SOIL TEST CROP RESPONSE STUDIES IN CASSAVA IN LATERITE SOILS OF KERALA

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled **Soil test crop response studies in Cassava in laterite soils of Kerala** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
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KUMARI SWADIJA. O

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

AICARP	-	All India Co-ordinated Agronomic Research Project
ANOVA	-	Analysis of variance
BCR	-	Benefit cost ratio
CD	-	Critical difference at 5%
CTCRI	-	Central Tuber Crops Research Institute
FGE	-	Fertility gradient experiment
FIB	-	Farm Information Bureau
FYM	-	Farmyard manure
ha^{-1}	-	Per hectare
HCN	-	Hydro cyanic acid
IARI	-	Indian Agricultural Research Institute
K	-	Potassium
KAU	-	Kerala Agricultural University
kg	-	kilogram
LAI	-	Leaf area index
N	-	Nitrogen
POP	-	Package of Practices
RBD	-	Randomised block design
STCR	-	Soil test crop response
STL	-	Soil Testing Laboratory
STVs	-	Soil test values
t	-	tons
TNAU	-	Tamil Nadu Agricultural University
°C	-	Degree Celsius

INTRODUCTION

INTRODUCTION

Fertilizers have played a key role in increasing foodgrain production in India. There is a strong relationship between fertilizer consumption and foodgrain production in the country over years. The consumption of fertilizer nutrients in the country increased from 0.79 million tonnes in 1965-66 to 15 million tonnes in 1995-96 with a corresponding increase in foodgrain production from 72.4 million tonnes to 190.4 million tonnes (Singh, 1996 and Venkatramani, 1996). Nevertheless, there exists a wide gap between demand for fertilizers and their production that has necessitated their import leading to spiralling of fertilizer prices. Thus, fertilizers constitute one of the most effective and costlier inputs in increasing crop production and their rationalised use needs no emphasis.

The generalised state level fertilizer recommendations of crops are based on fertilizer trials conducted in research stations and in farmers' fields. Adoption of this fertilizer recommendation uniformly throughout a region does not ensure economy and efficiency in fertilizer use since variations in soil fertility are not taken into account. It leads to wastage of fertilizers in some cases and under usage in some others. Scientific and economic fertilizer use must take into account the soil fertility status as well as the crop needs. This has necessitated the formulation of fertilizer dose for crops based on soil tests.

Soil testing is to the art of crop production what thermometer is to the medical profession. It involves collection of soil samples, extraction and estimation of available nutrients, interpretation of soil test data and formulation of fertilizer recommendation. In order to interpret soil test values, peculiarities of both the soil and crop have to be taken into consideration. Different soils with given soil test values for nutrients differ in their capacity to supply nutrients to crops. Crops vary in their nutrient requirements and in their response to added nutrients in different soils. Soil test values should be closely correlated with nutrient uptake by crops and hopefully with the yield for making fertilizer recommendations.

Soil test crop response correlation studies based on fertility gradient approach provides a basis for soil test calibration for site specific and situation specific formulation of fertilizer dose. In this approach, soil fertility variations are created in the same field. Actual soil test values for soil available nutrients are then determined in the laboratories and correlated with crop responses to applied nutrients as observed in the field. Accordingly, fertilizer prescription equations can be derived for recommending fertilizer doses for maximum yield, economic yield and specific yield targets of crops. Such soil test based recommendations ensure balanced use of soil and fertilizer nutrients for sustained crop production. The fertilizer prescription equations have to be test verified in farmers' fields before they are recommended for large scale adoption.

There is an absolute need to make fertilizer recommendation based on soil properties or in taxonomical terms based on soil types due to heterogeneous nature of soils (Goswami, 1986). However, recommendation on fertilizer needs of crops cannot be developed for each piece of land because such exercises are not only laborious but also expensive. Instead, experiments can be conducted for a crop or cropping sequence on a benchmark soil which represents a larger area in a particular region and results of experiments can be extrapolated profitably to other areas of the same or similar soils.

Organic manures are indispensable from manurial schedules to restore and maintain soil fertility under tropical conditions. High soil temperatures in these areas lead to rapid decomposition of the organic matter which is a very necessary component for the soil to remain productive (Dalzell *et. al.*, 1987). Moreover, Indian soils are poor in organic matter and in major plant nutrients. The environmental hazards caused by prolonged or heavy rates of mineral fertilization can be easily mitigated by optimising the fertilizers with judicious application of organics. The complementary use of organics and inorganics helps not only in increasing nutrient use efficiency but also in sustaining high yields of crops. Hence soil test crop response studies are being conducted under integrated plant nutrition system.

Cassava (*Manihot esculenta* Crantz) is an important tuber crop grown in more than 80 countries of the humid tropics. It is a high-calorie staple food for nearly 500 million people in the world (George *et. al.*, 1996). It ranks sixth among major contributors of food in the world, the others being wheat, rice, maize, potato and barley in that order (Ghosh *et. al.*, 1988). Globally, 58% of cassava is used as food, 28% as food or feed ingredients and 4% in alcohol and starch industries (Nayar, 1994a).

Cassava is the secondary staple food of Kerala. It is cultivated in 1.14 lakh hectares in Kerala with a production of 23.44 lakh tonnes (FIB, 1997) which accounts for 60% of area and 54% of production of cassava in our country. At present, cassava occupies 10% of the total food crop area in Kerala. The scope for extending area under cassava is meagre but the demand for starchy tubers for domestic and industrial purpose is increasing. Proper fertilization is necessary in order to realize the full yield potential of cassava, eventhough it can be grown in soils of marginal fertility. This can be achieved by fertilizer recommendation based on soil test crop response studies carried out in each soil type.

Laterite is the most extensive soil group in Kerala covering about 65% of land area (KAU, 1989a). In general, laterite soils are poor in organic matter, nitrogen, phosphorus and potassium. They have low cation exchange capacity, high phosphorous fixing capacity and poor water holding capacity. They are generally acidic with pH ranging from 4.5 - 6.2. Cassava is mainly cultivated in laterite soils (Nayar, 1994b). So judicious application of organic manures along with fertilizers seems to be an essential requirement to exploit the yield potential of cassava by sustaining soil productivity.

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

1. To establish the relationship of soil available and applied nutrients with tuber yield of cassava through a response surface model.
2. To provide a basis for fertilizer recommendation for maximum and economic tuber yield at varying soil test values.
3. To derive a basis for making soil test based balanced fertilizer recommendation for specific yield targets.
4. To evaluate the conjoint use of organic manure and fertilizer in relation to soil test values.
5. To test the validity of the developed equations.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Fertilizers applied on the basis of soil tests takes into consideration the fertility status of the soil and ensures balanced fertilizer use. There is a need for balancing the nutrients between components of fertilizer amongst themselves and also those applied with those already available from the soil in order that efficiency and economy in fertilizer use can be achieved.

Soil testing is the key weapon in the armoury of a soil scientist and an agronomist for advisory work on judicious fertilizer use in crop production ... Unless it leads to a correct appraisal of the fertility status of the soil and prediction of fertilizer required for obtaining a targeted yield or maximum returns, it is only a gimmick (Kanwar, 1971).

Many successful attempts have been made by scientists for proper soil test calibration in order to make soil test as a predictive tool for fertilizer recommendation. Literature on various approaches for soil test based fertilizer recommendation for crops and nutritional requirement of the test crop, cassava var. M-4 based on agronomic experiments are reviewed in this chapter.

2.1. Soil test based fertilizer recommendation

The economic and judicious use of fertilizers based on soil tests was reported by many scientists (Ramamoorthy *et. al.*, 1969; Kanwar, 1971; Ramamoorthy and Velayutham, 1972, 1974 and 1976; Goswami and Singh, 1979; Mostra and Singh, 1981; Beringer, 1985; Velayutham *et. al.*, 1985; Goswami, 1986 and Sharma *et. al.*, 1990).

Several approaches have been put forth by scientists for soil test based fertilizer recommendation. These approaches aim at utilising both soil and fertilizer nutrients judiciously and efficiently in a manner best suited to different soil - crop - climatic conditions in the block/ state/ country. Important approaches are reviewed hereunder.

2.1.1. Fertilizer recommendation based on soil fertility classes

Parker *et. al.*, (1951) put forth the nutrient index approach which was based on soil test values (STVs) of different nutrients where the soil samples were classified into low, medium and high categories.

This is very useful for formulating area wise fertilizer recommendation or comparing fertility levels of different areas.Soil fertility maps of any compact area can be prepared by plotting nutrient indices on an outline map of the area.

Making use of the services of soil testing laboratories of IARI and the results of ad-hoc research projects, standard soil testing procedures were identified and STVs were experimentally grouped into categories like low, medium and high (Muhr *et. al.*, 1965 and Perur *et. al.*, 1973). The general agronomic fertilizer recommendations were equated to the medium level of soil fertility and the fertilizers were adjusted empirically by increasing or reducing these levels by 30 - 50% for conditions of low and high soil fertility respectively. Some scientists have also classified these ratings into categories as very low, low, medium, high and very high. This system of fertilizer recommendation is generally used by soil testing laboratories in India for the practical reason that such grouping reduces the complexity of making recommendation.

Numerous follow-up trials in cultivators` fields called the ABC trials conducted all over the country proved that fertilizer recommendations based on soil tests were on the average found to be 11% superior in net profit to those based on agronomic trials (Ramamoorthy and Velayutham, 1972).

Nambiar *et. al.*, (1977) proposed ten class system instead of three or five soil fertility categories, which provides greater accuracy in fertilizer adjustments to soil test data. The soil testing laboratories in Kerala have adopted this system to give fertilizer recommendation for crops based on soil testing.

Over the generalised recommendation, this system is an improvement since the fertilizer adjustments are made not entirely on qualitative basis but on a semi-quantitative basis. The fertilizer dose is formulated as a percentage of the generalised recommendation based on soil fertility class and not based on actual STVs. The difference between soil types and the limits for different crops were not taken into account in these calibrations (Reddy *et. al.*, 1985). Thus the quantity of fertilizers recommended on the basis of soil testing is somewhat arbitrary (Biswas and Mukherjee, 1990).

2.1.2. Fertilizer recommendation based on critical level

Cate and Nelson (1965) described the simplified method for studying the relationship between STVs and percentage yield of the maximum. The aim was to find out the critical soil test level below which the probability of getting of an economic response to added fertilizer is high and above which the probability of such response is very low. The critical limits of available nutrients are established by adopting the graphical procedure (Cate and Nelson, 1965) or statistical procedure (Cate and Nelson, 1971).

The soil testing laboratories in Andhra Pradesh recommend phosphatic fertilizer based on soil critical limit method (Krishnamoorthy *et. al.*, 1963). Goswami *et. al.*, (1971) reported that average yield response was high in soils below critical level of soil available phosphorus (P) than those above it, particularly in red, mixed red and black soils for rice and wheat.

Tandon (1987) has summarised critical limits of available P for various crops as reported by different workers in various soil and agroclimatic situations. But Cox (1992) from the nine years study on 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 limit rather than a true single value which limits its use for soil test based fertilizer recommendation.

The obvious advantage of knowing the critical level is that fertilizer addition is not warranted for soils which test above the critical limit. The drawback of this approach is that it does not provide how much to adjust the fertilizer dose for varying STVs below the critical level i.e., quantification for each individual situation is not possible. Only the probability of yield response can be predicted but not the actual yield. Therefore, this concept is more suitable for micronutrients and not for macronutrient fertlizer recommendation (Singh and Sharma, 1994).

2.1.3. Fertilizer recommendation for a certain percentage of maximum yield

The basis for fertilizer recommendation for a certain percentage of maximum yield is Mitscherlich - Bray approach. In this approach, an empirical relationship is developed between percentage yield and soil and fertilizer nutrients on the basis of which fertilizer doses can be recommended for various percentages of maximum yield for a given STV. It is normally adopted for calibrating soil tests for immobile nutrients.

The modified Mitscherlich - Bray equation (Tisdale *et. al.*, 1990) for calibration of fertilizer dose is

$$\textbf{Log (A-Y) = log A - C}_1\textbf{b - Cx} \qquad \text{...........(2.1)}$$

where A is maximum yield (100% yield) with all nutrients at adequate levels, Y is percentage yield with all nutrients except that being studied, b is the STV, C_1 is proportionality factor for soil form of nutrient, C is proportionality factor for added form of nutrient and x is fertilizer dose. This has the added advantage since it takes care of the efficiency of soil as well as added nutrients.

The maximum yield A in the modified Mitscherlich - Bray equation is calculated by extrapolation method as given by Ranganathan *et. al.*, (1969) or sometimes it may be taken as the highest yield obtained in a particular region.

Contrary to the mobile concept of Bray, the same equation can be employed for studying the nitrogen (N) response (Ranganathan *et. al.*, 1969; Mosi *et. al.*, 1973 and Balasundaram, 1978).

Mosi *et. al.*, (1979), Shete and Sonar (1993) and Santhi (1995) have used this approach for calculation of fertilizer requirements of different crops based on STVs.

Presently, this approach is being adopted by the Department of Agriculture, Tamil Nadu for giving site and situation specific fertilizer recommendation for major crops. They have made a policy decision and recommend fertilizer N, P_2O_5 and K_2O for 87.5, 94 and 94 per cent yield sufficiencies as well as for 94, 98 and 98 per cent yield sufficiencies (Santhi 1995).

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

2.1.4. Fertilizer recommendation for maximum yield / profit

2.1.4.1. Deductive approach

The deductive approach developed by Colwell (1968) involves the conduct of multi-location trials scattered over a large area and the pooled data are utilised to establish soil test crop response (STCR) correlation. Many workers have adopted Colwell's approach for soil test calibrations and optimisation of fertilizer nutrients for different crops (Velayutham *et. al.*, 1978 and Mosi *et. al.*, 1987).

Based on Colwell's approach, multi-location STCR experiments were conducted in farmers' fields under the All India Co-ordinated Research Project (AICRP) for Investigations on STCR Correlation. The data from these experiments have not met with much success in deriving soil test based fertilizer calibration in India (Velayutham *et. al.*, 1985). The data from multi-location trials showed insignificant correlation in most cases, which might be due to heterogeneity in the soil population studied, climatic conditions and management practices vitiating the real relationship (Reddy *et.' al.*, 1985).

2.1.4.2. Inductive approach

The inductive approach was developed by Ramamoorthy (1968). In this approach, all the needed variation in soil fertility level is obtained not by selecting soils at different locations as in the earlier studies but by deliberately creating it in one and the same field which is used for STCR studies. This helps to minimise the variations caused due to climate, management, etc. Thus a new technique of STCR correlation studies based on fertility gradient approach has been developed in the

AICRP for Investigations on STCR Correlation (Ramamoorthy and Velayutham, 1971).

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

Ramamoorthy (1974) established a significant relationship between STVs, fertilizer dose and crop yield by fitting a multiple regression using a quadratic response function. From the statistically significant multiple regression equation, simple relationship between STVs and fertilizer dose is derived for maximum yield and maximum profit per hectare of different crops.

According to Reddy *et. al.*, (1985) multiple regression analysis offers the greatest promise in accurately evaluating the effects of soil and fertilizer nutrients on both the plant uptake of nutrients and yield. It enables the study of number of factors simultaneously in contrast to Mitscherlich - Bray approach where one nutrient is studied at a time (Ahmed, 1985).

Sankar (1992) has pointed out that the multiple regression models are more efficient and useful for studying fertilizer response under varying levels of soil fertility for different crops in different soils.

In the earlier STCR correlation studies, only inorganic treatments were included . Later organic / biofertilizer treatments were also included and STCR studies were conducted under integrated plant nutrition system (Raniperumal *et. al.*, 1984; Murugappan, 1985; Sumam, 1988; Mercykutty, 1989; Swadija *et. al.*, 1993; TNAU, 1994; Santhi, 1995 and KAU, 1996).

Highly significant relations between crop yields, STVs and fertilizer doses indicated by the coefficients of determination as high as 0.8 or more have been obtained for different varieties of crops like rice, maize, wheat, sorghum, bajra, ragi, soybean, groundnut, sugarcane, cotton etc., in different soil types (Singh and Sharma, 1978; Randhawa and Velayutham, 1982; Raniperumal *et. al.*, 1982 and 1984;

Velayutham *et. al* , 1985 ; Boopathi, 1988, Sumam, 1988 ; Mercykutty, 1989 and Santhi, 1995).

In Tamil Nadu, fertilizer adjustment equations for varying STVs for maximum yield and maximum 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 Mercykutty, 1989) and groundnut (Raniperumal *et. al.*, 1982 and TNAU, 1994) in different soil types. On the contrary, optimisation of fertilizer dose was not possible for the cotton var. MCU- 5 in red calcareous soil of Bhavanisagar and tapioca var. H-.226 in red calcareous soil of Salem (TNAU, 1994). Similar result was also reported by Sankar *et. al.*, (1991) for banana grown in vertisol of Maharashtra.

Singh and Sharma (1978) have reported that optimisation was possible for only fertilizer N for arhar var. Pusa Ageti. They have reported the optimum dose of only fertilizer K for maximum and economic yield of wheat var. HD 1982, maize var. Ganga 5 and cotton var. PS 9.

Sankar *et. al.*, (1987) have calibrated regression models for kharif and rabi rice data for prediction of yield and optimisation of fertilizer N, P and K nutrients at varying STVs. Optimisation of P alone was found to be possible using the model of rabi season and optimisation of both N and P was possible in the kharif season using the kharif model.

The soil test based fertilizer adjustment equations were calibrated only for N and P nutrients for economic yield production of rabi sorghum in the black soils of Maharashtra (Sankar *et. al.*, 1988). Fertilizer N could only be optimised for maximum yield and profit per hectare of rice var. ASD. 16 in Manakkarai soil series (TNAU, 1994). Optimisation was possible for fertilizer N and P for maximum and economic yield of rice var. IR20 in Manakkarai soil series (TNAU, 1994) and var. ASD 18 and ADT 36 in Irugur sòil series (Santhi, 1995) and not for fertilizer K.

2.1.5. Fertilizer prescription for targeted yield of crops

Ramamoorthy *et. al.*, (1967) showed that **Liebig's law of minimum** operates equally well for N, P and K for wheat (Sonora-64) contrary to the general belief that it is applicable only to mobile nutrients like N. A significant linear relationship has been reported between grain yield and total uptake of nutrients. They have worked out a theoretical background for fertilizer application for various yield targets of wheat var. Sonora 64. Accordingly, they put forth the targeted yield approach, originally advocated by Troug (1960) by which fertilization can be done for different yield targets through balanced fertilization.

The fertilizer dose based on the targeted yield approach is worked out considering the amount of nutrients removed per unit quantity of economic produce, initial fertility status of the soil, efficiency of nutrients present in the soil and added through fertilizers and possibly nutrient interactions as well (Ramamoorthy, 1973). Thus, it is based on the principle of balanced nutrition. It is in this context, that in the STCR investigations not only yields are targeted but in the process judicious use of fertilizer is also practised (Singh and Sharma, 1978).

The concept of targeted yield approach resolves the much debated approaches viz., fertilizing the soil and fertilizing the crop and provides the real balance between the applied nutrients among themselves and with the available nutrients in the soil. Thus a new dimension to the value and utility of soil testing has been brought up by this concept (Velayutham, 1979).

Extensive studies have been conducted at TNAU, Coimbatore based on the targeted yield approach and have derived useful fertilizer prescription equations for achieving desired yield targets of 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.*, 1995). The test verification trials conducted in farmers' fields have established the validity of the developed equations.

The targeted yield equations have been reported by Dhillon *et. al.*, (1978) and Dev *et. al.*, (1985) for wheat in Ludhiana and Gurdaspur, Singh and Sharma (1978) for different crops in Delhi; Dev *et. al.*, (1978) for rice in tropical acid brown soils; Kadam *et. al.*, (1985) for groundnut in Ottur soil series in Rahuri, Chand *et. al.*, (1986) for greengram in Punjab and Sankar *et. al.*, (1991) for banana in vertisol in Maharashtra.

In Maharashtra, the targeted yield approach is exclusively used by the State Department of Agriculture for giving fertilizer recommendation for field crops (Velayutham and Reddy, 1990).

Reddy *et. al.*, (1991) have developed fertilizer prescription equations for obtaining desired yield targets of different varieties of groundnut at varying soil fertility levels in red soil at Bhavanisagar and Hyderabad, black soil at Rahuri and alluvial soil at Dholi. It was found that the fertilizer requirements varied with the soil type, crop variety and the climate.

In Kerala, Swadija *et. al.*, (1993) have worked out fertilizer prescription equations for desired yield targets of rice var. Bharathi in Marukil soil series. The equations were successfully test verified in farmers' fields. Fertilizer prescription equations have also been derived for specific yield targets of rice in lowland acid laterite soils of Kerala (KAU, 1996).

The results from large number of follow - up experiments conducted in different soil - agro - climatic regions of the country under the AICRP for Investigations on STCR Correlation reveal that yield targets can be achieved within ±10% deviation, if the targets chosen are not unduly high (Ramamoorthy *et. al.*, 1970 ; Chand *et. al.*, 1984 and Raniperumal *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; and Velayutham, 1979; Raniperumal *et. al.*, 1982; Velayutham *et. al.*, 1985 and TNAU, 1994 in different crops).

Several scientists have indicated the superiority of fertilizer dose based on targeted yield approach over the general or blanket fertilizer recommendation. Ramamoorthy and Pathak (1969) have proved that fertilizer application based on targeted yield approach would be the most economical. Ramamoorthy *et. al.*, (1971) opined that area wise fertilizer recommendations can be formulated based on yield targets and nutrient index of the soil. Tandon (1976) observed that fertilizing for targeted yields of wheat increased the net returns by 23% and also value cost ratio (VCR) by 18% above generalised recommendation. Doharey *et. al.*, (1977) obtained targeted yields of wheat and higher net returns by adopting prescription - based fertilizer dose. The blanket recommendation has led to an indiscriminate use of fertilizers.

The results of 25 farmers' field trials in Punjab revealed that additional benefit over generalised state fertilizer dose was obtained for targets of 70, 80 and 90 qha^{-1} of rice yield where balanced fertilization of crop on the basis of soil tests was followed (Chand *et. al.*, 1984); optimisation of P application in soils testing higher than 24 kg ha^{-1} (Olsen P) and of K with values more than 160 kg ha^{-1} (NH_4OAC - K) gave satisfactory yield performance upto 80 q ha^{-1}.

Based on large number of field experiments, Velayutham *et. al.*, (1985) reported higher response (kg grain per kg nutrient) for fertilizer dose based on targeted yield equations in comparison to general recommended dose for different crops. Similar result was also reported by Dev *et. al.*, (1985) in wheat in Punjab.

Higher monetary returns were obtained under targeted yields of groundnut in Ottur soil series at Rahuri, as compared to yields obtained under recommended fertilizer dose for the crop (Kadam *et. al.*, 1985). The fertilizer dose for targeted yields of groundnut recorded the highest VCR in test verification trials (Raniperumal *et. al.*, 1986). Eventhough the yield increased with target, the VCR showed a reverse trend. Corroborative results have been reported by Raniperumal *et. al.*, (1987) in rice, Verma *et. al.*, (1987) in rice and wheat and TNAU (1994) in sorghum, sugarcane, groundnut, soybean and tapioca.

Targeted yield approach is also useful for appropriate fertilizer tailoring with organics or biofertilizers coupled with cost effectiveness. Raniperumal *et. al.*, (1984) worked out a basis for adjusting the dose of chemical fertilizers for different levels of organic manures through soil test calibration that are possible to do in the AICRP for Investigations on STCR Correlation.

Prescription equations involving the conjoint use of organics and inorganics have been developed by Murugappan (1985) in sugarcane with farmyard manure (FYM), Sumam (1988) in maize with FYM, Raniperumal *et. al.*, (1988) in ragi with FYM, Mercykutty (1989) in ragi with Azospirillum, Duraisamy *et. al.*, (1989) in ragi with FYM and Baskaran *et. al.*, (1994) in tapioca with composted coirpith. It has been possible to achieve targeted yield within ± 10% deviation in test verification trials . Higher benefit cost ratio (BCR) has also been reported in these trials for prescription based fertilizer dose. As the yield targeted increased, the BCR showed a declining trend.

The findings of Prasad and Prasad (1993) lend support to the fact that conjoint application of fertilizers and organic manures lead to efficient use of fertilizer and considerable saving in fertilizers. For an yield level of 40 q ha^{-1} of rice, in a soil testing 300, 30 and 150 kg ha^{-1} of available N, P and K, 96, 76 and 72 kg ha^{-1} of N, P_2O_5 and K_2O were applied as fertilizers. For the same fertility status, integrated use of 39, 38 and 53 kg ha^{-1} of N, P and K as fertilizers and 5 t ha^{-1} of FYM were found to produce the same level of yield . Thus Tandon (1994) has rightly pointed out that this approach also indicated the magnitude of contribution by the organic/ biological sources of plant nutrients complimenting fertilizers in meeting nutrient requirement of crops.

The fertilizer prescription equations developed for a particular variety of a crop for a particular soil type can be suitably extrapolated to other varieties of the same crop and to similar soils.

Raniperumal *et. al.*, (1986) have found that the fertilizer prescription equations developed for the groundnut var. POL - 2 in Irugur soil series holds good for the var. TMV - 7 and also for allied soil series (Somayannur and Palladam) or association.

The fertilizer prescription equations developed for the rice var. Bhavani on Noyal alluvium at Coimbatore fitted well for other varieties like IR 20, IR 50, Ponni, CO 43 and Paiyur - 1 in the same soil type with the yield upto 50 q ha^{-1} (Raniperumal *et. al.*, 1987). Similarly the adjustment equations developed for the ragi var. CO 11 were found suitable for the var. CO 12 also (Duraisamy *et. al.*, 1989).

Fertilizer application based on targeted yield approach provides for the maintenance of soil fertility (Velayutham and Raniperumal, 1976). In the test verification trials with rice in vertisols, the post harvest soil analysis revealed slight reduction in $KMnO_4$ - N status only, without much depletion in other nutrients (Raniperumal *et. al.*, 1984). With groundnut, the post harvest soil analysis of 10 locations indicated a slight increase in available N and P status while the K status followed a reverse trend, when fertilizers were applied based on targeted yield approach (Raniperumal *et. al.*, 1986). The results of

16 test verification trials with rice on Noyal alluvium indicated that the fertility status was not altered considerably by following the prescription concept of fertilizer application (Raniperumal *et. al.*, 1987).

