15cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	23	23.9	16.2	23.5	2	130	178
2	21	22.4	16.9	13.2	1.2	150	120
3	29	68.1	24.5	30.4	2.4	160	180
4	18	56.6	18.3	12.6	0.8	180	175
5	21	61.7	23.8	20	1.1	105	145
6	18	46.9	16.6	27.5	2.2	120	163
7	19	55.9	20.3	39.2	1.7	135	165
8	19	73.6	27.3	15.7	1.4	55	130
9	18	59.0	22.7	28.8	0.7	105	148
10	18	58.4	19.6	27.6	1.8	110	135
11	21	56.4	20.8	31.3	1.4	125	120
12	22	64.4	21.1	17.3	1.1	110	145
13	20	65.0	26.7	23.4	1.0	110	140
14	20	63.9	23.3	39.4	2.4	140	120
15	19	53.2	17.5	13.5	1.0	150	105
16	20	46.4	15.1	37.5	2.2	143	140
17	22	71.3	23.3	25.3	1.6	115	115
18	20	56.5	20.8	12.5	1.2	105	120
19	18	35.9	10.2	30.6	2.5	165	150
20	19	70.3	21.8	28.7	2.5	145	128
21	22	67.3	23.8	37	0.5	135	115
22	24	75.8	31.1	38.6	2.7	140	135
23	18	49.6	16.9	25.6	3.1	160	140
24	19	56.3	18.7	19.1	1.7	165	155

APPENDIX 6

Strip 3 Soil micro nutrient contents (ppm) 0-30cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	23	49.8	15.2	16.9	0.7	140	220
2	17	45.1	15.6	39.5	1.0	163	190
3	20	56.8	16.7	15.3	1.4	120	140
4	19	66.3	23	20.8	0.7	135	113
5	19	61.2	22.7	35.4	0.9	125	142
6	18	89	22.7	22.4	0.9	110	117
7	15	100	24.9	10.6	1.2	100	145
8	19	58.4	17.8	27.8	0.8	130	145
9	21	70.1	22.6	14.4	0.8	105	113
10	20	85.9	33.3	9.5	0.7	150	152
11	22	80.3	30.1	18.6	0.7	145	163
12	20	57.6	22	18.3	0.6	115	143
13	20	59.3	18.2	13.2	0.9	110	128
14	29	50.2	21.6	24.8	0.4	125	128
15	22	65.6	32.9	21.8	0.6	100	175
16	19	82.7	37.1	12.7	0.6	105	145
17	23	61.3	22.2	16.2	0.4	150	150
18	23	81.3	26.4	17.8	0.4	145	175
19	19	65.7	21	22.3	0.7	205	190
20	41	70.9	26.2	26.6	0.4	110	145
21	25	70.9	22.7	18.7	0.2	165	125
22	24	48.7	18.7	19.9	0.4	185	148
23	20	61.7	22.2	27	0.4	165	164
24	19	47.1	15.2	41.8	0.4	190	153

APPENDIX 7

Strip 3 Soil micro nutrient contents (ppm) 0-15cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	19	42.9	14.8	41.8	0.4	170	175
2	21	45.4	16.1	29.8	0.5	178	180
3	20	53.7	17.7	16.5	0.9	145	173
4	21	63.1	24	29.2	0.9	155	183
5	24	53.1	22.7	14.9	0.8	135	191
6	22	62.6	22.3	18	0.5	105	178
7	26	64	18.5	12.4	0.7	115	180
8	24	59.3	18.7	16.4	0.2	75	65
9	20	68.2	23.4	9.7	0.7	125	200
10	20	61.5	26.7	16.1	0.7	105	165
11	19	66.4	26.1	17.0	1.0	135	200
12	21	58	21.8	11.1	1.5	150	190
13	18	66.2	22.1	20.7	0.4	90	150
14	21	54.8	21.5	14.8	0.8	150	153
15	21	64.8	24.0	12.6	0.7	125	175
16	21	76.4	21.2	13.6	1.5	130	153
17	20	70.1	20.3	14.6	1.2	135	173
18	21	52	17.7	13.8	0.5	150	170
19	18	73.9	20.4	13.4	0.8	200	170
20	21	69.9	26.7	13.6	0.9	90	168
21	20	67.2	20	15.3	1.1	105	173
22	18	58.9	21.4	15.6	1.1	160	154
23	20	84.9	25.2	17.1	2.7	110	105
24	19	59.6	15.7	10.2	0.8	185	165

