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Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala

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By

K. SAJNANATH

THESIS

Submitted for the partial fulfilment of
the requirement for the degree

DOCTOR OF PHILOSOPHY

Faculty of Agriculture
Kerala Agricultural University

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2011

DECLARATION

I hereby declare that the thesis entitled " **Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the 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, associateship, fellowship or similar title, of any other University or Society.

Vellanikkara,
20-06-2011.

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CERTIFICATE

Certified that this thesis, entitled **"Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala"** is a record of research work done independently by **K. Sajnanath,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

2/08/11

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(K. Sajnanath)

Dedicated

to

AICRP on STCR
Vellanikkara Centre

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Abbreviations

No.	*Abbreviations*		*Expansions*
1.	AICRP	:	All India Co-ordinated Research Project
2.	CEC	:	Cation exchange capacity
3.	EC	:	Electrical conductivity
4.	FGE	:	Fertility Gradient Experiment
5.	g	:	Gram
6.	ha	:	Hectare
7.	IARI	:	Indian Agricultural Research Institute
8.	ICAR	:	Indian Council of Agricultural Research
9.	K	:	Potassium (element)
10.	KAU	:	Kerala Agricultural University
11.	KFC	:	K - fixing capacity
12.	kg	:	Kilogram
13.	m	:	Metre
14.	M	:	Molar (Concentration)
15.	mg	:	Milligram
16.	ml	:	Millilitre
17.	N	:	Normal (Concentration)
18.	N	:	Nitrogen (element)
19.	OC	:	Organic carbon
20.	P	:	Phosphorus
21.	PFC	:	P - fixing capacity
22.	POP	:	Package of practices (Crops) of KAU
23.	RBD	:	Randomized block design
24.	STCR	:	Soil Test Crop Response
25.	STCR 1	:	Soil Test Crop Response for an yield target of 30 t/ha
26.	STCR 2	:	Soil Test Crop Response for an yield target of 35 t/ha
27.	STL	:	Soil testing laboratory recommendation
28.	STV	:	Soil test values
29.	t	:	Tonne
30.	T	:	Targetted yield
31.	TCE	:	Test Crop Experiment
32.	TNAU	:	Tamil Nadu Agricultural University
33.	VE	:	Verification Experiment

INTRODUCTION

INTRODUCTION

The term 'soil' is often expanded in the form as 'source of infinite life'. These resources have to be used on the basis of sound principles of resource management, so as to enhance productivity, prevent degradation and pollution and also to reduce the loss of good agricultural lands to non-farm purposes. The agricultural land use decisions are often carried out without any practice of need based use in the soil resources and resource analysis techniques.

Among the natural resources, soils are vital for sustenance of mankind. The need for rational use of this resource is more relevant now than ever before. Pressure on land is increasing due to multiplicity of uses to which it is put and the variety of needs it has to satisfy. The pressure on soil has resulted in overuse or misuse of these finite resources and thus we find ourselves landed in problems of ecology and environment. Any fruitful attempt on management and maintenance of soil health on sustainable basis should be based on the resource potential of soil. Further, crop suitability and productivity are products of fertility capability of the soil. Thus it becomes essential to know the soil parameters that will have an impact on crop production and other uses of the land. The process of improving the nutrient supplying power of soil by fertilizer application will be designed after soil testing is carried out.

Conventional methods of crop management depending on soil resources will not be fruitful since the management practices adopted for the last so many years led to a situation which is highly detrimental to the sustenance of the living organism in the soil. A typical soil should possess all characters that can be utilised by all land users i.e., both flora and fauna in the soil. However, a soil becomes healthy only when it is balanced with the sustenance of the above two sectors. In the context of crop production, detailed investigation of soil fertility parameters and interaction of nutrient elements are essential for efficient crop management in terms of nutrients.

An efficient fertilization means optimisation of soil nutrient replenishment with minimisation of nutrient losses to the environment (Maene, 2001). Continued use of unbalanced fertilizers result in depletion of soil nutrients provided through the fertilizers and consequent decline in fertilizer responses. For improving nutrient use efficiency the nutrient management programmes are to be based on soil properties, especially on its inherent capacity to supply nutrients to crop. The real balance for maximum yield is not that between the applied nutrients but that after taking into account the relative contribution from soil and fertilizer (Ramamoorthy, 1993). Soil test data should be correlated with nutrient uptake by crops for making efficient fertilizer recommendation. From this data, fertilizer prescription equations are derived for a particular crop in particular soil type. Then these equations are test verified in farmers' fields before large scale adoption. Such soil test based fertilizer recommendation avoids the wastage or under usage of fertilizers.

Soil testing is one of the best scientific means for quick and reliable determination of soil fertility status. Soil test crop response study in the field provides soil test calibration between the level of soil nutrients as determined in the laboratory and the crop response to fertilizers as observed in the field for predicting the fertilizer requirements of the crop. There are various methods for fertilizer recommendations; viz. general recommendation, (ii) based on soil fertility rating, (iii) based on critical level of available nutrient, (iv) based on nutrient index, (v) recommendation for a certain percentage of maximum yield, (vi) recommendation for economic yield, and (vii) targeted yield approach.

The fertilizer recommendations based on agronomic/semi-quantitative approaches or methods did not give expected yield responses and therefore a need was felt for refinement of fertilizer recommendations for varying soil test values for wide range of crop production. For this purpose the All India Co-ordinated Research Project on Soil Test Crop Response Correlation was started in 1967 by ICAR with the following objectives:

(i) To develop relationship between soil test and crop response to fertilizers and from the results thus obtained to provide the calibration for fertilizer recommendations based on soil testing,

(ii) To obtain/derive a basis for fertilizer recommendations for specific yield targets,

(iii) To evaluate the extent to which fertilizer requirements of the crops can be reduced in relation to conjoint use of organic manures, and

(iv) To derive a basis for making fertilizer recommendations for whole cropping sequence based on initial soil tests

Soil test crop response (STCR) approach is the study of quantitative relationship between soil test values, applied nutrients and resultant crop yield. This will enable to prescribe the nutrient requirements of the crôp to obtain a desired yield. Merits of this approach are (i) it ensures the achievement of desired yield target within ± 10% deviation under optimum management conditions, (ii) efficient use of fertilizers according to soil fertility and crop requirement ensures high profit and response to applied fertilizers and (ii) it offers wide choice of fixing appropriate yield target according to the availability of resources and soil fertility.

Cucumber (*Cucumis sativus L.*), belongs to the family Cucurbitaceae, commonly called as salad cucumber, is an upcoming important vegetable crop in Kerala. It is known as *'kakkari'* in local language and used primarily as fresh for salad and as cooked for vegetable preparations. Since it contains 95% water and very less carbohydrate, it is used largely by diabetic patients in their diet. It occupies predominant place in cultivation during the second crop season and in summer rice fallows of Kerala. The cultivation practices are almost similar to oriental pickling melon. The harvesting should be at the right stage of the crop for use as fresh ones.

The results of experiments from Kerala Agricultural University showed that the variety AAUC-2 is suitable to various agro-ecological situations prevalent in the state. The fertilizer recommendation for this crop is 70 kg nitrogen, 25 kg phosphorus and 25 kg potassium per hectare, apart from 20 to 25 tons of farmyard manure (KAU, 2007). Full quantity of farmyard manure, half dose of nitrogen and full doses of phosphorus and potassium have to be applied as basal dose. Remaining half dose of nitrogen is to be applied as top dressing in two equal split doses at vining and full blooming stages.

The present attempt was to explore the nutrient interaction aspects when the STCR approach was adopted for the cultivation of the crop.

A detailed inventory on the STCR method in cucumber and its consequent use of quantification of fertilizers for targeted yield with new technologies generated, would facilitate extrapolation of the technologies to other areas of similar soil characteristics within and outside the state. This would also help farmers in rational use of fertilizer resources for crop management and thus the environmental conditions will be in safe condition for sustainable production.

An interaction occurs when the response of one or a series of factors is modified by the effects of one or more factors. When this is between plant nutrients it is termed as nutrient interaction. When the response to two or more nutrients used together is greater, less and equal than the sum of their individual response, a positive, negative and no interaction respectively is said to have occurred. A balanced application of all the essential plant nutrients would result in balanced growth. This attempt will help the production sector to use threshold level of nutrient resources from the point of view of fertility management after considering the interaction properties of nutrients.

Therefore, this programme of research entitled 'Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala' was formulated with the following objectives:

(i) to arrive at fertilizer prescription methods based on soil test crop response experiments for cucumber,

(ii) to verify the derived prescription equation in farmers' fields,

(iii) to elucidate the nutrient interactions in soil plant system and

(iv) to suggest modifications for the refinement of this approach for a better fertilizer recommendation for targeted economic yield.

REVIEW OF LITERATURE

Soil fertility is one major component investigated all over the world in connection with crop production. When the practice of plant nutrition became important, the concepts of integrated nutrient management, nutrient use efficiency, soil test based nutrient supply, eco-friendly nutrient management etc. were projected with their relevance. In order to ensure balanced fertilization, the fertilizer should be applied on the basis of soil test values. Here it is necessary to have a balance between the nutrients that is supplied from the fertilizers and those already available from the soil in order to have an efficient and economic use of fertilizers. In the method of soil test crop response correlations, the nutrient interaction is also to be considered. The available literature on the areas pertaining to the current study has been scanned and collated hereunder. Since the crop under study is an upcoming one, the works carried out with above topics in other crops including cucurbitaceous ones are mostly pooled here.

2.1 Approaches in fertilizer recommendation based on soil testing

There are several reports on the fertilizer recommendation based on soil testing and interpretations from different parts of the country and from abroad. Some of the works are quoted below.

For making the soil testing as a predictive tool for fertilizer recommendation, many successful attempts have been made by the scientists in different parts of world. Literature on various approaches for soil test based fertilizer recommendation for crops and nutritional requirement of the various crops based on the fertilizer experiments are targeted yield approach (Truog, 1960), critical level approach (Cate and Nelson, 1965), inductive approach (Ramamoorthy *et al.*, 1967) are reviewed in this chapter. There are many different approaches and some of them are general / blanket recommendation, nutrient index approach (Parker *et al.*, 1967), deductive approaches (Colwell, 1968), regression analysis approach (Hanway, 1971), DRIS (Beaufils, 1973), ten-class system (Nambiar *et al.*, 1977). The maximum yield concept has also gained importance accordingly. According to this concept an economically viable maximum yield research system comprises of improved varieties, increased plant population, balanced use of N, P and K fertilizers, improved fertilizer placement, use of secondary and micronutrients etc. (Portch, 1988). Recent works in maximum yield research was reported from Kerala by Meerabai *et al.* (2001) in coconut and Susan (2003) in cassava. In the present study, importance is given to targeted yield approaches.

2.1.1 Nutrient Index Approach

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 was put forward by Parker *et al.* (1967). This is useful for formulating the area wise fertilizer recommendations. This soil fertility class based fertilizer recommendations are generally followed by soil testing laboratories in India for the practical reason that such grouping reduces the complexity of making recommendations.

The simplified method for studying the relation between STVs and percentage yield of the maximum was described by Cate and Nelson (1965). The critical limits of available nutrients are established by adopting graphical procedures (Cate and Nelson, 1965) and statistical procedure (Cate and Nelson, 1971) and linear response plateau (LRP) model (Anderson and Nelson, 1975). The difference between the soil types and limits of various crops were not taken into account in these calibrations (Reddy *et al.*, 1985). Biswas and Mukharjee (2000) stated that the quantity of fertilizer recommended on the basis of soil testing is somewhat arbitrary.

With the help of this approach, it was easy to determine soil test value beyond which fertilizer application is not required. It does not give information about how much fertilizer is to be applied in quantitative terms with different soil test values. Only probability of yield response can be predicted but not the actual yield. Therefore the yield concept is more suitable for micronutrients and not for macronutrients (Singh and Sharma, 1994).

2.1.2 Fertilizer Recommendation for certain percentage of maximum yield

Mitscherlich (1909) developed a model for expression of the growth rate for different levels of an essential immobile nutrient in the soil. He stated that the increase in yield per unit of the added nutrient was proportional to the difference between maximum attainable and the actual yield. Bray (1948) modified the concept by introducing efficiency coefficients to soil test and applied form of nutrients and hence it was called Mitscherlich - Bray model.

In Kerala, Nambiar *et al.* (1977) proposed the ten class system to prescribe the fertilizer recommendation. They have categorised the lower fertility level to three classes, medium to four classes and higher to three classes. For each fertility class, recommendations are given based on the package of practices for each crop. But this model also has not satisfied the balanced fertilization and high level of fertilizer use efficiency.

2.1.3. Targeted Yield Approach

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

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

Ramamoorthy *et al.* (1967) showed that Liebig's law of minimum operates equally well for N, P and K for wheat (Sonora-64). In this approach fertilizer dose is calculated by considering the amount of nutrients removed per unit quantity of economic produce, initial fertility status of soil, efficiency of nutrients supplied and present in the soil and added through fertilizers and possible nutrient interactions. Reddy *et al.* (1985) reported that the fertilizer use efficiency was at least 30 per cent more in targeted yield approach, based on soil test than the general recommendation as revealed by the response ratio.

Ramamoorthy and Pathak (1969) reported that the targeted yield based fertilizer application would be the most economical approach. The targeted yield equations developed for a particular variety of crops for a particular soil type can be suitably extrapolated to other varieties of the same crops and to similar soils (Velayutham, 1979). Dhillon *et al.* (1978) and Dev *et al.* (1985) developed targeted yield equations for wheat in Ludhiana and Gurdaspur .Targeted yield equations were developed by Chand *et al.* (1986) for greengram in Punjab, Dev *et al.* (1978) for rice in tropical acid brown soils and Singh and Sharma (1978) for many crops in Delhi. Targeted yield equations were developed for rice in Punjab, based on the farmers field trial conducted at different locations (Chand *et al.*, 1984).

Extensive studies have been conducted at Tamil Nadu Agricultural University, Coimbatore based on targeted yield approach and has derived useful equation for the desired yield target for crops like rice, maize, ragi, groundnut, black gram, soya bean, sugarcane, sunflower etc. (Rani Perumal *et al.*, 1982, 84, 87 and 88, and Loganathan *et al.*, 1995).

Fertilizer application based on the targeted yield approach provides the assurance for the maintenance of soil fertility (Raniperumal and Velayudham, 1982). Organic manures and fertilizers can also effectively be used along with the appropriate fertilizer recommendations of targeted yield concept. Dose of chemical fertilizers are adjusted according to the level of application of organics through soil test calibrations (Raniperumal *et al.*, 1984).

The targeted yield equations have been reported by Reddy *et al.* (1985) for groundnut in Bhavanisagar, Tamil Nadu (red soil), Rahuri (Black soil) and Dholi (Alluvial soil). Raniperumal *et al.* (1987) reported that the fertilizer adjustment equation developed for rice var. Barathi is also suitable for varieties like IR 50, Ponni and Paiyur -1 in the same soil types. The prescription equations developed for the ragi var. CO11 is also suitable for var. CO12 (Duraiswami *et al.,* 1989). The targeted yield model is useful for computing fertilizer doses for varying soil test values for obtaining different yield targets. The derived doses are then tested under farmers' field conditions for their reproducibility before they are generalised for large scale adoption (Sanker *et al.,* 1989).

In Maharashtra, the State Department of Agriculture gave fertilizer recommendation for field crops based on targeted yield equation (Velayutham and Reddy, 1990).

Reddy and Ahmed (1999) proposed that for obtaining a given yield a definite quantity of nutrients must be taken up by the plant. This forms the basis for fertilizer recommendation for targeted yield of a crop. In Hisar, Singh *et al.* (2000) developed targeted yield equation for mutated wheat, barley and cotton.

The targeted yield equations have been reported by Raniperumal *et al.* (1986); Reddy and Ahmed (1999) in groundnut, Santhi *et al.* (1999) in rice-rice-pulse sequence, Tamboli and Sonar (1999) for wheat and chickpea, Maragatham (1995) for sunflower, Sharma *et al.* (1990), Suri and Verma (1999) and Verma *et al.* (2002) for maize and wheat, Ahmed *et al.* (2000) for castor. In Andhra Pradesh, Meena *et al.* (2001) developed fertilizer prescription equation for onion.

2.1.3 Regression Analysis Approach

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

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

where

Y	= Crop yield (kg ha^{-1})
A	= Intercept
b_1 to b_{15}	= Regression coefficients
SN, SP, SK	= Soil available N, P and K nutrients (kg ha^{-1})
FN, FP, FK	= Fertilizer N, P and K nutrients (kg ha^{-1})

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

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

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

where

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

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

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

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

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

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

2.2. Soil test crop response correlation studies

The targeted yield approach under STCR strikes a balance between fertilizing the crop and the soil. In the targeted yield approach, it is assumed that there is a linear relationship between the grain yield and nutrient uptake of the crop. This approach forms the basis for the national programme on All India Co-ordinated Research Project of STCR correlation studies. In this context, in STCR investigation judicious use of fertilizer is practiced along with the objective of targeted yield (Singh and Sharma, 1978). This approach brought up a new dimension to the value and utility of soil testing (Velayutham, 1979). Soil test calibration is intended to establish a relationship between soil nutrient levels and crop response to fertilizer. Complexity in soil test crop response studies (STCR) arises due to great diversity of soils, climate, crops and management practice (IISS, 1999)

The uptake of nutrients from the soil and fertilizer together should be in a ratio, which is actually needed by the specific variety of the crop. This is possible only by fertilizer application based on targeted yield model and not by any other method of fertilizer prescription (Ramamoorthy, 1993). Experiments based on this concept are being conducted in seventeen centres in the country and fertilizer adjustment equations have been developed mostly for field crops (Rao and Srivastava, 2002).

The AICRP on STCR conducted large number of experiments all over the country in different agro climatic regions. It revealed that the yield targets could be achieved within ± 10 per cent deviation, if the targets chosen are not unduly high. Under this scheme various scientists worked out the prescription equations for different crop varieties like rice (Ramamoorthy *et al.*, 1967, Chand *et al.*, 1984 and Raniperumal *et al.*, 1987); wheat (Sekhon *et al.*, 1976; Singh and Sharma, 1978 and Dev *et al.*, 1985); green gram (Chand *et al.*, 1986); ragi (Raniperumal *et al.*, 1986; Duraisamy *et al.*, 1989) green gram and groundnut (Loganathan *et al.*, 1995).

Reddy *et al.* (1991) developed the targeted yield equations for groundnut in Bhavanisagar, Tamil Nadu (red soil), Rahuri (black soil) and Dholi (Alluvial soil). In

Adhra pradesh, the targeted yield equation for maize was developed by Reddy and Ahmed (2000). Ray *et al.* (2000) developed the fertilizer prescription equation based on targeted yield for jute, rice and wheat in West Bengal. The targeted yield approach with integrated plant nutrition system (IPNS) is also effectively used for appropriate fertilizer recommendation with organics. Based on the level of application of organic manure, the dose of chemical fertilizers gets adjusted through soil test calibration (Raniperumal *et al.*, 1984).

This model is useful for computing fertilizer doses for varying soil test values for obtaining different yield targets. The derived doses are then tested under farmer's field conditions for their reproducibility before they are generalized for large scale adoption (Sankar *et al.*, 1989). In Kerala, Swadija (1997), Jayalakshmi (2001), Nagarajan (2003) and Sidha (2005) computed the targeted yield equations under IPNS for cassava, ginger, coleus and groundnut respectively. They have taken FYM as organic source.

According to Prasad and Prasad (1993) the conjoint application of fertilizers and organic manures lead to efficient nutrient use of fertilizer and considerable saving in fertilizers. Tandon (1994) rightly pointed out that this approach also indicated the magnitude of contribution by the organic/ biological sources of plant nutrients complementing fertilizers in meeting nutrient requirement of crops. By using targeted yield equation under IPNS the fertilizer doses were worked out for different crops like turmeric and rice (Kharif and rabi) during 2001 and for Nendran banana during 2000-2001 in laterite soils of Kerala (KAU, 2004).