Important approaches have been discussed on their scope and limitations to make soil test calibration on sound footing. The STCR correlation studies based on fertility gradient approach has provided a basis for quantitative fertilizer adjustments based on soil tests in spite of the diversities in soil, crop, climate and management practices. Thus, the review of literature has indicated the need for research on soil test - crop response correlation for improving the soil testing service programme for maximisation of yield and profit, optimization of fertilizer use and maintenance / build up of soil fertility for sustainable soil and crop productivity. No such work has hitherto been done in Kerala in upland crops and hence the present study.

2.3. Nutritional requirement of cassava

Cassava being the secondary staple food in Kerala, attempts have been made to formulate optimum nutrient management practices for maximising its productivity. The nutrient requirement of cassava varies with the cultivar, cropping system, management practices, etc.. So literature on the nutritional requirement of pure crop of cassava mainly of var. M-4 is briefly presented here.

2.3.1. Nutrient removal by cassava

Cassava extracts substantial quantities of nutrients from the soil especially N and K. Compared to other major crops, cassava removes large quantities of nutrients from the soil particularly K (Thampan, 1979).

Howeler (1981) reported that on an average, cassava extracts about 2.3 kg N, 0.5 kg P and 4.1 kg K per ton of roots when only the roots are removed from the field. If the whole plant is removed for forage and planting material these quantities would increase to 4.91 kg N 1.08 kg P and 5.83 kg K per ton.

Experiments conducted at Central Tuber Crops Research Institute (CTCRI) revealed that most of the varieties under favourable conditions, remove 180 - 200 kg N, 15 - 22 kg P and 140 - 160 kg K to yield 30 t ha^{-1} of fresh tubers (CTCRI, 1983).

STCR studies conducted in cassava in Tamil Nadu indicated that the var. H-226 required 4.16, 0.62 and 4.64 kg ha^{-1} of N, P and K respectively to produce one ton of fresh tuber (Baskaran *et. al.*, 1994).

The effect of fertilization on the uptake of nutrients has been studied by many workers. Increased rates of N application resulted in increased uptake of N and K as observed by Nair (1982).

Vijayan and Aiyer (1969) observed increase in the uptake of P by cassava with higher levels of P application upto 66 kg ha^{-1}. However, studies conducted at CTCRI revealed that the effect of higher levels of P on P content and P uptake was not significant (CTCRI, 1982).

With increasing rates of N and P application increased K uptake was observed in acid laterite soils of Kerala (Rajendran *et. al.*, 1976).

Pushpadas and Aiyer (1976) reported that application of K increased the K content of tissues of cassava petioles but decreased the N and P contents.

2.3.2. Nutrient inter-relationships

Harper (1973) on reviewing literature observed that cassava demands a considerable amount of potash which is made use of in the synthesis and translocation of starch. According to him, N is also required, although too high a rate of N may stimulate leaf and stem development at the expense of root growth. The ratio of N and K is thus considered critical in cassava nutrition.

Studies conducted by Rajendran *et. al.*, (1976) revealed that $N:K_2O$ ratio of 1:1 (at 100 kg ha^{-1} of each) was optimum for all the varieties tried for maximum tuber yield in acid laterite soils of Kerala.

Nair (1982) found that optimum $N: K_2O$ ratio was 1:1.25 for red loam soils of Vellayani and 1: 2 for sandy loam soils of Kayamkulam. Nair and Aiyer (1985) also found that $N: K_2O$ ratio of 1:1.28 was optimum for cassava grown in red loam soils.

Vijayan and Aiyer (1969) and Prema *et. al.*, (1975) stressed the importance of $N: P_2O_5$ ratio of 3:2 in the fertilization programme of cassava for higher yield and better quality.

A faulty P:K ratio is known to reduce the N uptake by plants (Thampan, 1979).

2.3.3. Response of cassava to organic manures

Cassava responds to both bulky and concentrated organic manures. A study conducted in India by Saraswat and Chettiar (1976) revealed that FYM application can substantially meet the N requirements of cassava. The highest yield of 33.4 t ha^{-1} was obtained when 66.6% of N was applied as calcium ammonium nitrate and the balance as FYM at 150 kg N ha^{-1}. The next higher yield of 31.9 t ha^{-1} was obtained when 66.6% of N was applied as FYM and the balance as calcium ammonium nitrate at the same rate of N application.

About 10-15 t ha^{-1} of any bulky organic manure supplimented with the required quantity of inorganic fertilizers is the best manurial combination for cassava (Thampan, 1979). The concentrated organic manures, being rich in plant nutrients can even replace the inorganic fertilizers on an equivalent nutrient basis.

Studies conducted at CTCRI revealed that the basal application of FYM at 12.5 t ha^{-1} was beneficial in enhancing the yield and quality of tubers and maintaining the soil fertility status (Mohankumar *et. al.*, 1976 and Pillai *et. al.*, 1987).

In a multi-locational trial on cassava var. M-4, application of FYM increased tuber yield by 2 t ha^{-1} irrespective of the levels of fertilizers applied (KAU, 1989b).

2.3.4. Response of cassava to fertilizers

A scan of literature on the effect of N, P and K fertilizers on cassava reveals differential response of the crop to different rates of N, P and K application.

A combination of 150 kg N and 100 kg P_2O_5 ha^{-1} was reported to be optimum for M-4 and H-105 varieties of cassava by Vijayan and Aiyer (1969).

Cock (1975) found that cassava has an optimum leaf area index (LAI) of 2.5 - 3.5 and higher rates of fertilization might lead to excessive top growth and LAI of more than four. Higher levels of fertility increased leaf size and rate of leaf formation, but had no effect on leaf longevity.

Pushpadas and Aiyer (1976) found that the best nutrient combination for the varieties M-4 and H-105 was 250 kg K_2O and 600 kg of CaO in conjunction with 150 kg N and 100 kg P_2O_5 ha^{-1}.

Application of 100 kg N, 50 kg P_2O_5 and 150 kg K_2O in conjunction with 600 kg of CaO ha^{-1} seemed to be the most promising by Pillai and George (1978) for realising the maximum tuber yield of M-4 variety.

Cassava growth under low fertility restricted its leaf area, but maintained leaf photosynthetic efficiency (CIAT, 1979). Further the distribution index was higher, indicating that most of the carbohydrates produced were transported to the roots (CIAT, 1980).

Cassava is very sensitive to over fertilization, making it excessively leafy particularly at higher plant populations (Howeler, 1980)

In soils having moderate to high available N and K, the cassava crop (varieties M-4 and H - 2304) may not require more than

50 kg ha^{-1} of N and K_2O for obtaining tuber yields around 15 to 17 t ha^{-1} (Ashokan and Nair, 1982).

Under rainfed condition in acid laterite soils of Kerala maximum tuber yield was recorded at 100 kg K_2O ha^{-1} with the varieties M-4 and H-2304 (Nair, 1983).

Preliminary reports of a manurial experiment to fix the fertilizer dose for cassava indicated that among the levels of N tried (25, 50, 75 and 100 kg ha^{-1}) the highest tuber yield was obtained at 75 kg N ha^{-1} (KAU, 1984).

Nair and Aiyer (1985) observed that cassava responded to K application upto 128 kg K_2O ha^{-1} in a microplot experiment in red loam soil.

In an adaptive trial on the nutritional requirement of cassava in the red and sandy loam soils, the highest yield of tubers was obtained when an NPK dose of 50-50-100 kg ha^{-1} was given (KAU, 1987).

Ashokan *et. al.*, (1988) found 60 kg N and 60 kg K_2O ha^{-1} as the optimum doses of N and K for local varieties.

2.3.5. Combined effects of manures and fertilizers

In acid laterite soils, 100 kg K_2O ha^{-1} in conjunction with 12.5 t FYM ha^{-1} containing 40 kg potash appeared to be sufficient for the cassava var. M-4 to sustain tuber yield of 18.5 t ha^{-1} (Rajendran *et. al.*, 1976).

For continuous cultivation of cassava in laterite soil, combined application of FYM and NPK has been found to be highly beneficial in increasing the yield and quality of tubers (Pillai et. al 1987).

Application of N, P_2O_5 and K_2O at 100, 50 and 100 kg ha^{-1} respectively along with 12.5 t ha^{-1} of FYM recorded the highest yield of 13.4 t ha^{-1} of cassava var. M-4 in a multi-locational trial (KAU, 1989).

Nair *et. al.*, (1988) obtained 45 kg P_2O_5 ha^{-1} as the economic optimum dose of P in acid laterite soil in conjunction with 12.5 t ha^{-1} of FYM containing about 0.08% P.

In the laterite soil, combined application of 12.5 t ha^{-1} of cowdung and soil test based fertilizer recommendation of 35 kg N, 58 kg P_2O_5 and 47 kg K_2O ha^{-1} (T_2) gave higher tuber yields of 11.36 t ha^{-1}

(KAU, 1992). The Package of Practices recommendation of 50 kg each of N, P_2O_5 and K_2O ha^{-1} along with 12.5 t ha^{-1} of cowdung (T_1) produced only 10.05 t ha^{-1} of tuber yield. An increase of 11.52 % in tuber yield was obtained when fertilizers were applied on the basis of soil tests. The soil test based fertilizer recommendation recorded higher net profit of Rs. 2093 ha^{-1} as compared to T_1 (Rs 741 ha^{-1}).

The fertilizer recommendation by KAU (1993) for cassava var. M-4 and other local varieties is 50:50:50 kg N, P_2O_5 and K_2O ha^{-1} along with 12.5 t of FYM ha^{-1}.

2.3.6. Effect of fertilization on soil fertility status

Research on this aspect indicates the need for proper fertilization of cassava to maintain the soil fertility status.

Rajendran *et. al.*, (1971) observed that N application at and above 100 kg ha^{-1} resulted in an increase in soil available N ranging from 16 to 75 kg ha^{-1} . A slight increase in the available N status of acid laterite soil due to N application has also been reported by Mohankumar and Maini (1977).

In acid laterite soils, potash application at and above 100 kg ha^{-1} maintained the soil available K at a more or less steady level, when a good crop of cassava was grown with an average yield of 25 - 30 t ha^{-1} of tubers (Rajendran *et. al.*, 1976). At lower levels of K fertilization, the depletion of soil available K in the soil after the crop increased, suggesting the possibility of a small residual effect due to higher rates of K application.

The results of a long term fertilizer experiment in Malaysia revealed that the soil fertility would deplete under successive cropping with cassava if the rate of fertilizer application was just enough to maintain the yield (Chan, 1980). The total soil N reduced due to cropping with cassava at all levels of N application (0 to 112 kg ha^{-1}) and was apparently not affected by N application. But available P status of the soil increased with increased levels of P application to the crop. However, the exchangeable K and water soluble K in the soil were not affected by the levels of K applied (0 to 156 kg ha^{-1}) to cassava.

Nair (1982) reported significant increase in available N and K status of the soil under cassava, due to increased levels of fertilizer application, both in sandy and red loam soils.

Studies conducted at CTCRI revealed that continuous application of P at 44 kg ha $^{-1}$ resulted in build up of available P status of the soil to the extent of 100 kg P ha^{-1} (CTCRI, 1983).

Soil analysis data after five years of continuous cultivation of cassava revealed an increase in organic carbon content and available N, P and K status due to combined application of FYM and fertilizers (Pillai *et. al.*, 1987). It was also observed that continuous application of 100 kg P_2O_5 ha^{-1} was a high dose for cassava since the build up of P was very high especially with FYM.

The effect of continuous application of manures (FYM and wood ash) and fertilizers for cassava on the chemical properties of acid laterite soil was examined after 12 years by Kabeerathumma *et. al.*, (1991). They observed that the soil reaction was not very much affected except in the case of ash wherein an appreciable increase in soil pH was noticed (4.7 to 6.1). Inclusion of FYM in the treatment increased the level of organic carbon and available N and P in the soil, maximum being recorded in all of them for NPK + FYM treatment. But no appreciable increase in K could be observed in NPK + FYM treatment. Continuous application of NPK fertilizers raised the available status of the respective nutrients and the build up of P was found to be very high as compared to other nutrients.

Howeler (1996) has pointed out the need to apply annually about 80 - 120 kg K_2O ha^{-1} for cassava when grown continuously on the same soil in order to maintain soil fertility and sustain high yields.

Review of literature has indicated the necessity for balanced fertilization for cassava to sustain crop and soil productivity. Apart from the availability of nutrients in adequate quantities, it is also necessary to have a proper balance between the nutrients present in the soil and in the plant (Nayar, 1994b). An attempt is being made to establish soil test crop response correlation in cassava in order to prescribe soil test based fertilizer dose for cassava. In generating such data, differences between major soil groups and differences within a soil group in other modifying soil properties must be taken into account (Velayutham *et. al.*, 1980). Although many high yielding varieties of cassava have been released, even today the var. M-4 remains as the most popularly cultivated one for edible purpose. So the present study is undertaken in cassava var. M-4 in laterite soils of Kerala.

MATERIALS AND METHODS

MATERIALS AND METHODS

With the primary objective of investigating the soil test crop response relationship of cassava in laterite soils of Kerala for efficient fertilizer use, an investigation was undertaken at the College of Agriculture, Vellayani. The technique of inductive methodology developed by Ramamoorthy (1968) as followed in AICRP for Investigations on STCR Correlation (Reddy *et. al.*, 1985) was adopted for this investigation. The field experiments consisted of fertility gradient experiment (FGE), STCR experiment using fertilizers and organic manure and technology verification trial. The details of experimental site, season and weather conditions, field experiments conducted, methods of soil and plant analysis and statistical methods adopted are presented in this chapter.

3.1. Experimental site

3.1.1 Location

The FGE and the STCR experiment were conducted in the Instructional Farm attached to the College of Agriculture, Vellayani.

The technology verification trial was conducted in the laterite soil in three farmers' fields in Thiruvananthapuram district and Instructional Farm, Vellayani.

The Instructional Farm, Vellayani is located at 8^0 30' N latitude and 76° 54' E longitude at an altitude of 29 m above mean sea level.

The experimental area was under a bulk crop of sorghum for the previous season.

3.1.2. Soil

The soil of the experimental site was laterite which comes under the order Oxisol. The soil belongs to the family of loamy skeletal Kaolinitic isohyperthermic Rhodic Haplustox.

The physical and chemical properties of the soil before starting the experiment are given in Table-1. The soil was sandy loam in texture with 30.2% water holding capacity. It was acidic with a pH of 5 having high P fixing (70.8%) and K fixing (34.5%) capacities. It was low in organic carbon and available N and K contents and medium in available

P content. It had a very low cation exchange capacity of 4.7 cmol (p^+) kg^{-1}.

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

Property	Unit	Value
Mechanical composition :		
Sand	%	76.50
Silt	%	18.00
Clay	%	5.00
Texture	-	Sandy loam
Water holding capacity	%	30.20
pH	-	5.00
Electrical conductivity	dS m^{-1}	<0.05
Cation exchange capacity	cmol (p^+) kg^{-1}	4.70
P fixing capacity	%	70.80
K fixing capacity	%	34.50
Organic carbon	%	0.39
Available N	kg ha^{-1}	231.00
Available P	kg ha^{-1}	17.65
Available K	kg ha^{-1}	35.00

3.2. Season

The FGE, the first of the series was conducted during April-May, 1994. The STCR experiment and the technology verification trial were conducted during the main cassava planting season of June to March in 1994-95 and 1996-97 respectively.

3.3. Weather conditions

Vellayani experiences a humid tropical climate. The weather parameters (month-wise) recorded during the cropping periods are presented in Appendix-I and II and also presented graphically in Fig.1 and Fig.2. In general, the weather conditions were favourable for satisfactory growth of crops during 1994-`95 and 1996-`97.

3.4. Fertility gradient experiment

The FGE was a preparatory experiment wherein the STCR experiment was conducted in the subsequent season. The experiment was conducted to create sufficient variations in soil fertility in one and the

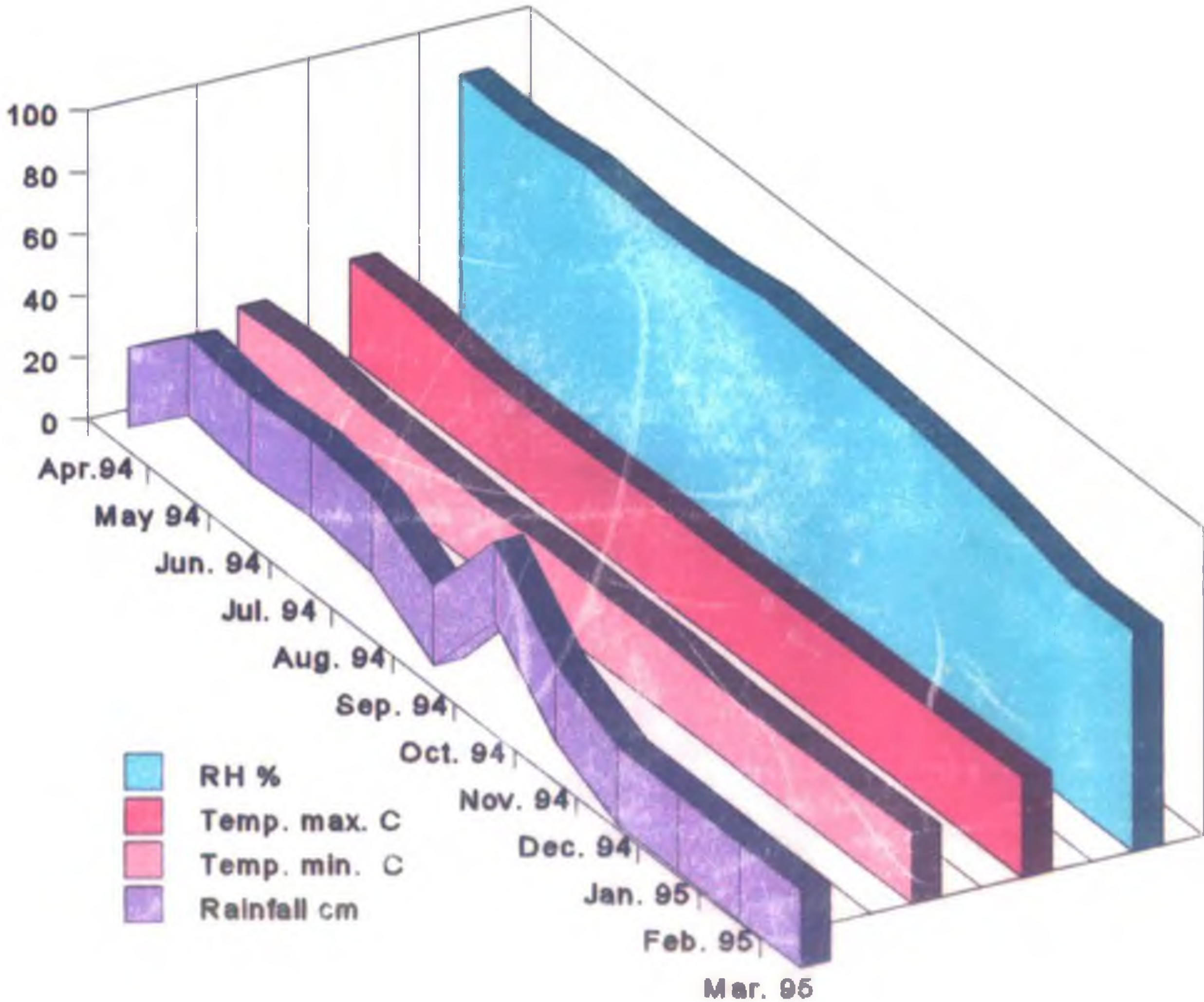

Fig. 1. Weather parameters from April '94 to March '95.

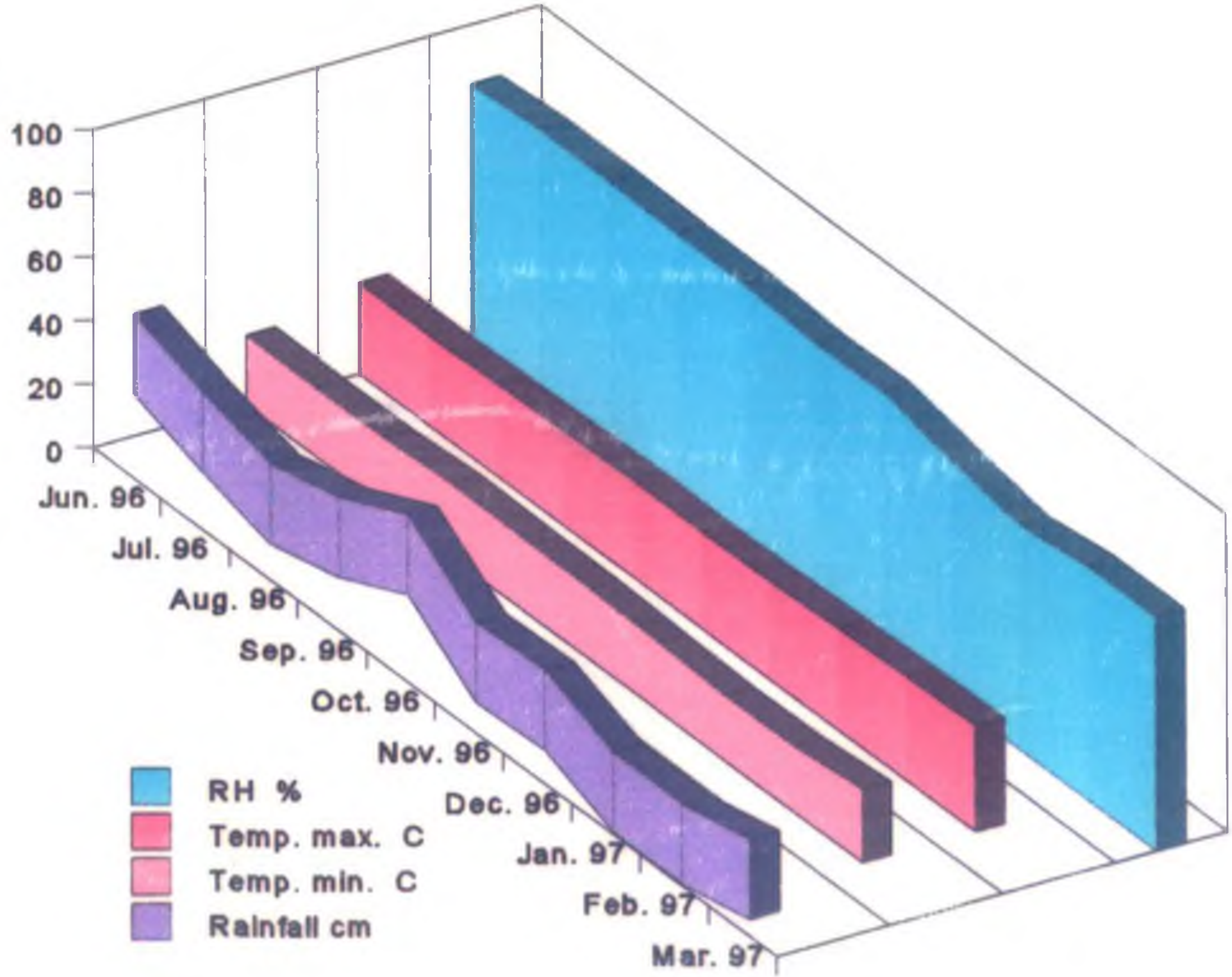

Fig. 2. Weather parameters from June '96 to March '97.

same field.

3.4.1. Lay out of the experiment

The experimental area was prepared and divided into four equal strips each having 120 x 5.5 m size and each strip into four blocks.

The lay out plan of the experiment is given in Fig. 3.

3.4.2 Treatments

Graded doses of N as Urea (46% N), P as Superphosphate (16% P_2O_5) and K as Muriate of potash (60% K_2O) applied in four strips (I to IV) formed the treatments for this experiment. The doses of N, P and K were fixed as outlined in the Instruction Manual for STCR studies (Reddy *et. al.*, 1985).

Strip-I	N_O P_O K_O	- No fertilizers
Strip-II	$N_{½}$ $P_{½}$ $K_{½}$	- Half the standard dose
Strip-III	N_1 P_1 K_1	- Standard dose
Strip-IV	N_2 P_2 K_2	- Double the standard dose

where N_1 = 150 kg N ha^{-1}.

P_1 = 20 ppm P ha^{-1} (since the P fixing capacity of the soil was too high).

K_1 = K enough to give 150 kg ha^{-1} of exchangeable K (assessed from K fixation curve of the soil).

The actual quantities of N, P and K applied in strips are given in Table -2.