APPENDIX 8

Strip 4 Soil micro nutrient contents (ppm) 0-30cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	39	62	23.5	14.8	1	173.5	178
2	31	50	11.2	15.8	2.2	170.2	163
3	32	52.8	22.2	34.9	0.7	205	180
4	36	52.2	17.3	12	1.8	200	210
5	49	50.0	15.5	15.4	0.7	145	210
6	32	44.0	17.9	16.3	0.7	190	215
7	30	41.0	16.9	10.3	0.6	140	190
8	43	42.8	15.2	11.2	0.6	170	180
9	40	38.6	13.3	12.4	0.7	150	200
10	42	48.4	18.3	14.3	0.7	200	205
11	41	36.4	12.4	17.2	0.6	175	220
12	34	26.4	11.7	13.2	0.7	160	200
13	39	55.1	22.2	13.4	0.7	175	200
14	35	39.2	14.9	13.4	0.6	140	150
15	30	38.8	14	14.2	0.6	120	150
16	25	39.0	15	18.3	1.0	165	210
17	34	41.0	14.7	21.5	0.7	130	170
18	33	31.9	10.6	14	0.7	150	205
19	33	38.2	13.8	24.8	0.6	135	180
20	32	32.6	10	22.5	0.9	205	173
21	17	34.9	10.4	31.3	1.3	210	185
22	19	39.5	14.7	27.5	1.4	200	180
23	18	43.2	12.5	13.8	0.8	190	215
24	18	36.5	13	11	0.7	110	200

APPENDIX 9

Strip 4 Soil micro nutrient contents (ppm) 0-15cm depth

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	21	52.4	20.1	14.9	1.1	170	160
2	17	47.2	14.9	24.8	1.0	162	152
3	15	39.0	15.2	19	1.4	200	173
4	18	38.1	12.1	18.6	1.0	205	200
5	16	38.3	14	26	1.2	136	200
6	19	40.6	16.1	36.5	2.7	180	205
7	19	38.4	13.9	12.3	0.4	136	135
8	19	38.2	14.4	15.3	1.4	140	173
9	24	37.0	15.6	15.4	1.0	190	220
10	18	48.3	17.7	16.1	1.1	110	205
11	21	57.6	18.6	20.5	0.9	120	250
12	21	37.5	14.6	18.7	1.3	165	240
13	16	46.8	16.7	14.9	1.2	150	190
14	21	52.6	16.5	23.2	1.3	170	140
15	24	49.7	15.5	22.1	1.2	195	133
16	20	45.5	17.3	16.9	1.1	158	205
17	19	50.9	17.5	23.8	1.4	126	163
18	22	39.4	11.3	22.8	1.2	140	190
19	20	57.8	21	23.9	1.4	125	168
20	21	38.5	12.8	27.4	1.2	200	153
21	22	53.5	16.5	30.9	1.2	205	170
22	21	48.6	16.2	22.4	1.0	190	162
23	21	56.0	13.7	26.7	1.0	180	200
24	17	37.0	12.3	10.6	0.6	100	190

APPENDIX 10

Strip 1 Leaf micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	120	14500	5125	3580	310	43375	2710
2	120	12000	9125	3960	300	22375	2740
3	200	16500	6500	6560	340	39250	3230
4	160	12250	5500	4060	270	33625	2840
5	240	15875	10625	4880	340	62000	2670
6	320	15125	11000	5660	450	41375	2960
7	120	8875	12375	4980	330	37750	2630
8	240	9375	6625	4330	340	39000	3060
9	160	10000	9375	3920	270	30000	2410
10	160	19625	5000	1990	310	37875	2260
11	120	14000	4625	2490	280	19625	2120
12	160	21500	7000	2580	350	28000	2930
13	40	15625	7375	5530	360	39375	3340
14	120	14625	7500	2940	310	51875	4120
15	240	14000	6625	5130	440	27250	3770
16	200	20125	7625	5620	310	44875	2530
17	360	13000	5625	4550	310	24625	3610
18	200	10875	8000	3040	290	54750	4020
19	400	17125	9125	5020	280	25000	2840
20	120	10500	5250	3210	340	31250	5220
21	160	11500	4750	3250	230	30750	3000
22	120	3500	6375	3580	260	23000	3140
23	120	2750	4125	2980	230	21000	2810
24	160	3610	3625	3510	300	21250	4380