Prescription equations involving the conjoint use of organics and inorganics have been reported by Raniperumal *et al.* (1982) and Duraiswamy *et al.* (1989) in ragi with FYM, Mercykutty (1989) in ragi with Azospirillum, Bhaskaran *et al.* (1994) in cassava with composted coir pith, Santhi (1995) in rice with FYM and phosphobacteria, Jha *et al.* (1997) in maize with FYM. In Hisar, Singh *et al.* (2000) formulated the targeted yield equations for barley, cotton and wheat. Soil test based targeted yield equation has been developed for bhindi, potato and sugarcane in

Karnataka (GKVK, 2002). It was also reported by Santhi *et al.* (2002) in onion with FYM and *Azospirillum*, Verma *et al.* (2002) in maize and wheat with FYM.

The targeted yield equations developed for a particular variety of crop for particular soil type can be suitably extrapolated to other variety of the same crop and the similar soils (Velayutham, 1979). The prescription equation developed for the ragi variety CO-11 fitted well for the variety CO-12 also (Duraisamy *et al.*, 1989). Raniperumal *et al.* (1986) have found that the fertilizer prescription equations developed for the groundnut variety POL-2 holds good for the variety TMV-7. Similarly the fertilizer adjustment equation with organics developed for the rice variety Bhavani were found suitable for other varieties like Ponni, IR-20, IR-50, CO-43 and Paiyur-1 in the same soil type (Raniperumal *et al.*, 1987).

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

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

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

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

Combined use of organics and inorganics enhance the nutrient use efficiency. Hence soil test crop response correlation studies are conducted under integrated nutrition system (Tandon, 1994).

The test verification trials in the farmer's field also established validity of the equation. Soil test based fertilizer requirements for different yield targets of castor in dry land alfisol were developed by Ahmed *et al.* (2000).

Dhillon *et al.* (2006) conducted an experiment and the results of the study showed the superiority of the target yield concept over the other practices as it gave higher yields and optimal economic returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis (±10 percent deviation from the target) in majority of the crops thus establishing the utility of the adjustment equations for recommending soil test based fertilizer application to the farmers.

A field experiment was conducted during 2002-04 and 2004-05 for plant cane-ratoon-wheat cropping system on a medium deep black soil (Vertisol) in Padegaon, Maharashtra, India, to assess the feasibility and economics of fertilizer application based on soil test and targeted yield approach in a sugarcane-based cropping system. Significantly the highest cane yield and commercial cane sugar (CCS) were obtained in the treatment with target yield of 150 t/ha (More *et al.* 2007).

The yield targets for sugarcane (in terms of cane and cane sugar yield) and those of upland paddy were achieved. The highest gross and net monetary returns for two seasons was observed for treatment with target 40 q ha^{-1} + residual effect of FYM + biofertilizer, while for paddy, the highest gross and net monetary returns were recorded for treatment with target 40 q ha^{-1} and treatment with target 30 q ha^{-1} + residual effect of FYM + biofertilizer. Soil pH, EC and organic carbon content after completing the two cycles were slightly influenced by the different treatments. The available nitrogen and potassium slightly decreased, while available phosphorus remained constant (Kadam *et al.* 2007).

A field experiment was conducted during rabi season in Orissa, to formulate a soil test-based fertilizer recommendation for targeted yield of groundnut under rice-groundnut cropping system in an Inceptisol by Pradhan *et al.* (2007). Results showed that the yield of groundnut increased with the increase in fertilizer application rates. The optimum NPK fertilizer application rates at various soil test values for attaining 25-35 q ha^{-1} of groundnut yield can be computed using the fertilizer adjustment equation.

2.3. STCR studies in Kerala

In Kerala, Hassan *et al.* (2001) specified the necessity for alternate soil test based recommendations for Kerala instead of the already prevailing techniques in the state. The fertilizer prescription equations were worked out for rice (Swadija *et al.* 1993), cassava (Swadija, 1997) and ginger (Jayalakshmi, 2001). Nagarajan (2003) and Sidha (2005) have formulated fertilizer prescription equations for desirable yield targets of coleus and groundnut respectively in the laterite soils. For crops like

Nendran banana, turmeric, rice (Aiswarya and Kanakam), sweet potato, ashgourd, bhindi, snakegourd,brinjal, chilli,pumpkin,coleus, groundnut, cucumber, bittergourd and for amaranthus, targeted yield equations have been developed for the laterite soils of Kerala. Front line demonstration trials have been conducted for the crops like, Nendran banana, turmeric and cassava (KAU, 2008).

2.4. Nutrient Correlations

Micronutrient research has gained considerable importance recently as a consequence of multiple cropping with high yielding and fertilizer responsive crops. Heavy fertilization and intensive cropping have laid to nutritional imbalance particularly for the micronutrients, whose range of deficiency normally is very narrow. Obviously, a knowledge of soil types, its fertility status and soil conditions promoting deficiencies or sufficiencies will be a best approach for achieving reliable information about the need of the micronutrients. The correlation between the micronutrients and macronutrients will give light to the practice of judicious use of chemical fertilizers in integrated nutrient management and thus lead to a situation of eco friendly crop management.

Ramaswamy (1965) observed positive correlation between organic carbon and nitrogen, organic carbon and phosphorus and nitrogen and phosphorus in his study on fertility status of the soils of Fairy Falls in Kodaikanal Hills. The soils contain appreciable organic matter, which helps to retain moisture and improve the physical property of soils.

2.5. Nutrient Interactions

An interaction occurs when the response of one or a series of factors is modified by the effects of one or more factors. When this is between plant nutrients it is termed as nutrient interaction. When the response to two or more nutrients used together is greater, less and equal than the sum of their individual response, a positive, negative and no interaction respectively is said to have occurred. A balanced application of all the essential plant plant nutrients would result in balanced growth.

Organic manures like FYM and green manures in combination with inorganic phosphatic fertilizers increased phosphorous content in wheat (Gupta and Das, 1954). In melon, level of nitrogen application did not affect early yield or average weight of fruit (Peterson, 1958). Lingle and Wight (1961) conducted a fertilizer trial in melon with four levels of N (0, 60,120, & 240 kg ha^{-1}) and 3 levels of P_2O_5 (0, 25 & 125 kg ha^{-1}) and found that P fertilization was necessary for early maturity. Increased nitrogen application increased yield, but fertilizer treatment had no effect on fruit size. Shortage of nitrogen or potassium adversely affects cucumber shape (Bradley *et al.*, 1961). Higher rates of N cause a reduction in total yield in melon (Brantley and Warren, 1961). Everett (1963) recorded a significant yield increase with organic and inorganic fertilizer combinations in cucumber.

An increase in yield with increased nitrogen application, but not with phosphorus and potassium application was reported by Dhesi *et al.* (1964) in melon. Positive yield response for phosphorus and potassium in melon was reported by Sutton (1965). Increased nitrogen and phosphorus application increased yield in bitter gourd where as potassium produced a slight reduction in yield (Dhesi *et al.,* 1966). Haworth *et al.* (1966) reported that in potato, FYM with fertilizer produced much higher yield than mineral fertilizer alone. Calcium, magnesium and potassium contents in leaf tissues of squashes were dependent on the amount of nitrogen and phosphorus applied (Thomas, 1966). Increased application of nitrogen raised the nitrogen content and reduced the phosphorus and potassium contents in squashes (Thomas and MacLean, 1967).

Application of 25 t ha^{-1} of fresh cattle manure increased the yield of egg plant and cabbage but reduced the yield of cucumber and tomato (Omori *et al.,* 1972). Mathan *et al.,* (1974) reported that inorganic form of nitrogen, phosphorus and potassium nutrients produced the maximum yield whereas organic form produced the minimum yield. Nath (1976) reported that P need not be applied to cucumber under tropical conditions. Cantliffe (1977) reported that nitrogen has a direct influence on the mineral nutrient composition of pickling cucumber leaf tissues. Nilson (1979) reported that organic fertilizers increase the contents of phosphorus and calcium in the dry matter where as the amount of potassium and magnesium were uninfluenced by the fertilizer used. In a comparison study with N (0, 60 and 120 kg ha^{-1}), P_2O_5 (0, 45 and 90 kg ha^{-1}) and K_2O (0, 45 and 90 kg ha^{-1}) in oriental pickling melon, response to N was observed to be quadratic and the optimum level was 96.6 kg ha^{-1} but P_2O_5 application did not show any significant effect. Response of K_2O was linear with respect to the fruit yield (Hassan *et al.,* 1984).

Joseph (1985) reported that the highest dose of N, P and K gives the highest values for N content in melon fruits. Ragimova (1987) observed that FYM @ 20 t ha^{-1} with N: P: K @ 90:90:60 kg ha^{-1} along with Mn, Cu and Co produced highest yield in cucumber. An increase in leaf nitrogen content up to 4.33 per cent of dry weight was reported in cucumber, when a nitrogen dose of 300 per cent or more than that of recommended dose was applied (Al-Sahaf and Al-Khafagi, 1990). In *Cucumis melo,* no nitrogen accumulation occurred at normal fertilizer rate (80 g N, 12 g P_2O_5, 10 g K_2O and 40 g CaO /plant) during warm season. But during the cool season, nitrogen accumulation occurred even at a fertilizer rate half of the normal amount (Kim *et al.,* 1991). In *Cucumis melo,* Buzetti and Hernandez (1993) reported that when different doses of nitrogen were applied, the leaf content increased correspondingly.

Yalcn and Topcuoglu (1994) reported that in cucumber, plant dry weight, fruit yield and concentrations of P, N, K, Ca and Mg increased with increasing rate of P application. Park and Chiang (1997) reported that in aeroponic study of *Cucumis sativus* the leaf nitrogen content increased with the concentration of nitrogen in the nutrient solution. Sirohi (1997) reported that an application of 120-150 kg Urea, 250 kg SSP and 80 kg Potassium sulphate is useful for raising a successful cucurbit vegetable. Patil *et al.* (1998) conducted experiment in cucumber var. Himangi with N fertilizer at 50, 100, 150 or 200 kg ha^{-1}, phosphorus at 50 or 100 kg ha^{-1} and potassium at 50 or 100 kg ha^{-1} and it was shown that average yields were highest (145.5 kg ha^{-1}) with 150 kg N + 50 kg P + 50 kg K ha^{-1} and average fruit diameter, number of fruits per plant were also highest in this treatment. Navarro *et al.* (1999) reported that the increase of Ca^{2+} concentration in the nutrient solution under saline conditions improved vegetative growth and fruit yield in melon. In nutrient culture experiments, cucumber var. Chinesische, Si had no direct effect on P uptake or translocation to the shoot. It is suggested that Si could act as a beneficial element under conditions of nutrient imbalance (Marschner *et al.*, 1999).

Tuncay *et al.* (1999) reported that in cucumbers, when the effects of leaf nutrient contents on quality characteristics (fruit diameter, fruit length, TSS, acidity, pH, dry matter, fruit firmness and colour) were considered, K had significant positive direct effects on all of the quality traits with the exception of dry matter, which was affected positively by P. Leaf Ca content had negative direct effects on all of the quality traits. In Cucumber, Alphonse and Saad (2000) observed an increase in vine length and yield on combined application of FYM and chicken manure. In pumpkin, Bage *et al.* (2000) reported an early yield with application of cowdung compared to other organic manures like mahua cake, mustard cake and surja. Hadid *et al.*, (2001) recorded higher fruit weight in cucumber by application of chicken manure compared to other organic manures.

In a field experiment conducted in southern Greece, Panagiotopoulos (2001) observed that nitrogen and potassium levels did not alter significantly the fruit yield in *Cucumis melo* and he also reported that nitrogen concentration of the recently matured leaves at the initial fruit stage reached high levels ranging between 4.8 and 5.3 per cent while decreasing to 2.5-3.6 per cent at harvest time and the same trend was found for leaf P, K and Mg but the opposite trend for Ca.

An experiment was carried out in Nagaland, India, to assess the appropriate nitrogen levels for the optimum growth, yield and quality of cucumber and it was reported that nitrogen application markedly influenced the vegetative growth, bearing habit, yield and quality of fruits. In general, nitrogen applied @ 50 kg ha^{-1} gave the best results (Jaksungnaro and Akali, 2001). Potassium fertilizer application significantly enhanced the yield and enhanced the contents of ascorbic acid of cucumber (Guo *et al.*, 2004). Rodriguez and Pire (2004) conducted a study in Cantaloupe crop in Venezuela and it was reported that at harvest, the highest levels of K, Ca and Mg were found in the petioles and the lowest values were found in the lamina, root and ripe fruits. The highest levels of N and P were found in the lamina and ripe fruits and the lowest in the roots. They also reported the total extraction of macronutrients were 75 kg N, 7 kg P, 64 kg K, 62 kg Ca and 10 kg Mg per hectare when 28,440 kg of fruits were harvested. K fertilizer application reduced the content of other nutrients in cucumber, although low K rates increased the nutrient uptake of the crop (Guo *et al.,* 2004).

Experiments were conducted in Bangalore, Karnataka and it was reported that in cucumber the effect of varying N levels was significant on the weight, length, girth, volume and flesh thickness of fruits and plant N, P, K uptake and the application of various P levels also had positive influence on fruit length and volume and plant NPK uptake, whereas the different K levels had no significant effect on the fruit characters and P and K uptake by the plant (Umamaheswarappa *et al.,* 2005). In *Cucumis melo*, the yield and uptake of nitrate, phosphate, potassium and magnesium were greater with nutrient solutions containing high levels of Ca and there is no significant difference observed among the nutrient solutions studied for the quality parameters of fruits measured (Salas *et al.,* 2005). Gul *et al.* (2007) reported that organic manuring decreased the total yield by 22.4 per cent in comparison to inorganic nutrient solution in cucumber.

In cucumber cultivars, increasing N concentration in nutrient solution caused reduction in fruit yield and number, decreased fruit dry matter and increased total nitrogen and amount of phosphorus, but decreased potassium and calcium. This showed antagonistic effect of elements (Soltani *et al.,* 2007). Experiments were performed in an open field using melon plants (*Cucumis melo* var. Prodigio). The total marketable fruit yield and fruit nitrogen content linearly increased with N levels. Antioxidant compounds decreased after storage but were not affected by N fertilization levels (Ferrante *et al.,* 2008)

2.5.1 Interaction between N and P

Among the major nutrients, role of N and P are dominant in most cropping systems, their interaction are probably the most important of all interactions. Since the use of major nutrients especially N and P is very liberal due to high response of Urea and comparatively less price of both sources of fertilizers, interaction fetches less importance. It is well known that increased growth requires more of both N and P, indicating that mutually synergistic effects result in both growth stimulation and enhanced uptake of the two nutrients.

Terman *et al.* (1977) reported that many workers have demonstrated that N-P interaction effects on yield are primarily attributable to N induced increase in P absorption by the plant.

An experiment in black soil at Dharward showed that among the different N and P levels, the N and P_2O_5 (40 kg ha $^{-1}$) gave the largest yield in groundnut. At higher levels of N and P, no further increase in yield is possible due to high fertility of soil (available P 48 kg ha $^{-1}$, and total N =0.063 per cent) (Biswas and Prasad, 1991).

2.5.2 Interaction between N and K

A study on tropical oil plants concluded the absence of a clear NK interaction. This may be consequence of the small number of N deficiencies in plants and very slight action of N and K metabolism (Ollagmier and Ocho, 1973).

The application of potassium influences nitrogen use efficiency at higher levels of N application. The application of 20 kg K_2O resulted in a yield increase of rice (3 q/ha at 40 kg N level). However the increase was three times more as N level increased from 40-120 kg/ha at the same K level (Biswas and Prasad, 1991).

2.5.3 Interaction between P and K

A positive significant correlation between P and K contents of 14th leaf in coconut was observed by Wahid *et al.* (1977). In coconut highest yield of 8491 nuts ha^{-1} was obtained in P_1K_2 combination followed by P_1K_1 and P_2K_2 with 7561 and 7377 nuts ha^{-1} respectively and were on par with each other. Application of K at K_1 (450 g palm^{-1}) and K_2 (900 g palm^{-1}) showed a depression in yield when the dose of P was increased to P_2 level.

2.5.4 Interaction between K and Mg

Brunin (1970) working on Tall varieties of coconut, noted that for K Levels between 0.7 per cent and 1.2 per cent, the application of high rates of Mg fertilizers significantly reduced K. He also concluded from other experiments that while there was a good relationship between leaf Mg and yield, the extra production expected from Mg application when Mg was below the critical level would be possible only if K deficiency was corrected.

Coomans (1977) noted that heavy Mg deficiency was induced in hybrid coconuts by potassic fertilization. Mg manuring on the contrary had no effect on leaf K Levels. The action of K was preponderant, and the effect of Mg only manifested itself in the presence of K.

Bandyopadhyay and Goswami (1988) reported that the application of Ca or Mg increased the concentration of K in soil solution, but decreased exchangeable K, in laterite soil than in alluvial and black soils. Also the uptake of K by wheat was influenced by relative abundance of available Ca and Mg in soil.

Jaganathan (1990) reported the results of two experiments on K-Mg interaction in coconut conducted in lateritic gravels (Ultisols) in wet and intermedidate agroclimatic zones of Sri Lanka. Significantly yield responses to differential K treatments in the wet zones were noted. Differential Mg treatments did not give rise to yield response. Results also indicated the usefulness of nut water analysis as an additional diagnostic tool for Na, K and Cl.

2.5.5 Interaction between P and Zn

The reviews on this aspect of plant nutrition clearly indicate that the subject has met with many apparent contradictions, which have probably partially arisen as a result of the special conditions under which each investigation has been conducted. This anomalous behaviour is illustrated by the fact that some workers have found that increasing P levels reduced Zn uptake and yield as a result of an assumed P induced Zn deficiency. Studies by Gamiron *et al.* (1969) with corn in the field showed that addition of P to a P sufficient soil will not stimulate growth but many in fact significantly reduce yield as a result of P induced Zn deficiency.

Boawn and Legget (1964) reported that Zn and P appaeared to be mutually antagonistic whenever either element exceeded some threshold value.

Examination of data from a factorial field experiment with corn in which a significant P x Zn interaction was obtained revealed the following (Takkar *et al.,* 1976). At low tissue P/Zn ratio obtained at low soil P levels, yields were low, consistent with the P deficiency symptoms. Intermediate P/Zn ratios were obtained when applications of both P and Zn were made to the soil. At high P/Zn ratios obtained with high P and zero Zn applications, severe Zn deficiency symptoms were observed and yield decreased accordingly.

Mehta and Singh (1988) reported that higher levels of Zn reduced P uptake significantly over control in mustard. P application which increases plant growth may decrease Zn concentrations in tops to deficient levels by dilution with decreasing Zn uptake.

2.5.6 Interaction between P and Ca

Changes in soil pH brought about by liming may have profound effects on the availability of many elements to crops. Liming has been reported to increase (Ryan and Smillie, 1975; Jakala *et al.,* 1977; Parfitt, 1977 and Smyth and Sanchez, 1980) decrease (Amrasiri and Olsen, 1973 and Friesen *et al.,* 1980) or not affect (Cabala and Fassbender, 1971 and Jones and Fox, 1978) soil P availability.

2.5.7 Interaction between P and Fe

The interactions between P and Fe indicate that the process is not very simple being complicated both by the levels of acidity or alkalinity in the soil materials and by the nature of the rhizosphere of the particular crop. The great affinity between Fe and P both in the soil and in the plant can severely complicate any attempt to explain the P-Fe interaction, because the product formed can precipitate or be chemisorbed in the soil after addition or during the translocation and assimilation process.