Table-2. Graded doses of N, P and K applied in strips for the fertility gradient experiment

Strip	Treatment	Fertilizer doses (kg ha^{-1})		
		N	P_2O_5	K_2O
I	$N_0 P_0 K_0$	0	0	0
II	$N_{½} P_{½} K_{½}$	75	50	90
III	$N_1 P_1 K_1$	150	100	180
IV	$N_2 P_2 K_2$	300	200	360

3.4.3. Gradient crop

A preparatory crop of fodder maize (*Zea mays* L.) cv. African Tall was raised following usual agronomic practices (KAU, 1993) except the treatments. The seeds were obtained from TNAU, Coimbatore. The seeds were dibbled at a spacing of 30 x 15 cm on

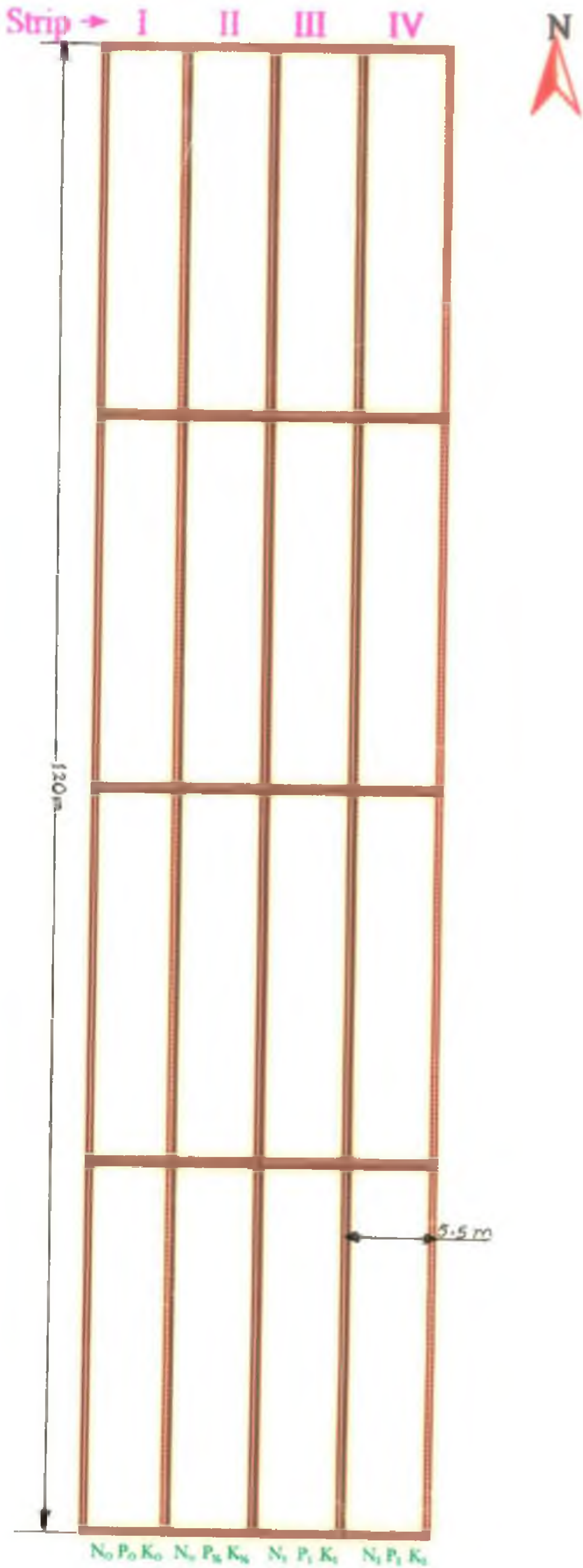

Fig. 3. Lay out of fertility gradient experiment.

7-4-1994 and the crop was harvested on 25-5-1994.

3.4.4. Observations recorded

3.4.4.1. Green fodder yield

At harvest, the green fodder yield of the gradient crop was recorded block wise leaving one border row all round in each block and expressed in t ha^{-1}.

3.4.4.2. Dry fodder yield

Ten sample plants at random were cut from each block prior to general harvest. After recording fresh weight, the plant samples were dried in an oven at $60 \pm 5^{0}C$ to constant dry weight. From these observations, dry fodder yield was computed block wise in t ha^{-1}.

3.4.5. Uptake of nutrients

Sixteen composite plant samples, one from each block, were analysed for N, P and K contents adopting the respective analytical methods given in Table-3. Uptake of N, P and K by the crop was

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 (1966)
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	Bray and Kurtz (1945)
Available K	Neutral normal ammonium acetate method	Hanway and Heidal (1952)
Plant analysis		
Total N	Modified micro - Kjeldahl method	Jackson (1973)
Total P	Vanado - molybdo - phosphoric yellow colour method	Jackson (1973)
Total K	Flame photometry	Piper (1966)

calculated by multiplying their contents in the plant by dry weight and expressed in kg ha^{-1}.

3.4.6. Soil analysis

Soil samples were collected from 0 - 30 cm depth from each block prior to fertilizer application and analysed for organic carbon and available N, P and K contents. The methods of soil analysis adopted are given in Table-3. A composite soil sample of the whole field was analysed for mechanical composition, water holding capacity, pH, soluble salts, cation exchange capacity, organic carbon and available N, P and K contents. It was also analysed for P and K fixing capacities based on which the doses of P and K were fixed for this experiment. Soil samples were also collected from each block after the harvest of the gradient crop and analysed for organic carbon and available N, P and K contents.

3.4.7. Statistical analysis

The data on fodder yield , nutrient uptake by the gradient crop and soil analysis after FGE 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 (CD) is provided wherever F-test was significant.

The statistical analysis was performed using IBM - PC AT/386 computer installed in the Department of Agricultural Statistics, College of Agriculture, Vellayani.

3.5. STCR experiment

This experiment was carried out to establish quantitative relationship between STVs, applied nutrients and the resultant crop yield. This experiment was superimposed in the four fertility gradients created as per the set design of the STCR experiment (Reddy *et. al.*, 1985).

3.5.1. Test crop

The test crop was cassava and the variety used was M-4 (Malayan-4) which is a very popular variety in the state due to its excellent cooking quality. It is an introduction from Malaysia and is a tall growing variety maturing in ten months. This variety yields on an average 12-14 t ha^{-1} of tubers and produces medium sized tubers with low HCN and about 29 % starch content on fresh weight basis. Virus free planting materials were obtained from Farming Systems Research

Station, Kottarakkara.

3.5.2. Treatments

Factorial combinations of four levels of N , three levels of P and five levels of K along with three levels of FYM formed the treatments. The treatment levels and doses of nutrients applied are given in Table- 4.

3.5.3. Design and lay out of the experiment

Each strip was divided into 24 plots of 4.5 x 4.5 m size since there were 20 treatment combinations and four controls in each strip. The FYM levels were superimposed in the four blocks already created.

Design	- Response surface design
Treatments	- 24
Number of strips	- 4
Number of blocks	- 4
Number of plots per strip or block	- 24
Plot size	- Gross- 4.5 x 4.5 m (36 plants)
	- Net - 3.0 x 3.0 m (16 plants)

Table-4. Details of treatment structure for the test crop, cassava

Treatment combination			
No.	N	P_2O_5	K_2O
T_1	0	0	0
T_2	0	0	0
T_3	0	0	0
T_4	0	0	0
T_5	0	0	1
T_6	1	0	1
T_7	1	1	1
T_8	0	0	2
T_9	0	1	2
T_{10}	1	0	2
T_{11}	1	1	2
T_{12}	2	0	2
T_{13}	2	1	2
T_{14}	2	2	2
T_{15}	0	0	3
T_{16}	1	1	3
T_{17}	2	2	3
T_{18}	3	0	3
T_{19}	3	1	3
T_{20}	3	2	3
T_{21}	2	1	4
T_{22}	2	2	4
T_{23}	3	1	4
T_{24}	3	2	4

Nutrient levels	Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})
	N	P_2O_5	K_2O	
0	0	0	0	0
1	50	50	50	6.25
2	100	100	100	12.50
3	150	-	150	-
4	-	-	200	-

Spacing - 75 x 75 cm

System of planting - Mound system

The lay out of the experiment is presented in Fig. 4.

3.5.4. Manures and fertilizers

The nutrient contents of FYM and the fertilizers used are presented in Table-5.

The FYM as per treatments was applied at the time of land preparation. Full dose of P and one third of N and K were applied as basal dressing. The remaining doses of N and K were applied in two equal splits at second and third months after planting along with weeding and earthing up.

Table-5. Nutrient contents of organic manure and fertilizers used

Fertilizers / organic manure	Nutrient content
Urea	46 % N
Super phosphate	16 % P_2O_5
Mussorie rock phosphate	20 % P_2O_5
Muriate of potash	60 % K_2O
Farmyard manure	0.48 % N, 0.32 % P_2O_5 0.38 % K_2O

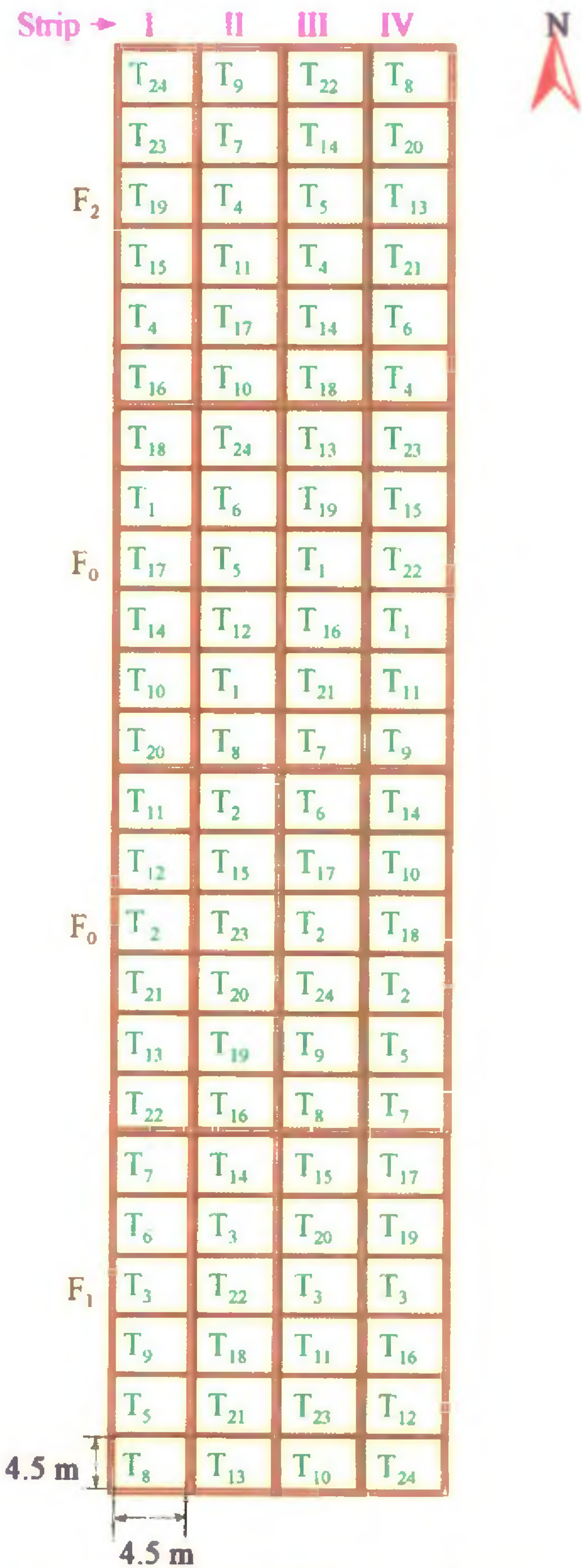

Fig. 4. Lay out of STCR experiment.

3.5.5. Observations recorded

3.5.5.1. Tuber yield

After carefully pulling out the plants from the net plot, the tubers were separated, cleaned and fresh weight recorded and expressed in t ha^{-1}.

3.5.5.2. Top yield

The fresh weight of stem and leaves of the plants from the net plot were recorded and expressed in t ha^{-1}.

3.5.5.3. Utilisation index

Utilisation index (UI) is the ratio of root weight to top (stem and leaves) weight. It is an important yield determinant of cassava (Obigbesan, 1973). This was worked out from the already recorded observations, on fresh weight basis.

3.5.6. Uptake of nutrients

Three plants standing diagonally in the same direction were selected at random from each net plot as sample plants. The sample plants were uprooted prior to general harvest and separated out into stem, leaf blade, petiole, tuber flesh and rind . Fresh weights of each part were recorded and sub-samples were taken for estimating the dry weight. The sub-samples were dried in an oven at 60 ± 5°C to constant dry weight. Then the dry weight of each plant part was computed in t ha^{-1}.

Stem, leaf blade, petiole, tuber flesh and rind 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 by the plant at harvest was calculated from the nutrient contents and dry weights of plant parts and expressed as kg ha^{-1}.

3.5.7. Soil analysis

Plot wise soil samples were collected from 0 - 30 cm depth 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.

3.5.8. Statistical analysis

3.5.8.1. Correlation

Simple linear correlation was used to determine the nature and degree of relationship between the various parameters (Snedecor and Cochran, 1968). The computed values of correlation coefficient (**r**) were tested for their significance using Student's **t**-test with n-2 degrees of freedom.

3.5.8.2. Multiple correlation and regression analysis

Simple correlation coefficient expresses the relationship between each independent variable with the dependent variable. But the dependent variable is not solely influenced by any one independent variable but by all of them through their direct, reciprocal and interaction relationships. Thus the need for multiple regression analysis arises.

The multiple correlation coefficient (**R**) represents the zero order correlation between the actual and predicted values of the dependent variable obtained from the independent variables under consideration. The square of multiple correlation coefficient (R^2)

represents the proportion of the total variation explained by the relevant independent variables included in the regression model.

The relationship between STVs, applied FYM and fertilizer doses and the resultant tuber yield of cassava was established through multiple regression using the quadratic model (Snedecor and Cochran, 1968) as given below:

$$Y = \pm A \pm b_1\, FYM \pm b_2\, FYM^2 \pm b_3\, SN \pm b_4\, SN^2 \pm b_5\, SP \pm b_6\, SP^2 \pm b_7\, SK \pm b_8\, SK^2 \pm b_9\, FN \pm b_{10}\, FN^2 \pm b_{11}\, FP \pm b_{12}\, FP^2 \pm b_{13}\, FK \pm b_{14}\, FK^2 \pm b_{15}\, SN\, FN \pm b_{16}\, SP\, FP \pm b_{17}\, SK\, FK \quad \text{..........(3.1)}$$

where Y = Tuber yield ($t\ ha^{-1}$)

A = Intercept ($t\ ha^{-1}$)

b_i = Regression coefficients ($t\ ha^{-1}$)

FYM = Dose of FYM applied ($t\ ha^{-1}$)

SN, SP, SK = Available soil N, soil P and soil K ($kg\ ha^{-1}$) respectively

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

The multiple regression analysis was employed to describe the nature of the functional relationship between tuber yield, the dependent variable and the set of independent variables, namely, the STVs and applied nutrients and to know the significant contributors towards changes in the dependent variable. The k+1 parameters of the regression equation were estimated by the Principle of Least Squares. The test of significance of the coefficient of determination / predictability R^2 was done by F-test with $f_1 = k$ and $f_2 = n-k-1$ degrees of freedom. The partial regression coefficient b_i in the multiple regression analysis indicated the expected changes in the dependent variable (Y_i) for unit change in the independent variable x_i where the other independent variables x_j ($j \neq I, j=1......k$) are held constant. Statistical significance of partial regression coefficients were tested by using the Student's **t**-test with n-k-1 degrees of freedom.

3.5.9. Fertilizer recommendation for maximum and economic yield - Multiple regression model

From the quadratic response surface fitted through multiple regression of tuber yield with STVs and applied nutrients, simplified fertilizer adjustment equations were derived for recommending fertilizers for maximum and economic yield of cassava at varying STVs.

3.5.10. Fertilizer prescription for specific yield target -Targeted yield model

From the data on STVs, tuber yield and nutrient uptake by cassava, fertilizer prescription equations were developed for recommending fertilizers for specific yield targets of cassava with and without FYM.

3.5.10.1. Calculation of basic parameters

3.5.10.1.1. Nutrient requirement (NR)

Nutrient requirements in terms of N, P_2O_5 and K_2O in kg per ton of tuber were calculated from all plots using the following formulae.

$$\text{kg N required per ton of tuber production} = \frac{\text{Total uptake of N (kg ha}^{-1}\text{)}}{\text{Tuber yield (t ha}^{-1}\text{)}}$$

$$\text{kg } P_2O_5 \text{ required per ton of tuber production} = \frac{\text{Total uptake of } P_2O_5 \text{ (kg ha}^{-1}\text{)}}{\text{Tuber yield (t ha}^{-1}\text{)}}$$

$$\text{kg } K_2O \text{ required per ton of tuber production} = \frac{\text{Total uptake of } K_2O \text{ (kg ha}^{-1}\text{)}}{\text{Tuber yield (t ha}^{-1}\text{)}}$$

3.5.10.1.2. Per cent contribution of nutrients from soil (CS)

The per cent contribution of nutrients from soil were calculated utilising the data from absolute control plots.

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

$$\% \text{ contribution of } P_2O_5 \text{ from soil} = \frac{\text{Total uptake of } P_2O_5 \text{ in control plot (kg ha}^{-1}\text{)}}{\text{STV for available } P_2O_5 \text{ in control plot (kg ha}^{-1}\text{)}} \times 100$$

$$\% \text{ contribution of } K_2O \text{ from soil} = \frac{\text{Total uptake of } K_2O \text{ in control plot (kg ha}^{-1}\text{)}}{\text{STV for available } K_2O \text{ in control plot (kg ha}^{-1}\text{)}} \times 100$$

3.5.10.1.3. Per cent contribution of nutrients from fertilizer (CF)

The per cent contribution of nutrients from fertilizers were calculated using the data obtained from plots treated with fertilizers only and no FYM was applied, after deducting soil contribution.

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

$$\text{\% contribution of } P_2O_5 \text{ from fertilizer} = \frac{\text{Total uptake of } P_2O_5 \text{ in fertilizer treated plot (kg ha}^{-1}\text{)} - \left[\text{STV for available } P_2O_5 \text{ in treated plot} \times \frac{\text{Average CS}}{100}\right]}{\text{Fertilizer } P_2O_5 \text{ applied (kg ha}^{-1}\text{)}} \times 100$$

$$\text{\% contribution of } K_2O \text{ from fertilizer} = \frac{\text{Total uptake of } K_2O \text{ in fertilizer treated plot (kg ha}^{-1}\text{)} - \left[\text{STV for available } K_2O \text{ in treated plot} \times \frac{\text{Average CS}}{100}\right]}{\text{Fertilizer } K_2O \text{ applied (kg ha}^{-1}\text{)}} \times 100$$

3.5.10.1.4. Per cent contribution of nutrients from FYM (COM)

The per cent contribution of nutrients from FYM were calculated incorporating the data from FYM applied plots but treated with no fertilizers, after allowing for soil contribution.

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

$$\%\ \text{contribution of } P_2O_5 \text{ from FYM} = \frac{\text{Total uptake of } P_2O_5 \text{ in FYM treated plot (kg ha}^{-1}\text{)} - \left[\text{STV for available } P_2O_5 \text{ in treated plot} \times \frac{\text{Average CS}}{100}\right]}{P_2O_5 \text{ applied through FYM (kg ha}^{-1}\text{)}} \times 100$$

$$\%\ \text{contribution of } K_2O \text{ from FYM} = \frac{\text{Total uptake of } K_2O \text{ in FYM treated plot (kg ha}^{-1}\text{)} - \left[\text{STV for available } K_2O \text{ in treated plot} \times \frac{\text{Average CS}}{100}\right]}{K_2O \text{ applied through FYM (kg ha}^{-1}\text{)}} \times 100$$

3.5.10.2. Targeted yield equations

The basic parameters calculated were transformed into workable fertilizer adjustment equations for prescribing fertilizer dose for any yield target, based on soil tests as given below:

Without FYM

$$FN = \frac{NR}{CF/100} T - \frac{CS}{CF} SN \qquad \text{..........(3.2)}$$

$$FP_2O_5 = \frac{NR}{CF/100} T - \frac{CS}{CF} SP \times 2.29 \qquad \text{..........(3.3)}$$

$$FK_2O = \frac{NR}{CF/100} T - \frac{CS}{CF} SK \times 1.21 \qquad \text{..........(3.4)}$$

With FYM

$$FN = \frac{NR}{CF/100} T - \frac{CS}{CF} SN - \frac{COM}{CF} ON \qquad \text{..........(3.5)}$$

$$FP_2O_5 = \frac{NR}{CF/100} T - \frac{CS}{CF} SP \times 2.29 - \frac{COM}{CF} OP \times 2.29 \qquad \text{..........(3.6)}$$

$$FK_2O = \frac{NR}{CF/100} T - \frac{CS}{CF} SK \times 1.21 - \frac{COM}{CF} OK \times 1.21 \qquad \text{..........(3.7)}$$

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

FP_2O_5 = Fertilizer P_2O_5 in kg ha^{-1}

FK_2O = Fertilizer K_2O in kg ha^{-1}

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

CS = % nutrient contribution from soil

CF = % nutrient contribution from fertilizer

COM = % nutrient contribution from FYM

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

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

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

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

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

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

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

3.6. Technology verification trial

This trial was undertaken to test the validity of the fertilizer prescription equations developed.

3.6.1. Crop and variety

Cassava var. M-4 (same as that of the test crop) and cultural practices as in the main experiment were adopted.

3.6.2. Treatments

i. Package of Practices recommendation for fertilizers - POP

ii. Fertilizer recommendation by Soil Testing Laboratory - STL

iii. Fertilizer dose for an yield target of 15 t ha^{-1} -T_1

vi. Fertilizer dose for an yield target of 20 t ha^{-1} -T_2

v. Fertilizer dose for an yield target of 25 t ha^{-1} -T_3

FYM	- 6.25 t ha^{-1} applied uniformly with all treatments
Design	- RBD
Plot size	- 10.5 x 10.5 m^2

3.6.3. Location

The trial was conducted in the laterite soil in three farmers' fields in Thiruvananthapuram district and also in the research station, namely,Instructional Farm, Vellayani. The addresses of the farmers are:

i. Shri. P. Thankappan Nair, Padmavilasom, Koliyoor.

ii. Shri. C. Sukumaran Nair, Premavilasom, Kalliyoor.

iii. Shri. J. David, Parankimamvila veedu, Kakkamoola.

3.6.4. Soil analysis

Soil samples were collected from all fields prior to the trial to analyse the nutrient status based on which calibration of fertilizer doses was done. The soil samples were analysed for pH, organic carbon and available N, P and K contents following the analytical methods in Table-3. Post harvest soil samples were also collected from each plot in all locations and analysed.

3.6.5. Observations recorded

At harvest plot wise tuber yield of cassava were collected from each location.

3.6.6. Statistical analysis

Statistical procedure was employed to test the validity of the equations developed for fertilizer prescription. The data relating to tuber yield of cassava in different locations were analysed using the ANOVA technique for RBD and the significance was tested by F-test (Snedecor and Cochran, 1968). The variation in yield obtained from the targeted yield was examined by χ^2-test.

3.6.7. Economic analysis

The economics of fertilizer application for cassava as per different treatments was worked out considering the cost of cultivation including the cost of fertilizers and prevailing market price of the tuber. The net income (Rs ha^{-1}), benefit - cost ratio (BCR), net returns per rupee invested and net returns per rupee invested on fertilizers were calculated as follows:

i. Net income (Rs. ha^{-1}) = Gross income- Cost of cultivation

ii. Benefit - cost ratio $= \dfrac{\text{Gross income}}{\text{Cost of cultivation}}$

iii. Net returns per rupee invested $= \dfrac{\text{Net income}}{\text{Cost of cultivation}}$

iv. Returns per rupee invested on fertilizers $= \dfrac{\text{Gross income - Cost of cultivation excluding cost of fertilizers}}{\text{Cost of fertilizers}}$

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

Fertilizer recommendation for profitable and sustained crop production can be done based on soil testing. The soil test calibration and fertilizer recommendation must be based on local field experiments which should provide significant correlation between soil test and crop response to fertilizers. Hence the present study was undertaken to establish soil test crop response correlation for soil test based balanced fertilizer prescription for cassava var. M-4 in laterite soils of Kerala.

The field experiments consisted of fertility gradient experiment, STCR experiment and technology verification trial. The results and related discussion are presented in this chapter.

4.1. Fertility Gradient Experiment

The yield of a crop is assumed to be a function of soil fertility (S) and applied fertilizers (F) at constant levels of other factors affecting yield. Mathematically, this relationship is expressed as

$$Y = f\ (S, F) \qquad \text{...........(4.1)}$$

Then it is necessary to have a set of data points covering appropriate range of values of each controllable variable (F or fertilizer dose) at different levels of uncontrollable variable (S or Soil fertility) for proper soil test calibration and optimisation purposes. Since the different levels of soil fertility cannot be expected to occur at one place, different sites have to be selected to represent different levels of soil fertility. However in the present study, all the needed variation in soil fertility was deliberately created in one and the same site in order to ensure homogeneity in the soil population studied, management practices adopted and climatic conditions prevailing. This technique of inductive methodology (Ramamoorthy, 1968) is being followed in AICRP for Investigations on STCR Correlation (Reddy *et. al.*, 1985).

The experimental area was divided into four equal strips and each strip into four blocks for the particular lay out of the experiment. A deliberate attempt was made to create a gradient in soil fertility from Strip I to IV by applying graded doses of N, P and K to each of the strips. A preparatory crop of fodder maize var. African Tall was raised so that fertilizers would undergo reactions with the soil, plant and microbiological agencies during the cropping period. By comparing the

Plate 1. Fertility gradient experiment - gradient crop: Fodder maize - a general view.


STCR Studies in Cassava
Expt 1. Fertility Gradient Experiment
Crop _ FODDER MAIZE
Treatments _ 4 Strips
3 N_1 P_1 K_1
4 N_2 P_2 K_2
N_1 - 150 kg N ha-1
P_1 - P Fixing Capacity
K_1 - 150 kg K ha-1
Date of sowing.7-4-94

response of the gradient crop in the four strips as well as STVs before and after the gradient experiment, it can be checked whether sufficient fertility gradient has been created or not. The data was also analysed statistically to confirm the build up of fertility gradient.

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 status prior to the conduct of FGE and just after the harvest of the gradient crop (fodder maize). The data on soil analysis is furnished in Table-6.

The soil nutrient status prior to the conduct of FGE (Table-6) ranged from 0.379 to 0.431 % of organic carbon and 231 to 250.3, 11.18 to 18.82 and 30.25 to 34.25 kg ha^{-1} for available N, P and K respectively. The analysis of soil samples collected after the harvest of the fodder maize revealed that the ranges were 0.300 to 0.345% for organic carbon and 207.91 to 234.85, 15 to 36.47 and 37 to 221.25 kg ha^{-1} for available N, P and K contents respectively.

There was no pronounced change in organic carbon and

Table-6. Soil fertility status before and after fertility gradient experiment

Strip	Fertilizer dose kg ha^{-1}			Before fertility gradient experiment				After fertility gradient experiment			
	N	P_2O_5	K_2O	Organic carbon %	Available N kg ha^{-1}	Available P kg ha^{-1}	Available K kg ha^{-1}	Organic carbon %	Available N kg ha^{-1}	Available P kg ha^{-1}	Available K kg ha^{-1}
I	0	0	0	0.379	231.0	11.18	30.25	0.300	207.90	15.00	37.00
II	75	50	90	0.431	246.4	18.82	34.25	0.330	219.45	33.53	66.25
III	150	100	180	0.401	250.3	18.23	32.75	0.338	227.15	35.00	130.50
IV	300	200	360	0.371	231.0	18.53	33.25	0.345	234.85	36.47	221.25
Mean				0.396	239.7	16.69	32.63	0.328	223.30	30.00	113.75
CD								0.022	11.791	4.759	21.479

available N status of the soil after the FGE (Table-6). In tropical soils it is very difficult to build up N status because of ephemeral nature of soil N in the tropics on account of higher rate of mineralization of organic matter and volatilization loss of N in gaseous form (Balasundaram, 1978). The experiment was conducted during the summer season (April - May, 1994) and the mean maximum and minimum temperatures during the period were 32 and 25.7^{0}C. High temperature might have augmented the decomposition of organic matter (Dalzell *et. al.*,1987) and volatilization loss of N. A definite relation between the contents of organic carbon and available N in the soil is well established in this experiment also.