APPENDIX 11

Strip 1 Root micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	200	3125	4500	540	160	219250	3040
2	120	2625	6250	570	130	175500	2830
3	80	2125	6625	840	150	202250	2770
4	120	2875	6250	830	160	212750	3240
5	160	3375	7625	650	140	188000	2830
6	120	2875	7125	660	170	229125	2750
7	240	3750	6125	750	160	241875	3250
8	200	3500	5625	750	180	238250	3270
9	200	1875	7560	610	140	219500	2750
10	440	2750	7250	750	170	250875	2900
11	200	4625	6625	620	160	262750	3140
12	120	3500	4250	540	130	210250	2700
13	160	750	5625	700	130	239250	3190
14	160	2750	5375	770	140	249625	3560
15	360	1875	5375	540	130	230125	3060
16	200	1000	5000	700	150	24200	3020
17	160	1625	6500	500	120	207210	3070
18	160	2125	6500	660	160	22350	3510
19	160	1625	5875	660	150	208750	3220
20	320	3000	5875	740	200	27232	4230
21	160	1375	4375	700	120	218250	3020
22	160	1875	4875	700	120	210125	4140
23	280	3625	7875	750	190	296125	3290
24	240	3375	6000	570	150	223625	3330

APPENDIX 12

Strip 1 Rhizome micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	1440	3133	3800	300	360	9450	728
2	1280	2667	5250	230	280	10746	556
3	1320	2186	6190	240	240	9222	522
4	1360	2877	6173	240	320	8650	632
5	1560	3378	7633	210	290	10075	618
6	1160	2125	7025	190	370	7900	586
7	1120	3260	6135	210	300	6925	588
8	1160	3560	5677	190	260	5600	560
9	1160	1877	7723	280	260	6575	524
10	1040	2780	7280	290	310	12975	616
11	1040	4630	6683	200	270	7075	498
12	1120	3800	4180	270	360	13220	676
13	1280	1105	4960	290	300	13038	630
14	1440	2800	4895	310	380	13375	598
15	1240	1910	5660	360	360	9650	692
16	1280	1210	4890	260	280	8675	618
17	1480	1620	5950	310	380	13750	850
18	1160	2138	6160	250	360	13525	876
19	1240	1635	5915	300	360	13523	872
20	1260	3120	5820	270	410	14230	1038
21	1200	1380	4116	230	310	14243	638
22	1200	1890	4226	330	380	11900	710
23	1000	3680	6115	190	270	9200	572
24	1120	3380	5113	220	240	9225	650

APPENDIX 13

Strip 2 Leaf micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	140	14625	6500	2710	280	35750	3670
2	80	21125	8375	2610	250	26125	3680
3	80	13625	7375	2970	270	33000	3010
4	80	15375	10125	1930	260	44500	3760
5	80	14378	8000	2710	250	31125	2790
6	40	16000	5750	2150	210	40250	3210
7	40	23375	9625	4560	310	38250	3690
8	160	21250	5250	2370	290	34125	3330
9	40	21750	7125	5470	270	37125	3610
10	40	23000	7000	2850	280	29000	2950
11	40	23500	5375	2860	280	32875	2700
12	40	14875	8875	4190	260	34500	3030
13	40	17625	8625	4960	270	37750	3740
14	40	16500	10000	1100	200	43500	3700
15	40	16625	3500	3130	200	22375	2140
16	40	8500	5000	2750	240	36125	3590
17	40	16375	9000	4290	320	34375	3620
18	120	21250	10750	2860	250	33500	3450
19	80	12875	5250	3310	270	29625	3280
20	160	13625	5250	2180	350	23625	2510
21	40	12125	5000	2170	290	19000	2830
22	160	14375	6625	3680	370	25500	2480
23	280	14375	6000	2370	410	43750	4880
24	160	19250	6500	2690	360	46000	3100

APPENDIX 14

Strip 2 Root micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	280	1250	4875	740	180	234125	3150
2	440	1500	12250	520	200	250125	3730
3	760	1625	6250	390	170	183500	2480
4	240	3750	4500	310	120	16475	2130
5	200	2000	6375	420	150	213000	2500
6	640	2875	6375	620	180	240625	3150
7	600	1625	8250	850	150	208500	3100
8	160	2125	5000	480	190	212000	2790
9	280	2125	7000	750	180	225500	3940
10	320	2875	7625	580	140	196500	3410
11	240	2625	4750	440	150	190875	2460
12	240	1750	8000	400	110	151125	2460
13	400	1750	4875	460	110	161000	2410
14	120	1750	5750	410	100	202375	2260
15	720	1000	4875	530	180	171180	2520
16	120	1125	4875	700	150	181125	2510
17	440	1375	8000	450	660	202875	2200
18	160	1375	8000	380	110	181125	2240
19	120	1125	4625	540	120	202875	2590
20	80	1250	5375	460	180	227125	2340
21	120	1075	6125	360	120	183375	1960
22	120	1125	5250	570	170	235250	2250
23	400	4375	4250	400	160	188875	2190
24	640	2375	5250	500	170	248250	2620