As far as the importance of P-Fe interaction in cropping system is considered, it has to be realized that they are likely to occur only at elevated pH levels, which in most agricultural systems should be avoided. Watanabe *et al.* (1965) observed extensively Fe deficient plants when the P level in a nutrient solution was increased from 0.2 to 0.6 mM with Fe EDDHA at 40 mM.

Ayed (1970) opined that the concentration of Fe-P in tomato roots in nutrient solution was eight to ten times higher than in the tops, due to iron phosphate precipitated in roots. Electrophoretic measurements indicate that Fe moves or translocate in plants as anion chiefly as iron citrate (Tiffin, 1970).

Khan *et al.* (1985) reported in coconut that the increase in soil available P levels was not found to influence in either way the contents of Fe, Mn, Cu, and Zn in the plants. Though a depression in the absorption of Fe-Mn, and Cu were seen at higher P levels, differences shown by the palm were not statistically significant.

2.5.8 Interaction between P and Mn

Dahiya *et al.* (1990) studied the effect of P and Mn application on drymatter yield, their concentrations and uptake in pea and reported that the P application had decreased Mn concentration and its uptake. Also the concentration of P and Mn in plant tissue was negatively correlated.

Kudayarova and Kvaratskheliya (1991) studied the effect of fertilizer phosphates on solubility of Ca, Mg, Mn, Zn and Fe compounds in grey forest soil and reported that fertilizer P from complexes and increase the solubility of compounds containing Ca, Mg, Mn, Fe etc. and the newly formed complexes migrate to lower layers of soil.

2.5.9 Interaction between N and Zn

Applied N has been reported as a possible cause of Zn deficiency in citrus plants. Ozanne (1955) observed an increase severity of Zn in subterranean clover as the N supply increased regardless of N sources. He suggested that increase in N supply caused more Zn to be retained in the roots as a Zn protein complex. Soltanpour (1969) found that N accentuated uptake of P and Zn despite substantial dilution caused by yield increase from N.

2.5.10 Interaction between Fe and Zn

Watanabe *et al.* (1965) found that the corn yield was depressed two fold as the Zn level was increased from 0.75 to 2.25 mM when the Fe level was 40 mM as Fe EDDHA. At this higher level of Zn in the nutrient solution, the plants were Fe chlorotic at all P levels, but the deficiency symptoms disappeared when Fe level was increased to 80 mM. These data indicated that a favourable nutrient balance is essential for good growth, but the data do not show the mechanism of interaction between Fe and Zn.

Jackson *et al.* (1967) found that when P needs of sweet corn met, Zn deficiency became dominant and the plants contained very high levels of Fe. Addition of Zn increased growth and led to a marked reduction in Fe concentration in the plants.

Warnock (1970) measured a relation between P induced Zn deficiency in corn and the concentration and mobility of Fe and Mn within the plant. The relative mobility of Fe and Mn was inversely related to the mobility of Zn.

2.5.11 Interaction between Fe and Cu

High Cu or Zn concentration in a nutrient solution has been shown to produce Fe chlorosis of citrus. The toxic effect of Cu at a high level of supply was decreased by addition of Fe, but the adverse effect of high Cu was never completely overcome by Fe.

Spencer (1966) showed that high Cu levels applied to soil reduced the Fe content in leaves of citrus. Chashier *et al.* (1967) showed that nutrient interactions involving Fe and Cu explained the frequent occurrence of Cu deficiency on soils of high organic matter content rather than chemical fixation of Cu. Applied Fe reduced the uptake and concentration of Cu in oats only where Cu had been added to peat.

2.5.12 Interaction between Fe and Mn

Fe and Mn are interrelated in their metabolic functions with the effectiveness of one determined by the proportionate presence of the other. Grasmanis and Leeper (1966) reduced toxic Mn levels in apple leaf from 100 to 35 ppm by injecting Fe citrate into the tree or by applying FeEDTA to the soil. Knezek and Greinert (1971) applied inorganic and chelated forms of Fe and Mn to a Mn deficient Houghton muck, pH 6.5. The data indicated that Mn was rapidly displaced from MnEDTA by Fe and the released Mn was inactivated as an organic complex by the organic soil. In organic soil the application of $MnSO_4$ corrected the Mn deficiency of the plants.

2.6. Impact on biometric and quality parameters of fruits

Even though the STCR practice of nutrient management is wide spread, the effect of more fertilizers on biometric as well as on fruit quality is not studied much. The storage life and quality of cucurbitaceous crops with respect to the effect of nutrition has been recognized for quite some time. The nature and amount of various nutritional parameters influence the value of consumable food. The plant nutrients applied to the soil can alter the food values of the crop. Fischer and Parrith (1951) reported over application of N impaired the keeping quality of apple.

There was highly significant negative correlation between nitrogen content in leaves and storage life of apple (Eggert, 1961). Nitrogen, phosphorus and potassium application to irrigated cucumber improved dry matter and Vitamin C contents (Bolotskikh, 1969).

Nitrogen had a little effect on melon size, earliness or storage quality in melon (Pew and Gardner, 1972). Maximum average values for fruit weight, length and breadth of fruit were recorded by the treatment which received the highest dose of nitrogen in the inorganic form and the maximum vitamin C content was found in standard N, P and K (70:25:25 kg ha^{-1} N, P_2O_5, and K_2O) in inorganic form (Joseph, 1985).

Highest rotting percentage was observed with fruits under the treatment which received the highest dose of N, P and K (105, 27.5 and 27.5 kg ha^{-1}) completely in the inorganic forms in melon (Joseph, 1985). In cucumber, female flowers/plant showed highly significant positive correlations with number of primary branches, fruit yield and fruits/plant and longer vine length increased the number of male flowers and produced heavier fruits (Rastogi and Arya, 1990). Excessive N supply, however, reduced fruit quality. At high rates of N, cucumber yield showed no further increase with increasing application rate (Liu and Chen, 1996).

Marti and Mills (2002) conducted an experiment in sweet potato (*Ipomoea batatas*) in USA and it was reported that, the yield, dry weight partitioning, or nutrient-use efficiency can be increased by manipulating nitrogen and potassium nutrition. Demiral and Koseoglu (2005) conducted an experiment in *Cucumis melo* in the coastal Mediterranean region of Turkey and it was reported that it is possible to improve fruit quality by applying as much as 600 mg l^{-1} additional K to the plants without a reduction in yield.

Liu *et al.* (2006) reported that N applied at proper rates tended to increase the quality of cucumber. Lester and Jifon (2007) reported that in Cantaloupe (*Cucumis melo* (reticulatus group)), fruit quality parameters were directly related to plant potassium concentration during fruit growth and maturation.

The fruit quality of musk melon in organic farming system was increased to a certain extent, but all these quality parameters were not affected by fertilizer amount (Song *et al.*, 2008).

MATERIALS AND METHODS

The main campus of the Kerala Agricultural University is situated in Madakkathara and Vellanikkara villages of Thrissur Taluk, Thrissur District, about 9 km from Thrissur on the Thrissur-Palakkad national highway (Fig.1). The total area taken for experiment is 0.56 acre. The field was located at 10°31'N latitude and 76°13'N longitude at an altitude of 25 m above mean sea level. The experiment under report was carried out during November 2006 - May 2007.

3.1.1.2. Soil type

The soil appears to have developed from the weathered material derived from the rock forms. It is having lateritic characteristics, which comes under the order Ultisol.

3.1.1.3 Physico – chemical properties of the initial Soil Sample

The basic physico-chemical properties of the soil were analysed and furnished in table 1.

Table 1. The basic physico-chemical properties of the initial soil sample

Sl. No.	Properties	Unit	Value
1	Texture	-	Sandy clay loam
2	pH	-	5.50
3	EC	dS m^{-1}	0.04
4	CEC	Cmol(p+) kg^{-1}	4.31
5	Available Nitrogen	Kg ha^{-1}	321.42
6	Available Phosphorus	Kg $h^{-1}a$	20.51
7	Available Potassium	Kg ha^{-1}	298.56
8	Organic Carbon (OC)	%	1.02
9	P fixing capacity (PFC)	%	81.80
10	K fixing capacity (KFC)	%	8.90

3.1.1.4. Climate

The climate of the area is humid tropical with an average annual rainfall of 3324 mm and temperature ranging from 20.8 to 36 °C. Weather data of Vellanikkara (monthly average) during the experimental time was presented in Appendix I.

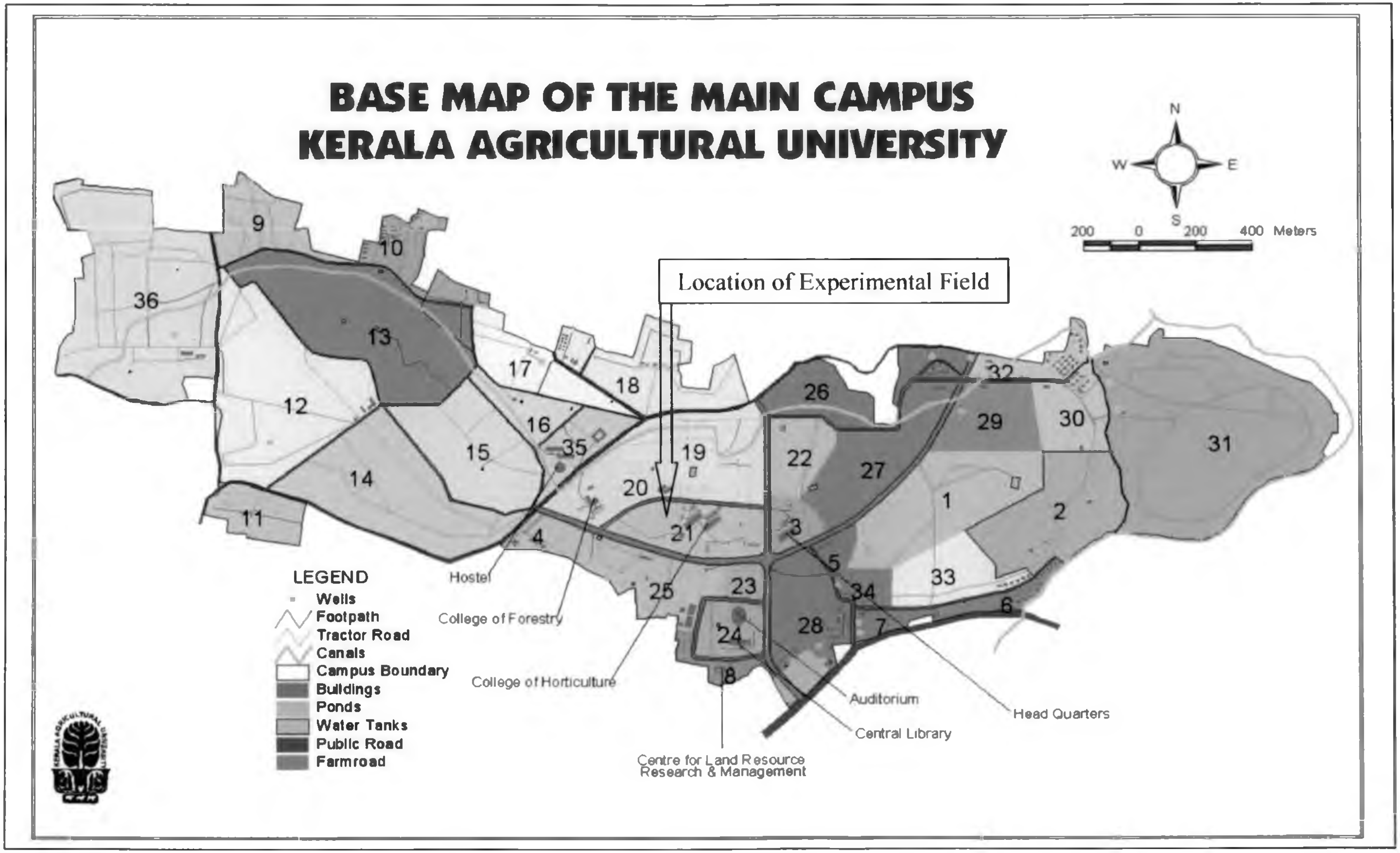

Fig. 1 Location of field of Fertility Gradient Experiment and Test Crop Experiment (Experimental Field of AICRP on STCR)

3.1.1.5. ***Experimental details***

3.1.1.5.1. ***Layout of the Experiment***

The selected field was divided into three equal strips (Fig.2). Three soil samples were collected from each strip both from 0-15 cm and 0-30 cm depths. These soil samples were used to study the status of major available nutrients of the experimental area before the conduct of fertility gradient experiment.

Field layout

Crop : Fodder maize

Plot size : 25 m x 10 m for each strip

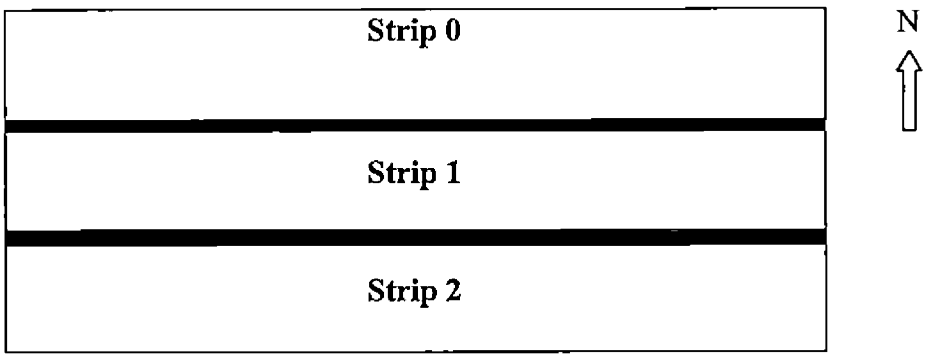

Fig. 2 Field layout for Fertility Gradient Experiment

3.1.1.5.2. ***Treatments***

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

Table 2. Treatment structure for FGE

Strip	Treatment	Fertilizer dose (kg ha^{-1})		
		N	P_2O_5	K_2O
0	$N_0P_0K_0$	0	0	0
1	$N_1P_1K_1$	150	100	180
2	$N_2P_2K_2$	300	200	360

3.1.1.5.3. Gradient Crop

A gradient crop of maize (*Zea mays*) variety CO-1 was raised following the usual agronomic practices (KAU, 2007) except the treatments. The seeds were sown by broadcasting on 20-11-06 and crop was harvested on 16-01-07.

3.1.1.5.4. Observations Recorded

3.1.1.5.4.1. Green Fodder Yield

At harvest, strip wise fodder yield was recorded and expressed in t ha^{-1}. The data was used for the calculation of total dry matter production.

3.1.1.5.4.2. Dry Fodder Yield

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

3.1.1.5.4.3. Uptake of Nutrients

The composite plant samples (one from each strip) were analysed for the content of the major nutrients viz., N, P and K. The analytical methods adopted are detailed in later sections. The uptake of nutrients was calculated using plant dry weight and the nutrient content.

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

3.1.2. Test Crop Experiment

The test crop experiment was conducted in the field where FGE was carried out. The crop was raised with 24 treatments with two replications in each strip. The pits were arranged in eight rows and six columns (Fig. 3).

Strip 0	**FYM – 2**	**FYM - 1**	**FYM – 0**
Strip 1	**FYM – 1**	**FYM - 0**	**FYM – 2**
Strip 2	**FYM – 0**	**FYM - 2**	**FYM – 1**

Fig. 3 Field layout for Test Crop Experiment

A high yielding variety of cucumber AAUC-2 was used for the experiment. Factorial combinations of 4 levels each of N, P_2O_5, and K_2O along with 3 levels of FYM including a control form the treatment combinations. The treatment levels and doses of nutrient are given in Table 3.

Table 3. Nutrient levels for Test Crop Experiment

Nutrient levels	Fertilizer dose (kg ha^{-1})			FYM (t ha^{-1})
	N	P_2O_5	K_2O	
0	0	0	0	0
1	35	12.5	12.5	12.5
2	70	25	25	25
3	140	50	50	-

Treatment combinations are given below:

	S_0	S_1	S_2
FYM-0	000, 022, 112, 233, 323, 333, 311, 332	000, 232, 331, 122, 222, 202, 322, 212	000, 211, 321, 111, 220, 121, 223, 221
FYM-1	000, 221, 321, 223, 111, 220, 211, 121	000, 032, 022, 112, 233, 323, 333, 311	000, 232, 212, 322, 202, 222, 331, 122
FYM-2	000, 122, 331, 222, 202, 322, 212, 232	000, 211, 221, 223, 321, 111, 220, 121	000, 022, 112, 233, 323, 333, 311, 332

Each strip was divided into 24 plots that include 21 treatment combinations and 3 controls. All other cultural operations were done as per the package of practices of KAU (2007). Plot wise initial soil samples were collected, analysed for pH, Electrical Conductivity, Organic Carbon, available N, P, K, Ca, Mg, Fe, Mn, Cu and

Zn. The uptake of all the above said nutrients was estimated at flowering stage of growth as well as at harvest. The fruit yield, total dry matter production and nutrient uptake by the crop were recorded. The fertilizer prescription equations were developed for recommending fertilizer doses for specific yield targets of the test crop.

3.1.2.1 Design of the Experiment

Each strip was divided into 48 pits with a spacing of 2 x 1.5 m size. The forty eight pits in each strip are alloted the 21 treatment combinations along with the three control treatments in three levels of the FYM on the 3 strips.

Design	: Fractional factorial
Treatments	: 24
No. of strips	: 3
No. of pits/strip	: 24
Total no. of plots	: 72
Spacing	: 2 x 1.5 m
System of planting	: Pit system

3.1.2.2 **Manures and Fertilizers**

Farmyard manure was applied in the pits as per treatments. Fertilizers were applied as basal doses and topdressing. The nutrient content of organic manure used are presented in Table 4.

Table 4. Nutrient contents of organic manure and fertilizers used

Fertilizers / Organic manure	Nutrient content (%)
Urea	46% N
Rajphos	18% P_2O_5
Muriate of potash	60% K_2O
FYM	0.47% N, 0.38% P and 0.46% K

3.1.2.3 Management Practices

Management practices like taking pit, irrigation etc. were carried out as per package of practice recommendation for the different treatments. After the application of FYM, it was incorporated to the soil. In addition, soil drenching and spraying of plant protection chemicals were done whenever needed. The plots were covered with mulch to avoid damage to fruit.

3.1.2.4 Observations Recorded

3.1.2.4.1 Yield

The treatment wise fruit yields were recorded as when the harvest was done. The total fresh weights till the last harvest were expressed in kg ha^{-1}.

3.1.2.4.2 Total dry matter production

After the final harvest, the plants were carefully pulled out from each treatment plot and tied as a lot. The fresh weights were noted and a known weight of plant sample was kept for drying. The fruits were cut into pieces air dried for 3-4 days and later kept for drying in hot air oven. The corresponding weights were also recorded. These samples were ground and stored for further analysis.

3.1.2.4.3 Uptake of Nutrients

The nutrient uptake was computed from the total dry matter production and percentage content of nutrients in plant and fruits. Fresh plant samples (500 g) of each pit and a part of fruit sample were weighed out. The samples were air dried and dried uniformly in hot air oven at 70°C. The samples were analysed by standard methods for the contents of N, P, K, Ca, Mg, Fe, Mn, Cu and Zn at harvest using the standard methods. The total uptake of N, P and K was computed from the nutrient contents and dry weights of plant parts and expressed as kg ha^{-1}. The data were utilized for deriving the fertilizer prescription equation.

3.1.2.4.4 Soil Analysis

Soil samples were collected from two different depths (0-15 and 0-30 cm) after land preparation but before fertilizer application for the test crop. These samples were analysed for organic carbon and available nutrients viz., N, P, K, Ca, Mg, Fe, Mn, Cu and Zn adopting the standard analytical methods.