The statistical analysis of the data on soil analysis after FGE revealed no significant variation in available N between the strips. In the case of organic carbon, Strip-I which received no fertilizer was significantly different from other fertilized strips which were on par.

After FGE, available P status of the soil increased in all strips than the initial contents which might be attributed to the application of graded levels of P (Table-6). There was an increase in available P in Strip-I after the gradient experiment even without any addition of P. This might be due to the fact that the maize roots forage P from deeper layers and concentrate in surface soil. But Strip-I was significantly lower in available P content than other fertilized strips. Even though 22 to 88 kg ha^{-1} of water soluble P was applied in Strip- II to IV, all strips were on par in available P content. The lack of significant difference in available P content between the Strip-II, III and IV after FGE might be due to high P fixing capacity of the laterite soil (KAU, 1989a and Varghese and Byju, 1993) and significant increase in uptake of P by fodder maize from Strip-II to IV (Table-7).

The increase in available K status after FGE (Table-6) might be due to the application of K levels over and above the K fixing capacity of the soil. Significant increase in available K was also observed from Strip-I to IV . The experiment was conducted during summer season and only 33.9 cm. of rainfall was received. So the chances of leaching loss were less and applied K might have been retained in available form in the soil.

The graphical presentation of the soil analysis data after FGE (Fig. 5) showed an operational range of fertility gradient from Strip-I to IV in terms of organic carbon and available N and P status of

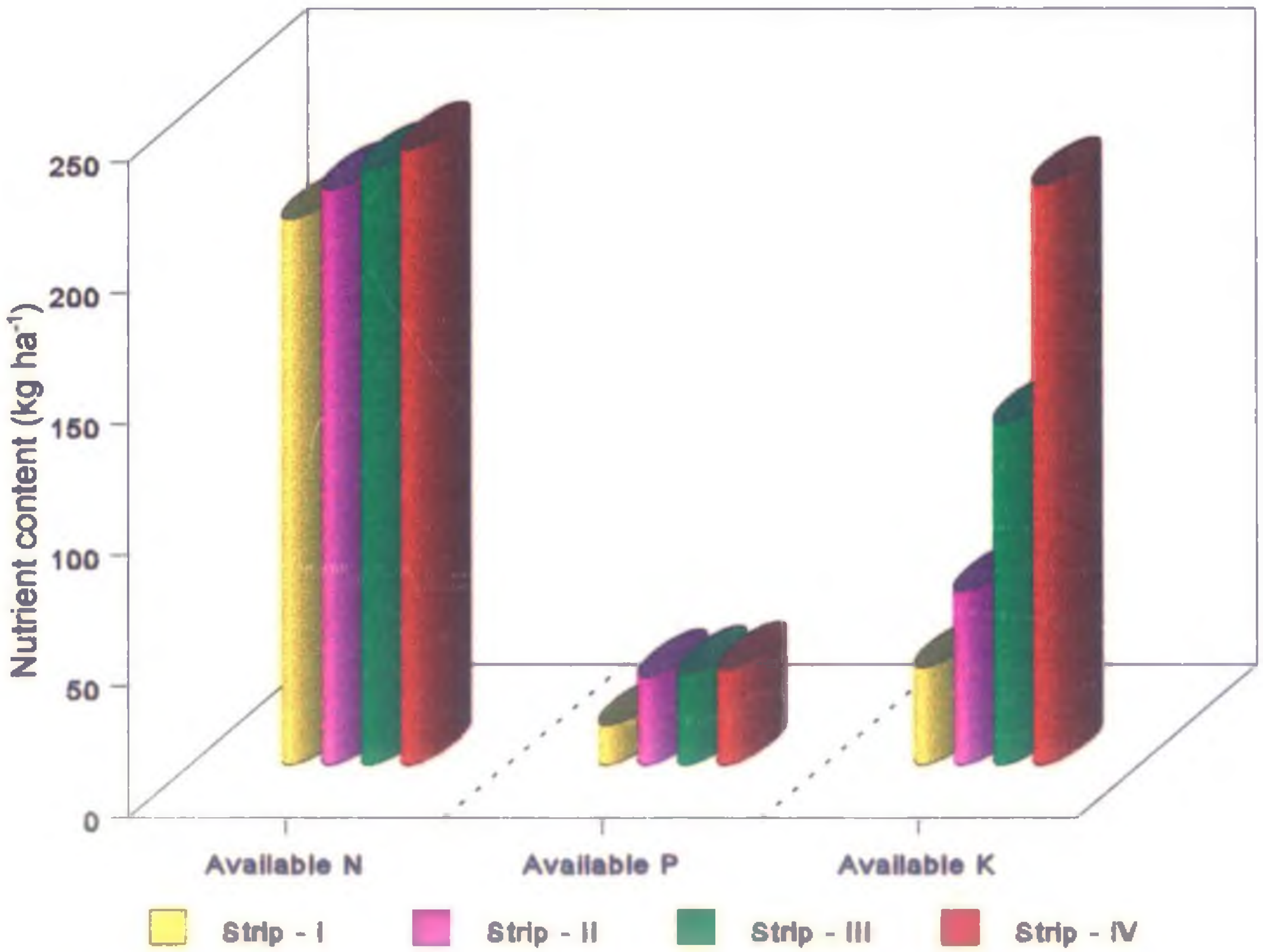

Fig. 5. Soil fertility status after fertility gradient experiment.

the soil while there was a steep gradient in terms of available K. Thus, a gradient in soil fertility could be created by the application of graded doses of N, P and K. Creation of such fertility gradients by N, P and K application has been already reported (Swadija *et. al.*, 1993 and TNAU, 1994).

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 IV (Table-7) with increase in the levels of N, P and K applied

Table-7. Effect of graded doses of N, P and K on fodder yield and nutrient uptake by fodder maize

Strip	Fertilizer dose kg ha^{-1}			Fodder yield (t ha^{-1})		Nutrient uptake (kg ha^{-1})		
	N	P_2O_5	K_2O	Green	Dry	N	P	K
I	0	0	0	5.588	0.542	9.10	1.78	9.59
II	75	50	90	18.883	1.728	33.86	6.69	59.17
III	150	100	180	28.708	2.500	55.31	10.96	121.59
IV	300	200	360	40.930	3.429	81.19	17.09	190.40
CD				2.431	0.387	6.518	2.396	14.081

Plate 2. Fodder maize in Strip - I $N_0 P_0 K_0$

Plate 3. Fodder maize in Strip - II $N_{1/2} P_{1/2} K_{1/2}$


$N_0P_0K_0$


$N_{\frac{1}{2}}P_{\frac{1}{2}}K_{\frac{1}{2}}$

Plate 4. Fodder maize in Strip - III $N_1 P_1 K_1$

Plate 5. Fodder maize in Strip - IV $N_2 P_2 K_2$


$N_1P_1K_1$

to the strips. Crop yield is a function of soil fertility under optimal levels of other production factors. Thus the build up of a gradient in soil fertility is reflected in the crop response data (Fig.6 and 7). The statistical analysis of the data showed that strips differed significantly in fodder yield and nutrient uptake by the gradient crop, which lends support to the fact that fertility gradient has been created.

4.2. STCR experiment

In experimenting for soil test calibration, the crop yield associated with every possible combination of the different levels of all variables must be measured. To do this, the system at each experimental plot must be described quantitatively. In one sense, each plot becomes an experiment in which all variable factors and the resultant yield are measured. But in a large sense, all experimental plots for any one crop species are part of one main experiment, since the data will be combined to obtain a multiple regression equation for a given soil and crop situation.

After the creation of fertility gradient, the STCR experiment was conducted in the same field by raising the test crop, cassava var.

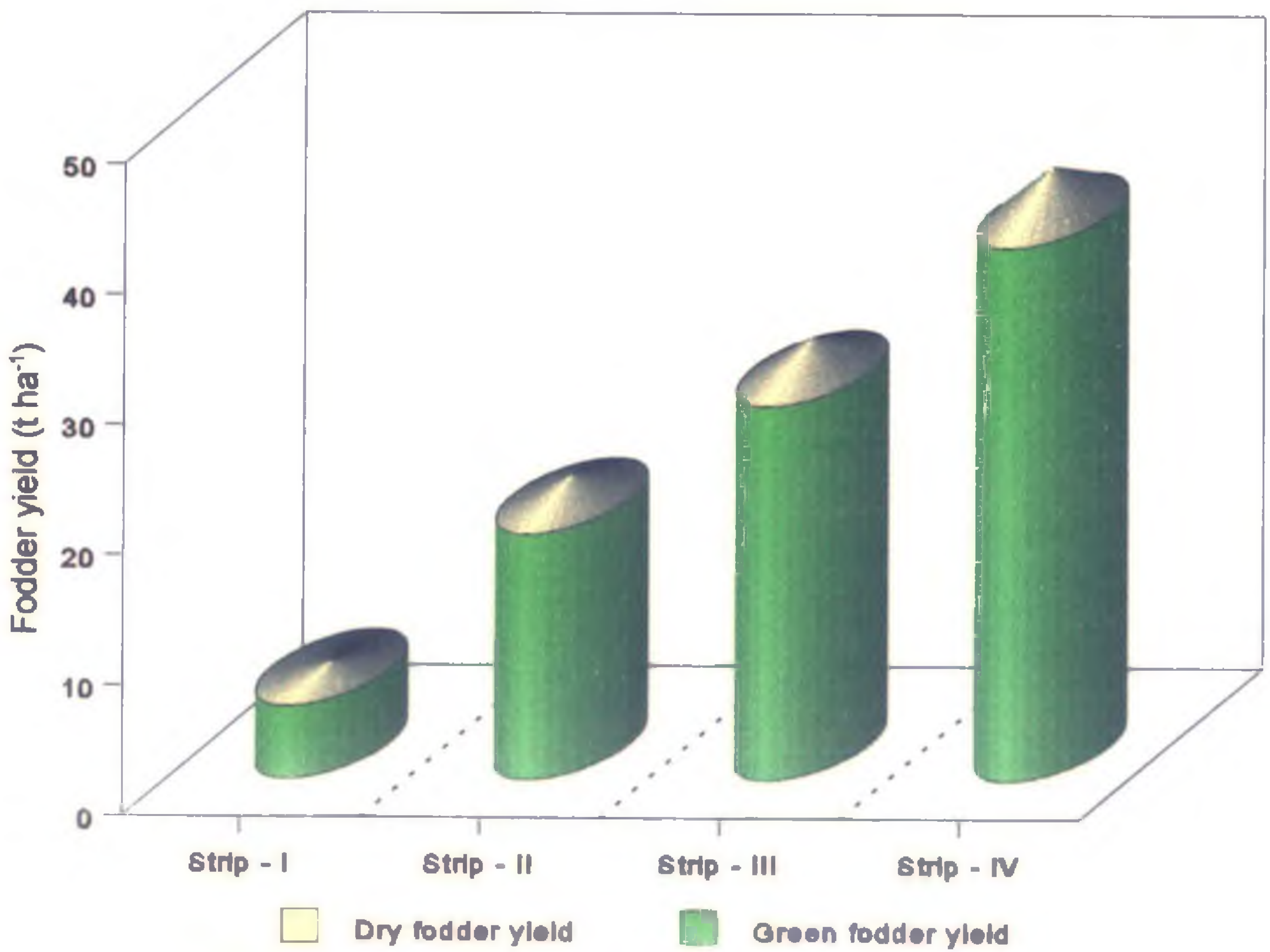

Fig. 6. Yield of the gradient crop - fodder maize.

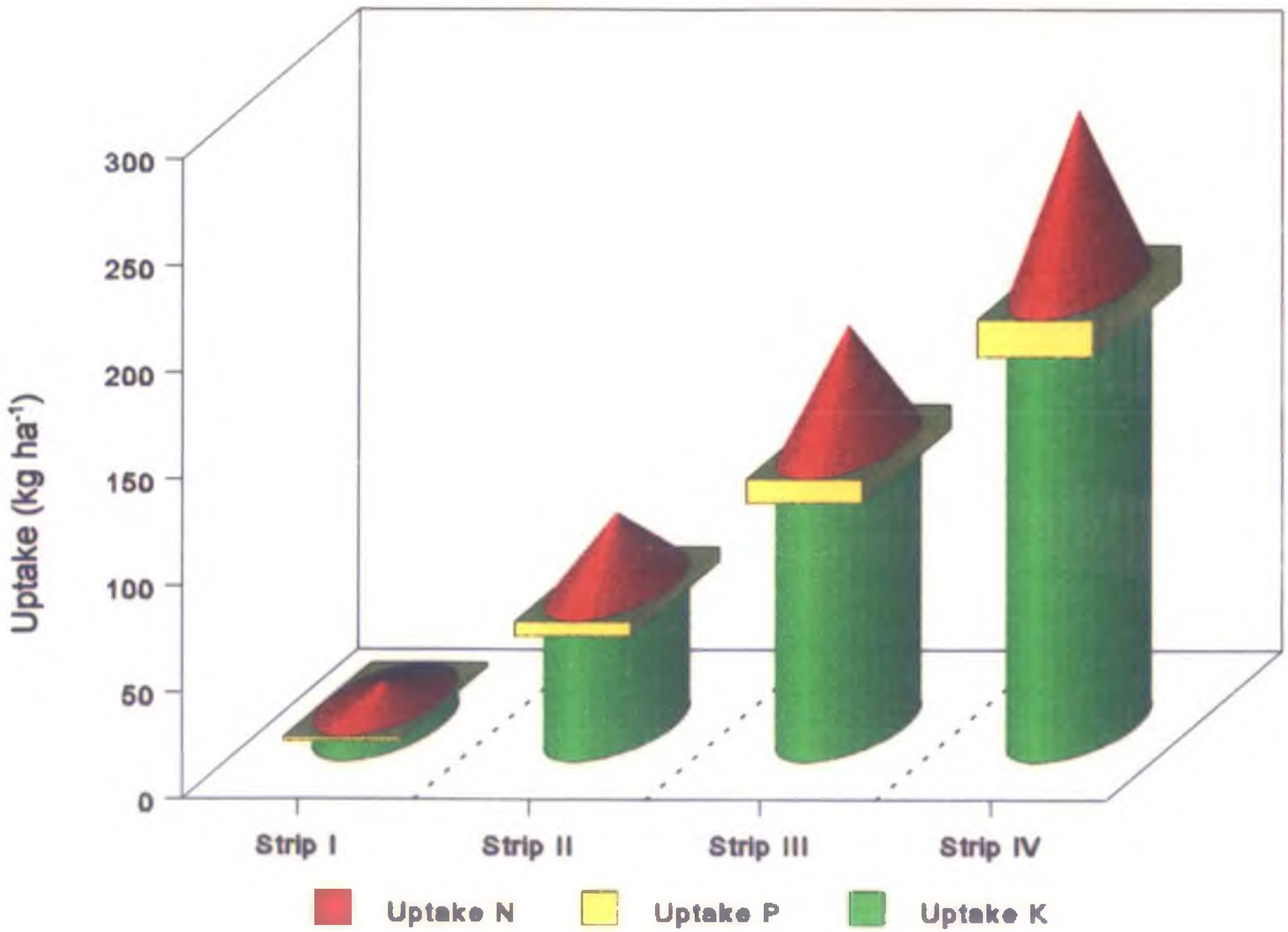

Fig. 7. Uptake of N, P and K by the gradient crop - fodder maize.

M-4. The real relationship between soil fertility, applied nutrients and the resultant crop yield was evaluated in the same soil type under uniform environmental conditions and management practices.

Use of judicious combination of organic and inorganic sources of nutrients is important for effecting economy in fertilizer use and enhancing nutrient use efficiency. Hence in the present STCR experiment three levels of FYM, the most commonly used organic manure were also included as treatments which were applied across the strips in four blocks (Reddy *et. al.*, 1985). The fertilizer treatments were so applied that each strip as well as each FYM block received all the treatment combinations. The gradient in soil fertility was from Strip-I to IV.

The control plots mentioned in the following pages means those plots in each strip (two per strip) which received no FYM or fertilizer for cassava. The treated plots refers to those plots (22 per strip) which received either FYM or fertilizer alone or a combination of both treatments (Table-4 and Fig. 4).

4.2.1. Pre-planting soil analysis

Analysis of soil samples collected prior to application of nutrients and planting of cassava was done for estimating the contribution of nutrients from the soil. The soil samples were analysed for organic carbon and available N, P and K and the data is given in Table-8 to 11. The mean values of the STVs in each strip are given in Table-12.

Organic carbon content in the soil varied from 0.255 to 0.315, 0.300 to 0.360, 0.300 to 0.390 and 0.330 to 0.405% in Strip-I, II, III and IV respectively (Table-8) and the corresponding mean values were 0.289, 0.327, 0.341 and 0.343 (Table-12).

Available N status (Table-9) ranged from 184.8 to 215.6, 200.2 to 231.0, 215.6 to 246.4 and 215.5 to 261.8 kg ha^{-1} in Strip-I, II, III and IV respectively. The average values in the respective strips (Table-12) were 208.54, 217.53, 227.79 and 233.57 kg ha^{-1}.

Soil available P (Table-10) registered a range in values from 8.74 to 20.68, 22.86 to 48, 23.33 to 51.86 and 26.71 to 48.41 kg ha^{-1} in Strip-I, II, III and IV with mean values of 14.63, 34.09, 35.01 and

37.33 kg ha^{-1} in Strip-I, II, III and IV respectively (Table-12).

Table-8. Organic carbon content (%) of soil prior to STCR experiment

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	0.285	0	0.330	0	0.300	0	0.330
0 0 0	0	0.255	0	0.330	0	0.330	0	0.330
0 0 0	1	0.285	1	0.330	1	0.330	1	0.330
0 0 0	2	0.270	2	0.300	2	0.360	2	0.345
0 0 1	1	0.285	0	0.315	2	0.360	0	0.360
1 0 1	1	0.300	0	0.330	0	0.300	2	0.405
1 1 1	1	0.285	2	0.300	0	0.360	0	0.345
0 0 2	1	0.300	0	0.300	0	0.330	2	0.330
0 1 2	1	0.300	2	0.315	0	0.315	0	0.345
1 0 2	0	0.315	2	0.330	1	0.330	0	0.330
1 1 2	0	0.300	2	0.330	1	0.330	0	0.330
2 0 2	0	0.285	0	0.330	2	0.375	1	0.345
2 1 2	0	0.270	1	0.360	0	0.360	2	0.330
2 2 2	0	0.300	1	0.360	2	0.390	0	0.330
0 0 3	2	0.285	0	0.300	1	0.300	0	0.330
1 1 3	2	0.285	0	0.300	0	0.345	1	0.345
2 2 3	0	0.300	2	0.315	0	0.300	1	0.405
3 0 3	0	0.270	1	0.360	2	0.390	0	0.345
3 1 3	2	0.285	0	0.315	0	0.360	1	0.330
3 2 3	0	0.300	0	0.315	1	0.345	2	0.345
2 1 4	0	0.285	1	0.345	0	0.390	2	0.330
2 2 4	0	0.285	1	0.360	2	0.360	0	0.360
3 1 4	2	0.300	0	0.330	1	0.300	0	0.330
3 2 4	2	0.300	0	0.345	0	0.315	1	0.330

Table-9. Available N (kg ha^{-1}) in soil prior to STCR experiment

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	200.2	0	215.6	0	215.6	0	215.6
0 0 0	0	200.2	0	215.6	0	215.6	0	231.0
0 0 0	1	215.6	1	215.6	1	215.6	1	231.0
0 0 0	2	215.6	2	215.6	2	215.6	2	231.0
0 0 1	1	215.6	0	215.6	2	215.6	0	231.0
1 0 1	1	200.2	0	200.2	0	231.0	2	261.8
1 1 1	1	215.6	2	215.6	0	231.0	0	231.0
0 0 2	1	215.6	0	200.2	0	231.0	2	231.0
0 1 2	1	215.6	2	215.6	0	231.0	0	231.0
1 0 2	0	200.2	2	215.6	1	231.0	0	231.0
1 1 2	0	215.6	2	215.6	1	231.0	0	231.0
2 0 2	0	215.6	0	215.6	2	231.0	1	231.0
2 1 2	0	200.2	1	231.0	0	231.0	2	231.0
2 2 2	0	200.2	1	231.0	2	246.4	0	231.0
0 0 3	2	215.6	0	200.2	1	231.0	0	231.0
1 1 3	2	215.6	0	215.6	0	231.0	1	231.0
2 2 3	0	215.6	2	215.6	0	215.6	1	261.8
3 0 3	0	215.6	1	231.0	2	246.4	0	231.0
3 1 3	2	215.6	0	215.6	0	231.0	1	231.0
3 2 3	0	215.6	0	215.6	1	246.4	2	231.0
2 1 4	0	200.2	1	231.0	0	231.0	2	231.0
2 2 4	0	184.8	1	231.0	2	231.0	0	246.4
3 1 4	2	200.2	0	231.0	1	215.6	0	231.0
3 2 4	2	200.2	0	215.6	0	215.6	1	231.0

Table-10. Available P (kg ha^{-1}) in soil prior to STCR experiment

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	14.79	0	24.28	0	31.27	0	39.37
0 0 0	0	8.91	0	22.86	0	23.33	0	39.37
0 0 0	1	12.44	1	35.86	1	26.27	1	26.82
0 0 0	2	20.68	2	33.17	2	27.93	2	26.71
0 0 1	1	11.27	0	35.86	2	30.40	0	44.60
1 0 1	1	10.68	0	35.86	0	27.70	2	41.90
1 1 1	1	10.09	2	29.36	0	29.37	0	45.22
0 0 2	1	14.89	0	40.79	0	33.33	2	43.17
0 1 2	1	10.09	2	47.29	0	46.68	0	29.24
1 0 2	0	12.62	2	40.95	1	38.33	0	36.98
1 1 2	0	11.27	2	30.63	1	40.00	0	27.97
2 0 2	0	13.62	0	29.43	2	31.67	1	29.92
2 1 2	0	19.50	1	40.78	0	32.53	2	38.10
2 2 2	0	14.79	1	34.44	2	29.37	0	35.71
0 0 3	2	11.30	0	26.82	1	51.86	0	34.31
1 1 3	2	13.62	0	28.09	0	38.73	1	27.38
2 2 3	0	8.74	2	48.00	0	41.67	1	45.87
3 0 3	0	15.97	1	37.14	2	45.00	0	48.41
3 1 3	2	20.30	0	30.48	0	31.03	1	47.14
3 2 3	0	14.79	0	28.09	1	51.67	2	40.63
2 1 4	0	19.50	1	35.71	0	38.73	2	41.46
2 2 4	0	20.68	1	29.36	2	27.70	0	29.24
3 1 4	2	20.30	0	33.02	1	28.90	0	45.70
3 2 4	2	20.30	0	39.99	0	36.67	1	30.63

Table-11. Available K (kg ha^{-1}) in soil prior to STCR experiment

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	42	0	78	0	118	0	200
0 0 0	0	33	0	55	0	106	0	240
0 0 0	1	39	1	67	1	100	1	240
0 0 0	2	28	2	75	2	152	2	200
0 0 1	1	28	0	55	2	106	0	160
1 0 1	1	37	0	76	0	148	2	300
1 1 1	1	36	2	59	0	168	0	200
0 0 2	1	27	0	66	0	100	2	300
0 1 2	1	50	2	70	0	108	0	210
1 0 2	0	38	2	78	1	156	0	200
1 1 2	0	36	2	59	1	160	0	220
2 0 2	0	34	0	65	2	124	1	210
2 1 2	0	28	1	83	0	164	2	280
2 2 2	0	50	1	83	2	98	0	240
0 0 3	2	40	0	57	1	140	0	200
1 1 3	2	32	0	53	0	132	1	185
2 2 3	0	37	2	80	0	148	1	180
3 0 3	0	32	1	80	2	136	0	195
3 1 3	2	39	0	65	0	128	1	180
3 2 3	0	40	0	55	1	120	2	305
2 1 4	0	26	1	76	0	110	2	245
2 2 4	0	30	1	68	2	148	0	250
3 1 4	2	44	0	55	1	100	0	190
3 2 4	2	50	0	66	0	156	1	200

Available K (Table-11) ranged from 26 to 50, 53 to 83, 98 to 168 and 160 to 305 kg ha^{-1} in Strip-I, II, III and IV respectively. The average K contents in Strip-I to IV (Table-12) were 36.50, 67.67, 130.25 and 222.08 kg ha^{-1} respectively.

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

Particulars	Mean values of strips			
	I	II	III	IV
Organic carbon (%)	0.289	0.327	0.341	0.343
Available N (kg ha^{-1})	208.54	217.53	227.79	233.57
Available P (kg ha^{-1})	14.63	34.09	35.01	37.33
Available K (kg ha^{-1})	36.50	67.67	130.25	222.08

Considering the STVs of all plots of the whole field (Table-8 to 11), it could be seen that the soil fertility status ranged from 0.255 to 0.405% of organic carbon and 184.8 to 261.8, 8.74 to 51.86 and 26 to 305 kg ha^{-1} of available N, P and K respectively. Thus, necessary gradient in soil fertility was created in the field for conducting the STCR experiment.

4.2.2. Yield of cassava

The data on tuber yield of cassava recorded in the experiment is given in Table-13. The top yield (leaves + stem) obtained and utilisation index worked out are furnished in Appendix-III and IV. The mean values of tuber and top yield and utilisation index in each strip are depicted in Table-14 and Fig. 8.

As evident from the data in Table-13, the control plots in all the strips registered much lower tuber yield (4.56 to 13.30 t ha^{-1}) than the treated plots (8.87 to 31.84 t ha^{-1}) in the respective strips. The average tuber yield (Table-14) from control plots in Strip-I to IV were 4.89, 10.06, 12.83 and 8.93 t ha^{-1}. The respective mean top yield (leaves + stem) were 3.61, 6.68, 16.49 and 22.15 t ha^{-1}.