APPENDIX 15

Strip 2 Rhizhome micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	1040	1320	3873	120	290	5525	422
2	1120	1480	4875	110	230	5650	512
3	1120	1650	5890	150	310	5825	460
4	1040	3800	4600	130	220	8675	554
5	1040	2120	6175	120	230	7625	530
6	1120	2900	6166	120	260	9225	596
7	1160	1680	7800	170	270	4375	474
8	1120	2150	4820	130	230	7900	480
9	1080	2180	6820	190	290	3875	658
10	1040	2900	7125	150	290	7625	616
11	1040	2670	4720	160	300	10175	468
12	1000	1800	7800	110	240	6000	696
13	1080	1820	4820	320	260	7275	470
14	1040	1830	5765	160	210	7550	594
15	1200	1105	4960	160	310	7400	676
16	1120	1175	4965	130	240	4325	694
17	1200	1425	8105	240	330	10775	494
18	1160	1480	8210	160	240	6875	774
19	1120	1170	4630	160	270	5200	382
20	840	1280	5475	110	280	3375	404
21	480	1175	6170	170	240	7800	374
22	1000	1165	5280	150	240	5475	324
23	1040	3873	4276	100	190	4725	328
24	1120	2385	5236	130	260	9050	496

APPENDIX 16

Strip 3 Leaf micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	200	20250	11875	4010	270	46500	3760
2	320	34800	13750	4740	380	74250	4460
3	160	29375	14375	3590	440	53875	4930
4	120	27000	17375	4150	310	56115	3400
5	320	26625	11875	5630	350	51875	3380
6	240	24125	15500	6740	350	39875	3760
7	160	19250	7625	1980	260	50000	3770
8	200	24625	15250	4120	330	48625	3070
9	320	22000	14000	6700	360	74125	3280
10	240	25375	13000	4930	380	52500	4040
11	180	17625	9500	5500	320	77500	3200
12	240	11375	6250	2590	190	19750	1970
13	200	16000	9375	4670	280	32375	3520
14	120	15000	7625	5110	340	44750	4010
15	200	13625	6625	3900	270	48250	3190
16	320	19000	10125	4360	340	37125	3790
17	200	21250	8250	3610	280	41500	3360
18	240	13125	8250	4440	270	52375	4210
19	120	11250	10125	3090	280	56500	3470
20	240	15500	6250	3990	280	51875	4310
21	200	15375	6250	3030	310	55375	3410
22	80	10750	6130	2830	260	33375	3350
23	80	16000	8000	2380	310	48280	4060
24	40	14625	87500	4350	230	37125	4260

APPENDIX 17

Strip 3 Root micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	640	2625	6875	1110	150	280625	3170
2	240	2500	6000	890	230	325375	4380
3	560	1250	4625	730	260	287750	3200
4	740	3250	6500	860	250	257750	2820
5	440	3250	7375	960	280	308625	2890
6	1233	3250	6875	930	300	283625	3260
7	1040	1625	4625	750	310	264375	3200
8	1280	2000	5875	1130	300	294375	3500
9	1310	2375	5625	1070	260	402875	3360
10	920	1625	5250	870	210	222500	2940
11	1330	2625	4375	820	400	277750	3310
12	280	1875	3500	710	170	283125	2910
13	960	2000	5125	750	370	294125	3560
14	400	1375	5550	1050	210	340000	3290
15	440	1250	6250	1170	280	269875	3430
16	520	1250	5125	740	350	267250	3320
17	40	2125	4375	570	220	314000	3150
18	320	750	6500	1020	220	286750	3220
19	160	1875	5375	810	350	347250	4050
20	40	2875	2875	130	140	230250	1970
21	200	1125	3750	770	190	303625	3420
22	800	2375	7750	1150	270	313824	5230
23	40	2375	4500	630	180	335500	3450
24	200	2625	6500	1180	190	348810	3770