3.2 FERTILIZER PRESCRIPTION FOR SPECIFIC YIELD TARGET – TARGETED YIELD MODEL

In targeted yield concept fertilizer prescription equations were developed from the data on soil test values, yield and the nutrient uptake by the crop. From the equations, fertilizer recommendations are made for specific yield targets of the crop with FYM.

3.2.1 Calculations of Basic Parameters

3.2.1.1 Nutrient Requirement (NR)

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

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

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

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

3.4.1.2 Per cent Contribution of Nutrients from Soil (CS)

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

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

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

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

3.2.1.3 Per cent Contribution of Nutrients from Fertilizer (CF)

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

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

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

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

3.2.1.4 Per cent Contribution of Nutrients from FYM (COM)

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

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

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

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

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

3.2.2 Targeted Yield Equation

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

Without FYM

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

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

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

With FYM

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

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

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

Where

FN	=	Fertilizer N in kg ha^{-1}
F P_2O_5	=	Fertilizer P_2O_5 in kg ha^{-1}
F K_2O	=	Fertilizer K_2O in kg ha^{-1}

NR	=	Nutrient requirement of N or P_2O_5 or K_2O in kg t^{-1}
CS	=	% Nutrient contribution from soil
CF	=	% Nutrient contribution from fertilizer
COM	=	% Nutrient contribution from FYM
SN	=	STV for available N in kg ha^{-1}
SP	=	STV for available P in kg ha^{-1}
SK	=	STV for available K in kg ha^{-1}
ON	=	N applied through FYM in kg ha^{-1}
OP	=	P applied through FYM in kg ha^{-1}
OK	=	K applied through FYM in kg ha^{-1}
T	=	Yield target in t ha^{-1}

3.2.3 Multiple Regression Analysis

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

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

where

Y	= Crop yield (kg ha^{-1})
A	= Intercept
b_1 to b_{15}	= Regression coefficients
SN, SP, SK	= Soil available nutrients (kg ha^{-1})
FN, FP, FK	= Fertilizer nutrients (kg ha^{-1})

3.2.4 IISS model package for targeted yield

The Indian Institute of Soil Science, Bhopal has developed a software package for calculating the targeted yield using the data obtained from the test crop experiment. When we feed the different parameters like NR, CS, CF, COM in terms of N, P and K, the nutrient status of nutrient sources, it will develop an equation for different yield targets. The required parameters were calculated using data obtained from the analysis for the various parameters at different stages of the crop. The same was utilized for getting an equation for two targets; i.e. 30 t ha^{-1} and 35 t ha^{-1}. For verifying the equation, verification experiment was conducted.

3.3 Verification Experiment

3.3.1. Location

The Verification Experiments (VE) was conducted in the farmers' field at four locations; two each in Thrissur and Palakkad districts (Fig. 4). In Thrissur, one field was at Pallikandam and other was at Maraikkal. Third and fourth fields were at Ayiloor and Vithanassery respectively near Nenmara in Palakkad district. The total area taken for experiment was 0.10 acre in each location. The experiment under report was carried out during December 2007 - May 2008.

3.3.2. Soil type

The soils of the locations appeared to have developed from the weathered material derived from the rock forms. It is having lateritic characteristics.

3.3.3 Soil properties analyzed for the initial sample

The analysis of soil samples collected prior to experiment were carried out for major parameters

3.3.4. Climate

The climate of the area is humid tropical with an average annual rainfall of 3318 (Location 1 & 2) and 3299 mm (Location 3 & 4) and temperature ranging from

Fig. 4 Locations of Verification Experiment conducted in farmers' fields in four places

Locations : 1. Pallikkandam, 2. Maraikkal, 3. Ayiloor and 4. Vithanassery

21.1 to 36.6 °C in two districts. Weather data covering the experimental duration of two locations (monthly average) were presented in Appendix II.

3.3.5. Experimental details

The derived equation was test verified in the verification experiment conducted in the farmers' fields at four locations. The soil samples were collected before and after the experiment, at flowering stage and at harvest. The plant samples were collected at flowering stage and at harvest. The fruit samples also were collected plot wise from each treatment.

3.3.5.1. Layout of the Experiment

Three soil samples were collected from each location both from 0-15 cm and 0-30 cm depths. These soil samples were used to study the status of major available nutrients of the experimental area before the conduct of the experiment. The laid out design is RBD (Fig. 5).

R_4	R_2		R_1	R_3
T_2	T_5		T_4	T_5
T_3	T_4		T_3	T_4
T_5	T_2		T_1	T_3
T_4	T_1		T_2	T_1
T_1	T_3		T_5	T_2

N

Fig. 5 Field layout for Verification Experiment

3.3.5.2. Treatments

Treatment details of the experiment were as follows with four replications:

T_1 - Farmers' practices

T_2 - POP recommendation of KAU

T_3 - STL recommendation of Kerala

T_4 - STCR recommendation for target 1

T_5 - STCR recommendation for target 2

3.4. SAMPLE COLLECTION, PREPARATION AND PROCESSING

Soil samples were collected from selected sites identified for each experimental plot. The soil samples were transported, then air dried and powdered gently. The samples were sieved through a 2mm sieve. The plant samples were collected, dried in laboratory oven at 70°C, ground and used for analysis. The fruit samples were collected, sliced, dried outside, dried in oven at 70°C, ground and used for analysis.

3.5. LABORATORY INVESTIGATIONS ON SOIL SAMPLE

3.5.1. Mechanical Analysis

The texture of the soil samples (surface and subsurface) were estimated by the International Pipette Method. Textural triangle of USDA was referred to determine textural class of each sample (Piper, 1966., Gee and Bauder as described by Page, 1986).

3.5.2. Chemical properties

Soil fertility parameters for various electro-chemical properties and chemical constituents of the soil were analysed as per published procedures.

3.5.2.1. Soil pH and Electrical conductivity

The pH of the soil was determined by 1:2.5 soil water suspension using combined electrode in a μ pH System 362 of Systronics (Jackson, 1973.). Electrical conductivity was determined in the supernatant liquid of the soil water suspension (1:2.5) with the help of Systronics conductivity meter 304 (Jackson, 1973).

3.5.2.2. Organic carbon

Organic carbon of the soil was determined by wet digestion method of Walkley and Black (Walkley and Black, 1934).

3.5.2.3. Available Nitrogen

Available nitrogen in the soil samples was determined by alkaline permanganate method as described by Subbiah and Asija (1956).

3.5.2.4. Available Phosphorus

Available phosphorus in the soil samples was determined by extracting with Bray No.1 reagent and estimating colorimetrically by vanadomolybdic-ascorbic acid blue colour method using Spectronic 20 spectrophotometer (Bray and Kurtz, 1945).

3.5.2.5. Available Potassium, Calcium and Magnesium

Available potassium was extracted with neutral-normal ammonium acetate solution. The content of the element in the extract was determined by flame photometry using ELICO flame photometer and calcium and magnesium were determined using Perkin Elmer atomic absorption spectro-photometer (Jackson, 1973).

3.5.2.6. Cation Exchange Capacity

The cation exchange capacity was estimated by the method proposed by Hendershot and Duquette (1986). The exchangeable cations (Ca, Mg, Na, K, Al, Fe, and Mn) present in the exchange sites in soil were replaced by 0.1M $BaCl_2$ solution and the thus extracted cations were estimated.

Four grams of the soil sample was taken in a conical flask and 40ml of 0.1M $BaCl_2$ solution was added. The sample was then shaken for 2 hrs and filtered through Whatman No. 42 filter paper. Filtrate was used for aspiration to a Perkin Elmer Atomic Absorption Spectrophotometer for determination of Ca, Mg, Fe and Mn. Sodium and potassium were determined with the help of Elico flame photometer. Aluminium was estimated colorimetrically using aluminon (Hsu, 1963; Jayman & Sivasubramaniam, 1974). The sum of the exchangeable cations expressed in Cmol (p+) kg^{-1} soil was recorded as CEC of the soil

3.5.2.7. P and K Fixing Capacity

P- fixing capacity of the soil was determined by incubating 2 grams each of soil samples for 96 hrs with various concentrations of phosphorus solutions prepared out of potassium di-hydrogen ortho phosphate. Various P concentrations used were 0, 25, 50, 75, 100, 125, 250, 375 and 500ppm. One milli litre of the P solution was added to 2g of the soil and then it was kept for incubation. After incubation the labile phosphorus was extracted using Bray No.1 and was estimated by vanadomolybdic-ascorbic acid blue colour method (Ghosh *et al.*, 1983).

The K fixing capacity was estimated using the equilibrium with potassium chloride as described by Waugh and Fitts (1966).

3.5.2.8. Available Micronutrients (Fe, Mn, Cu and Zn) in soil

Available micronutrients in both surface and subsurface samples were extracted using 0.1M HCl (Sims and Johnson, 1991). Four grams of soil with 40 ml of 0.1M HCl was shaken for 5 minutes. It was filtered through Whatman No. 1 filter paper and the filtrate was collected and analysed for Fe, Mn, Cu and Zn using Perkin Elmer Atomic Absorption Spectrophotometer.

3.6. LABORATORY INVESTIGATIONS ON PLANT SAMPLE

The plant samples were analysed for total nutrients such as N, P, K, Ca, Mg, Fe, Mn, Cu and Zn at the flowering and harvest stages of the crop.

3.6.1. Total Nitrogen

Total nitrogen in plant samples were determined by the modified Microkjeldahl method (Tandon, 1994). The powdered plant samples were first subjected to wet digestion using sulfuric acid and digestion mixture. The digested sample is then distilled for the Nitrogen estimation.

3.6.2. Total phosphorus

Total phosphorus in the plant sample was estimated after digestion of the sample with 2:1 nitric – perchloric acid mixture. Phosphorus in the digest was determined by the Vanado - molybdate yellow colour method (Koening and Johnson, 1942) measuring the colour intensity in a spectrophotometer (Model: Analyst 400).

3.6.3. Total potassium

Total potassium in the plant sample was estimated after digestion of the sample with 2:1 nitric – perchloric acid mixture. The content in the digested plant sample was determined by flame photometry (Jackson, 1973) using flame photometer (Model: Elico CL361).

3.6.4. Total Calcium and Magnesium

Total Ca and Mg in the plant sample were estimated after digestion of the samples with 2:1 nitric – perchloric acid mixture. The Calcium and magnesium content in the samples were estimated using EDTA titration method (Cheng and Bray; 1957 and Barrow and Simpson; 1968)

3.6.5. Total micronutrients

The di-acid extract of the sample is analysed using Perkin Elmer Atomic Absorption Spectrophotometer (Model: Analyst 400).

3.7. Laboratory investigations on fruit sample

The observations on parameters like length, girth and weight of the fruit samples, no. of fruits per plant and fruit yield per plant were taken. The total content of P, Fe and Ca at harvest of the crop and keeping quality under normal condition were estimated. The fruit samples were collected from the various treatments, dried to constant moisture and powdered for the nutrient analysis. The fruit samples were analysed for the various nutrients using the methods for plant analysis.

3.8. Biometric observations

The observations on parameters like length of vine, inter nodal distance, number of leaves and female flowers at various stages of crop were taken.

3.9. Total dry matter production

The treatment wise total dry matter production was assessed at the harvest of the crop.

3.10. Keeping quality

The fruit samples were kept in room condition and possibility of getting rotten was estimated and presented as keeping quality.

3.11. Data Processing and Statistical Analysis

Data generated through physical and chemical analysis of the samples were tabulated and organised for information generation. The data were presented in three stages; fertility gradient experiment, test crop experiment and verification crop experiment.

Statistical analysis were carried out to study interaction of plant nutrients in the soil, using MSTAT software in a personal computer.

RESULTS

RESULTS

A sustainable production scenario in agricultural sector can be achieved by managing the economics of production, in such a way that the yield level must be maintained at a satisfactory level with minimum resources through various methods for maximum input use efficiency. Fertilizer recommendation for profitable and sustained crop production can be done based on soil testing. To obtain significant correlation between soil test values and crop response to fertilizers, the soil test calibration and fertilizer recommendation must be based on local field experiments. Hence the present study was undertaken to establish soil test based balanced fertilizer prescription for cucumber var. AAUC-2 in the laterite soils of Kerala. The prescription equations developed in this study can be used for fixing fertilizer doses for different yield targets of cucumber and these doses can be compared with other fertilizer recommendations prevalent in the state and fertilizer doses can be adjusted based on specific objectives and available resources of the farmers. The field experiments consisted of three stages viz.; Fertility Gradient Experiment (FGE), test crop experiment (STCR experiment) and Verification experiment (VCE). The results of the experiments are presented in this chapter in the same order.

4.1. Fertilizer Gradient Experiment

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

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

The experimental area was divided into three equal strips for developing a fertility gradient among the strips. A deliberate attempt was made to create a gradient in soil fertility from strip 0 to 2 by applying graded doses of N, P and K (Table 2). An exhaustive crop of fodder maize, variety CO-1 was raised in all the strips. The field views of the gradient crop experiment at various stages were shown in Plate 1. The soil test values before and after the experiment was computed for checking the response of the gradient crop in all the three strips to know whether sufficient fertility gradient has been created or not. The data were 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 0 to 2 was confirmed by assessing the soil nutrient content after the harvest of fodder maize (gradient crop). The data on soil analysis before and after the fertility gradient experiment were furnished in Tables 5 and 6.

The soil nutrient status prior to the conduct of FGE (Table 5) ranged from 1.00 to 1.20 per cent of organic carbon, 341.51 to 357.00 kg ha^{-1} available N, 13.18 to 16.07 kg ha^{-1} available P and 300.51 to 405.31 kg ha^{-1} available K for surface level. The values for subsurface samples ranged from 1.01 to 1.03 per cent of organic carbon, 318.83 to 328.47 kg ha^{-1} available N, 16.17 to 16.73 kg ha^{-1} available P and 269.33 to 409.60 kg ha^{-1} available K.

The concentration of Ca, Fe and Mn were higher in surface samples than the subsurface samples. But the content was higher in the subsurface level than surface level in the case of Mg, Cu and Zn.

The analysis of soil samples collected after the harvest of the fodder maize revealed that the ranges were 0.90 to 1.17 per cent for organic carbon, 327.86 to 368.39 kg ha^{-1} available N, 12.88 to 17.47 kg ha^{-1} available P and 310.59 to 415.30 kg ha^{-1} available K for surface samples in strips (Table 6). The values for subsurface

Field : Far view

Strip 0

Strip 1

Strip 2

Harvesting

Plate 1. Different stages of Fertility Gradient Experiment conducted at Experimental Field of AICRP on STCR

Table 5. Soil fertility status before FGE at surface and subsurface level

	pH	EC	CEC	PFC	KFC	OC	Available nutrients (kg ha^{-1})								
Surface		dS m^{-1}	Cmol kg^{-1}	%	%	%	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Strip 0	4.87	0.02	3.65	55.71	17.75	1.20	357.00	13.18	300.51	47.07	11.73	38.01	101.62	12.31	1.10
Strip 1	5.03	0.02	3.14	60.25	17.83	1.22	341.51	15.51	379.81	47.93	10.39	31.66	147.24	9.41	0.95
Strip 2	4.93	0.03	3.10	61.41	18.50	1.00	348.30	16.07	405.31	47.70	10.60	35.99	131.94	10.65	1.02
Mean	4.94	0.02	3.30	59.12	18.03	1.14	349.33	14.92	361.90	47.57	10.91	35.22	126.93	10.79	1.02
Subsurface															
Strip 0	4.93	0.02	3.04	57.87	17.52	1.01	318.83	16.17	269.33	36.07	12.07	21.21	104.31	20.48	0.95
Strip 1	5.13	0.03	3.40	66.56	16.71	1.02	314.53	16.43	352.83	38.33	11.77	41.14	98.63	8.49	1.10
Strip 2	5.07	0.02	3.34	58.92	17.12	1.03	328.47	16.73	409.60	50.83	13.43	30.61	120.36	9.64	1.25
Mean	5.04	0.02	3.26	61.12	17.12	1.02	320.28	16.44	343.92	41.74	12.42	30.99	107.77	12.87	1.10

Table 6. Soil fertility status after FGE at surface and subsurface level

	pH	EC	CEC	PFC	KFC	OC	Available nutrients (kg ha^{-1})								
Surface		$dS\ m^{-1}$		%	%	%	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Strip 0	4.77	0.02	3.74	55.44	17.92	1.17	327.86	12.88	310.59	44.23	11.60	33.97	98.67	11.79	1.00
Strip 1	4.80	0.02	3.30	60.80	17.78	1.15	347.57	15.53	399.84	45.97	11.07	33.37	138.40	8.95	0.89
Strip 2	4.90	0.02	3.17	64.79	19.55	0.90	368.39	17.47	415.30	45.27	11.33	36.47	125.00	10.75	0.67
Mean	4.82	0.02	3.40	60.34	18.41	1.07	347.94	15.29	375.20	45.16	11.33	34.60	120.69	10.49	0.85
Subsurface															
Strip 0	4.90	0.027	3.147	57.260	17.523	0.97	313.60	12.14	307.51	44.367	11.467	20.367	101.667	19.183	0.813
Strip 1	5.03	0.03	3.47	65.82	16.71	1.05	327.51	15.11	389.18	45.97	11.77	39.57	95.53	11.23	1.00
Strip 2	5.10	0.03	3.42	63.27	17.12	0.87	328.30	17.01	405.44	46.77	13.17	29.67	118.63	9.60	0.84
Mean	5.01	0.03	3.34	62.11	17.12	0.96	323.14	14.75	367.38	45.70	12.13	29.87	105.28	13.34	0.88

samples ranged from 0.87 to 1.05 per cent for organic carbon, 313.60 to 328.30 kg ha^{-1} available N, 12.14 to 17.01 kg ha^{-1} available P and 307.51 to 405.44 kg ha^{-1} available K in strips.

The concentration of Ca became more or less same in both levels while that of Fe and Mg were higher in surface sample than the subsurface samples. In the case of Mg, Cu and Zn, the contents were still higher in the subsurface samples than surface samples.

4.1.2 Yield and Uptake of Nutrients by Gradient Crop

The green and dry fodder yield of the gradient crop (fodder maize) as well as the nutrient uptake was computed strip wise. The results on yield and uptake of nutrients by fodder maize were furnished in Table 7. The maximum green and dry fodder yields were observed in strip 2 (S_2) which were 23.11 and 4.79 t ha^{-1} respectively, whereas the minimum were recorded in strip 0 (S_0) with values 6.69 and 1.37 t ha^{-1} respectively.

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

Strip	Fertilizer dose (kg ha^{-1})			Fodder yield (t ha^{-1})		Nutrient uptake (kg ha^{-1})		
	N	P_2O_5	K_2O	Green	Dry	N	P	K
0	0	0	0	6.69	1.37	33.89	5.98	39.37
1	150	100	180	19.02	3.91	85.02	16.66	219.36
2	300	200	360	23.11	4.79	96.21	21.43	277.69

The nutrient uptake is calculated from the nutrient content of maize and dry fodder yield. The highest nutrient uptake of N, P and K were obtained for strip 2 (S_2), with values 96.21, 21.43 and 277.69 kg ha^{-1} respectively (Table 7). The analysis of the data showed that the strips differed significantly in fodder yield and nutrient uptake by gradient crop which lend support to the creation of fertility gradient.

4.2. Test Crop Experiment

After the creation of fertility gradient, the test crop experiment was conducted in the same field by raising the test crop, cucumber var. AAUC-2. Each strip was divided into 24 plots of equal size (2 x 1.5 m). The general field view of STCR experiment was shown in Plate 2. 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.

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

The treatment structure was in such a way that each strip as well as each FYM blocks received all the treatment combinations. The gradient in soil fertility was from strip 0 to 2. Each strip contained three control plots, those plots which received no FYM or fertilizer for the test crop. The treated plots refer to those plots (21 per strip) which received either FYM or fertilizers alone or a combination of both treatments.