The tuber yield in the control plots depends upon soil available nutrients in the absence of applied nutrients. With increase in soil fertility status from Strip-I to IV, the tuber yield increased upto Strip-III and then declined, whereas the top yield increased progressively from 3.61 (Strip-I) to 22.15 t ha^{-1} (Strip-IV). However utilisation index increased from 1.41 in Strip-I to 1.51 in Strip-II and decreased to 0.78 in

Strip-III and 0.41 Strip-IV (Table-14).

Table-13. Tuber yield of cassava (t ha^{-1}) as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	4.56	0	9.53	0	13.30	0	10.18
0 0 0	0	5.22	0	10.59	0	12.37	0	7.69
0 0 0	1	9.41	1	17.44	1	22.78	1	14.24
0 0 0	2	11.72	2	21.36	2	18.04	2	21.35
0 0 1	1	10.43	0	9.73	2	20.43	0	10.52
1 0 1	1	11.40	0	17.09	0	14.28	2	14.58
1 1 1	1	11.84	2	23.94	0	18.28	0	22.06
0 0 2	1	11.39	0	14.78	0	14.21	2	15.24
0 1 2	1	11.63	2	24.90	0	13.57	0	11.43
1 0 2	0	9.01	2	24.62	1	23.03	0	13.02
1 1 2	0	8.87	2	25.54	1	22.22	0	17.72
2 0 2	0	14.84	0	17.89	2	19.72	1	17.35
2 1 2	0	12.82	1	22.89	0	20.58	2	14.78
2 2 2	0	16.92	1	25.39	2	24.40	0	18.69
0 0 3	2	18.25	0	12.11	1	21.80	0	11.89
1 1 3	2	20.83	0	21.94	0	24.14	1	19.04
2 2 3	0	20.38	2	31.84	0	24.42	1	22.12
3 0 3	0	18.91	1	21.44	2	17.31	0	17.14
3 1 3	2	23.13	0	30.16	0	14.73	1	17.95
3 2 3	0	14.11	0	27.28	1	23.08	2	24.59
2 1 4	0	17.90	1	25.22	0	25.32	2	22.26
2 2 4	0	20.48	1	25.94	2	21.55	0	17.37
3 1 4	2	20.48	0	25.44	1	24.69	0	26.51
3 2 4	2	16.50	0	25.35	0	15.14	1	14.87

Table-14. Strip wise mean yield of cassava

Particulars	Mean values of strips			
	I	II	III	IV
Control plots				
Tuber yield (t ha^{-1})	4.89	10.06	12.83	8.93
Top yield (t ha^{-1})	3.61	6.68	16.49	22.15
Utilisation index	1.41	1.51	0.78	0.41
Treated plots				
Tuber yield (t ha^{-1})	15.06	22.38	20.17	17.49
Top yield (t ha^{-1})	9.94	13.01	22.02	26.43
Utilisation index	1.63	1.74	0.98	0.69
All plots				
Tuber yield (t ha^{-1})	14.21	21.35	19.56	16.78
Top yield (t ha^{-1})	9.41	12.49	21.56	26.08
Utilisation index	1.61	1.72	0.96	0.66

In the control plots, the maximum tuber yield of 13.3 t ha^{-1} was observed in Strip-III with STVs of 215.6, 31.27 and 118 kg ha^{-1} available N, P and K respectively (Table-15). The minimum yield obtained was 4.56 t ha^{-1} from Strip-I with STVs of 200.2, 14.79 and

Table-15. Maximum and minimum tuber yield obtained due to treatments

Particulars	Strip	Soil test values (kg ha^{-1})			Fertilizer doses (kg ha^{-1})			FYM (t ha^{-1})	Tuber yield (t ha^{-1})
		N	P	K	N	P_2O_5	K_2O		
Control plots									
Maximum yield	III	215.6	31.27	118	0	0	0	0	13.30
Minimum yield	I	200.2	14.79	42	0	0	0	0	4.56
Treated plots									
Maximum yield	II	215.6	48.00	80	100	100	150	12.5	31.84
Minimum yield	I	215.6	11.27	36	50	50	100	0	8.87

42 kg ha^{-1} of available N, P and K respectively. In the absence of applied nutrients, the tuber yield increased with increase in soil fertility status.

In the treated plots (Table-13), the tuber yield varied from 8.87 to 23.13, 9.73 to 31.84, 13.57 to 25.32 and 10.52 to 26.51 t ha^{-1} in Strip-I, II, III and IV respectively. The mean tuber yield from treated plots were 15.06, 22.38, 20.17 and 17.49 t ha^{-1} in Strip-I to IV with corresponding top yield of 9.94, 13.01, 22.02 and 26.43 t ha^{-1} (Table-14).

Among the treated plots, the highest tuber yield of 31.84 t ha^{-1} was obtained from Strip- II which received 12.5 t ha^{-1} of FYM and 100,100 and 150 kg ha^{-1} of N, P_2O_5 and K_2O as fertilizers when the STVs were 215.6, 48 and 80 kg ha^{-1} of available N, P and K (Table-15). The lowest tuber yield of 8.87 t ha^{-1} was registered with Strip-I by the application of 50,50 and 100 kg ha^{-1} of N, P_2O_5 and K_2O respectively in the plot in which the STVs were 215.6, 11.27 and 36 kg ha^{-1} of available N, P and K.

Considering all plots in each strip, the average tuber yield obtained were 14.21, 21.35, 19.56 and 16.78 t ha^{-1} in Strip-I, II, III and IV respectively (Table-14). The average top yield showed a progressive

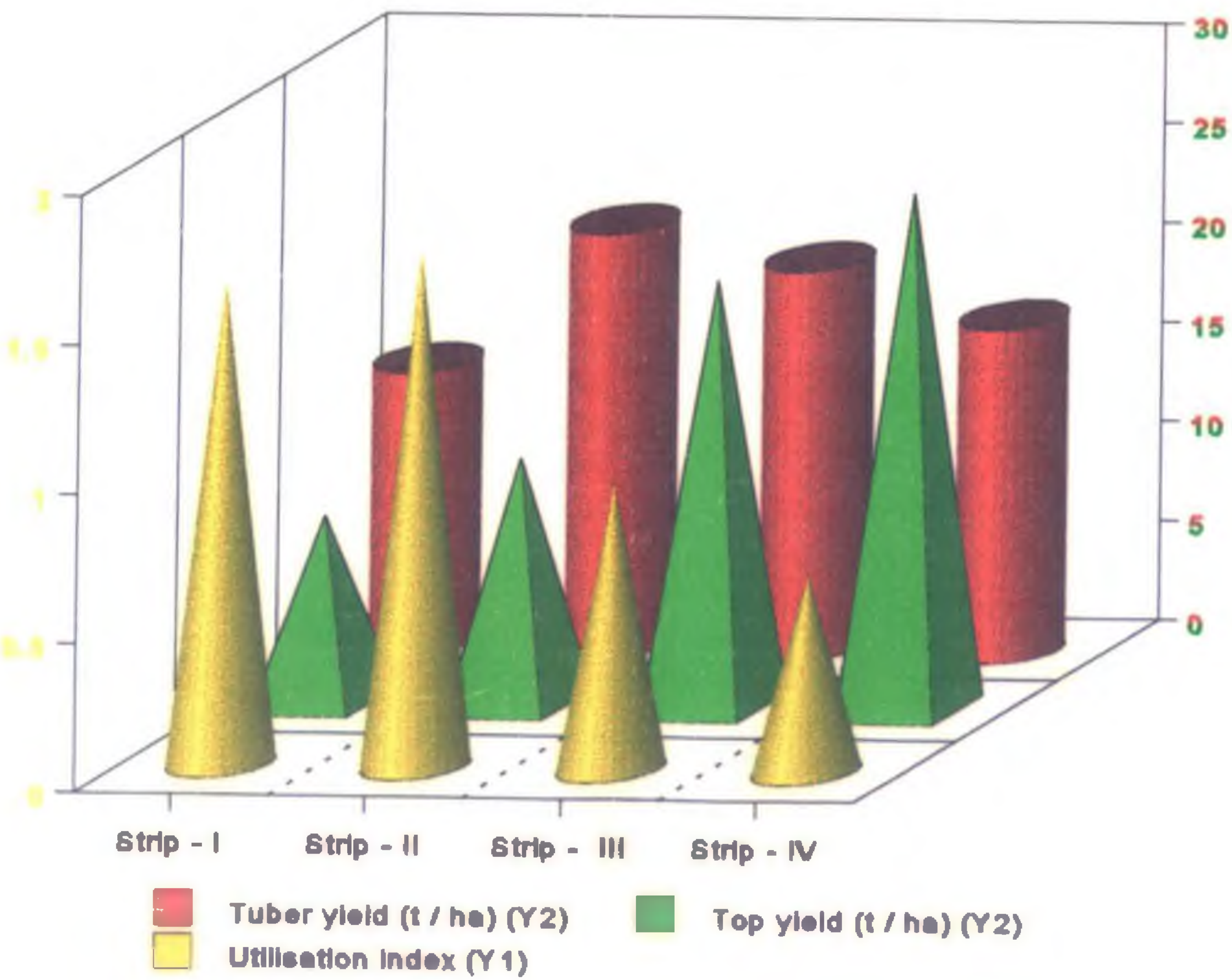

Fig. 8. Yield of cassava as influenced by available and applied nutrients.

increase from 9.41 in Strip-I to 26.08 t ha^{-1} in Strip-IV while the average utilisation index showed a declining trend from Strip-II (1.72) to Strip-IV (0.66).

A critical study of the data from the present experiment revealed that the vegetative growth was favoured with increase in soil fertility levels without producing corresponding increase in tuber yield. Corroborative findings have been reported by Cock (1975) and Howeler (1980). At higher fertility levels, a good amount of photosynthates might have been diverted for increased top growth resulting in reduced tuber yield.

With increase in the supply of primary nutrients, there is every chance for reduction in availability, uptake and utilisation of secondary and micronutrients. The imbalance in nutrition might have contributed for reduction in tuber yield at higher fertility levels. Similar results were reported by Anderson (1973) and Ashokan and Sreedharan (1977). Magnesium deficiency is reported to be induced by high content of K in the soil. Higher applications of muriate of potash may also cause chloride induced sulphur deficiency (Nair and Mohankumar, 1989).

Plate 6. STCR experiment - test crop : Cassava var. M-4.- a general view.

Plate 7. A gradient in vegetative growth exhibited by cassava in Strip-I to IV.


STCR Studies in Cassava Var M4
N _ 0.50.100 and 150 kg N ha-1
Design _ Response Surface Design
Date of Planting _ 15.6.94

4.2.3. Nutrient uptake by cassava

The data on uptake of N, P and K at harvest are given in Table-16 to 18. The mean values in each strip are given in Table-19 and graphically presented in Fig. 9.

Uptake of N, P and K ranged from 29.79 to 225.34, 5.56 to 41.29 and 15.08 to 231.48 kg ha^{-1} (Table-16 to 18). The uptake of N and K was almost equal while the crop absorbed only lesser quantities of P. Several scientists have reported that cassava extracted substantial quantities of N and K from the soil but the removal of P was relatively low (Thampan, 1979; Howeler, 1981; CTCRI, 1983; Kabeerathumma *et. al.*, 1988 and Nair, *et al.*,1988).

In the control plots (Table-19), uptake of N registered mean values of 31.49, 48.59, 93.22 and 122.60 kg ha^{-1} in Strip-I, II, III and IV respectively. The mean P uptake in Strip-I to IV were 5.86, 8.56, 17 and 15.80 kg ha^{-1} .Uptake of K recorded mean values of 16.7, 37.7, 83.5 and 110 kg ha^{-1} in Strip- I to IV.

The increase in uptake of nutrients in control plots from Strip-I to IV indicated increased availability of nutrients from the soil.

Table-16. Uptake of N (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	29.79	0	50.93	0	85.90	0	123.43
0 0 0	0	33.19	0	46.25	0	100.53	0	121.73
0 0 0	1	61.26	1	83.81	1	138.81	1	136.38
0 0 0	2	75.74	2	77.97	2	135.04	2	137.49
0 0 1	1	43.76	0	60.84	2	110.70	0	122.34
1 0 1	1	49.18	0	88.96	0	142.65	2	171.45
1 1 1	1	56.83	2	110.20	0	175.79	0	200.57
0 0 2	1	48.02	0	72.62	0	141.77	2	176.32
0 1 2	1	67.84	2	112.08	0	141.24	0	144.80
1 0 2	0	46.73	2	155.12	1	181.32	0	179.35
1 1 2	0	57.61	2	130.07	1	205.22	0	200.71
2 0 2	0	91.35	0	142.91	2	148.16	1	194.65
2 1 2	0	56.10	1	197.42	0	117.06	2	205.65
2 2 2	0	76.76	1	148.44	2	194.74	0	190.45
0 0 3	2	103.88	0	44.76	1	186.53	0	138.28
1 1 3	2	114.37	0	66.68	0	192.37	1	206.69
2 2 3	0	109.54	2	186.73	0	175.67	1	206.20
3 0 3	0	130.03	1	138.75	2	93.40	0	195.26
3 1 3	2	156.56	0	183.19	0	120.99	1	225.34
3 2 3	0	83.55	0	170.06	1	212.41	2	210.87
2 1 4	0	85.59	1	125.71	0	180.46	2	133.95
2 2 4	0	88.06	1	160.93	2	168.28	0	149.21
3 1 4	2	145.81	0	99.16	1	182.05	0	191.67
3 2 4	2	136.43	0	138.89	0	139.30	1	182.43

Table-17. Uptake of P (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	6.15	0	9.12	0	16.55	0	16.92
0 0 0	0	5.56	0	8.00	0	17.45	0	14.67
0 0 0	1	8.87	1	14.57	1	24.23	1	25.81
0 0 0	2	10.83	2	14.65	2	20.56	2	24.33
0 0 1	1	8.34	0	13.49	2	23.54	0	20.76
1 0 1	1	8.43	0	20.19	0	18.79	2	18.17
1 1 1	1	8.81	2	26.27	0	28.06	0	32.64
0 0 2	1	7.72	0	14.21	0	20.06	2	22.24
0 1 2	1	8.27	2	24.93	0	22.17	0	17.22
1 0 2	0	6.78	2	26.95	1	25.38	0	20.00
1 1 2	0	7.10	2	27.55	1	35.59	0	24.35
2 0 2	0	9.50	0	20.25	2	20.96	1	32.08
2 1 2	0	7.43	1	31.68	0	19.79	2	24.01
2 2 2	0	9.17	1	20.11	2	23.50	0	30.63
0 0 3	2	11.84	0	8.41	1	23.20	0	17.06
1 1 3	2	14.10	0	23.56	0	28.22	1	35.26
2 2 3	0	12.02	2	41.29	0	26.24	1	24.84
3 0 3	0	10.62	1	19.67	2	14.38	0	26.37
3 1 3	2	15.65	0	36.86	0	15.73	1	35.57
3 2 3	0	10.67	0	23.88	1	35.48	2	25.78
2 1 4	0	9.25	1	18.98	0	25.94	2	23.02
2 2 4	0	10.19	1	26.29	2	16.61	0	20.29
3 1 4	2	14.29	0	23.68	1	28.03	0	28.81
3 2 4	2	10.83	0	19.96	0	16.36	1	25.60

Table-18. Uptake of K (kg ha^{-1}) at harvest as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	15.08	0	39.11	0	81.87	0	114.30
0 0 0	0	18.31	0	36.29	0	85.13	0	105.73
0 0 0	1	32.43	1	60.18	1	125.56	1	145.29
0 0 0	2	35.61	2	71.73	2	126.56	2	161.28
0 0 1	1	32.69	0	37.08	2	151.36	0	102.39
1 0 1	1	37.14	0	56.27	0	121.04	2	145.85
1 1 1	1	39.84	2	87.52	0	145.98	0	165.18
0 0 2	1	40.85	0	53.00	0	91.30	2	175.04
0 1 2	1	38.86	2	99.29	0	118.68	0	137.25
1 0 2	0	27.99	2	108.89	1	130.60	0	161.07
1 1 2	0	34.64	2	115.04	1	190.53	0	179.89
2 0 2	0	47.92	0	79.11	2	135.80	1	166.02
2 1 2	0	34.74	1	152.89	0	172.14	2	168.58
2 2 2	0	48.80	1	129.70	2	199.29	0	231.48
0 0 3	2	64.54	0	44.44	1	146.48	0	115.20
1 1 3	2	66.84	0	74.37	0	162.04	1	208.51
2 2 3	0	63.77	2	163.85	0	172.34	1	207.36
3 0 3	0	67.34	1	129.30	2	100.07	0	186.00
3 1 3	2	93.10	0	123.99	0	132.37	1	208.08
3 2 3	0	53.19	0	115.89	1	180.29	2	213.57
2 1 4	0	53.62	1	101.19	0	149.94	2	208.68
2 2 4	0	61.27	1	174.92	2	162.54	0	131.25
3 1 4	2	83.08	0	101.72	1	183.13	0	211.39
3 2 4	2	88.32	0	88.24	0	162.58	1	186.04

Table-19. Strip wise mean uptake of N, P and K (kg ha^{-1}) at harvest

Particulars	Mean values of strips			
	I	II	III	IV
Control plots				
Uptake of N	31.49	48.59	93.22	122.60
Uptake of P	5.86	8.56	17.00	15.80
Uptake of K	16.70	37.70	83.50	110.00
Treated plots				
Uptake of N	85.68	122.51	158.36	177.28
Uptake of P	10.03	22.61	23.31	25.22
Uptake of K	52.12	98.57	148.21	173.43
All plots				
Uptake of N	81.17	116.35	152.93	172.72
Uptake of P	9.68	21.44	22.78	24.44
Uptake of K	49.17	93.50	142.82	168.14

In the treated plots (Table-19), enhanced rate of absorption of nutrients was observed in all the strips than in the respective control plots.

In general, the mean values of N uptake in Strip I, II, III and IV were 81.17, 116.35, 152.93 and 172.72 kg ha^{-1} respectively. The

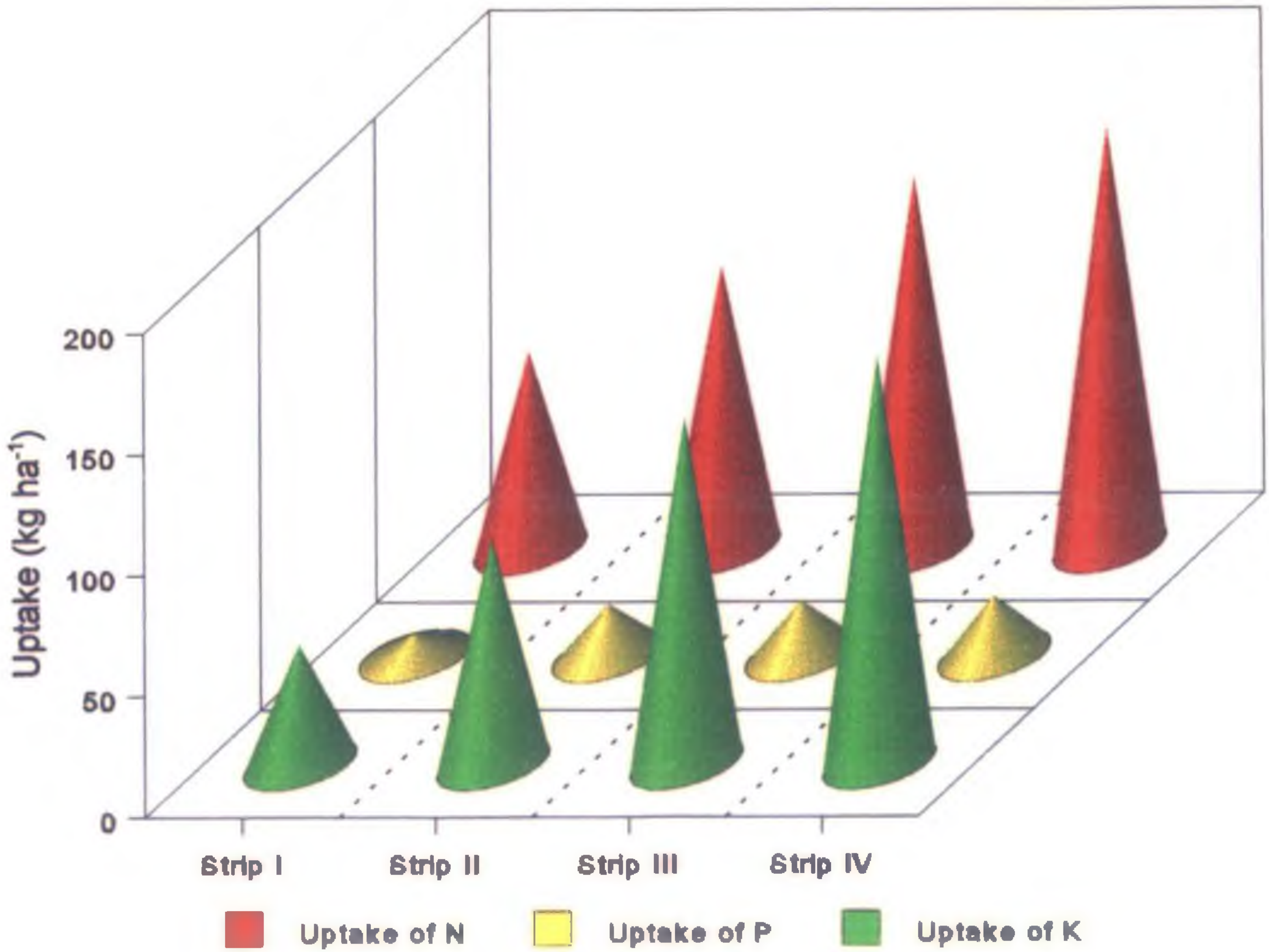

Fig. 9. Uptake of N, P and K by cassava as influenced by available and applied nutrients.

average P uptake were 9.68, 21.44, 22.78 and 24.44 kg ha^{-1} in Strip- I to IV. The mean values of K uptake were 49.17, 93.50, 142.82 and 168.14 kg ha^{-1} in Strip- I, II, III and IV respectively.

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

4.2.4. Correlation studies

4.2.4.1. Nutrient uptake and yield

Simple correlation coefficients between nutrient uptake at harvest and yield of cassava are depicted in Table-20.

Tuber yield was positively correlated with uptake of N, P and K. This corroborates with the findings of Rajendran *et. al.*, (1976), Nayar (1986) and Devi (1995). Inter correlations between uptake of N, P and K were also significant. The top yield also showed positive correlation with uptake of nutrients.

Negative correlation was observed between nutrient uptake and utilisation index. The increased uptake of nutrients resulted in higher top yield without increasing tuber yield thus lowering utilisation index.

Table-20. Correlation coefficients between nutrient uptake at harvest and yield of cassava

	Uptake of N	Uptake of P	Uptake of K	Tuber yield	Top yield
Uptake of P	0.8231**				
Uptake of K	0.8952**	0.8182**			
Tuber yield	0.5939**	0.6802**	0.5249**		
Top yield	0.8156**	0.6889**	0.8880**	0.4058**	
Utilisation index	-0.5439**	-0.3440**	-0.6360**	0.1300	-0.7950**

** Significant at 1% level

4.2.4.2. Nutrient uptake with available and applied nutrients

Uptake of nutrients showed positive correlations with available and applied N, P and K as evident from Table-21. The organic carbon content of the soil also showed positive relationship with nutrient uptake. It could be seen that higher correlations were observed between nutrient uptake and available nutrients than between nutrient uptake and applied nutrients. Hence increase in nutrient uptake from Strip- I to IV was observed in the present study.

Table-21. Correlation coefficients of uptake of nutrients with available and applied nutrients

	N uptake	P uptake	K uptake
Organic carbon	0.5271**	0.4860**	0.6174**
Available N	0.6347**	0.5182**	0.6894**
Available P	0.6418**	0.6953**	0.6653**
Available K	0.6255**	0.4950**	0.7544**
Fertilizer N	0.4343**	0.2785**	0.3716**
Fertilizer P_2O_5	0.3916**	0.2796**	0.3674**
Fertilizer K_2O	0.3937**	0.2269**	0.3400**
FYM	0.1941	0.1753	0.2082*

* Significant at 5% level

** Significant at 1% level

4.2.4.3. Yield with available and applied nutrients

The correlation coefficients of yield with soil available and applied nutrients are presented in Table-22.

Tuber yield was positively related to organic carbon and available N and P contents in the soil. The top yield was positively correlated with soil nutrient status prior to planting of cassava whereas utilisation index was negatively correlated with soil nutrient status.

Table-22. Correlation coefficients of yield with available and applied nutrients

	Tuber yield	Top yield	Utilisation index
Organic carbon	0.2947**	0.5191**	-0.4269**
Available N	0.2228*	0.6553**	-0.5929**
Available P	0.4232**	0.6366**	-0.4334**
Available K	0.0311	0.7906**	-0.7938**
Fertilizer N	0.5096**	0.2748**	0.0066
Fertilizer P_2O_5	0.4836**	0.2423*	0.0724
Fertilizer K_2O	0.5167**	0.2984**	0.0271
FYM	0.3190**	0.2222*	-0.0629

* Significant at 5% level

** Significant at 1% level

Applied nutrients either in the form of organics or inorganics showed positive correlations with tuber and top yield. The magnitude of correlation between tuber yield and applied nutrients was higher than that between tuber yield and soil nutrients. In contrast, the coefficients were higher between top yield and soil nutrients than those between top yield and applied nutrients. This indicated that the top yield was influenced by initial soil fertility status. The progressive increase in top yield obtained in the present experiment from Strip-I to IV (Table-14) supports this fact. The tuber yield is observed to be influenced by applied nutrients.

4.2.5. Response to applied nutrients

4.2.5.1. Farmyard manure

The data obtained from plots which received FYM alone at different levels with no fertilizer is given in Table-23. In each strip two plots were maintained so that neither FYM nor fertilizer was applied.