APPENDIX 18

Strip 3 Rhizhome micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	1280	2650	5040	340	200	9900	722
2	1160	3100	5800	200	250	6125	534
3	1320	1330	4510	180	280	7300	558
4	1160	3300	6400	240	230	9472	602
5	1160	3230	6960	470	300	12525	486
6	1120	3600	6910	250	360	7500	570
7	1120	1670	4715	240	260	11621	594
8	1120	2120	5920	200	190	3750	570
9	1120	2360	5610	170	170	3600	368
10	520	1680	5320	220	330	9521	440
11	400	2675	4380	380	310	11250	782
12	280	1375	3610	240	280	8875	716
13	320	2105	5130	290	250	13400	626
14	240	1360	5580	380	370	8100	452
15	360	1270	6230	370	330	8125	666
16	400	1290	5180	250	330	13425	476
17	280	2150	4390	180	250	8125	460
18	240	1100	6510	200	310	937	524
19	240	1850	5410	180	340	9575	594
20	640	2900	2910	240	280	9850	770
21	1240	1150	3780	250	300	13436	606
22	1120	2400	7800	680	270	10925	582
23	1320	2510	4466	170	330	9075	660
24	1200	2715	6165	260	240	13175	760

APPENDIX 19

Strip 4 Leaf micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	280	20	10000	1650	260	57500	4270
2	160	17.5	5000	3740	250	56250	3760
3	160	6625	2500	2450	320	51250	4280
4	240	20	10000	3610	290	50250	4460
5	200	11.25	3750	4520	330	71250	4010
6	160	15000	8750	1790	240	61250	3810
7	160	17500	7500	3770	330	67500	4250
8	160	16250	11250	2360	220	76250	4200
9	160	18750	6250	1760	350	52500	4550
10	200	16250	7500	2990	330	57500	4660
11	160	12500	5000	2060	220	46200	3720
12	280	33750	13750	5370	460	57250	6640
13	240	18750	7500	1860	270	47500	5510
14	160	13750	7500	2520	290	60000	3760
15	280	15000	7500	3140	290	76000	4750
16	240	15000	7500	2390	300	57250	5190
17	240	11250	6250	3230	290	57000	4960
18	200	27500	17500	1770	260	72500	5890
19	240	23750	16250	2060	370	70000	5470
20	200	15000	10000	1460	230	62250	4440
21	200	16250	10000	3000	280	63200	4840
22	200	15000	7500	2140	300	76250	4180
23	200	23750	12500	2210	220	67000	5280
24	240	17500	10000	2520	290	67250	4860

APPENDIX 20

Strip 4 Root micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	160	1750	4125	1000	190	369125	4200
2	200	1600	7750	1180	240	3965100	3450
3	160	1540	4500	790	210	391125	4140
4	160	1750	5250	1140	230	428750	3300
5	160	1250	3625	800	180	366625	3200
6	160	3125	5875	740	190	357375	3190
7	80	2500	4750	760	160	325625	3460
8	120	2500	7125	850	220	401000	3110
9	240	1750	5550	1390	180	383128	3120
10	120	15375	3375	780	200	312625	2980
11	120	2125	3500	1030	170	250625	3930
12	120	2500	6500	1030	220	372750	3830
13	80	2875	4750	880	200	377875	3630
14	80	2625	5000	730	190	415125	3740
15	120	1750	5875	1080	190	355625	3760
16	120	3000	6375	940	210	360125	3880
17	120	3750	5750	770	240	331375	3990
18	120	3250	5625	730	220	395375	3270
19	80	2750	5750	750	180	464500	3660
20	120	2500	3500	880	200	316375	3760
21	160	1250	2750	830	170	318821	3110
22	280	1250	5500	1140	180	397625	3060
23	120	2875	5125	1140	170	382875	3690
24	160	1250	5150	1050	270	383021	3680

APPENDIX 21

Strip 4 Rhizhome micro nutrient contents (ppm)

T	Na	Ca	Mg	Cu	Zn	Fe	Mn
1	360	1800	3895	380	290	11256	842
2	440	1750	6950	350	290	13750	788
3	320	1560	5125	300	300	14500	838
4	240	1780	5335	300	200	11750	722
5	240	1280	3785	500	1670	11450	878
6	280	3000	6100	190	250	12750	814
7	280	2600	5250	160	180	6250	598
8	240	2800	6750	310	190	9256	574
9	360	1620	5560	580	200	17000	886
10	320	4600	3365	340	890	12750	740
11	360	2150	3895	220	300	17000	936
12	400	2300	6600	190	200	6250	770
13	440	2900	4900	180	200	17500	886
14	400	2700	5100	180	190	12600	772
15	320	1800	5600	220	180	5250	980
16	320	3200	6475	310	280	9250	896
17	280	3250	5980	210	200	8500	738
18	200	3700	5715	210	220	7600	642
19	360	2800	5800	240	190	7500	842
20	280	2600	3150	200	190	16750	868
21	360	1260	2800	190	190	8500	704
22	360	1280	5600	180	190	7230	670
23	280	2965	5230	170	150	8650	562
24	240	1560	5200	210	160	13500	762