4.2.1 Soil analysis on pre-experimental sample

The analysis of soil samples collected prior to the application of fertilizers was done for estimating the contributions of nutrients from the soil. The soil samples were analysed for pH, EC, organic carbon, available N, P and K. The mean values of soil nutrient content before the STCR experiment were given in tables 8, 9 and 10.

From the above tables, it was observed that the pH varied from 4.30 to 5.00, 4.40 to 5.30 and 4.70 to 5.20 in strips 0, 1 and 2 respectively. The ranges of values for EC recorded were from 0.053 to 0.095, 0.032 to 0.158 and 0.042 to 0.20 dS m^{-1}. Organic carbon content in the soil varied from 0.99 to 1.43, 0.56 to 1.51 and 0.73 to 1.00 per cent in strips from 0 to 2 respectively. Available N status ranged from

Growing stage

Flowering stage

Harvesting stage

Plate 2. Different stages of Test Crop Experiment conducted at Experimental Field of AICRP on STCR

366.91 to 523.71, 175.62 to 470.40 and 197.57 to 301.06 kg ha^{-1} in strips 0, 1 and 2 respectively. The soil available P registered a range in values from 6.41 to 20.09, 7.27 to 18.38 and 11.11 to 22.66 kg ha^{-1} in the strips. The available K content ranged from 247.30 to 516.10, 333.31 to 494.59 and 327.94 to 532.22 kg ha^{-1} in strips 0, 1 and 2 respectively.

Considering the soil properties of all plots, the soil fertility status ranged from 0.56 to 1.51 per cent of organic carbon, 175.62 to 523.71 kg ha^{-1} available N, 6.41 to 22.66 kg ha^{-1}available P and 247.30 to 532.22 kg ha^{-1}available K respectively (Tables 4, 5 and 6). From the data it is obvious that necessary gradient in soil fertility was created in the field for conducting the STCR experiment.

Table 8. Soil fertility status before TCE in Strip 0

Treatments	pH	EC	O.C.	Available nutrients (kg ha^{-1})		
		dS m^{-1}	%	N	P	K
1.	5.0	0.063	0.99	523.71	12.82	430.08
2.	4.6	0.053	1.00	501.76	8.55	419.33
3.	4.7	0.053	1.01	517.44	10.26	424.70
4.	4.3	0.063	0.99	508.03	10.69	456.96
5.	4.6	0.074	1.00	504.90	11.11	451.58
6.	4.9	0.053	1.06	501.76	11.54	440.83
7.	4.6	0.074	1.02	504.90	8.55	446.21
8.	4.5	0.095	1.02	501.76	8.98	435.46
9.	4.6	0.053	1.12	420.22	19.66	376.32
10.	4.3	0.074	1.10	366.91	17.95	247.30
11.	4.5	0.074	1.13	376.32	17.10	295.68
12.	4.6	0.053	1.12	392.00	17.10	344.06
13.	4.5	0.074	1.11	407.68	17.53	349.44
14.	4.4	0.095	1.10	404.54	19.24	333.31
15.	4.6	0.074	1.13	410.82	19.66	365.57
16.	4.5	0.095	1.12	388.86	20.09	338.69
17.	4.8	0.095	1.43	439.04	11.11	516.10
18.	4.9	0.084	1.33	392.00	6.41	381.70
19.	4.8	0.074	1.38	404.54	8.98	483.84
20.	4.6	0.063	1.41	401.41	9.83	462.34
21.	4.7	0.084	1.42	379.46	10.69	451.58
22.	4.6	0.074	1.39	407.68	11.11	467.71
23.	4.9	0.063	1.38	429.63	10.26	456.96
24.	4.6	0.084	1.36	423.36	9.83	478.46

Table 9. Soil fertility status before TCE in Strip 1

Treatments	pH	EC	O.C.	Available nutrients (kg ha^{-1})		
		dS m^{-1}	%	N	P	K
1.	4.9	0.147	13.40	420.22	14.53	494.59
2.	4.9	0.126	11.60	363.78	7.27	349.44
3.	4.7	0.116	13.40	420.22	12.82	483.84
4.	4.8	0.137	13.50	423.36	14.11	473.09
5.	4.6	0.147	13.60	426.50	14.53	456.96
6.	4.7	0.158	13.40	420.22	13.68	467.71
7.	4.6	0.147	13.20	413.95	13.25	462.34
8.	4.8	0.158	13.20	413.95	14.96	451.58
9.	5.3	0.053	15.00	470.40	17.10	446.21
10.	4.9	0.032	14.00	439.04	16.24	354.82
11.	5.1	0.042	15.00	470.40	17.10	430.08
12.	5.0	0.042	13.00	407.68	17.53	419.33
13.	5.0	0.053	14.00	439.04	17.53	424.70
14.	5.1	0.042	13.00	407.68	17.95	397.82
15.	5.3	0.042	14.00	439.04	18.38	403.20
16.	5.2	0.053	15.00	470.40	17.53	408.58
17.	4.7	0.084	6.60	206.98	18.38	387.07
18.	4.4	0.074	5.60	175.62	12.82	333.31
19.	4.6	0.095	5.70	178.75	13.25	381.70
20.	4.7	0.084	5.80	181.89	14.96	376.32
21.	4.6	0.084	5.90	185.02	17.10	387.07
22.	4.5	0.095	6.00	188.16	17.53	387.07
23.	4.4	0.074	6.10	191.30	17.10	381.70
24.	4.5	0.095	6.00	188.16	17.10	370.63

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Table 10. Soil fertility status before TCE in Strip 2.

Treatments	pH	EC	O.C.	Available nutrients (kg ha^{-1})		
		dS m^{-1}	%	N	P	K
1.	5.0	0.126	0.88	260.29	18.38	532.22
2.	5.1	0.042	0.73	197.57	17.10	473.09
3.	5.0	0.116	0.89	250.88	17.10	478.46
4.	5.1	0.105	0.88	254.02	17.53	467.71
5.	5.2	0.116	0.90	257.15	17.95	456.96
6.	5.0	0.126	0.90	250.88	17.10	516.10
7.	4.9	0.105	0.89	260.29	17.53	489.22
8.	4.9	0.116	0.88	250.88	17.95	494.59
9.	5.1	0.200	0.96	266.56	22.66	430.08
10.	4.7	0.158	0.84	263.42	12.82	327.94
11.	5.0	0.168	1.00	266.56	21.37	419.33
12.	5.1	0.179	0.96	269.70	21.80	419.33
13.	4.9	0.200	0.94	263.42	22.23	403.20
14.	4.8	0.189	0.90	257.15	21.80	403.20
15.	5.0	0.200	0.92	260.29	21.37	419.33
16.	5.1	0.189	0.98	266.56	21.37	397.82
17.	5.1	0.063	0.92	297.92	14.96	360.19
18.	5.2	0.053	0.77	285.38	11.11	344.06
19.	5.0	0.053	0.90	294.78	14.53	349.44
20.	5.1	0.042	0.92	291.65	14.96	365.57
21.	5.1	0.063	0.94	288.51	14.11	360.19
22.	5.2	0.074	0.90	301.06	14.53	349.44
23.	5.1	0.063	0.92	288.51	14.11	365.57
24.	5.2	0.053	0.91	297.92	14.96	344.06

The mean values of organic carbon were 1.17, 1.15 and 0.90 per cent respectively for strips 0, 1 and 2. Available N registered mean values of 337.86, 347.57 and 368.39 kg ha^{-1} for strips 0, 1 and 2 respectively. The mean values of available P were 12.88, 15.53 and 17.47 respectively for strips 0, 1 and 2 and that of K were 310.59, 399.84 and 415.30 kg ha^{-1} (Table 11).

Table 11. Strip wise mean values of soil nutrient content before STCR experiment

Particulars	Strip		
	0	1	2
Organic carbon (%)	1.17	1.15	0.90
Available N (kg ha^{-1})	327.86	347.57	368.39
Available P (kg ha^{-1})	12.88	15.53	17.47.
Available K (kg ha^{-1})	310.59	399.84	415.30

4.2.2 Yield of cucumber

The data on fruit yield as influenced by treatments were recorded in the Table 12-14. The strip wise mean values of fruit yields were given in Tables 15. As evident from the data the control plots in all the strips registered lower yield (10839 to 18440 kg ha^{-1}) than the treated plots (21195 to 21618 kgha^{1}) (Table 15).

In the treated plots, the fruit yield varied from 1231.25 to 41640, 10087 to 37724 and 11673.75 to 40448.75 kg ha^{-1} in strips 0, 1 and 2 respectively (Table 12-14). The mean fruit yields from treated plots were 21618, 21195 and 21494 kg ha^{-1} (Table 15). Considering all plots in each strip, the average fruit yield recorded were 20608, 20285 and 21127 kg ha^{-1} (Table 15).

Table 12. Fruit yield in different treatments of TCE in Strip 0

	Treatments				Yield
	FYM (t ha $^{-1}$)	N (kg ha $^{-1}$)	P_2O_5 (kg ha $^{-1}$)	K_2O (kg ha $^{-1}$)	(kg ha $^{-1}$)
1.	25	0	0	0	16995
2.	25	35	25	25	24001
3.	25	140	50	12.5	40561
4.	25	70	25	25	39908
5.	25	70	0	25	30256
6.	25	140	25	25	41640
7.	25	70	12.5	25	25276
8.	25	70	50	25	21605
9.	12.5	70	25	12.5	16100
10.	12.5	140	25	12.5	32272
11.	12.5	70	25	50	25131
12.	12.5	35	12.5	12.5	16888
13.	12.5	0	0	0	13373
14.	12.5	70	25	0	22453
15.	12.5	70	12.5	0	27221
16.	12.5	35	25	12.5	24268
17.	0	0	25	25	1231
18.	0	35	12.5	25	3238
19.	0	70	50	50	5638
20.	0	0	0	0	2147
21.	0	140	25	50	5262
22.	0	140	50	50	6498
23.	0	140	12.5	12.5	4518
24.	0	140	50	25	8110

Table 13. Fruit yield in different treatments of TCE in Strip 1

	Treatments				Yield
	FYM ($t\ ha^{-1}$)	N ($kg\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)	K_2O ($kg\ ha^{-1}$)	($kg\ ha^{-1}$)
1.	12.5	140	50	25	29612
2.	12.5	0	25	25	20612
3.	12.5	35	12.5	25	16798
4.	12.5	70	50	50	23552
5.	12.5	0	0	0	26790
6.	12.5	140	25	50	23860
7.	12.5	140	50	50	26385
8.	12.5	140	12.5	12.5	37723
9.	0	70	50	25	10087
10.	0	140	50	12.5	10303
11.	0	0	0	0	7221
12.	0	35	25	25	11370
13.	0	70	25	25	13377
14.	0	70	0	25	11396
15.	0	140	25	25	13730
16.	0	70	12.5	25	10598
17.	25	0	0	0	21307
18.	25	70	12.5	12.5	25823
19.	25	70	25	21	26495
20.	25	70	25	50	30238
21.	25	140	25	12.5	22731
22.	25	35	12.5	12.5	37363
23.	25	70	25	0	23932
24.	25	35	25	12.5	27376

Table 14. Fruit yield in different treatments of TCE in Strip 2

	Treatments				Yield
	FYM (t ha^{-1})	N (kg ha $^{-1}$)	P_2O_5 (kg ha $^{-1}$)	K_2O (kg ha $^{-1}$)	(kg ha $^{-1}$)
1.	0	70	12.5	12.5	17615
2.	0	140	25	12.5	26552
3.	0	35	12.5	12.5	17358
4.	0	70	25	0	14906
5.	0	35	25	12.5	18763
6.	0	70	25	50	25597
7.	0	0	0	0	15640
8.	0	70	25	12.5	16856
9.	25	0	25	25	25832
10.	25	35	12.5	25	20141
11.	25	70	50	50	26733
12.	25	0	0	0	30895
13.	25	140	25	50	30858
14.	25	140	50	50	34762
15.	25	140	12.5	12.5	26540
16.	25	140	50	25	40448
17.	12.5	70	50	25	24581
18.	12.5	70	12.5	25	20261
19.	12.5	140	25	25	19820
20.	12.5	70	0	25	11737
21.	12.5	70	25	25	13097
22.	12.5	140	50	12.5	11673
23.	12.5	35	25	25	11803
24.	12.5	0	0	0	4575

In the control plots, the minimum yield of 2147.50kg ha^{-1} was recorded in strip 0 with STVs of 401.41, 9.83, and 462.34 kg ha^{-1} available N, P and K respectively.

The maximum yield of 30895 kg ha^{-1} was obtained from strip 2 with STVs of 269.70, 21.80, and 419.33 kg ha^{-1} available N, P and K respectively (Table 14).

Among the treated plots, the highest fruit yield of 41640 kg ha^{-1} was obtained from strip 0 (T_6) which received 25 t ha^{-1} FYM and 140:25:25 kg ha^{-1} of N, P_2O_5 and K_2O as fertilizers, where the STVs were 501.76, 11.54, 440.83 kg ha^{-1} of available N, P and K respectively. The minimum yield of 1231.25 kg ha^{-1} was obtained from strip 0 (T_{17}) with STVs of 439.04, 11.11 and 516.10 kg ha^{-1} available N, P and K respectively (Table 14).

Table 15. Strip wise mean yield of cucumber

Fruit yield (kg ha^{-1})	Strip 0	Strip 1	Strip 2
Control plots	10839	18440	17037
Treated plots	21618	21195	21494
All plots	20608	20285	21127

4.2.3 Nutrient uptake by Cucumber

The nutrient uptake of the crop was calculated separately for the different parts of the plant and fruit for all the treatments. The total nutrient uptake of N, P and K by cucumber is represented in Table 16, 17 and 18. Uptake of N, P and K ranged from 8.745 to 144.64, 0.65 to 55.54 and 8.06 to 103.91 kg ha^{-1} in strips 0, 1 and 2 respectively. The mean values in each strip were also calculated.

4.2.4 Soil analysis on post-experimental sample

The data on post soil analysis are furnished in Table 19 to 24. From table 25, it was observed that there is increase in pH and decrease in EC in all the strips. In the case of strip 0, OC, N and K levels are decreased much. P is also decreased from 12.88 to 10.05 kg ha^{-1}. In the case of strip 1, OC and N levels are not changed much. P is increased and the depletion of K is high. In the case of strip 2, the level of the OC, N and P increased and the depletion of K is high here also.

Table 16. Nutrient uptake in different treatments of TCE in Strip 0

Treatments					Nutrient uptake (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha $^{-1}$)	P_2O_5 (kg ha $^{-1}$)	K_2O (kg ha $^{-1}$)	N	P	K
1.	25	0	0	0	38.34	13.03	39.52
2.	25	35	25	25	57.36	29.79	41.54
3.	25	140	50	12.5	88.86	49.11	78.48
4.	25	70	25	25	85.82	55.54	96.18
5.	25	70	0	25	106.43	53.18	73.72
6.	25	140	25	25	109.93	53.19	95.51
7.	25	70	12.5	25	49.45	32.20	63.16
8.	25	70	50	25	59.52	21.99	42.79
9.	12.5	70	25	12.5	55.25	10.16	28.89
10.	12.5	140	25	12.5	109.68	16.34	64.16
11.	12.5	70	25	50	67.18	14.03	47.17
12.	12.5	35	12.5	12.5	34.92	7.82	33.59
13.	12.5	0	0	0	33.51	8.32	22.57
14.	12.5	70	25	0	74.84	13.16	45.84
15.	12.5	70	12.5	0	87.49	10.37	47.28
16.	12.5	35	25	12.5	57.30	11.02	37.61
17.	0	0	25	25	8.75	0.65	9.40
18.	0	35	12.5	25	16.17	1.48	11.00
19.	0	70	50	50	30.06	3.84	21.12
20.	0	0	0	0	9.75	0.88	8.06
21.	0	140	25	50	11.92	1.84	10.56
22.	0	140	50	50	15.86	2.05	15.31
23.	0	140	12.5	12.5	13.54	2.50	13.92
24.	0	140	50	25	20.29	3.09	18.60

Table 17. Nutrient uptake in different treatments of TCE in Strip 1

Treatments					Nutrient uptake (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha $^{-1}$)	P_2O_5 (kg ha $^{-1}$)	K_2O (kg ha $^{-1}$)	N	P	K
1.	12.5	0	0	0	96.62	12.39	44.17
2.	12.5	35	25	25	40.60	5.42	33.72
3.	12.5	140	50	12.5	43.09	9.54	43.35
4.	12.5	70	25	25	54.63	8.91	46.49
5.	12.5	70	0	25	61.09	21.32	60.94
6.	12.5	140	25	25	75.34	10.97	46.22
7.	12.5	70	12.5	25	101.85	13.72	67.21
8.	12.5	70	50	25	123.28	23.99	90.02
9.	0	70	25	12.5	41.37	3.61	21.65
10.	0	140	25	12.5	29.51	3.50	25.12
11.	0	70	25	50	24.14	3.32	18.73
12.	0	35	12.5	12.5	38.18	3.46	23.88
13.	0	0	0	0	62.16	4.15	48.18
14.	0	70	25	0	38.99	5.19	29.36
15.	0	70	12.5	0	43.08	6.47	34.88
16.	0	35	25	12.5	35.49	4.41	21.30
17.	25	0	25	25	78.07	11.58	52.75
18.	25	35	12.5	25	75.53	11.95	61.39
19.	25	70	50	50	79.81	14.28	56.06
20.	25	0	0	0	94.79	17.01	53.06
21.	25	140	25	50	61.11	11.99	52.14
22.	25	140	50	50	86.15	14.45	48.33
23.	25	140	12.5	12.5	73.52	12.72	70.80
24.	25	140	50	25	76.41	15.00	70.62

Table 18. Nutrient uptake in different treatments of TCE in Strip 2

Treatments					Nutrient uptake (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha $^{-1}$)	P_2O_5 (kg ha $^{-1}$)	K_2O (kg ha $^{-1}$)	N	P	K
1.	0	0	0	0	56.14	7.41	59.96
2.	0	35	25	25	120.19	10.13	94.67
3.	0	140	50	12.5	71.23	7.08	64.84
4.	0	70	25	25	52.84	8.35	69.00
5.	0	70	0	25	93.07	14.14	62.52
6.	0	140	25	25	75.96	10.81	95.40
7.	0	70	12.5	25	47.40	6.67	37.03
8.	0	70	50	25	51.66	7.01	53.95
9.	25	70	25	12.5	96.28	11.37	63.18
10.	25	140	25	12.5	65.50	13.33	49.43
11.	25	70	25	50	67.85	18.01	55.75
12.	25	35	12.5	12.5	127.56	15.41	93.36
13.	25	0	0	0	119.68	17.55	91.96
14.	25	70	25	0	110.36	23.17	87.78
15.	25	70	12.5	0	144.64	15.99	103.91
16.	25	35	25	12.5	133.17	18.63	73.40
17.	12.5	0	25	25	50.78	12.05	42.20
18.	12.5	35	12.5	25	44.30	13.45	61.96
19.	12.5	70	50	50	70.44	9.69	53.71
20.	12.5	0	0	0	37.67	7.66	41.28
21.	12.5	140	25	50	28.43	7.66	35.79
22.	12.5	140	50	50	49.60	8.49	30.29
23.	12.5	140	12.5	12.5	45.81	10.21	34.11
24.	12.5	140	50	25	29.14	4.28	18.59