A perusal of the data in Table-23 indicated that higher yield were obtained from plots which received FYM alone. But the effects of F_1 (6.25 t ha^{-1}) and F_2 (12.50 t ha^{-1}) levels of FYM were found to be on par. The presence of nutrients like N, P and K in FYM and the improvement in physico-chemical properties of the soil might have resulted in higher yield in FYM applied plots (Ashokan and Sreedharan, 1977).

FYM is a store house of several nutrients besides N, P and K. Its regular application prevented the occurrence of zinc (Katyal and

Randhawa, 1983) and sulphur deficiencies (Nambiar and Abrol, 1989). Cassava appears to have a high requirement of zinc and is especially susceptible to zinc deficiency (Pillai, 1989). Zinc deficiency is also reported from majority of cassava areas in Thiruvananthapuram district. The long term cultivation of cassava in the same field with NPK fertilizers but without FYM resulted in acute zinc deficiency in cassava grown in a laterite soil in Kerala (Kabeerathumma *et. al.*, 1988).

Table-23. Effect of FYM on tuber yield

Levels of FYM ($t\ ha^{-1}$)	Tuber yield ($t\ ha^{-1}$)				
	Strip - I	Strip - II	Strip - III	Strip - IV	Mean
F_0 - Nil	4.56	9.53	13.30	10.18	9.12
F_0 - Nil	5.22	10.59	12.37	7.69	
F_1 - 6.25	9.41	17.44	22.78	14.24	15.97
F_2 -12.50	11.72	21.36	18.04	21.35	18.12
CD to compare F_0 with F_1 and F_2					2.299
CD to compare F_1 and F_2					3.754

More importantly FYM is known to improve soil physical environment. *It adds polysaccharides which are important in binding the*

Plate 8. Cassava growing in the plot without FYM / fertilizers in Strip-I.

Plate 9. Cassava growing in the plot with 6.25 t ha^{-1} FYM without fertilizers in Strip-I.


Strip I


Strip I

Plate 10. Cassava growing in the plot with 12.5 t ha^{-1} FYM without fertilizers in Strip-I.


Strip 1

soil particles together and for creating a stable soil structure (Abrol and Katyal, 1990). The organic manures improve infiltration and water retention characteristics of the soil. All these might have attributed to higher tuber yield in FYM applied plots even in the absence of fertilizers.

Table-24. Response of cassava to FYM

Levels of FYM (t ha^{-1})	Mean response - tuber yield (t ha^{-1})	Response per ton FYM
6.25	6.79	1.09
12.50	8.94	0.72

The response to FYM application was worked out and given in Table-24. It could be seen that the response was more at F_1 level (6.25 t ha^{-1}) than at F_2 level (12.5 t ha^{-1}), the response being measured from absolute control plots. The average response at F_1 level (6.25 t ha^{-1}) was 1.09 ton of tuber per ton of FYM while at F_2 level (12.5 t ha^{-1}) it was 0.72 ton tuber per ton of FYM.

4.2.5.2. Fertilizers

The response of cassava to fertilizers was worked out after eliminating the effect of FYM and soil nutrients and presented in Table- 25.

Table-25. Response of cassava to NPK fertilizers

Levels of nutrients (kg ha^{-1})	Mean response - tuber yield (t ha^{-1})	Response per kg nutrient
N		
50	4.59	91.72
100	7.79	77.86
150	7.91	52.75
P_2O_5		
50	6.95	139.06
100	8.25	82.49
K_2O		
50	2.37	47.34
100	3.88	38.75
150	7.80	52.02
200	8.67	43.33

It could be seen that response to N application was increased to 150 kg ha^{-1} but the response to 100 and 150 kg ha^{-1} of N were almost equal. The response per kg N was found to decrease when

N level was increased from 50 to 150 kg ha^{-1}.

Although increased response to P application was observed upto 100 kg P_2O_5 ha^{-1}, the response per kg P_2O_5 was reduced from 139.06 to 82.49 kg tuber when P_2O_5 was increased from 50 to 100 kg ha^{-1}.

The mean response to K application at 50 and 100 kg K_2O ha^{-1} was much lower than the response to same levels of N and P. However the response to K application increased upto 200 kg K_2O ha^{-1}. The response per unit quantity of K was fluctuating but was the highest at 150 kg K_2O ha^{-1}.

Laterite soils are generally low in organic matter and poor in available nutrients. Hence they respond to management practices and crops can be successfully grown by proper fertilization (KAU, 1989a). When the soil is deficient in a nutrient for high yield, the first added increment of the nutrient will result in a large yield increase. Defined by the law of diminishing returns, yield responses to fertilizer increments continue to diminish when moved up the fertilizer response curve.

4.2.6. Soil test calibration

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

i. Optimization of fertilizer nutrients for maximum and economic yield at varying STVs.

ii. Optimization of fertilizer nutrients for specific yield targets at varying STVs.

The calibration of soil test data arising out of such studies would enable site specific formulation of fertilizer dose for different purposes, viz., maximum yield (which is not more often the concern), economic yield which will only motivate the farmer to go in for fertilizer use and for a given yield target in the mind of the farmer. Soil test based fertilizer recommendation ensures balanced use of soil and fertilizer nutrients and maintenance of soil fertility.

4.2.6.1. Optimisation of fertilizer doses for maximum and economic yield at varying STVs-Multiple Regression Model

In the STCR programme, yield is determined as a function of soil and fertilizer nutrients, keeping all other factors at an optimum level, and is as given below.

Y = F [Soil N, Soil P, Soil K, Fertilizer N, Fertilizer P and Fertilizer K] ....(4.2)

where the available soil nutrients are estimated before the application of fertilizer nutrients for a given soil and crop situation.

In the present experiment, a wide range in both cassava yield and nutrient uptake was observed due to application of FYM and N, P and K fertilizers at varying STVs. Using the theory of regression, quadratic response models were calibrated with yield as a function of STVs and applied nutrients from both organic and inorganic sources. The model involved linear, quadratic and interaction terms of soil and fertilizer nutrients (Eqn. 3.1). The multiple regression model developed at IARI (Ramamoorthy, 1974) formed the basis for this calibration. The usefulness of multiple regression analysis for STCR studies has been highlighted by Ramamoorthy and Velayutham (1971), Reddy *et. al.*, (1985) and Sankar (1992).

The predictability of a model is indicated by the value of $\mathbf{R}^2$ and is tested by using **F** test. The regression coefficients are tested by **t** test for their significance. The multiple regression equations also provide information on the type of response for each nutrient for different crops (Singh and Sharma, 1978). Theoretically, eight types of responses for a nutrient are possible depending upon + or - sign for each of the three regression coefficients, viz., the coefficient for the linear, quadratic and interaction terms of the nutrient (Ramamoorthy, 1973; Ramamoorthy *et. al.*, 1974; Velayutham *et. al.*, 1985 and Sankar, *et. al.*, 1987). Among the eight types, the one with +, -, - signs respectively for the coefficients of linear, quadratic and interaction terms of the nutrient was considered to be the **normal** type for working out optima of a fertilizer nutrient at varying STVs. Therefore, it is necessary to take into account the actual form of response type existing in any given soil-crop-climatic complex in order that the best use is made of the available fertilizers.

Using the plot wise data on STVs, applied FYM and N, P and K fertilizers, and the resultant cassava tuber yield, multiple regression models of the following categories were calibrated:

a. Model with 15 variables comprising of 3 linear and 3 quadratic terms of soil nutrients (SN, SP and SK); 3 linear and 3 quadratic terms of fertilizer nutrients (FN, FP and FK) and 3 interaction terms of soil and fertilizer nutrients with available N (kg ha^{-1}) as a measure of soil N and utilising the data from F_0 blocks (without FYM)

b. Above with organic carbon % (OC) as a measure of soil N

c. Model with 15 variables as (a) utilising the data from all plots and available N as a measure of soil N

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

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

f. As above with OC as a measure of soil N

The different regression models are presented in Table-26 along with $\mathbf{R^2}$ values. All the models calibrated had significant and high

Table- 26. Tuber yield regressed with available and applied nutrients

Particulars	Multiple regression equation	R^2 value
FYM free plots		
SN as available N	$Y = -94.1056 + 0.8191\ SN + 0.6014\ SP + 0.0228\ SK - 0.005\ FN + 0.047\ FP + 0.0166\ FK - 0.0018\ SN^2 - 0.0067\ SP^2 - 0.0001\ SK^2 - 0.0006\ FN^{2**} - 0.0002\ FP^2 + 0.0001\ FK^2 + 0.0006\ SN\ FN + 0.0005\ SP\ FP - 0.0002\ SK\ FK$	0.7726**
SN as OC	$Y = -33.242 + 184.8988\ OC + 0.4854\ SP + 0.0307\ SK + 0.2037\ FN + 0.0696\ FP - 0.0008 FK - 252.6723\ OC^2 - 0.0049\ SP^2 - 0.0002\ SK^2 - 0.0005\ FN^2 - 0.0006\ FP^2 + 0.0001\ FK^2 - 0.2593\ OC\ FN + 0.0007\ SP\ FP - 0.0001\ SK\ FK$	0.7573**
All plots		
With 15 variables		
SN as available N	$Y = -211.733 + 1.8768\ SN^{**} + 0.6042\ SP^{**} - 0.0366\ SK + 0.1403\ FN + 0.0019\ FP + 0.0115\ FK - 0.004\ SN^{2**} - 0.0062\ SP^2 + 0.0001\ SK^2 - 0.0005\ FN^{2**} - 0.0001\ FP^2 + 0.0001\ FK^2 - 0.0002\ SN\ FN + 0.0012\ SP\ FP - 0.0002\ SK\ FK$	0.6243**
SN as OC	$Y = -35.3098 + 212.7603\ OC + 0.5164\ SP^{*} - 0.0254\ SK + 0.1681\ FN + 0.0193\ FP + 0.0133\ FK - 262.3305\ OC^2 - 0.0052\ SP^2 + 0.0\ SK^2 - 0.0004\ FN^{2*} - 0.0004\ FP^2 + 0.0001\ FK^2 - 0.2859\ OC\ FN + 0.0015\ SP\ FP - 0.0001\ SK\ FK$	0.5935**
With 17 variables		
SN as available N	$Y = -184.4717 + 0.4071\ FYM - 0.0041\ FYM^2 + 1.6465\ SN^{**} + 0.5612\ SP^{**} + 0.0006\ SK + 0.1366\ FN + 0.0067\ FP + 0.0193\ FK - 0.0036\ SN^{2**} - 0.0058\ SP^2 - 0.0\ SK^2 - 0.0005\ FN^{2**} - 0.0001\ FP^2 + 0.0001\ FK^2 - 0.0002\ SN\ FN + 0.0011\ SP\ FP - 0.0002\ SK\ FK$	0.7171**
SN as OC	$Y = -46.4694 + 0.4501\ FYM - 0.0051\ FYM^2 + 274.9365\ OC + 0.5158\ SP^{*} + 0.0103\ SK + 0.1809\ FN + 0.0164\ FP + 0.0178\ FK - 383.301\ OC^2 - 0.0055\ SP^2 - 0.0001\ SK^2 - 0.0004\ FN^{2*} - 0.0003\ FP^2 + 0.0\ FK^2 - 0.3025\ OC\ FN + 0.0013\ SP\ FP - 0.0001\ SK\ FK$	0.7028**

coefficients of determination as shown by $\mathbf{R}^2$ values (0.59 to 0.77). This indicated that the yield of cassava was related to the STVs and applied nutrients which formed a basis for predicting fertilizer doses for various purposes. Highly significant regression equations of crop yield with soil and applied nutrients with coefficients of determination >0.66 have been obtained by different workers for different crops in different soils (Singh and Sharma, 1978, Randhawa and Velayutham, 1982, Raniperumal *et. al.*, 1982 and 1984, Velayutham *et. al.*, 1985 and Santhi, 1995). The models involving available N as a measure of soil N had higher $\mathbf{R}^2$ values (Table-26) than the respective models with organic carbon as a measure of soil N but the increase was only 1-3% in all the cases.

4.2.6.1.1. Fertilizer recommendation for maximum and economic yield

From the quadratic regression equation site specific optimum doses of nutrients at varying STVs can be derived by differentiation. The regression equation fitted should have a high and significant coefficient of determination ($\mathbf{R}^2$ value) more than 0.66 so that the variation in yield is explained by the chosen explanatory variables (soil and applied nutrients) at least by 66%. The nutrient in question should also have the

(+,-,-) type or **normal** type of response behaviour. 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. Only in a (+,-,-) type of response situation, the nutrient is said to follow the law of diminishing returns and provides for derivation of soil test based fertilizer recommendation. The three coefficients are also required to be significant at least at 5% level of significance for optimisation.

The fertilizer recommendation by quadratic polynomial surface is made on the assumption that soil available and fertilizer nutrients act in a complementary way with each other in crop production implying that the fertilizer requirement decreases as the STV increases and vice versa.

Among the models calibrated (Table-26), the one with 15 variables calibrated utilising the data from F_0 blocks and available N as a measure of soil N had the highest predictability (77%). But any of the three fertilizer nutrients (FN, FP or FK) showed the **normal** or (+,-,-) type of response. In the similar model with organic carbon as a measure of soil N, only FN was found to have (+ ,-, -) type of response but no terms or regression coefficients were significant.

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 72% predictability which was significant also. Among the three fertilizer nutrients, only FN showed the **normal** or (+,-,-) type of response. For FP the response type was (+,-,+) and for FK it was (+, +, -). Hence optimisation of only fertilizer N was done.

Differentiating the regression equation partially with respect to FN, the soil test based fertilizer adjustment equation for recommending N dose was derived as:

$$\mathbf{FN = 136.6 - 0.2\ SN} \qquad \text{.......... (4.3)}$$

This is an adjustment equation of the **Fertilizer N** in terms of the **Soil Test N**. The FN derived from equation (4.3) is the optimum dose of fertilizer N (kg ha^{-1})for maximum tuber yield (t ha^{-1}) of cassava at a given STV for available N (kg ha^{-1}). Thus the fertilizer adjustment will ensure that the yield remains unaffected at different STVs of various fields if the fertilizer doses are adjusted accordingly (Singh and Sharma, 1978).

The equation (4.3) implied that the yield increased as long as the condition in equation (4.4) is satisfied. At higher levels of fertilizer

$$\mathbf{FN \leq 136.6 - 0.2\ SN} \qquad \text{..........(4.4)}$$

N above this level, the tuber yield will be decreased. In other words, fertilizer N has to be applied to the soil upto the level of 683 kg ha^{-1} of available N in order to get maximum tuber yield of cassava. The soils categorised as high in available N also need some quantity of N to be applied to get maximum tuber yield. Under tropical condition, the laterite soils are low in available N and require N fertilization to maximise cassava yield.

The equation (4.3) becomes the following for economic yield.

$$\mathbf{FN = 136.6 - 0.2\ SN - R} \qquad \text{............(4.5)}$$

where R is the ratio of cost of one kg of fertilizer N to price of one kg of cassava tuber. The fertilizer N derived from the above equation is the optimum dose of fertilizer N (kg ha^{-1}) for maximum profit per ha at a given STV for available N.

The fertilizer N requirements (FN) for maximum and economic yield were calculated by using the above equations for a range in STVs for available N (100 to 300 kg ha^{-1}) and given in Table-27. For calculating the fertilizer N requirements for economic yield, the existing cost of one kg of fertilizer N (Rs. 8.15) and the price of one kg of cassava tuber (Rs. 3.00) were taken into account. The results furnished in Table-27 clearly indicates that for a range of 100 to 300 kg ha^{-1} of available N in the soil, the fertilizer N requirement is reduced from 116.6 to 76.6 kg ha^{-1} for maximum yield and from 113.9 to 73.9 kg ha^{-1} for economic yield.

Similar multiple regression model calibrated with organic carbon as a measure of available N in the soil had also significant and higher coefficient of predictability (70%). In this model also, FN had (+,-,-) type of response behaviour while FP and FK had (+, -, +) and (+, +, -) types of response respectively. Hence optimization of fertilizer N for varying STV of organic carbon was done.

Table-27. Fertilizer N requirement for maximum and economic tuber yield at varying levels of available N in the soil

Available N (kg ha^{-1})	Fertilizer N (kg ha^{-1})	
	For maximum yield	For economic yield
100	116.6	113.9
150	106.6	103.9
200	96.6	93.9
250	86.6	83.9
300	76.6	73.9

The quantitative fertilizer adjustment equations for N at varying levels of organic carbon in the soil for maximum and economic tuber yield were derived.

For maximum yield,

$$\mathbf{FN = 226.13 - 378.13\ OC} \qquad \text{.............(4.6)}$$

where FN is fertilizer N kg ha^{-1} and OC is organic carbon% in the soil.

The equation (4.6) meant that tuber yield of cassava increases as long as the condition in equation (4.7) is satisfied.

$$FN \leq 226.13 - 378.13\ OC \qquad ....(4.7)$$

In other words, upto the level of 0.60 % OC in the soil, fertilizer N has to be applied to maximise the yield of cassava. For soils categorised as high in organic carbon, no external application of N is needed to achieve maximum yield. Tropical soils especially laterite are poor in organic matter and require N fertilization for getting maximum tuber yield, the quantity of which depends upon the content of organic carbon or available N in the soil.

For economic yield,

$$FN = 226.13 - 378.13\ OC - 1.25\ R \qquad ....(4.8)$$

where R is the ratio of cost of one kg of fertilizer N to sale price of one kg of cassava tuber.

The fertilizer N requirements for maximum tuber yield varied from 188.32 to 37.07 kg ha^{-1} (Table-28) at organic carbon contents of 0.10 to 0.50% in the soil whereas it varied from 184.92 to 33.67 kg ha^{-1} for economic tuber yield. For calculating fertilizer N dose for economic yield, the cost of one kg of fertilizer N was computed as Rs. 8.15 and price of one kg cassava tuber as Rs. 3.00.

Table-28. Fertilizer N requirement for maximum and economic tuber yield at varying levels of organic carbon in the soil

Organic carbon %	Fertilizer N (kg ha^{-1})	
	For maximum yield	For economic yield
0.1	188.32	184.92
0.2	150.50	147.10
0.3	112.69	109.29
0.4	74.88	71.48
0.5	37.07	33.67

The soil test calibrations could be done only for the nutrient N for maximum and economic yield of cassava at varying STVs for available N or organic carbon. There seems not much difference between the maximum and economic doses of fertilizer N based on the multiple regression model at the prevailing cost of fertilizers and price of tuber. Thus, the multiple regression model could modify the fertilizer recommendations for a change in STV as well as ratio of cost of fertilizer nutrient to that of produce making it dynamic so as to ensure more profit from fertilizer investment (Singh and Sharma, 1994).

The behaviour of applied P and K was found to produce responses other than **normal**. As a result optimisation of fertilizer doses for P and K could not be done through multiple regression model of quadratic type for maximum and economic tuber yield of cassava var. M-4 in the laterite soils. Several reports have been given under review of literature in which optimisation of only N or N and P or none of the nutrients was possible (Singh and Sharma, 1978; TNAU, 1994; Sankar *et. al.*, 1987, 1988 and 1991 and Santhi, 1995). Sankar (1992) reported that the general and economic fertilizer calibrations were found to exist mostly for N and P under all the regression models.

4.2.6.2. Optimisation of fertilizer doses for different yield targets - Targeted yield model

The relationship between yield of a crop and uptake of a nutrient will usually be linear in the normal range of soil nutrient status and fertilizer application. This implies that for obtaining a given yield a definite quantity of the nutrient must be taken up by the crop. Once this requirement is known for a given yield, the fertilizer required can be estimated taking into account the efficiencies of contribution of nutrients from the soil and fertilizer. The needed parameters for a given soil type-crop-agro-climatic condition are (I) nutrient requirement (NR) per unit of produce (grain or economic part); (ii) per cent contribution from the available nutrients in the soil (CS) and per cent contribution from the applied fertilizer nutrients (CF).

The data obtained from the STCR experiment provided a range in STVs, nutrient uptake and yield levels which enabled the calculation of the above parameters needed for developing targeted yield equations. The calculated values of these parameters are presented in Table-29 and depicted in Fig. 10.

Table-29. Basic data required for computing targeted yield equations

Nutrient	NR (kg t^{-1})	CS%	CF%	COM%
N	6.58	40.17	54.38	78.24
P_2O_5	2.37	41.33	47.00	57.33
K_2O	6.28	48.60	52.65	69.66

4.2.6.2.1. Nutrient requirement of cassava

Nutrient requirement (NR) is one of the three basic parameters for developing targeted yield equations. The nutrient requirements in terms of N, P_2O_5 and K_2O in kg per ton of tuber were worked out using the standard formulae given under **3.5.10.1.1.**

The estimates showed that cassava var. M-4 required 6.58 kg N, 2.37 kg P_2O_5 and 6.28 K_2O ha^{-1} to produce one ton of tuber (Table-29). As already pointed out, cassava is known to remove large quantities of nutrients from the soil especially N and K (Thampan, 1979). Low P requirement of cassava as compared to N and K has been reported by Howeler (1981), CTCRI (1983), Mohankumar *et. al.*, (1984), Kabeerathumma *et. al.*, (1988) and Nair *et. al.*, (1988).

The N and K_2O requirement for production of unit quantity of tuber is found to be approximately in the 1:1 ratio. Corroborative finding has been reported by Rajendran *et. al.*, (1976) in acid laterite soils of Kerala. P_2O_5 requirement is found to be about ⅓ of N and K_2O requirement. The STCR studies in cassava var. H-226 revealed nutrient requirements of 4.16, 0.62 and 4.64 kg ha^{-1} of N, P and K to produce one ton tuber as reported by Baskaran *et. al.*, (1994) from Tamil Nadu.

4.2.6.2.2. Soil and fertilizer efficiencies

A knowledge of the nutrient contribution from soil in terms of percentage of STV and from fertilizer and organic manure in terms of percentage of added nutrients is essential for recommending balanced fertilization for targeted yield of crops.

Soil efficiencies calculated using the formulae given under **3.5.10.1.2.** were 40.17, 41.33 and 48.60 % for N, P_2O_5 and K_2O respectively (Table-29). This implies that 40.17 % of soil available N, 41.33% soil available P_2O_5 and 48.60% soil available K_2O will be available for nutrition of cassava var. M-4 in laterite soils.

The fertilizer efficiencies worked out using the formulae given under **3.5.10.1.3.** were 54.38, 47 and 52.65 for N, P_2O_5 and K_2O for cassava in laterite soils (Table-29).

It was evident that CF values were higher than CS values. The increase in CF values for N and K could be attributed to split application of these nutrients (3 splits). The phosphatic fertilizer used was Mussorie rock phosphate and gradual solubilization and availability of P from it might have contributed for enhanced CF value for fertilizer P. Mussorie rock phosphate along with FYM has been found to be a better source of P by Kabeerathumma and Mohankumar (1990) for

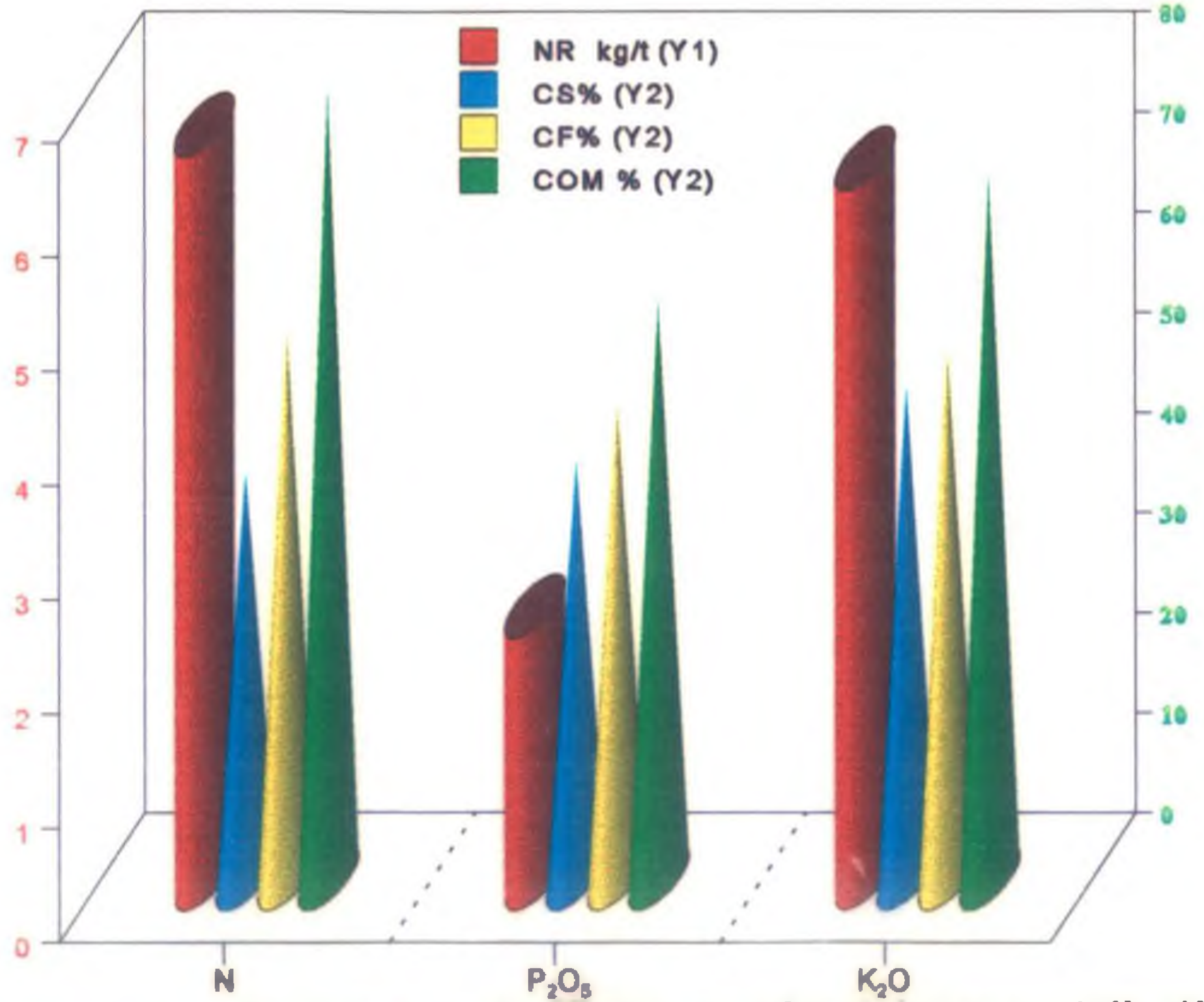

Fig. 10. Nutrient requirement and efficiency of nutrient contribution from soil, fertilizers and FYM for cassava var. M-4 in laterite soil.

cassava in acid laterite soil due to slow and steady rate of release of P from it.