SOIL TEST CROP RESPONSE STUDIES ON GINGER IN LATERITE SOILS OF KERALA

By

M. JAYALAKSHMI

ABSTRACT OF A THESIS

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Faculty of Agriculture
Kerala Agricultural University

Department of Soil Science and Agricultural Chemistry
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680654
KERALA

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ABSTRACT

To establish soil test based balanced fertilizer prescription for ginger variety Maran in laterite soils of Kerala, an investigation was undertaken at the College of Horticulture, Vellanikkara. The field study consisted of fertility gradient experiment and STCR experiment.

The fertility gradient experiment was conducted during March-April 2000 in the farm attached to the College. The desired gradient in soil fertility was created in one and the same field by applying graded doses of N, P and K fertilizers and raising fodder maize var. Co.1.

The STCR experiment was conducted in the same field during May-Nov 2000 using the test crop, ginger variety Maran. The treatments consisted of fractional factorial combinations of four levels of N (0, 50, 100 and 200 kg ha^{-1}), three levels of P (0, 37.5, 75kg P_2O_5 ha^{-1}) and five levels of K (0, 37.5, 75, 150 and 300kg K_2O ha^{-1}) along with three levels of farmyard manure (0, 15 and 30 t / ha) fitted in a response surface design.

Using multiple regression model, the fertilizer adjustment equation for N at varying soil test values for available N for maximum rhizome yield (t ha^{-1}) of ginger in laterite soil was derived as **FN = 153 - 0.28SN** where FN is fertilizer N (kg ha^{-1}) and SN is soil available N (kg ha^{-1}).

At varying soil test values for organic carbon % (OC) and Phosphorous kg / ha the above equations become **FN = 312.94 - 518.4 OC** and **FP = 79.8 - 0.94SP** for maximum rhizome yield.

The behaviour of fertilizer K was found to produce responses other than 'normal' and hence optimization could not be done for fertilizer K for maximum rhizome tuber yield at varying soil test values.

The nutrient requirements of ginger variety Maran were estimated to be 2.1, 0.3, 5.6kg N, P_2O_5 and K_2O respectively to produce one kg of rhizome. In the laterite soil, the efficiencies of contribution of nutrients from the soil for ginger were calculated as 10.1,6.9 and 44% N, P_2O_5 and K_2O respectively. The fertilizer efficiencies were worked out as 27.3, 10.9 and 53.2% N, P_2O_5 and K_2O respectively. The efficiencies of contribution of nutrients from farmyard manure were calculated as 30, 7 and 60% N, P_2O_5 and K_2O respectively.

From the above basic data, fertilizer prescription equations for specific yield targets of ginger var. Maran in the laterite soil were derived as given below.

Without FYM

$$FN = 7.8T - 0.37\,SN$$

$$FP = 2.8T - 0.64\,SP$$

$$FK = 10.6T - 0.835\,K$$

With FYM

$$FN = 7.8T - 0.37SN - 1.11\,ON$$

$$FP = 2.8T - 0.64\,SP - 0.7\,OP$$

$$FK = 10.6T - 0.835\,SK - 1.13\,OK.$$

Where,

FN, FP, FK - Fertilizer N, P_2O_5, and K_2O respectively in Kg/ha.

T - Target of fresh rhizome yield in t/ha.

SN, SP, SK - Soil available N, P and K in kg/ha respectively.

ON, OPOK - quantities of N, P and K supplied through organic manure in kg/ha.

Based on the fertilizer prescription equations ready reckoners were developed for different yield targets.

The study has revealed the superiority of fertilizer application over the semi quantitative approach followed in the soil testing laboratories and the generalized package of practices recommendation followed in the state for the crop. The fertilizer dose can be adjusted based on the specific objective and available resources of the farmer.

To know the influence of native elements on yield soil and plant samples were analyzed for micronutrient contents. In soil Ca, Mg and Mn showed positive correlations and Zn, Fe showed negative correlations with yield.

In plant leaf magnesium and rhizome manganese showed positive correlation and rhizome iron showed negative correlation. Further path analysis was carried out to know the nutrient interactions.