Table 19. Post experiment data on soil in different treatments of TCE in Strip 0

Treatment structure					pH	EC	O.C.
Treatment	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})		dS m^{-1}	%
1.	25	0	0	0	4.8	0.042	0.8589
2.	25	35	25	25	4.45	0.063	0.7780
3.	25	140	50	12.5	4.85	0.063	0.9025
4.	25	70	25	25	4.9	0.063	0.9212
5.	25	70	0	25	5.1	0.0893	1.0332
6.	25	140	25	25	4.55	0.042	0.8776
7.	25	70	12.5	25	5.05	0.084	0.7344
8.	25	70	50	25	4.9	0.126	0.9149
9.	12.5	70	25	12.5	4.8	0.042	1.3985
10.	12.5	140	25	12.5	4.45	0.063	1.1354
11.	12.5	70	25	50	4.85	0.063	0.9692
12.	12.5	35	12.5	12.5	4.8	0.063	1.0754
13.	12.5	0	0	0	4.45	0.0893	0.9461
14.	12.5	70	25	0	4.85	0.042	0.8402
15.	12.5	70	12.5	0	4.9	0.063	0.9149
16.	12.5	35	25	12.5	5.1	0.063	1.0456
17.	0	0	25	25	5.1	0.0893	0.4481
18.	0	35	12.5	25	4.85	0.042	0.6971
19.	0	70	50	50	4.9	0.0525	0.8216
20.	0	0	0	0	5.1	0.0893	0.3672
21.	0	140	25	50	4.55	0.042	0.6971
22.	0	140	50	50	5.05	0.063	0.6722
23.	0	140	12.5	12.5	4.9	0.063	0.6349
24.	0	140	50	25	4.8	0.105	0.6349

Table 20. Post experiment data on soil in different treatments of TCE in Strip 0

Treatment structure					Available nutrients (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	N	P	K
1.	25	0	0	0	465.7	10.4	134.4
2.	25	35	25	25	393.57	13.1	118.72
3.	25	140	50	12.5	415.52	8.6	165.76
4.	25	70	25	25	418.66	8.4	107.52
5.	25	70	0	25	333.98	12.3	105.28
6.	25	140	25	25	191.3	9.5	118.72
7.	25	70	12.5	25	228.93	11.4	109.76
8.	25	70	50	25	266.56	12.4	114.24
9.	12.5	70	25	12.5	227.36	11.16	163.52
10.	12.5	140	25	12.5	210.11	9.21	103.04
11.	12.5	70	25	50	191.3	13.9	91.84
12.	12.5	35	12.5	12.5	194.43	4.56	76.16
13.	12.5	0	0	0	92.512	10	78.4
14.	12.5	70	25	0	333.98	6.42	71.68
15.	12.5	70	12.5	0	327.71	17.3	85.12
16.	12.5	35	25	12.5	335.55	10.38	85.12
17.	0	0	25	25	177.18	10.2	94.08
18.	0	35	12.5	25	271.26	4.6	98.56
19.	0	70	50	50	335.55	11.9	112
20.	0	0	0	0	81.536	7.9	67.2
21.	0	140	25	50	186.59	9.2	105.28
22.	0	140	50	50	174.05	11.8	105.28
23.	0	140	12.5	12.5	213.25	6.1	76.16
24.	0	140	50	25	213.25	10.4	96.32

Table 21. Post experiment data in different treatments of TCE in Strip 1

Treatment structure					pH	EC	O.C
Treatment	FYM ($t\ ha^{-1}$)	N ($kg\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)	K_2O ($kg\ ha^{-1}$)		$dS\ m^{-1}$	%
1.	12.5	0	0	0	6.25	0.037	1.35
2.	12.5	35	25	25	5.35	0.042	1.08
3.	12.5	140	50	12.5	5.45	0.037	0.90
4.	12.5	70	25	25	5.35	0.047	1.01
5.	12.5	70	0	25	5.20	0.047	1.43
6.	12.5	140	25	25	5.45	0.042	1.35
7.	12.5	70	12.5	25	5.35	0.042	1.40
8.	12.5	70	50	25	5.20	0.042	1.50
9.	0	70	25	12.5	5.60	0.047	1.09
10.	0	140	25	12.5	5.45	0.042	1.00
11.	0	70	25	50	5.35	0.042	1.03
12.	0	35	12.5	12.5	5.20	0.042	0.82
13.	0	0	0	0	6.25	0.053	0.84
14.	0	70	25	0	5.35	0.026	0.91
15.	0	70	12.5	0	5.10	0.037	1.03
16.	0	35	25	12.5	5.10	0.042	1.05
17.	25	0	25	25	5.35	0.053	1.17
18.	25	35	12.5	25	5.20	0.026	1.23
19.	25	70	50	50	6.25	0.037	1.24
20.	25	0	0	0	5.35	0.053	1.39
21.	25	140	25	50	5.10	0.026	1.12
22.	25	140	50	50	5.10	0.037	1.24
23.	25	140	12.5	12.5	6.25	0.053	1.09
24.	25	140	50	25	5.35	0.037	1.30

Table 22. Post experiment data in different treatments of TCE in Strip 1

Treatment structure					Available nutrients (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	N	P	K
1.	12.5	0	0	0	225.79	11.00	165.76
2.	12.5	35	25	25	213.25	9.06	98.56
3.	12.5	140	50	12.5	189.73	12.60	94.08
4.	12.5	70	25	25	192.86	4.70	78.40
5.	12.5	70	0	25	90.94	10.20	80.64
6.	12.5	140	25	25	330.85	6.00	73.92
7.	12.5	70	12.5	25	326.14	17.50	89.60
8.	12.5	70	50	25	332.42	10.00	87.36
9.	0	70	25	12.5	381.02	9.60	257.60
10.	0	140	25	12.5	417.09	8.40	268.80
11.	0	70	25	50	412.38	20.80	277.76
12.	0	35	12.5	12.5	365.34	12.30	273.28
13.	0	0	0	0	396.70	8.40	331.52
14.	0	70	25	0	279.10	7.40	239.68
15.	0	70	12.5	0	343.39	11.80	250.88
16.	0	35	25	12.5	501.76	11.60	338.24
17.	25	0	25	25	348.10	63.50	89.60
18.	25	35	12.5	25	401.41	83.20	87.36
19.	25	70	50	50	421.79	81.80	91.84
20.	25	0	0	0	363.78	94.40	96.32
21.	25	140	25	50	396.70	77.40	107.52
22.	25	140	50	50	279.10	101.50	112.00
23.	25	140	12.5	12.5	343.39	71.30	91.84
24.	25	140	50	25	501.76	77.80	109.76

Table 23. Post experiment data in different treatments of TCE in Strip 2

Treatment structure					pH	EC	O.C.
Treatment	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})		dS m^{-1}	%
1.	0	0	0	0	5.60	0.047	1.57
2.	0	35	25	25	5.45	0.042	1.50
3.	0	140	50	12.5	5.35	0.042	1.53
4.	0	70	25	25	5.20	0.042	1.38
5.	0	70	0	25	6.25	0.053	1.39
6.	0	140	25	25	5.35	0.026	1.44
7.	0	70	12.5	25	5.10	0.037	1.53
8.	0	70	50	25	5.10	0.042	1.54
9.	25	70	25	12.5	5.25	0.052	1.64
10.	25	140	25	12.5	5.15	0.026	1.68
11.	25	70	25	50	6.20	0.037	1.44
12.	25	35	12.5	12.5	5.35	0.053	1.39
13.	25	0	0	0	5.10	0.026	1.12
14.	25	70	25	0	5.10	0.037	1.24
15.	25	70	12.5	0	6.25	0.053	1.09
16.	25	35	25	12.5	5.35	0.037	1.30
17.	12.5	0	25	25	5.25	0.047	1.18
18.	12.5	35	12.5	25	5.15	0.026	1.20
19.	12.5	70	50	50	6.15	0.037	1.23
20.	12.5	0	0	0	5.30	0.284	1.33
21.	12.5	140	25	50	5.15	0.026	1.09
22.	12.5	140	50	50	5.10	0.037	1.22
23.	12.5	140	12.5	12.5	6.20	0.053	1.03
24.	12.5	140	50	25	5.30	0.037	0.76

Table 24. Post experiment data in different treatments of TCE in Strip 2

Treatment structure					Available nutrients (kg ha^{-1})		
Treatment	FYM (t ha^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	N	P	K
1.	0	0	0	0	379.46	9.50	235.20
2.	0	35	25	25	417.09	8.20	246.40
3.	0	140	50	12.5	412.38	9.80	262.08
4.	0	70	25	25	365.34	11.30	264.32
5.	0	70	0	25	396.70	8.40	327.04
6.	0	140	25	25	279.10	7.40	237.44
7.	0	70	12.5	25	343.39	11.80	250.88
8.	0	70	50	25	501.76	11.60	338.24
9.	25	70	25	12.5	349.66	38.50	89.60
10.	25	140	25	12.5	399.84	41.60	87.36
11.	25	70	25	50	421.79	54.50	91.84
12.	25	35	12.5	12.5	363.78	46.10	96.32
13.	25	0	0	0	396.70	20.90	107.52
14.	25	70	25	0	279.10	27.50	112.00
15.	25	70	12.5	0	343.39	16.60	91.84
16.	25	35	25	12.5	501.76	27.10	109.76
17.	12.5	0	25	25	348.10	37.20	91.84
18.	12.5	35	12.5	25	399.84	49.50	89.60
19.	12.5	70	50	50	415.52	49.40	96.32
20.	12.5	0	0	0	362.21	38.10	100.80
21.	12.5	140	25	50	396.70	39.80	109.76
22.	12.5	140	50	50	279.10	28.10	114.24
23.	12.5	140	12.5	12.5	343.39	18.70	94.08
24.	12.5	140	50	25	297.92	4.60	87.36

Table 25. Comparison of strip wise average pre and post experimental data

		pH	EC (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Pre experimental data	S0	4.63	0.072	1.17	337.86	12.88	310.59
	S1	4.80	0.091	1.15	347.57	15.53	399.84
	S2	5.04	0.116	0.90	368.39	17.47	415.30
Post experimental data	S0	4.84	0.067	0.85	261.66	10.05	103.51
	S1	5.46	0.041	1.15	335.62	30.47	158.01
	S2	5.45	0.050	1.33	374.75	25.68	155.49

4.2.5 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.

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

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

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

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

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

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

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

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

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

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

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

From the regression equation developed in such method, fertilizer doses can be computed by differentiation and for that the regression equation should have higher per cent of variance explained. Using this statistical method, a programme (IPNS Calculator) was developed by the team of scientists under the leadership of Dr. Abhishek Rathore at IISS, Bhopal. They verified and corrected this programme several times by interacting with users of it.

4.2.5.2. IPNS programme prepared by IISS

The IPNS programme prepared by Indian Institute of Soil Science, Bhopal was used to predict equation for test crop. The programme was developed by a team scientists led by Dr. Abhishek Rathore. The yield, nutrient uptake, soil test values, treatments, quantity of FYM, nutrient requirements, contribution from soil, contribution from fertilizers etc. can be entered into the excel sheet of the programme. The data at various strips should be entered separately in different levels as prepared separate sheets in Excel. In the result sheet, there is option for generate equation and ready reckoner for various soil test values to achieve the selected target yield.

4.2.5.3 Fertilizer Prescription for Targeted Yield

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

Fertilizer prescription equations for cucumber can be represented as

	Basic Data				Fertilizer adjustment Eqns
	NR (kg t^{-1} of fruit)	CS (%)	CF (%)	OM (%)	
N	3.30	16.71	53.78	0.47	FN = 0.61 T – 0.31 SN
P_2O_5	0.30	58.28	42.26	0.38	FP_2O_5 = 0.06 T – 1.38 SP
K_2O	2.20	9.33	16.68	0.46	FK_2O = 0.13 T – 0.06 SK

Where,

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

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

ON, OP, OK are N, P and K in Organic matter (OM) in per cent respectively

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

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

The same was utilized for getting an equation for two targets; i.e. 30 t ha^{-1} and 35 t ha^{-1}. For verifying the equation, verification experiments were conducted.

4.3. Verification Experiment (VE)

The developed equations were verified by Verification Experiment (VE) was conducted in the farmers' fields at four locations; two each in Thrissur and Palakkad districts (Fig. 4). In Thrissur, the fields are at Pallikandam and Maraikkal. In Palakkad district, the fields were at Ayiloor and Vithanassery. The crop was raised with cucumber var. AAUC-2 in four locations. The area was divided and 20 pits of equal size (2 x 1.5 m) were taken. The layout of the field was done as per the design mentioned ealier. The general view of the field and various stages of the crop at different locations of the experiment were shown in plates 3-6. The real relationship between soil fertility, applied nutrients and the resultant crop yield was evaluated in the field conditions and management practices were adopted as per package of practices (KAU, 2007).

Field view

Flowering stage

Harvesting stage

Plate 3. Different stages of Verification Experiment conducted at Pallikandam

Field view

Observations on plant and fruit parameters

Plate 4. Different stages of Verification Experiment conducted at Maraikkal

Field view

Plate 5. Different stages of Verification Experiment conducted at Ayiloor

Field view

Crop management and taking observations in the field

Plate 6. Different stages of Verification Experiment conducted at Vithanassery

4.3.1. Analysis of pre-experimental soil sample

In this study, the original fertility status of the soil was analysed and based on these values, the quantity of feritlizers required for yield targets of 30 and 35 t ha^{-1} of fruit yield for the crop were calculated.

In order to study the fertility status of the soil, initial soil samples were collected from the four fields and analysed for the various physico chemical characteristics like pH, EC, CEC, organic carbon and the nutrients like N, P, K , Ca, Mg, Fe, Mn, Cu and Zn. The available N, P, K and organic carbon contents were used to calculate the quantity of fertilizers needed to be applied using the IPNS programme. The average values for the physico chemical parameters are given in the Table 26.

4.3.2. Treatments in verification experiments

The field trials were conducted in four farmer's fields with five treatments with four replications. As detailed in table 27, in the first location, for the first treatment (T_1) nutrient application was done as per the farmers' practices. The fertilizer applied was only 500 kg ha^{-1} of fertilizer mixture and 25 t ha^{-1} of FYM.

Table 26. Soil fertility status before the verification experiment at surface and subsurface level

	pH	EC	CEC	PFC	KFC	OC	Available nutrients (kg ha^{-1})								
Surface		dS m^{-1}	Cmol (p^+) kg^{-1}	%	%	%	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Pallikandam	5.70	0.07	3.35	65.75	19.75	0.81	272.00	81.00	392.00	57.50	11.70	48.00	101.60	12.35	1.11
Maraikkal	5.90	0.08	3.19	66.25	19.83	1.01	345.00	71.00	683.00	47.90	10.49	39.65	147.25	11.40	0.99
Ayiloor	5.60	0.10	3.38	69.46	18.75	1.09	265.00	70.00	67.20	57.70	10.90	39.99	106.95	10.60	1.11
Vithanassery	5.90	0.09	3.63	69.10	19.09	1.02	255.00	71.00	68.50	67.50	10.95	39.22	102.95	10.75	1.11
Subsurface															
Pallikandam	5.79	0.06	3.78	67.80	17.33	0.80	270.50	80.75	390.00	56.50	11.60	41.21	101.31	12.48	0.99
Maraikkal	5.95	0.07	3.98	66.50	16.44	1.00	335.00	70.50	681.00	46.50	10.50	40.14	138.63	10.49	1.11
Ayiloor	5.67	0.09	3.78	68.90	17.56	1.07	244.00	70.10	66.20	57.10	10.76	40.61	100.36	10.64	1.29
Vithanassery	5.98	0.09	3.57	71.10	17.78	1.04	247.00	70.50	67.50	67.10	10.87	40.99	101.77	10.87	1.25

Table 27. Treatments of the verification experiment at four locations

		Nutritional inputs applied				
Location	Treatments	FYM ($t\ ha^{-1}$)	Fertilizer Mixture ($kg\ ha^{-1}$)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)
Pallikandam	Farmers' practice	25	500.00			
	KAU	25	0.00	70.00	25.00	25.00
	STL	25	0.00	70.15	18.00	19.50
	STCR (30 $t\ ha^{-1}$)	25	0.00	98.90	12.60	15.45
	STCR (35 $t\ ha^{-1}$)	25	0.00	128.80	12.60	22.05
Maraikkal	Farmers' practice	25	400.00			
	KAU	25	0.00	70.00	25.00	25.00
	STL	25	0.00	66.70	18.90	18.00
	STCR (30 $t\ ha^{-1}$)	25	0.00	75.90	12.60	12.75
	STCR (35 $t\ ha^{-1}$)	25	0.00	106.95	12.60	12.75
Ayiloor	Farmers' practice	25	375.00			
	KAU	25	0.00	70.00	25.00	25.00
	STL	25	0.00	81.65	26.55	28.95
	STCR (30 $t\ ha^{-1}$)	25	0.00	101.20	27.00	36.00
	STCR (35 $t\ ha^{-1}$)	25	0.00	131.10	29.25	42.00
Vithanassery	Farmers' practice	25	550.00			
	KAU	25	0.00	70.00	25.00	25.00
	STL	25	0.00	86.25	27.00	31.50
	STCR (30 $t\ ha^{-1}$)	25	0.00	103.50	29.25	39.00
	STCR (35 $t\ ha^{-1}$)	25	0.00	133.40	31.05	42.00

In the second treatment (T_2), general recommendations of KAU for oriental pickling melon viz, 70: 25: 25 kg ha^{-1} of N: P_2O_5: K_2O was followed. For providing this recommendation, the quantities of urea, rajphos and muriate of potash used were 152.00, 138.50 and 41.70 kg ha^{-1} respectively.

In treatmentT_3, soil test based recommendation (as followed by Soil Testing Laboratory), the needed quantity of fertilizers were calculated based on the soil fertility status .The quantities applied were 138.50, 35.00 and 11.00 kg ha $^{-1}$ of urea, rajphos and muriate of potash respectively.

In the treatment T_4 i.e, STCR recommendation for target of 30 t ha^{-1} yield, the amount of fertilizers applied were 44.83, 12.50, 13.19 kg ha^{-1} of urea, rajphos and muriate of potash respectively.

In the treatment T_5 i.e, STCR recommendation for target of 35 t ha^{-1} yield, the amount of fertilizers applied were 58.56, 12.50, 18.73 kg ha^{-1} of urea, rajphos and muriate of potash respectively. The amounts of fertilizers were calculated using the same method as that of T_4.

In all the treatments, FYM @ 25 t ha^{-1} was applied. The details of inputs applied in different locations are given in table 27.

4.3.3. Analysis of soil samples at flowering stage

Soil samples were drawn at the flowering stage of the crop from all the treatments and analysed for the parameters pH, EC, CEC, OC, N, P, K, Ca, Mg, Fe, Mn, Cu and Zn of the soil. The statistical data obtained are given in the table 28.

4.3.4 Analysis of soil samples at harvest stage

The results of analysis of soil samples at harvest are furnished in the table 28. The values were taken as average of four locations since the equation can be verified for all the places.

4.3.5 Analysis of plant sample at flowering stage

The results of analysis of plant samples at flowering stage are furnished in the table 29. The treatment wise values were taken as average of four locations since the equation can be verified for all the places.