4.2.6.2.3. Organic manure efficiency

The organic manure efficiencies (COM) for N, P and K nutrients were worked out adopting the formulae given under **3.5.10.1.4**.

COM values were 78.24, 57.33 and 69.66 % for N, P_2O_5 and K_2O. These values were higher than CS and CF values (Table-29). Lesser loss of nutrients from organic manure might have contributed for increased efficiency of FYM than those of soil and fertilizers. The increased uptake of nutrients in these plots is reflected in higher tuber yield of cassava in the plots in which only FYM was applied as external source of nutrients.

4.2.6.2.4. Fertilizer prescription for targeted yield of cassava

The fertilizer adjustment equations developed as given under **3.5.10.2.** for prescribing fertilizers for specific yield targets of cassava without FYM are as follows :

$$\mathbf{FN = 12.10\ T - 0.74\ SN} \qquad \text{...........(4.9)}$$

$$FP_2O_5 = 5.04\ T - 2.02\ SP \qquad \ldots\ldots\ldots\ldots(4.10)$$

$$FK_2O = 11.93\ T - 1.10\ SK \qquad \ldots\ldots\ldots\ldots(4.11)$$

where FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O respectively in kg ha^{-1} , T is the target of tuber yield in t ha^{-1} and SN, SP and SK are soil available N, P and K in kg ha^{-1} respectively .

The fertilizer recommendations based on the above equations are more quantitative, precise and meaningful because the combined use of soil and plant analysis is involved in it. Marschner (1986) and Koshino (1994) have emphasised the need for combined use of soil and plant analysis for recommending fertilizers for crops than one method alone.

With FYM, the equations are as given below:

$$FN = 12.10\ T - 0.74\ SN - 1.44\ ON \qquad \ldots\ldots\ldots\ldots(4.12)$$

$$F\ P_2O_5 = 5.04\ T - 2.02\ SP - 2.79\ OP \qquad \ldots\ldots\ldots\ldots(4.13)$$

$$FK_2O = 11.93\ T - 1.10\ SK - 1.58\ OK \qquad \ldots\ldots\ldots\ldots(4.14)$$

where ON, OP and OK are quantities of N, P and K supplied through organic manure in kg ha^{-1} . Similar fertilizer prescription equations for specific yield targets of rice in Kerala have been reported by Swadija *et. al.*,(1993) and KAU (1996).

The integrated use of organic manure and fertilizers will lead to a considerable saving in fertilizers as seen from the targeted yield equations with FYM. This is in conformity with the findings of Duraisamy *et. al.*, (1989), Prasad and Prasad (1993) and Santhi (1995). Organic manures build up soil fertility for fertilizers to be fruitful. The organics promote soil fertility in physical and biological terms for the inorganics to act with higher use efficiency. Substituting at least a part of fertilizer N with organics and biological sources will keep the ecology sound and help in sustainable agriculture.

Based on targeted yield equations, ready reckoners can be prepared for prescribing fertilizer doses either as inorganics alone or in combination with organics for specific yield targets at varying STVs keeping in view the availability of organic source and financial resource of the farmer.

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). From the point of view of soil-plant system, this approach is also unique in the sense that it provides the scientific basis for balanced fertilization not only between the fertilizer nutrients themselves but also that with the soil available nutrients. The sum of the available quantities from the soil and fertilizer together for the different nutrients should be in the same ratio in which they are actually needed by the crop and it is possible only by fertilizer application for targeted yield of crops (Ramamoorthy, 1993).

Fertilizer use and yield targets can be manipulated both for maintaining soil fertility and for obtaining higher profits from fertilizer investment. The estimate of fertilizer requirement for the assigned production targets in an area for different crops can be worked out based on yield targeting and nutrient index of soil fertility. Based on the efficiency of crops to utilise native and applied nutrients, fertilization of crops could be regulated so as to obtain high fertilizer use efficiency for a crop sequence. Under conditions of fertilizer scarcity or with limited resources, a farmer can obtain higher production by covering large area with lower yield targets (higher than yield levels normally obtained) than by applying the same quantity of fertilizers over smaller acreage with higher yield target (Ramamoorthy and Velayutham, 1974; Chand *et. al.*, 1984 and Velayutham *et. al.*, 1985).

4.2.7. Critical levels of soil test values

The soil test based fertilizer adjustment equations for specific yield targets also provide the means for calculating critical levels of nutrients in the soil above which response to fertilizer application cannot be expected for the indicated targets of yield (Randhawa and Velayutham, 1982, Chand *et. al.*, 1984 and Santhi, 1995). The critical levels of available N ($KMnO_4$-N), P (Bray-P) and K (NH_4OAc-K) in the laterite soil were calculated when fertilizers alone were used and under integrated use of organics and fertilizers for cassava. The results are presented in Table-30.

When fertilizers alone were used, the critical levels of available N, P and K were 245.3, 37.4 and 162.7 kg ha^{-1} respectively (Table-30) to achieve 15 t ha^{-1} of tuber yield. This means that no fertilizer need be applied above these STVs of available N, P and K to achieve an yield target of 15 t ha^{-1}. Similarly, the critical levels of

Table 30. Critical levels of soil test values in relation to fertilizer requirement for specific yield targets

Yield target (t ha^{-1})	STVs (kg ha^{-1}) beyond which fertilizer response is negligible								
	With fertilizers alone			With fertilizers + 6.25 t ha^{-1} FYM			With fertilizers + 12.5 t ha^{-1} FYM		
	Available N	Available P	Available K	Available N	Available P	Available K	Available N	Available P	Available K
15	245.3	37.4	162.7	196.6	26.1	147.7	148.0	14.8	132.8
20	327.0	49.9	216.9	278.4	38.6	202.0	229.7	27.3	187.0
25	408.8	62.4	271.1	360.1	51.1	256.2	311.5	39.8	241.2

available N, P and K were 327, 49.9 and 216.9 kg ha^{-1} respectively for 20 t ha^{-1} of yield target. The critical levels were increased to 408.8, 62.4 and 271.1 kg ha^{-1} of available N, P and K respectively when the tuber yield target was increased to 25 t ha^{-1}. So the critical level will be increased with increase in the yield target. Corroborative results have been reported by Chand *et. al.*, (1986) in green gram and Santhi (1995) in rice. Randhawa and Velayutham (1982) have also reported critical levels of STVs in relations to fertilizer requirements for different crops in different types of soils along with the yield levels the soil nutrients can support.

Under integrated use of organics and fertilizers, the critical STVs were reduced than when fertilizers alone were used (Table-30). The critical levels were further reduced with increase in the dose of organics (FYM). This in turn would result in saving of fertilizers. The contribution of N, P and K from FYM under integrated use of FYM and fertilizer have led to attaining of critical levels of nutrients in the soil well in advance as compared to that of fertilizer alone. This is in agreement with the findings of Santhi (1995).

4.3. Technology verification trial

The soil test based fertilizer prescription equationshave to be test verified in farmers' fields before recommending for large scale adoption. Hence technology verification trial was undertaken in the laterite soil in three farmers' fields at Koliyoor, Kalliyoor and Kakkamoola of Thiruvananthapuram district and Instructional farm, Vellayani.

The fertilizer doses for three yield targets of 15, 20 and 25 t ha^{-1} of cassava tuber were compared with POP recommendation of fertilizers (KAU, 1993) and fertilizer recommendation by the Soil Testing Laboratory, Thiruvananthapuram. The fertilizer doses for different yield targets, based on soil tests were worked out using targeted yield equations derived from the STCR experiment (4.12. to 4.14).

4.3.1. Soil Analysis

The soil samples from all locations were analysed to work out the fertilizer dose and the results are furnished in Table-31.

The soils were acidic with pH of 4.5 to 5.2. The soils were

Plate 11. Technology verification trial at Instructional Farm, Vellayani.

Plate 12. Technology verification trial in farmer's field at Koliyoor.


EXPT.III TECHNOLOGY
VERIFICATION TRIAL
IN CASSAVA VAR M4


EXPT.III TECHNOLOGY
VERIFICATION TRIAL
IN CASSAVA VAR M4

Plate 13. Technology verification trial in farmer's field at Kalliyoor.

Plate 14. Technology verification trial in farmer's field at Kakkamoola.


EXPT.III TECHNOLOGY
VERIFICATION TRIAL
IN CASSAVA VAR.M4


EXPT.III TECHNOLOGY
VERIFICATION TRIAL
IN CASSAVA VAR.M4

low in organic carbon (0.17 to 0.27%) and available N (109.8 to 200.7 kg ha^{-1}) at all locations. The field at Koliyoor was medium in available P (13.5 kg ha^{-1}) while all others were high in available P (25.5 to 42 kg ha^{-1}) status. With respect to K, the field at Koliyoor was low in available K (72 kg ha^{-1}), while those at Koliyoor and Vellayani were medium (192 and 120 kg ha^{-1} respectively) and the field at Kakkamoola was high in available K (360 kg ha^{-1}) content.

Table 31. Soil analysis prior to technology verification trial

Location	pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Koliyoor	5.0	0.27	200.7	13.5	72
Kalliyoor	4.5	0.22	150.5	25.5	192
Kakkamoola	5.2	0.20	109.8	33.0	360
Vellayani	4.5	0.17	156.8	42.0	120

4.3.2. Fertilizer prescription

The fertilizer doses fixed for different treatments are presented in Table-32. The fertilizer doses for different yield targets were worked out using targeted yield equations (4.12 to 4.14) based

Table 32. Fertilizer doses for technology verification trial

Location	Treatments	Fertilizer doses (kg ha^{-1})		
		N	P_2O_5	K_2O
Koliyoor	POP	50.00	50.00	50.00
	STL	59.00	47.00	59.00
	15 (t ha^{-1})	-	25.33	83.25
	20 (t ha^{-1})	57.48	50.53	142.90
	25 (t ha^{-1})	117.98	75.73	202.55
Kalliyoor	POP	50.00	50.00	50.00
	STL	59.00	24.00	42.00
	15 (t ha^{-1})	34.13	1.09	-
	20 (t ha^{-1})	94.63	26.29	10.90
	25 (t ha^{-1})	155.13	51.49	70.55
Kakkamoola	POP	50.00	50.00	50.00
	STL	59.00	13.00	13.00
	15 (t ha^{-1})	64.25	-	-
	20 (t ha^{-1})	124.75	11.14	-
	25 (t ha^{-1})	185.25	36.34	-
Vellayani	POP	50.00	50.00	50.00
	STL	59.00	13.00	42.00
	15 (t ha^{-1})	29.47	-	30.45
	20 (t ha^{-1})	89.97	-	90.10
	25 (t ha^{-1})	150.47	18.16	149.75

on soil tests.

Since the effects of F_1 (6.25 t ha^{-1}) and F_2 (12.5 t ha^{-1}) levels of FYM on tuber yield of cassava were found to be on par (Table-23) and also the average response per ton of FYM was more at F_1 level than at F_2 level as observed in the main experiment (Table-24), the FYM dose for the verification trial was fixed as 6.25 t ha^{-1}. The fertilizer doses for different yield targets were fixed after deducting the contribution of nutrients from FYM. On an average the FYM used for verification trial contained 0.4, 0.3 and 0.2% of N, P_2O_5 and K_2O respectively.

The STL recommendation for N was higher than that of the POP recommendation of 50 kg ha^{-1} at all locations since the fields were low in organic carbon and available N. The recommendation was 59 kg N ha^{-1} for all fields which tested 0.17 to 0.27% organic carbon and 109.8 to 200.7 kg ha^{-1} of available N.

The STL recommendation for P was slightly reduced than POP recommendation of 50 kg P_2O_5 ha^{-1} at Koliyoor (47 kg P_2O_5 ha^{-1}) where available P was medium and considerably reduced at other locations where available P in soil was high. For fields testing 33 and 42 kg available P ha^{-1} at Kakkamoola and Vellayani respectively, the STL has recommended the same quantity of fertilizer P (13 kg P_2O_5 ha^{-1}).

With respect to K, the STL recommendation was higher than POP recommendation of 50 kg K_2O ha^{-1} at Koliyoor (59 kg K_2O ha^{-1}) where available K was low and considerably reduced to 13 kg K_2O ha^{-1} at Kakkamoola where available K content was high. At Kalliyoor and Vellayani, the STL recommendation was same (42 kg K_2O ha^{-1}) even though the STVs for available K were 192 and 120 kg ha^{-1}.

Although the STL could modify the fertilizer doses depending on soil nutrient status, it is not possible to precisely quantify the fertilizer requirement for varying STVs falling within the same fertility class or to quantify the fertilizer requirement for specific yield targets.

A critical study of the data in Table-32 indicates that the fertilizer requirement decreased with increase in STVs and increased with increase in yield targeted as established in the AICRP for Investigations on STCR Correlation.

The fertilizer dose for N varied from 0 to 64.25 kg ha^{-1} for an yield target of 15 t ha $^{-1}$ with STVs for available N varying from 109.8 to 200.7 kg ha $^{-1}$ (Table-32). The critical level for available N with 6.25 t ha^{-1} FYM for an yield target of 15 t ha^{-1} has been calculated as 196.6 kg ha $^{-1}$ (Table-30). Hence no fertilizer N was required at Koliyoor for the yield target of 15 kg ha $^{-1}$ where available N was 200.7 kg ha $^{-1}$. With 6.25 t ha $^{-1}$ of FYM, the critical levels of STVs of available N for yield targets of 20 and 25 t ha $^{-1}$ were 278.4 and 360.1 kg ha^{-1}. In all locations, the available N was lower than these values and hence fertilizer N was applied to achieve 20 and 25 t ha $^{-1}$ of tuber yield. For the yield targets of 20 and 25 t ha $^{-1}$, the fertilizer dose for N varied from 57.48 to 124.75 and 117.98 to 185.25 kg ha $^{-1}$ depending on the content of available N in the soil.

The fertilizer dose for P varied from 0 to 25.33, 0 to 50.53 and 18.16 to 75.73 kg P_2O_5 ha^{-1} for the yield targets of 15, 20 and 25 t ha^{-1} (Table- 32). The critical STV for available P with 6.25 t ha^{-1} of FYM for the yield target of 15 t ha $^{-1}$ was 26.1 kg ha $^{-1}$ (Table 30). Hence no P was required to apply at Kakkamoola and Vellayani. For the target of 20 t ha $^{-1}$ of tuber yield, the critical value for available P has been worked out as 38.6 kg ha $^{-1}$ and hence no fertilizer P was applied at Vellayani for this yield target. Since the available P was less than the critical value of 51.1 kg ha $^{-1}$ for 25 t ha $^{-1}$ of yield target, fertilizer P was applied at all locations depending on available P status.

The fertilizer K requirements varied from 0-83.25, 0-142.90 and 0-202.55 kg K_2O ha $^{-1}$ for the yield targets of 15, 20 and 25 t ha $^{-1}$ depending on the content of available K in each location (Table-32). No fertilizer K was applied at Kalliyoor for 15 t ha $^{-1}$ of yield target since available K was more than the critical value of 147.7 kg ha $^{-1}$ (Table-30). Since the available K content of the field at Kakkamoola was more than the critical STVs for available K for yield target of 15, 20 or 25 t ha $^{-1}$, no fertilizer K was applied for any yield target.

The fertilizer doses for N, P and K for specific yield targets based on targeted yield approach varied at all locations depending on the STVs. Hence fertilizer recommendation based on this approach is site specific, quantitative and more precise than the STL recommendation. It enables the balanced use of soil and fertilizer nutrients. In balanced fertilizer use, the nutrient ratios are dynamic and vary not only with the STVs but also with a change in the yield target (Tandon, 1976).

4.3.3. Tuber yield achieved

The tuber yield obtained due to treatments from each location and the mean values are given in Table-33.

The results in Table-33 clearly brings out the importance of soil testing for efficient fertilizer use to achieve higher crop production. Among the treatments, the POP recommendation recorded the lowest tuber yield. This is in agreement with the finding of Kadam *et. al.*, (1985) in groundnut at Rahuri. The soil test based fertilizer recommendation arrived at by using the fertilizer prescription equations for an yield target of 25 t ha^{-1} of cassava tubers registered the highest tuber yield at all locations except Koliyoor wherein the yield target of 20 t ha^{-1} registered the highest tuber yield. Among the locations, Koliyoor recorded the highest yield for all the treatments except for the yield target of 25 t ha^{-1} for which Vellayani recorded the highest tuber yield.

The mean tuber yield obtained varied from 14.32 to 22.39 t ha^{-1} (Table-33) with the highest for the yield target of 25 t ha^{-1} and the lowest for the POP recommendation (Fig. II). An increase of 11.5% in the yield of cassava in laterite soil has been reported earlier for

Table 33. Tuber yield of cassava as influenced by different fertilizer doses

Treatment	Tuber yield (t ha^{-1})					Achievement (%)	χ^2 test
	Koliyoor	Kalliyoor	Kakkamoola	Vellayani	Mean		
POP	16.00	10.22	15.56	15.48	14.32	-	-
STL	17.90	11.51	16.22	16.13	15.44	-	-
15 (t ha^{-1})	16.78	13.77	16.56	16.49	15.98	106.53	0.62 ns
20 (t ha^{-1})	22.67	18.70	21.78	21.83	21.25	106.3	0.77 ns
25 (t ha^{-1})	20.35	20.80	23.33	25.06	22.39	89.6	1.68 ns
				CD	2.468		

ns - not significant

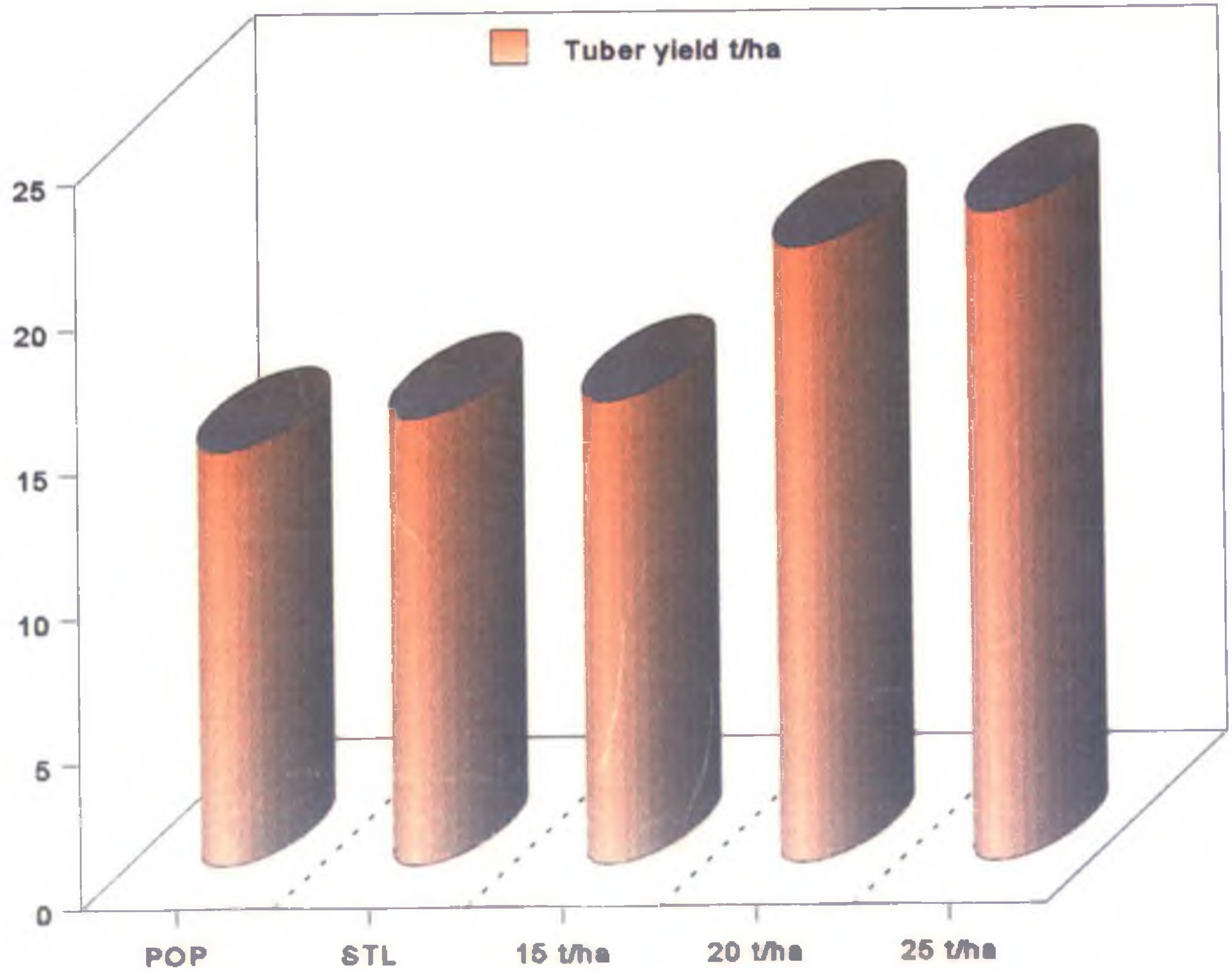

Fig. 11. Tuber yield of cassava as influenced by different fertilizer doses.

(1989) and Baskaran *et. al.*, (1994) could also achieve higher yield targets in crops like rice, groundnut, ragi and tapioca.

4.3.4. Economics of fertilizer application

The economics of fertilizer application in terms of net income, benefit cost ratio (BCR), net returns per rupee invested and returns per rupee invested on fertilizers at each location are given in Table-34. The mean values of economic parameters are given in Table-35.

The economics of cassava cultivation was worked out considering the cost of cultivation (excluding the cost of fertilizers) as Rs. 22,500 per ha uniformly for all treatments, cost of one kg of fertilizer N, P_2O_5 and K_2O as Rs. 8.15, Rs. 11.25 and Rs. 7 respectively and cost of tuber as Rs. 3 per kg.

The STL recommendation registered higher net income, BCR and net returns per rupee invested than the POP recommendation at all locations (Table-34). Similar results have been reported by KAU (1992) and Swadija *et. al.*, (1993) in rice. The fertilizer doses based on

Table 34. Economic evaluation of different fertilizer doses for cassava at each location

Location	Treatments	Cost of fertilizers per ha (Rs.)	Net income per ha (Rs.)	BCR	Net returns per rupee invested (Rs.)	Returns per rupee invested on fertilizers (Rs.)
Koliyoor	POP	1320.00	28180	2.18	1.18	22.35
	STL	1422.60	33777	2.41	1.41	24.74
	15 (t ha^{-1})	862.25	30978	2.33	1.33	36.93
	20 (t ha^{-1})	2047.45	47463	2.93	1.93	24.18
	25 (t ha^{-1})	3237.70	39312	2.56	1.53	13.14
Kalliyoor	POP	1320.00	10840	1.46	0.46	9.21
	STL	1044.85	14985	1.64	0.64	15.34
	15 (t ha^{-1})	288.35	25222	1.99	0.99	79.10
	20 (t ha^{-1})	1143.75	36456	2.54	1.54	32.87
	25 (t ha^{-1})	2345.25	41555	2.67	1.67	18.72
Kakkamoola	POP	1320.00	26860	2.13	1.13	21.35
	STL	718.10	29442	2.27	1.27	42.00
	15 (t ha^{-1})	521.60	30658	2.33	1.33	59.78
	20 (t ha^{-1})	1142.50	45697	2.93	1.93	41.00
	25 (t ha^{-1})	1912.75	45577	2.87	1.87	24.83
Vellayani	POP	1320.00	26620	2.12	1.12	21.17
	STL	921.10	28969	2.24	1.24	32.45
	15 (t ha^{-1})	461.50	30508	2.34	1.34	67.11
	20 (t ha^{-1})	1363.50	45626	2.91	1.91	34.46
	25 (t ha^{-1})	2483.15	54197	3.17	2.17	22.83

Table 35. Economics of cassava cultivation as influenced by different fertilizer doses

Treatment	Mean values			
	Net income per ha (Rs.)	BCR	Net returns per rupee invested (Rs.)	Returns per rupee invested on fertilizers (Rs.)
POP	23125	1.97	0.97	18.52
STL	26793	2.14	1.14	28.63
15 (t ha^{-1})	28666	2.25	1.25	60.73
20 (t ha^{-1})	43810	2.83	1.83	33.13
25 (t ha^{-1})	45160	2.82	1.81	19.88
CD		0.313	0.323	18.440

targeted yield equations for all yield targets recorded higher net income, BCR and net returns per rupee invested over the STL and POP recommendations except at Koliyoor. At Koliyoor, the fertilizer dose for the yield target of 15 t ha^{-1} recorded lower net income, BCR and net returns per rupee than the STL recommendation but higher than the POP recommendation. The fertilizer doses for 20 and 25 t ha^{-1} showed higher net income, BCR and net returns per rupee invested than the STL and POP recommendations. The available P and K status of the field at

Koliyoor was low and hence more fertilizers were needed to get the yield target of 15 t ha^{-1}. However, the yield obtained was proportionate to fertilizer doses applied at higher yield targets and hence the increase in economic parameters was also noticed.

The superiority of fertilizer dose based on targeted yield approach over the general recommended dose or blanket recommendation in recording higher net returns and BCR has been highlighted by Tandon (1976), Doharey *et. al.*, (1977), Chand *et. al.*, (1984), Dev *et. al.*, (1985), Kadam *et. al.*, (1985) and Raniperumal *et. al.*, (1986 and 1987). The blanket recommendation has lead to an indiscriminate use of fertilizers as reported by Doharey *et. al.*, (1977).

The returns per rupee invested on fertilizers was the highest for the lower yield target of 15 t ha^{-1} at all locations and the lowest for the POP recommendation except at Koliyoor (Table-34). The STL recommendation has lead to lower returns per rupee invested on fertilizers than all the yield targets at Kalliyoor, higher than the yield target of 20 and 25 t ha^{-1} at Koliyoor and Kakkamoola and higher than the yield target of 25 t ha^{-1} at Vellayani.