Table 28. Soil fertility parameters at flowering and harvest stages of verification experiment

Treatments	pH	EC	CEC	OC	Available nutrients (kg ha^{-1})								
At flowering stage		dS m^{-1}	Cmol (p^{+}) kg^{-1}	%	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Farmers' practice	5.05	0.040	3.90	1.20	544.88	21.03	369.25	77.22	11.48	92.34	153.83	12.11	1.04
KAU POP	5.13	0.055	3.98	1.32	642.88	18.33	629.80	65.02	10.22	99.18	106.96	8.97	0.93
STL recommendation	5.08	0.020	4.65	1.27	703.48	17.69	676.80	68.04	10.65	114.60	153.83	12.11	1.04
STCR (30 t ha^{-1})	4.98	0.068	4.33	1.37	595.84	23.89	428.15	53.89	10.83	94.47	139.50	10.93	1.04
STCR (35 t ha^{-1})	5.08	0.050	4.05	1.45	548.80	22.92	853.73	55.04	11.45	94.21	108.42	8.31	1.10
At harvest stage													
Farmers' practice	5.20	0.040	4.60	1.25	234.90	15.23	313.63	54.71	11.48	117.82	153.83	12.11	1.04
KAU POP	4.90	0.028	4.45	1.27	231.06	24.01	255.16	52.92	10.22	115.30	106.96	8.97	0.93
STL recommendation	4.43	0.055	4.23	1.14	239.04	26.68	225.57	60.56	10.65	108.14	153.83	12.11	1.02
STCR (30 t ha^{-1})	4.70	0.035	3.83	1.24	224.60	26.80	370.95	49.56	10.83	116.31	132.18	10.93	1.00
STCR (35 t ha^{-1})	4.78	0.035	4.60	1.29	260.64	23.88	288.24	65.86	11.45	101.51	103.91	8.31	0.95

Table 29. Plant nutrient contents at flowering and harvest stages

Treatments	Nutrients (%)								
At flowering stage	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
Farmers' practice	1.00	0.30	2.45	0.002	0.002	0.003	0.002	0.001	0.001
KAU POP	1.04	0.32	4.63	0.003	0.002	0.002	0.001	0.001	0.000
STL recommendation	1.23	0.30	3.61	0.004	0.002	0.002	0.001	0.001	0.000
STCR (30 t ha^{-1})	1.43	0.35	3.99	0.003	0.002	0.003	0.000	0.001	0.001
STCR (35 t ha^{-1})	1.32	0.32	3.65	0.004	0.001	0.004	0.002	0.002	0.001
At harvest stage									
Farmers' practice	1.020	0.305	2.160	0.003	0.002	0.000	0.003	0.000	0.000
KAU POP	1.260	0.293	4.900	0.002	0.001	0.000	0.001	0.000	0.001
STL recommendation	1.268	0.299	3.525	0.002	0.001	0.000	0.001	0.000	0.001
STCR (30 t ha^{-1})	1.333	0.367	3.025	0.003	0.000	0.000	0.001	0.000	0.000
STCR (35 t ha^{-1})	1.343	0.438	4.675	0.004	0.002	0.000	0.002	0.000	0.001

4.3.6 Analysis of plant samples at harvest stage

The results of analysis of plant samples at harvest stage are furnished in the table 29.

4.3.7 Analysis on fruit sample

The results of analysis of fruit samples are furnished in the tables 30.

4.3.8 Biometric observations

The results of biometric observations on plant characters at flowering and harvest stages are furnished in the table 31. The treatment wise data from different fields are presented in the figures 7 - 10.

Table 30. Nutrient contents of fruits with different treatments in four fields

Location	Treatments	N %	P%	K%	Ca %	Mg %	Fe %	Mn %	Cu %	Zn %
Pallikandam	Farmers' practice	0.49	0.49	3.20	0.0023	0.0011	0.0004	0.0002	0.0004	0.0004
	KAU POP	0.48	0.49	3.20	0.0023	0.0012	0.0004	0.0002	0.0004	0.0004
	STL recommendation	0.49	0.48	3.50	0.0025	0.0010	0.0005	0.0005	0.0003	0.0005
	STCR (30 t ha^{-1})	0.47	0.50	3.10	0.0024	0.0010	0.0003	0.0006	0.0003	0.0003
	STCR (35 t ha^{-1})	0.49	0.37	4.25	0.0025	0.0002	0.0003	0.0003	0.0004	0.0003
Maraikkal	Farmers' practice	0.48	0.36	4.25	0.0022	0.0016	0.0004	0.0005	0.0005	0.0004
	KAU POP	0.45	0.37	4.21	0.0006	0.0015	0.0004	0.0004	0.0003	0.0004
	STL recommendation	0.51	0.37	4.13	0.0025	0.0013	0.0005	0.0008	0.0001	0.0005
	STCR (30 t ha^{-1})	0.47	0.35	3.60	0.0025	0.0019	0.0002	0.0005	0.0002	0.0002
	STCR (35 t ha^{-1})	0.56	0.36	3.50	0.0024	0.0010	0.0002	0.0006	0.0001	0.0002
Ayiloor	Farmers' practice	0.51	0.33	3.90	0.0026	0.0014	0.0002	0.0005	0.0003	0.0002
	KAU POP	0.54	0.37	3.40	0.0031	0.0012	0.0001	0.0004	0.0005	0.0001
	STL recommendation	0.55	0.57	3.60	0.0035	0.0016	0.0003	0.0002	0.0006	0.0003
	STCR (30 t ha^{-1})	0.75	0.56	4.45	0.0026	0.0010	0.0005	0.0003	0.0001	0.0005
	STCR (35 t ha^{-1})	0.70	0.59	4.65	0.0028	0.0012	0.0006	0.0005	0.0002	0.0006
Vithanassery	Farmers' practice	0.69	0.55	4.68	0.0026	0.0015	0.0002	0.0009	0.0006	0.0002
	KAU POP	0.70	0.52	4.65	0.0026	0.0014	0.0003	0.0005	0.0005	0.0003
	STL recommendation	0.68	0.52	3.85	0.0028	0.0016	0.0002	0.0006	0.0008	0.0002
	STCR (30 t ha^{-1})	0.70	0.25	4.00	0.0031	0.0013	0.0003	0.0008	0.0002	0.0003
	STCR (35 t ha^{-1})	0.68	0.21	3.21	0.0026	0.0017	0.0004	0.0009	0.0001	0.0004

Table 31. Plant biometric parameters at flowering and harvest stages

Location	Treatments	Length of vine (m)	Internodal distance (cm)	Number of leaves $plant^{-1}$	Number of female flowers	Length of vine (m)	Internodal distance (cm)	Number of leaves $plant^{-1}$	Number of female flowers
		Flowering stage				Harvest stage			
Pallikandam	Farmers' practice	0.69	8.25	56.75	25.75	1.25	8.00	95.00	14.25
	KAU POP	1.43	10.50	118.00	28.50	2.33	10.50	143.25	17.50
	STL recommendation	1.61	10.75	126.00	32.75	2.50	10.75	149.25	20.50
	STCR (30 t ha^{-1})	2.53	10.50	167.25	33.25	3.05	11.00	184.00	22.25
	STCR (35 t ha^{-1})	2.53	10.50	154.50	35.50	3.15	10.00	150.50	22.00
Maraikkal	Farmers' practice	0.68	8.00	55.00	25.75	1.58	8.75	96.50	13.50
	KAU POP	1.49	10.25	114.50	28.50	2.45	10.50	146.00	17.25
	STL recommendation	1.55	10.50	123.25	32.00	2.55	10.75	150.00	20.25
	STCR (30 t ha^{-1})	2.20	10.75	163.50	32.50	3.25	11.25	186.75	22.50
	STCR (35 t ha^{-1})	2.55	10.50	154.75	35.50	3.40	10.25	163.25	22.75
Ayiloor	Farmers' practice	0.68	8.00	55.00	25.75	1.58	8.75	96.50	13.50
	KAU POP	1.43	10.50	118.00	28.50	2.33	10.50	143.25	17.50
	STL recommendation	1.55	10.50	123.25	32.00	2.55	10.75	150.00	20.25
	STCR (30 t ha^{-1})	2.53	10.50	167.25	33.25	3.05	11.00	184.00	22.25
	STCR (35 t ha^{-1})	2.55	10.50	154.75	35.50	3.40	10.25	163.25	22.75
Vithanassery	Farmers' practice	0.70	7.50	52.50	26.25	1.55	9.00	96.75	13.00
	KAU POP	1.45	10.00	116.75	28.50	2.33	10.50	143.25	17.00
	STL recommendation	1.56	10.25	122.00	32.25	2.58	10.75	150.50	19.50
	STCR (30 t ha^{-1})	2.58	10.50	167.00	33.00	3.15	10.50	183.00	22.00
	STCR (35 t ha^{-1})	2.60	10.25	158.50	35.50	3.35	15.25	164.00	22.00

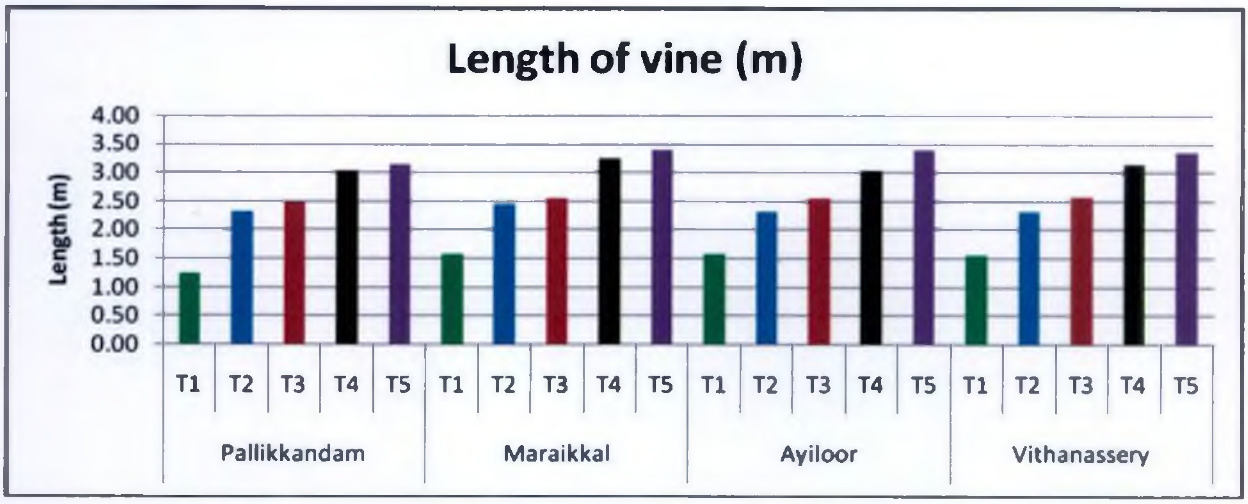


Fig. 7 Treatment wise variations observed in length of vine in four fields

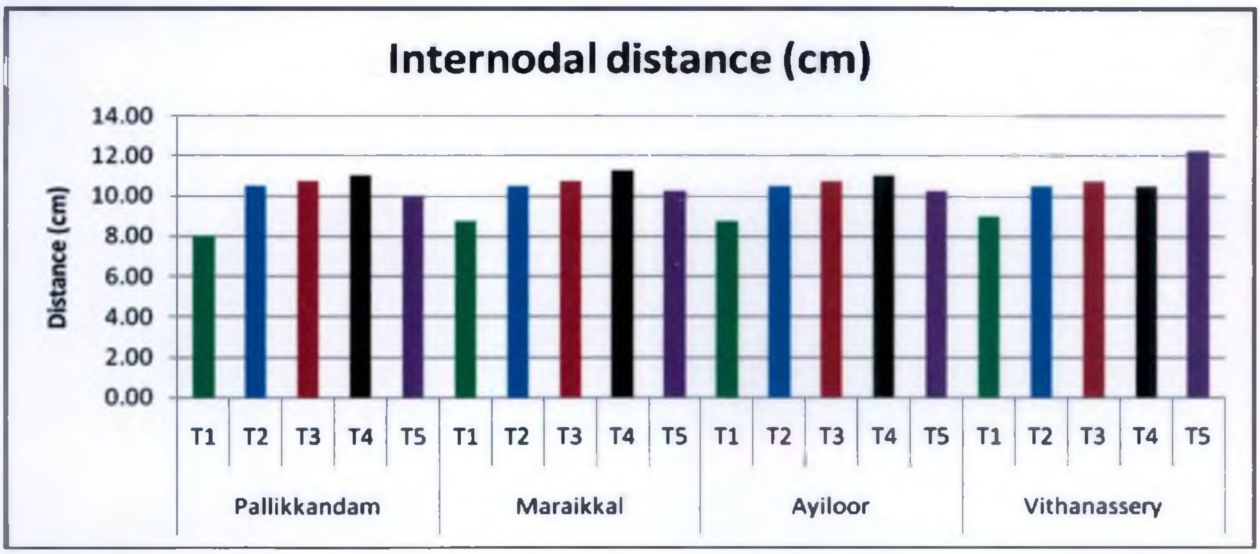


Fig. 8 Treatment wise variations observed in internodal distance in four fields

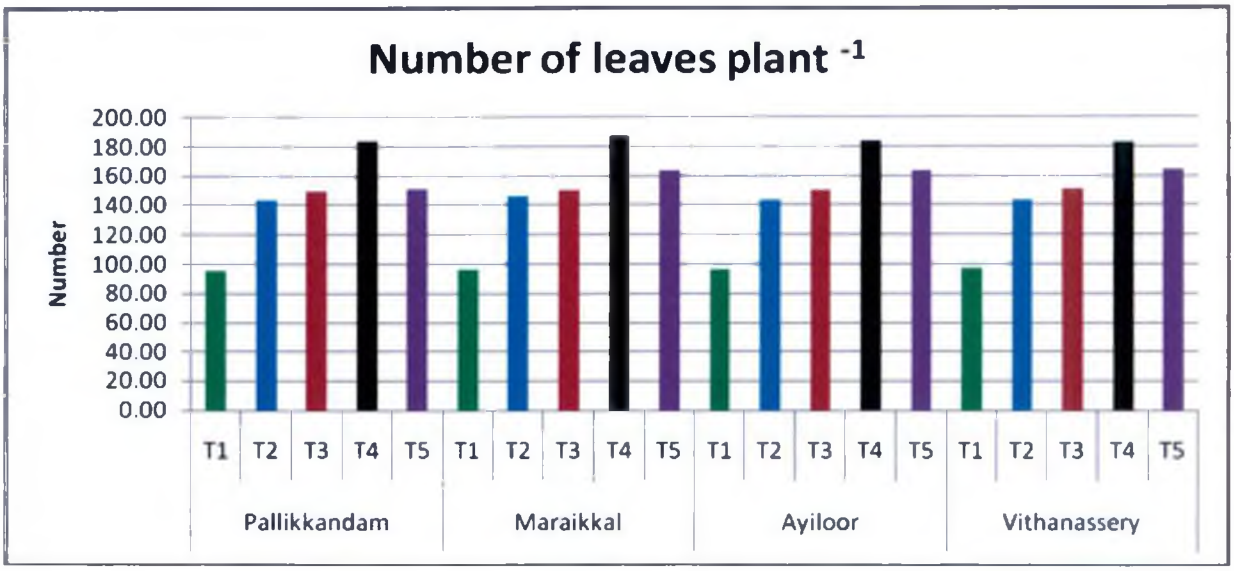


Fig. 9 Treatment wise variations observed in number of leaves in four fields

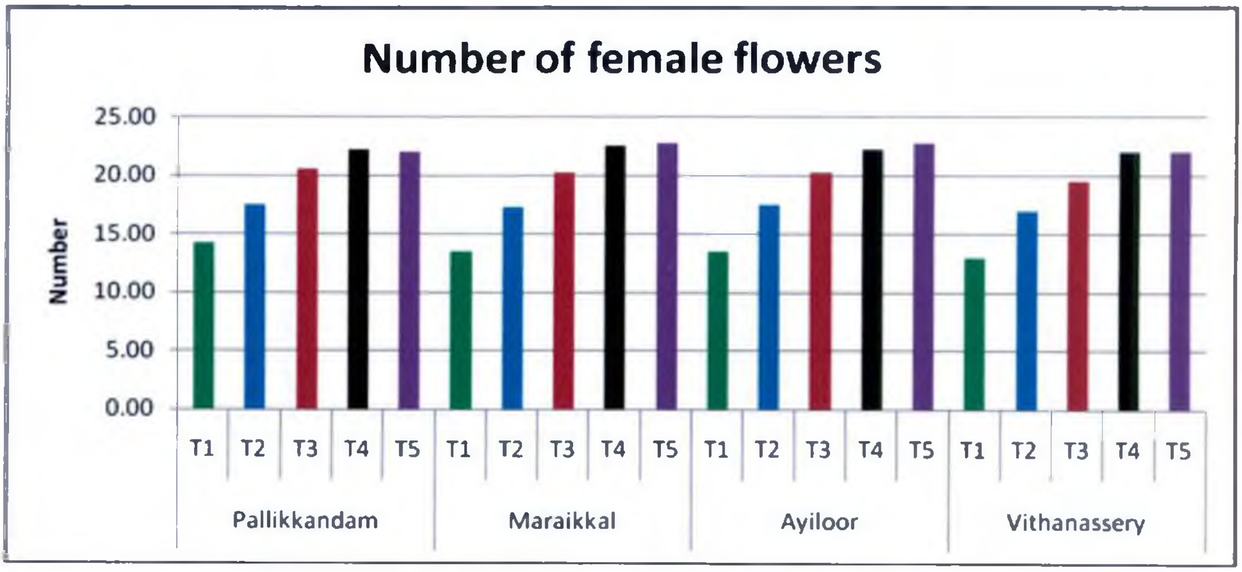


Fig. 10 Treatment wise variations observed in number of female flowers in four fields

4.4 Path Coefficient analysis

The direct and indirect contribution of different nutrients on yield can be found out by partitioning the correlation between yield and nutrient components into direct and indirect effects. The characters were soil nutrient contents at flowering and harvesting stages of the crop, plant nutrients of the vegetative parts at harvest and the fruit nutrients.

4.4.1 Direct and indirect effects of soil nutrients on the fruit yield

From the data obtained at flowering stage (Table 32), both organic carbon (0.589) and potassium (0.387) in soil were found to have high direct effect on yield with positive correlation (0.789), whereas pH (0.277), EC (0.265) and N (0.251) have moderate direct effect. The P (0.148) had low direct effect on yield with positive correlation (0.451). In all parameters mentioned above, except pH and N, had positive high correlation with yield. The OC had only moderate indirect effect through pH (0.216), EC (0.201), P (0.201) and K (0.293) with positive correlation.

It was observed from the data at harvest stage (Table 33) that Mg in soil had high (0.432) direct effect on yield with low correlation (0.123) whereas N (0.209), K (0.276) and Ca (0.265) had moderate direct effect with moderate correlation. Among the different parameters mentioned above, except pH and N, all others had positive high correlations with yield. The P, Mn and Zn had negative direct effect on yield.