The statistical analysis of the data on economics of fertilizer application (Table-35) clearly brings out the cost effectiveness of targeted yield approach for fertilizer prescription in conjunction with organics (Fig. 12) as reported by Raniperumal *et. al.*, (1988), Duraisamy *et. al.*, (1989) and Baskaran *et. al.*, (1994).

Raniperumal *et. al.*, (1986 and 1987) and Verma *et. al.*, (1987) have also reported that the BCR tended to decrease with increase in yield targets. In the present study, the BCR showed an increasing trend upto the highest yield target of 25 t ha^{-1} at Kalliyoor and Vellayani and only upto 20 t ha^{-1} at Koliyoor and Kakkamoola.

The fertilizer doses for the yield targets of 20 and 25 t ha^{-1} were on par and significantly superior to other treatments with respect to BCR and net returns per rupee invested (Table-35). All other treatments were found to be on par. Higher BCR in all the yield target treatments as compared to blanket recommendation has been reported by Raniperumal *et. al.*, (1986), Verma *et. al.*, (1987) and Duraisamy *et. al.*, (1989).

The return per rupee invested on fertilizers obtained with the

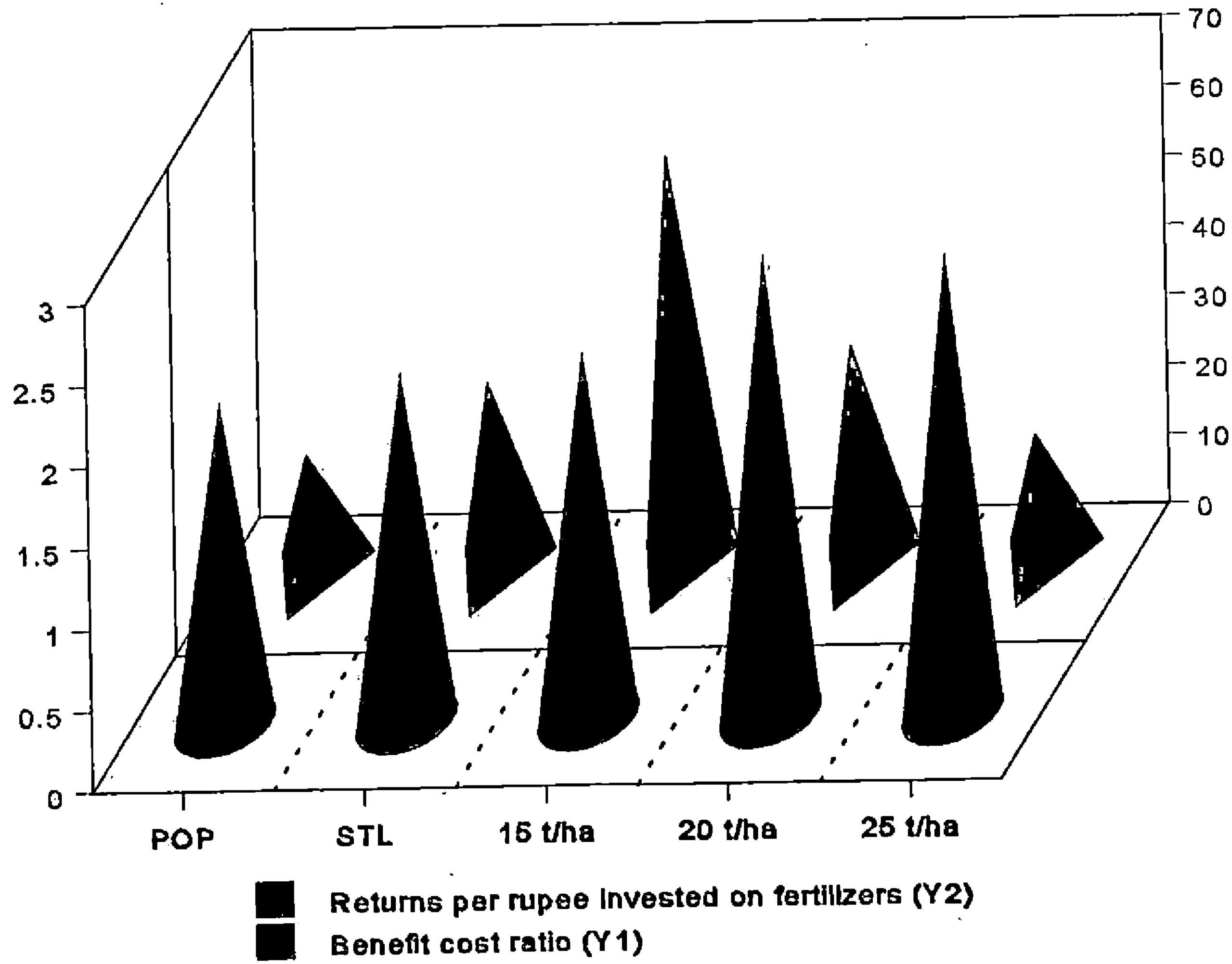

Fig. 12. Economics of cassava cultivation as influenced by different fertilizer doses.

lowest yield target of 15 t ha^{-1} (Rs.60.73) was significantly higher than those with all other treatments (Table-35). With the cost of cultivation excluding the cost of fertilizers remaining the same, the lower yield target of 15 t ha^{-1} could be achieved in all locations at a cost of fertilizers ranging from Rs.288.35 to 862.25 (Table-34) which was lower than all other treatments. This has led to the highest returns on fertilizer investment at lower yield target of 15 t ha^{-1}. This is in agreement with the findings of Swadija *et. al.*, (1993) in rice.

According to the law of minimum, the actual yield obtained is that given by the limiting nutrient. Therefore, when fertilizer is applied for lower yield targets, the excess of soil nutrients over and above the yield limiting nutrient which are unutilised by the crop under unfertilized conditions contribute favourably, with no extra cost of input and thereby increase the per cent profitability. Therefore, the output to input ratio would be the highest under conditions of fertilizer application for lower yield targets. In this way, lower yield targets in fact will also result in greater returns from fertilizer investment (Singh and Sharma, 1978). Although the highest return per rupee on fertilizers was obtained at lower yield target (15 t ha^{-1}), the highest net income was observed under the highest yield target (25 t ha^{-1}). Corroborative results have been reported by Swadija *et. al.*, (1993) in rice.

If maximum profit per ha (in terms of net income, BCR and net returns per rupee) is the motive the farmer can adopt fertilizer dose for the yield target of 20 t ha^{-1} and for the highest returns on fertilizer investment he can adopt fertilizer dose for 15 t ha^{-1}. The marginal farmers can adopt the fertilizer dose for lower yield target for which investment is comparatively lesser and achieve maximum benefit out of his limited resources. The tuber yield obtained and the economic parameters like BCR and net returns per rupee invested were on par with the yield target of 20 and 25 t ha^{-1} (Table-33 and 35). Hence progressive and financially sound farmers can apply fertilizers based on soil tests for the yield target of 20 t ha^{-1} and achieve higher tuber production in the region. Thus the fertilizer dose can be adjusted in accordance with the specific objective and available resources with the farmer.

4.3.5. Sustenance of soil fertility

The data on post-harvest soil fertility status of individual locations is given in Table-36. It could be observed that the variation in

Table 36. Post harvest soil fertility status at each location

Location / Treatment	pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Koliyoor					
POP	5.0	0.26	206.98	45	100
STL	4.5	0.24	210.11	45	160
15 (t ha^{-1})	4.5	0.26	210.11	51	80
20 (t ha^{-1})	5.0	0.24	213.25	45	160
25 (t ha^{-1})	4.8	0.26	216.38	44	180
Kalliyoor					
POP	4.5	0.24	166.21	42	100
STL	4.3	0.22	166.21	39	64
15 (t ha^{-1})	4.8	0.22	169.34	45	120
20 (t ha^{-1})	4.4	0.26	175.62	33	68
25 (t ha^{-1})	4.3	0.26	181.89	44	48
Kakkamoola					
POP	5.8	0.24	141.12	83	200
STL	5.5	0.26	141.12	63	200
15 (t ha^{-1})	5.2	0.24	141.12	55	140
20 (t ha^{-1})	5.1	0.27	144.26	48	200
25 (t ha^{-1})	5.3	0.26	147.39	60	160
Vellayani					
POP	4.5	0.26	175.62	63	100
STL	4.6	0.24	175.62	60	72
15 (t ha^{-1})	4.5	0.26	178.75	63	120
20 (t ha^{-1})	4.2	0.26	181.89	63	100
25 (t ha^{-1})	4.5	0.24	185.02	60	64

soil fertility status was not appreciable among the treatments. The results also revealed that the soil fertility status was not altered considerably by following targeted yield concept of fertilizer application as reported by Raniperumal *et. al.*, (1986 and 1987).

In general, there was an increase in post-harvest available N status, build up of available P and a reduction in available K status. Rajendran *et. al.*, (1976) have reported the depletion of soil available K at a higher rate at lower levels of K fertilization for cassava.

The targeted yield approach takes into account not only the desired yield level but also the nutrient removal associated with it. Thus it is evident that the fertilizer application based on targeted yield approach is not only helpful in getting desired yield targets and higher net income, BCR and net returns per rupee invested but also takes care of the maintenance of soil fertility to support sustained crop production.

SUMMARY

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With a view to establish soil test crop response correlation for soil test based balanced fertilizer prescription for cassava var. M-4 in laterite soils of Kerala, an investigation was undertaken at the College of Agriculture, Vellayani. The field investigation consisted of fertility gradient experiment, STCR experiment using fertilizer and organic manure and technology verification trial. The technique of inductive methodology developed by Ramamoorthy (1968) was adopted for this investigation.

The fertility gradient experiment was conducted during April-May 1994 in the Instructional farm, Vellayani. 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. African Tall.

The fodder yield and nutrient uptake by the gradient crop (fodder maize) increased progressively from Strip I to IV. The soil nutrient status after the gradient experiment showed an increasing trend from Strip I to IV.

After the harvest of the gradient crop, the STCR experiment was conducted in the same field during June '94 - March '95 using the test crop, cassava var. M-4. The treatments consisted of factorial combinations of four levels of N (0, 50, 100 and 150 kg ha^{-1}), three levels of P (0, 50 and 100 kg P_2O_5 ha^{-1}) and five levels of K (0, 50, 100, 150 and 200 kg K_2O ha^{-1}) along with three levels of FYM (0, 6.25 and 12.50 t ha^{-1}) fitted in a response surface design.

The salient results of the experiment are summarised below.

The tuber yield showed a declining trend at higher fertility levels. The average tuber yield obtained from Strip-I, II, III and IV were 14.21, 21.35, 19.56 and 16.78 t ha^{-1} respectively. The average top yield (leaves + stem) showed a progressive increase from 9.41 t ha^{-1} in Strip-I to 26.08 in Strip-IV. Utilisation index showed the same trend as that of tuber yield. The mean values were 1.61, 1.72, 0.96 and 0.66 in Strip-I, II, III and IV respectively.

Uptake of N, P and K increased progressively from Strip-I to IV. The mean N uptake in Strip-I, II, III and IV were 81.17, 116.35, 152.93 and 172.72 kg ha^{-1} respectively. Average P uptake values were 9.68, 21.44, 22.78 and 24.44 kg ha^{-1} in Strip-I to IV. The mean values of K uptake in Strip-I to IV were 49.17, 93.50, 142.82 and 168.14 kg ha^{-1} respectively.

Multiple regression model calibrated with yield as dependent variable and STVs for available N, P and K and applied nutrients (FYM and fertilizers) as independent variables had 72% predictability. Among the three nutrients, N showed the **normal** or (+,-,-) type of response and hence optimisation of only fertilizer N was done.

The fertilizer adjustment equation for varying levels of soil available N for maximum tuber yield (t ha^{-1}) of cassava in laterite soil was derived as **FN = 136.6 - 0.2** SN where FN is fertilizer N (kg ha^{-1}), SN is available N (kg ha^{-1}) in soil. For economic tuber production the equation becomes **FN=136.6 - 0.2 SN - R** where R is the ratio of cost of one kg of fertilizer N to price of one kg of tuber.

Similar multiple regression model calibrated with organic carbon as a measure of soil N had 70% predictability. In this model also, N showed the **normal** or (+,-,-) type of response behaviour and optimisation of fertilizer N was done.

For varying organic carbon% (OC) in the soil, the fertilizer adjustment equation for N becomes **FN = 226.13 - 378.13 OC** for maximum tuber yield and **FN = 226.13 - 378.13 OC - 1.25 R** for economic tuber yield.

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

The nutrient requirements of cassava var. M-4 were estimated to be 6.58, 2.37 and 6.28 kg N, P_2O_5 and K_2O respectively to produce one ton of tuber.

In the laterite soil, the efficiencies of contribution of nutrients from the soil for cassava were calculated as 40.17, 41.33 and 48.60% N, P_2O_5 and K_2O respectively.

The fertilizer efficiencies were worked out as 54.38, 47 and 52.65% N, P_2O_5 and K_2O respectively for cassava in laterite soil.

The efficiencies of contribution of nutrients from FYM for cassava in laterite soil were calculated as 78.24, 57.33 and 69.66% N, P_2O_5 and K_2O respectively.

The fertilizer prescription equations for specific yield targets of cassava var. M-4 in laterite soil were derived as given below.

Without FYM

$$FN = 12.10\ T - 0.74\ SN$$

$$FP_2O_5 = 5.04\ T - 2.02\ SP$$

$$FK_2O = 11.93\ T - 1.10\ SK$$

With FYM

$$FN = 12.10\ T - 0.74\ SN - 1.44\ ON$$

$$FP_2O_5 = 5.04\ T - 2.02\ SP - 2.79\ OP$$

$$FK_2O = 11.93\ T - 1.10\ SK - 1.58\ OK$$

where FN, F P_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O respectively in kg ha^{-1}, T is the target of tuber yield in t ha^{-1}, SN, SP and SK are soil available N, P and K in kg ha^{-1} respectively and ON, OP and OK are quantities of N, P and K supplied through organic manure in kg ha^{-1}.

The technology verification trial was undertaken during June '96 - March '97 in the laterite soil in three farmers' fields in Thiruvananthapuram district and also in the Instructional Farm, Vellayani. The treatments consisted of Package of Practices recommendation of fertilizer, fertilizer recommendation by the Soil Testing Laboratory and fertilizer doses for yield targets of 15, 20 and 25 t ha^{-1} along with a uniform dose of 6.25 t ha^{-1} of FYM for all treatments.

The important findings from the verification trial are furnished below.

Among the treatments, the POP recommendation produced the lowest tuber yield emphasising the need for site specific fertilizer recommendation based on soil tests.

The fertilizer dose for the yield target of 25 t ha^{-1} recorded the highest tuber yield at all locations except Koliyoor where the yield target of 20 t ha^{-1} produced the highest tuber yield.

Among the locations, Koliyoor recorded the highest tuber yield for all treatments except for the yield target of 25 t ha^{-1} for which Vellayani recorded the highest tuber yield.

The yield targets of 15 and 20 t ha^{-1} recorded more than cent per cent achievement and the yield target of 25 t ha^{-1} recorded about 90%

achievement. χ^2 test was not significant at all yield targets indicating no significant difference between yields targeted and achieved.

The tuber yields obtained with fertilizer doses for the yield targets of 20 and 25 t ha^{-1} were on par which were superior to other treatments. The economic parameters like BCR and net returns per rupee invested also showed the same trend.

At all locations, the POP recommendation registered the lowest net income, BCR and net returns per rupee invested.

The fertilizer dose based on targeted yield equations recorded higher net income, BCR and net returns per rupee invested over the STL recommendation.

BCR and net returns per rupee invested increased with increase in yield target at Vellayani and Kalliyoor and decreased at the highest yield target of 25 t ha^{-1} at Koliyoor and Kakkamoola.

The fertilizer dose for the yield target of 15 t ha^{-1} recorded significantly higher returns per rupee invested on fertilizers than other treatments. The lowest return per rupee invested on fertilizers was produced by the POP recommendation.

The study has revealed the superiority of fertilizer application based on targeted yield approach over the semi-quantitative approach employed in the soil testing laboratories and generalised state level Package of Practices recommendation for the crop. The fertilizer dose can be adjusted based on the specific objective and available resources of the farmer.

Future line of work

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 cassava under integrated nutrient supply system, that too in a cropping sequence.
3. Attempts may be done to predict post harvest soil fertility changes on the basis of which fertilizer dose for the next crop in the cropping sequence can be worked without further soil tests.
4. The research may be directed towards establishing 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.

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* original not seen

APPENDICES

Appendix-I.

Weather parameters from April '94 to March '95

Period	Mean Temperature °C		Mean relative humidity %	Total rainfall cm	No. of rainy days
	Maximum	Minimum			
Apr. 1994	31.9	25.1	83.2	7.2	10
May. 1994	32.0	26.2	82.6	26.4	9
Jun. 1994	28.9	23.8	85.5	22.7	21
Jul. 1994	28.7	23.1	83.8	23.9	17
Aug. 1994	29.3	22.5	84.3	21.1	14
Sep. 1994	30.2	24.1	87.4	6.9	6
Oct. 1994	29.7	23.4	85.6	36.5	18
Nov. 1994	30.4	23.4	83.6	12.4	9
Dec. 1994	31.2	22.2	81.4	0.9	1
Jan. 1995	31.3	22.6	77.0	0.8	1
Feb. 1995	32.0	23.1	71.7	-	-
Mar. 1995	32.7	23.7	72.0	0.5	3

Appendix-II.

Weather parameters from June '96 to March '97

Period	Mean Temperature °C		Mean relative humidity %	Total rainfall cm	No. of rainy days
	Maximum	Minimum			
Jun. 1996	29.8	22.0	81.2	25.8	16
Jul. 1996	28.6	21.5	83.2	17.3	18
Aug. 1996	29.3	21.8	83.1	10.7	18
Sep. 1996	30.1	23.2	82.5	16.2	15
Oct. 1996	30.8	22.8	82.5	26.8	16
Nov. 1996	30.6	22.5	80.5	9.0	17
Dec. 1996	31.1	21.6	81.1	9.8	10
Jan. 1997	32.3	20.6	75.5	-	-
Feb. 1997	33.0	21.0	70.9	-	-
Mar. 1997	33.5	23.1	73.8	0.5	2

Appendix-III.

Top (leaves+stem) yield of cassava (t ha^{-1}) as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	2.76	0	6.06	0	17.27	0	21.74
0 0 0	0	4.46	0	7.30	0	15.71	0	22.55
0 0 0	1	6.93	1	11.87	1	16.54	1	23.11
0 0 0	2	10.53	2	12.76	2	20.63	2	29.01
0 0 1	1	6.28	0	6.00	2	26.96	0	17.26
1 0 1	1	6.92	0	10.77	0	18.89	2	22.49
1 1 1	1	6.40	2	10.70	0	18.22	0	31.14
0 0 2	1	6.79	0	7.78	0	18.48	2	26.12
0 1 2	1	7.00	2	12.78	0	14.24	0	24.91
1 0 2	0	5.07	2	13.09	1	19.34	0	18.20
1 1 2	0	5.39	2	12.75	1	29.58	0	20.37
2 0 2	0	6.71	0	10.13	2	20.74	1	26.19
2 1 2	0	6.62	1	13.03	0	17.44	2	27.13
2 2 2	0	6.99	1	18.78	2	22.72	0	25.28
0 0 3	2	13.51	0	6.67	1	29.91	0	26.60
1 1 3	2	13.39	0	10.77	0	24.70	1	29.65
2 2 3	0	11.13	2	17.11	0	25.10	1	29.85
3 0 3	0	14.45	1	14.04	2	19.59	0	25.39
3 1 3	2	20.48	0	16.61	0	15.80	1	27.33
3 2 3	0	6.57	0	13.94	1	32.51	2	32.80
2 1 4	0	11.15	1	16.37	0	20.51	2	34.71
2 2 4	0	10.77	1	18.45	2	17.32	0	26.64
3 1 4	2	20.27	0	16.84	1	25.45	0	31.18
3 2 4	2	15.39	0	15.09	0	29.73	1	26.20

Appendix-IV.

Utilisation index as influenced by available and applied nutrients

Treatments N P K	FYM	Strip I	FYM	Strip II	FYM	Strip III	FYM	Strip IV
0 0 0	0	1.65	0	1.57	0	0.77	0	0.47
0 0 0	0	1.17	0	1.45	0	0.79	0	0.34
0 0 0	1	1.36	1	1.47	1	1.38	1	0.62
0 0 0	2	1.11	2	1.68	2	0.88	2	0.74
0 0 1	1	1.66	0	1.62	2	0.98	0	0.61
1 0 1	1	1.65	0	1.59	0	0.76	2	0.65
1 1 1	1	1.85	2	2.24	0	1.00	0	0.71
0 0 2	1	1.68	0	1.90	0	1.09	2	0.81
0 1 2	1	1.66	2	1.95	0	0.95	0	0.46
1 0 2	0	1.78	2	1.88	1	1.19	0	0.72
1 1 2	0	1.65	2	2.00	1	0.75	0	0.87
2 0 2	0	2.21	0	1.77	2	0.95	1	0.66
2 1 2	0	1.94	1	1.76	0	1.18	2	0.55
2 2 2	0	2.42	1	1.35	2	1.07	0	0.74
0 0 3	2	1.35	0	1.82	1	0.93	0	0.67
1 1 3	2	1.56	0	2.04	0	0.98	1	0.64
2 2 3	0	1.83	2	1.86	0	0.97	1	0.86
3 0 3	0	1.31	1	1.53	2	0.87	0	0.68
3 1 3	2	1.13	0	1.82	0	0.93	1	0.66
3 2 3	0	2.15	0	1.96	1	0.71	2	0.75
2 1 4	0	1.61	1	1.54	0	1.24	2	0.64
2 2 4	0	1.90	1	1.41	2	1.24	0	0.65
3 1 4	2	1.01	0	1.51	1	0.97	0	0.85
3 2 4	2	1.07	0	1.68	0	0.51	1	0.57

SOIL TEST CROP RESPONSE STUDIES IN CASSAVA IN LATERITE SOILS OF KERALA

BY

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ABSTRACT OF A THESIS
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ABSTRACT

An investigation was undertaken at the College of Agriculture, Vellayani to establish soil test crop response correlation for soil test based balanced fertilizer prescription for cassava var. M-4 in laterite soils of Kerala. The field investigation consisted of fertility gradient experiment, STCR experiment and technology verification trial.

The fertility gradient experiment was conducted during April-May 1994 in the Instructional farm, Vellayani. 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. African Tall.

The STCR experiment was conducted in the same field during June '94-March '95 using the test crop, cassava var. M-4. The treatments consisted of factorial combinations of four levels of N (0, 50, 100 and 150 kg ha^{-1}), three levels of P (0, 50 and 100 kg P_2O_5 ha^{-1}) and five levels of K (0, 50, 100, 150 and 200 kg K_2O ha^{-1}) along with three levels of farmyard manure (0, 6.25 and 12.50 t ha^{-1}) 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 tuber yield (t ha^{-1}) of cassava in laterite soil was derived as **FN = 136.6 - 0.2 SN** where FN is fertilizer N (kg ha^{-1}) and SN is soil available N (kg ha^{-1}). The equation becomes **FN = 136.6 - 0.2 SN - R** for economic tuber production where R is the ratio of cost of one kg of fertilizer N to price of one kg of tuber.

At varying soil test values for organic carbon% (OC) the above equations become **FN = 226.13 - 378.13 OC** for maximum tuber yield and **FN = 226.13 - 378.13 OC - 1.25 R** for economic tuber yield.

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

The nutrient requirements of cassava var. M-4 were estimated to be 6.58, 2.37 and 6.28 kg N, P_2O_5 and K_2O respectively to produce one ton of tuber. In the laterite soil, the efficiencies of contribution of nutrients from the soil for cassava were calculated as 40.17, 41.33 and 48.60% N, P_2O_5 and K_2O respectively. The fertilizer efficiencies were worked out as 54.38, 47 and 52.65% N, P_2O_5 and K_2O respectively . The efficiencies of contribution of nutrients from farmyard manure were calculated as 78.24, 57.33 and 69.66% N, P_2O_5 and K_2O respectively.

From the above basic data, fertilizer prescription equations for specific yield targets of cassava var. M-4 in the laterite soil were derived as given below.

Without FYM

$$FN = 12.10\ T - 0.74\ SN$$
$$FP_2O_5 = 5.04\ T - 2.02\ SP$$
$$FK_2O = 11.93\ T - 1.10\ SK$$

With FYM

$$FN = 12.10\ T - 0.74\ SN - 1.44\ ON$$
$$F\ P_2O_5 = 5.04\ T - 2.02\ SP - 2.79\ OP$$
$$FK_2O = 11.93\ T - 1.10\ SK - 1.58\ OK$$

where FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O respectively in kg ha^{-1} , T is the target of tuber yield in t ha^{-1}, SN, SP and SK are soil available N, P and K in kg ha^{-1} respectively and ON, OP and OK are quantities of N, P and K supplied through organic manure in kg ha^{-1}.

The technology verification trial was undertaken during June '96-March '97 in the laterite soil in three farmers' fields in Thiruvananthapuram district and also in the Instructional Farm, Vellayani. The treatments consisted of Package of Practices recommendation for fertilizer, fertilizer recommendation by the Soil Testing Laboratory and fertilizer doses for the yield targets of 15, 20 and 25 t ha^{-1} along with a uniform dose of 6.25 t ha^{-1} of farmyard manure for all treatments.

The fertilizer doses based on targeted yield equations recorded higher tuber yield and net income, benefit cost ratio and net returns per rupee invested over the fertilizer recommendation by the Soil Testing Laboratory and Package of Practices recommendation emphasising the need for site specific recommendation based on soil tests.

The yield targets of 15 and 20 t ha^{-1} recorded more than cent per cent achievement and the yield target of 25 t ha^{-1} recorded about 90% achievement. Higher tuber yield, benefit cost ratio and net returns per rupee invested could be achieved for the yield target of 20 t ha^{-1}. The fertilizer dose for the yield target of 15 t ha^{-1} recorded the highest returns per rupee invested on fertilizers.

The study has revealed the superiority of fertilizer application based on targeted yield approach over the semi-quantitative approach employed in the soil testing laboratories and generalised state level Package of Practices recommendation for the crop. In this approach, the fertilizer dose can be adjusted in accordance with the specific objective and available resources of the farmer.