4.4.2 Direct and indirect effects of plant nutrients on the fruit yield

The data obtained on plant analysis at flowering stage (Table 34) showed the direct and indirect effects of nutrients of vegetative plant parts on the fruit yield. High direct effect on yield was observed for P (0.397), K (0.812) and Mn (0.568) in plant whereas N (0.1) had a low direct effect. In all parameters mentioned above, except Mn, have positive high correlation with yield. K is having low correlation. The K has

Table 32. Direct and indirect effects of soil components on yield at flowering stage

	pH	EC	CEC	O.C.	Nutrient content (%)									Correlation with yield
		dS m^{-1}	Cmol kg^{-1}	%	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	
pH	**0.2765**	0.0007	0.004	***0.2155***	0.0569	0.0137	0.0566	0.0031	0.029	-0.312	-0.0015	-0.0001	0.0039	0.020
EC	0.0007	**0.2645**	-0.1622	***0.2007***	0.0838	0.0659	0.0927	-0.0107	-0.0005	0.035	-0.0042	0.0005	0.007	0.376
CEC	0.0572	0.1185	**0.0004**	0.022	0.0729	-0.0336	0.0425	-0.0059	0.0022	-0.0152	0.0032	0.0005	-0.0081	0.111
OC	-0.1012	0.0901	-0.0147	**0.5892**	-0.0062	0.0506	0.1919	-0.0238	-0.0018	0.0128	-0.0041	0.0006	0.0157	0.798
N	0.06	0.0057	0.1094	0.0142	**0.2507**	-0.0377	0.0907	0.0003	0.0049	-0.0509	-0.0022	-0.0003	0.0155	0.141
P	0.0255	0.1176	-0.0881	***0.2012***	0.0658	**0.1482**	-0.0382	-0.0114	-0.0022	0.0209	-0.0011	0.0004	0.0105	0.451
K	0.0405	0.0604	0.0427	***0.2925***	0.0607	-0.0147	**0.3865**	-0.0096	0.001	-0.028	-0.0054	-0.0003	0.0103	0.591
Ca	0.0227	-0.0752	-0.0614	-0.3726	-0.0023	-0.0449	-0.099	**0.0376**	-0.0024	-0.0039	0.0029	0.0002	-0.0157	-0.615
Mg	0.0722	0.0148	0.005	0.1058	0.1256	0.0323	-0.039	0.0089	**-0.0101**	0.0397	0.0042	0	0.0083	0.121
Fe	0.0921	-0.098	0.0631	-0.0806	-0.1407	-0.0331	0.1556	0.016	0.0043	**-0.0936**	-0.0008	0.0002	0.0209	-0.147
Mn	0.002	0.0051	0.0956	0.1051	0.0407	-0.012	-0.1612	0.0083	-0.0033	0.006	**0.0131**	0.0004	-0.0189	-0.331
Cu	-0.0188	-0.0711	0.1208	-0.2107	0.0482	-0.0314	-0.0774	-0.0053	0.0002	0.0118	0.0033	**0.0017**	-0.0122	-0.241
Zn	0.016	0.015	0.0478	0.1099	0.0452	0.0304	0.0604	-0.009	-0.0013	-0.034	-0.0037	0.0003	**0.0659**	0.157

Residual effect: 0.0673

Table 33. Direct and indirect effects of soil components on yield at harvest stage

	pH	**EC**	**CEC**	**O.C.**	**Nutrient content (%)**									**Correlation with yield**
		dS m^{-1}	Cmol kg^{-1}	%	**N**	**P**	**K**	**Ca**	**Mg**	**Fe**	**Mn**	**Cu**	**Zn**	
pH	**0.064**	0.0015	0.0022	0.025	0.0005	-0.3443	0.0607	-0.1149	0.113	0.0056	-0.0427	0.0141	-0.0255	0.019
EC	0.0005	**-0.0192**	-0.0189	0.0207	-0.0707	-0.0406	-0.0375	0.0476	0.0506	0.019	-0.0934	0.0166	0.012	-0.089
CEC	0	0.0073	**0.0497**	0.0058	0.0791	-0.2001	-0.0734	0.0472	0.0861	-0.0125	-0.0037	-0.0047	0.0049	-0.086
OC	-0.0024	-0.0059	-0.0036	**0.0676**	-0.0778	-0.039	0.0258	-0.0088	0.082	-0.0226	0.0627	0.0105	-0.0718	0.020
N	0.0002	0.0047	0.0106	0.0102	**0.2094**	-0.0342	-0.0118	-0.0586	0.0388	-0.0467	-0.0244	0.0067	-0.0157	0.212
P	0.0033	-0.0012	-0.0195	-0.004	0.015	**-0.6611**	-0.0386	-0.0041	-0.1888	-0.0304	0.1099	0.0042	-0.01	0.497
K	0.0014	0.0026	0.0102	0.006	0.0124	-0.0925	**0.2757**	-0.0394	0.1205	0.0063	-0.0393	0.0032	-0.0381	0.179
Ca	0.0028	-0.0034	0.0089	-0.022	-0.064	-0.0104	-0.041	**0.2649**	0.0072	-0.0108	0.085	0	-0.0132	0.249
Mg	0.0017	0.0022	0.0099	0.0128	0.026	-0.2889	0.0769	0.004	**0.432**	-0.0022	-0.0977	0.0008	-0.0465	0.123
Fe	-0.0003	-0.0034	-0.0056	-0.0137	-0.1211	-0.1796	0.0156	-0.0257	-0.0086	**0.1117**	-0.1126	0.0155	0.1657	-0.193
Mn	0.0009	0.0068	0.0006	0.0142	0.0206	-0.2427	0.0362	-0.0752	0.141	0.042	**-0.2993**	-0.0142	0.0167	-0.392
Cu	0.0016	-0.0057	0.0042	-0.0164	-0.0349	-0.0502	-0.0185	0.0038	-0.0065	0.0312	-0.0765	**-0.0556**	-0.0173	-0.241
Zn	0.0005	0.0007	0	0.0158	0.0141	-0.0211	0.0326	-0.0108	0.0624	-0.0574	0.0155	0	**-0.324**	0.204

Residual effect: 0.0257

Table 34. Direct and indirect effects of plant nutrients at flowering stage on yield

	Nutrient content (%)									Corrln with yield
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	
N	**0.0969**	***0.2115***	***0.732***	0.1362	-0.0198	0.0004	0.0401	0.014	0.0217	0.751
P	0.0515	**0.3977**	***0.4936***	-0.0547	-0.0229	0.002	***-0.3778***	-0.0103	0.0269	0.504
K	0.0873	***0.2416***	**0.8124**	0.1633	-0.022	0.0005	***-0.3725***	-0.0195	0.0166	0.208
Ca	0.0409	0.072	***0.4411***	**0.0003**	0.0047	0	-0.074	-0.0152	-0.0252	0.604
Mg	-0.0414	-0.1965	-0.3862	0.0303	**0.0464**	-0.0006	0.0445	0.0256	0.0005	-0.558
Fe	0.0465	0.0862	***0.4757***	0.1154	-0.0325	**0.0008**	0.0635	-0.0382	0.0801	0.798
Mn	-0.0704	-0.2643	***-0.5324***	-0.0392	0.0036	0.0001	**0.5684**	-0.0093	0.01	0.001
Cu	0.0004	0.0096	0.0487	0.1004	0.0261	0.0007	0.1157	**-0.0455**	0.0727	0.687
Zn	0.0161	0.0817	0.1032	-0.0578	-0.0285	0.0005	0.0402	0.0252	**0.0101**	0.264

Residual effect: 0.019

Table 35. Direct and indirect effects of plant nutrients at harvest on yield

	Nutrient content (%)									Corrln with yield
	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn	
N	**0.2324**	0.1006	***0.207***	0.1128	0.0732	0.0015	0.0173	-0.0005	0.0384	0.776
P	0.0876	**0.2669**	0.1225	***0.3075***	0.0322	0.0015	0.0042	-0.0021	0.0381	0.791
K	0.1931	0.1353	**0.2415**	0.179	0.0885	0.0012	0.0165	-0.0016	0.0263	0.878
Ca	0.0784	***0.2456***	0.1295	**0.334**	-0.0147	0.0026	-0.0053	-0.0009	0.0334	0.798
Mg	-0.1294	0.0654	-0.1626	0.0373	**-0.1315**	0.0004	-0.0138	0.0007	0.0007	-0.334
Fe	-0.0354	0.0411	0.0285	0.0856	-0.0047	**0.01**	0.0015	-0.0069	-0.0193	0.080
Mn	0.0662	0.0186	0.0656	0.0293	0.0299	0.0002	**0.0606**	0.0043	0.0043	-0.203
Cu	-0.0072	-0.0342	-0.0236	-0.0189	-0.0054	0.0044	-0.0164	**0.016**	-0.0092	0.095
Zn	0.1021	0.1163	0.0726	0.1277	-0.0011	0.0022	-0.003	-0.0017	**0.0874**	0.503

Residual effect: 0.0325

high indirect effect through N (0.732), P (0.494), Ca (0.441) and Fe (0.476) but having high negative indirect effect through Mn (-0.532).

From the table 35, it was observed from the data at harvest stage that, Ca in plant had high direct effect (0.334) on yield with high correlation (0.798) whereas N (0.232), P (0.267) and K (0.242) have moderate direct effects with high correlation. In all parameters mentioned above have positive high correlation with yield. The P has moderate indirect effect through Ca (0.246) with high correlation. In the same way K was also having moderate indirect effect through N (0.207) with high correlation. The Ca had high indirect effect on yield through P (0.308) with high correlation.

4.5 Yield and Economics of cultivation

The verification experiment conducted in four locations gave satisfactory results in terms of yield (Table 36,). The fruit yields obtained during each harvest were cumulated for finding out the final total yield. This was done treatment wise as well as location wise (Fig. 11). In all locations, STCR targets were achieved with a better B:C ratio compared to other treatments

Table 36 . Treatment wise yield from verification experiment

Location	Treatments	Yield (t ha^{-1}) Fresh Fruits	B:C ratio
Pallikandam	Farmers' practice	20.40	0.85
	KAU POP	24.46	1.04
	STL recommendation	26.15	1.12
	STCR (30 t ha^{-1})	30.13	1.29
	STCR (35 t ha^{-1})	35.39	1.51
Maraikkal	Farmers' practice	20.31	0.85
	KAU POP	25.10	1.07
	STL recommendation	26.18	1.12
	STCR (30 t ha^{-1})	30.72	1.31
	STCR (35 t ha^{-1})	35.18	1.50
Ayiloor	Farmers' practice	19.93	0.83
	KAU POP	24.44	1.04
	STL recommendation	25.17	1.07
	STCR (30 t ha^{-1})	29.88	1.27
	STCR (35 t ha^{-1})	35.02	1.48

Vithanassery	Farmers' practice	19.35	0.80
	KAU POP	24.73	1.05
	STL recommendation	25.64	1.09
	STCR (30 t ha^{-1})	30.23	1.28
	STCR (35 t ha^{-1})	34.87	1.47

The economic analysis (Benefit: cost analysis) of the different treatments were given in the table 36. The analysis revealed the superiority of the treatment, T_5 followed by treatment T_4. Although the total cost of cultivation was high in these treatments, the net profit and B: C ratio were also higher. Among the treatments, the treatment T_5 gave higher benefit cost ratio. The average B:C ratio obtained for different treatments were 0.83 (T_1), 1.05 (T_2), 1.10 (T_3), 1.29 (T_4) and 1.49 (T_5).

The investigation enabled to formulate a fertilizer prescription methods based on soil test crop response experiments for cucumber. The equation formulated, on verification experiment in farmers' fields were found to produce the targets fixed in different locations in Palakkad and Thrissur districts.

The investigation also threw light into the variations in the crop production depending upon the various treatments adopted. It also considered the various types of the nutrient interactions in soil, plant, and fruit components with respect to the yield of the crop.

DISCUSSION

DISCUSSION

The results of the study pertaining to different soil and plant parameters of the experimental areas and yield obtained were discussed. The soil, plant and fruit samples were taken for analysis from various stages of experiments. The analysis of surface and subsurface samples was undertaken to get an insight into the fertility status of the soils in a field and hence to design suitable management practices and modify the fertilizer recommendations in view of the existing resource potential. These data can be utilized for the exploitation of existing potential, for better management of soils, which serve as the medium for several crop production processes.

A trial was carried out to develop a fertilizer prescription equation useful for different targets of yield levels of the cucumber. The parameters necessary for the derivation of equation were found out from various field experiments. The soil test based fertilizer prescription equation developed for the cucumber in the laterite soils of Kerala has been test verified for the wider acceptability of the technique in the normal field conditions. The yield predictability of the equation was verified over the other treatments which are followed by farmers.

The comparison of different treatments was carried out with respect to yield obtained. The possibilities of recommendation of fertilizer prescription equation were studied. The effects of the nutrients, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients in the soil and plant with respect on the yield were carried out in the present investigation using the crop cucumber. The study also focused effects of treatments on quality parameters of the crop. In the case of verification experiment, the data obtained treatment wise from various locations were pooled and the average obtained was used for further statistical analysis.

The data were discussed under different titles as it was conducted in the field. The field experiments consisted of Fertility Gradient Experiment (FGE), test crop experiment (STCR experiment) and Verification crop experiment (VCE). The data obtained from the experiments are discussed in this chapter in the same order in which they were conducted.

5.1 FERTILITY GRADIENT EXPERIMENT

5.1.1 Soil Fertility Status before and after FGE

The soil fertility gradient created from strip 0 to 2 was confirmed by assessing the soil nutrient status prior to the conduct of FGE and just after the harvest of the gradient crop (fodder maize). The data on soil analysis was furnished in Table 1 and 2. The statistical analysis of the data showed that needed gradient has been created after FGE (Table 2). The data on the analysis of the soil samples after FGE revealed that the organic carbon content of the soil slightly declined in all the strips (Table 2). This may be due to the tendency of the soil to maintain a constant C: N ratio. It also reveals that at any nutrient status, the organic matter content has definite role in making nutrient available to plants and maintaining soil conditions favourable to plant growth (ISSS, 2002).

It was evident that there was an increase in the status of available N after the FGE at both depths except in S 0. The available nutrient N in the strip 0 was absorbed by the crop to a considerable level, for the growth and development. But the N content of the soil increased in strip 1 to 2. This may be due to the fact that the uptake of N by fodder maize might be compensated with the fertilizer application and high rate of mineralization at the high doses of fertilizer application.

While considering the available P after FGE, the P status of the soil increased in the strips 1 and 2 than the initial contents which may be due to the heavier dose of P application. There was a decrease in available P in strip 0 after FGE without any application of P. This might be due to the fact that maize roots might have absorbed available P from the surface soil.

The available K content after FGE increased from strip 0 to 2. This might be due the K fixing capacity of the soil and after effect of the application of heavier doses of K. During the experimental period the rainfall received was less and hence the chance of leaching loss was minimum from the soil. The fertility gradient, after FGE was illustrated in Fig. 5. From the figure it was seen that there was creation of gradient in N and P. The fertility gradient for K was less prominent compared to P.

The creation of such fertility gradient has been already reported (Jayalakshmi, 2001, Nagarajan, 2003 and Sidha, 2004). The results of analysis also confirmed that significant variation in soil fertility has been created in all the strips for all the nutrients.

In the case of micronutrients, a slight decrease was observed after the experiment than the before. The crop might have absorbed only less quantity of micronutrients during the experiment. The trend was similar in both levels for all the strips. The pH level was decreased slightly due to the experiment. There was no significant difference in other parameters.

5.1.2 Yield and Uptake of Nutrients by Gradient Crop

As evident from Table 3, the green and dry fodder yields increased progressively from strip 0 to 2 in accordance with the gradient in fertilizer application. The plant analysis data and total dry matter production were utilized for calculating the nutrient uptake by the crop. Among the three nutrients the uptake of potassium was found to be steep. Similar results were reported by Jayalakshmi (2001), Nagarajan (2003) and Sidha (2004). The crop yield is a function of soil fertility under optimal levels of other production factors. Thus the buildup of a gradient in soil fertility was reflected in the crop response data.

5.2 TEST CROP EXPERIMENT

5.2.1 Soil analysis on pre-experimental sample

The results of soil sample analysis furnished in the tables 4, 5 and 6 showed that necessary gradient in soil fertility parameters was created in the field for conducting the STCR experiment. Such gradient is essential for getting good correlation between crop yield and nutrient status of the medium.

5.2.2 Yield of Cucumber

As evident from the data, the control plots in all the strips registered lower yields than treated plots (Table 11). This might be due to the fact that the control plots depend upon only the soil available nutrients in the absence of applied nutrients.

While considering the strip wise yield, it was observed that the fruit yield increased from strip 0 to 1 and slightly decreased in strip 2. It showed a differential response of nutrients to yield in different fertility levels. In low to medium fertile soil the response was high and consequently the yield was also high. In high fertile soil (strip 2) the response was a little low and it was reflected in the yield also. This may be due to the operation of law of diminishing returns. Similar results were also obtained by Swadija (1997), Jayalakshmi (2001), Nagarajan (2003) and Sidha (2005). In high fertility level (strip 2), considerable amount of photosynthates might have been diverted for increased vegetative growth resulting in reduced fruit yield in comparison with other strips.

5.2.3 Nutrient Uptake by Cucumber

The total nutrient uptake of N, P and K by cucumber was calculated separately and presented in the tables 12, 13 and 14. Among the three nutrients highest uptake was registered by N followed by K and P. Application of P and K increased N uptake (Kulkarni *et al.*, 1986). Increased K uptake was due to higher doses of fertilizer K.

In general, the uptake of nutrients increased from strip 0 to 2 which could be attributed to the increased availability of nutrients from the soil due to fertility gradient created from strip 0 to 2. The considerable increase in uptake, especially in the case of N, was observed in the plots where enough FYM was applied compared to plots where it was not applied. This ensures the fact that both fertilizers and organic sources supply the nutrients to available pool.

5.2.4 Post experimental soil analysis

From the data furnished in Table 19 to 24, it was observed that the organic carbon content decreased in strip 0 and 1. But in the case of N, the depletion was noticed in strip 0 and 1, and an increase in strip 2. It may be due to the unutilized organic manures applied.

Compared to pre-planting soil analysis (Table 25), there was a decline in the available P after STCR experiment in strip 0 only (Table 25). This was due to the uptake of less P by cucumber. Being a vegetable crop, it needs only a normal quantity of P.

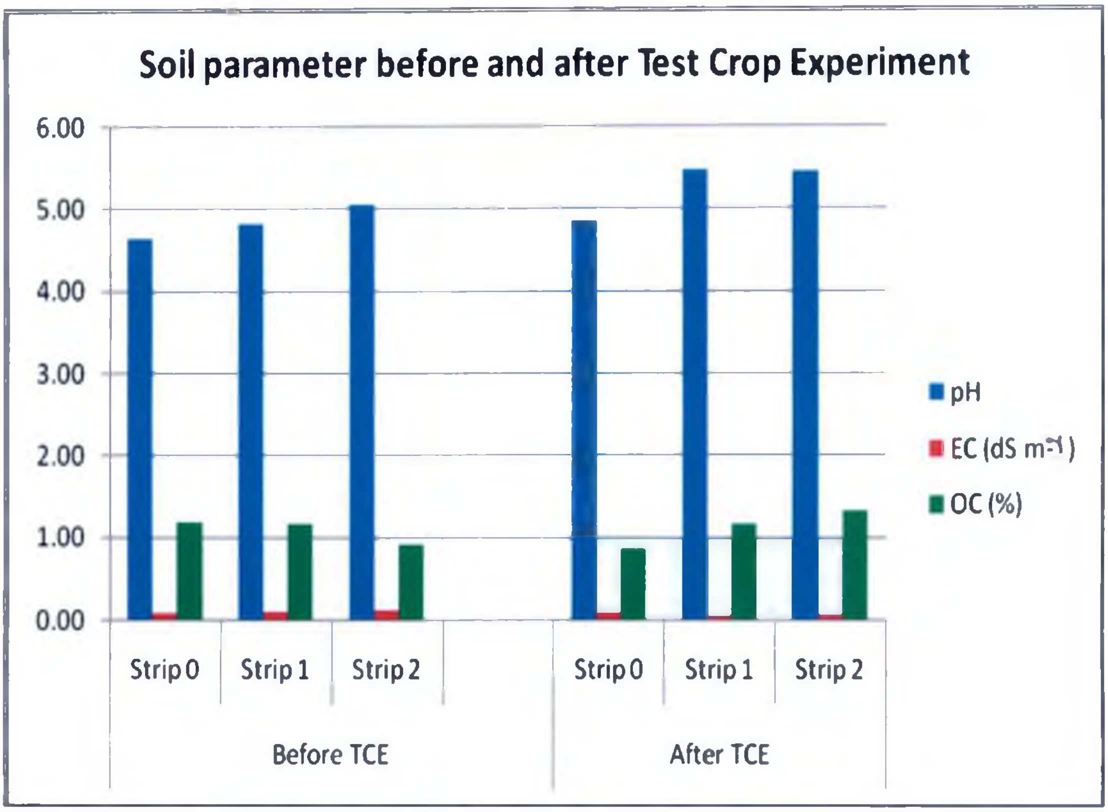
There was a greater depletion of K from the soil after STCR experiment in all the strips (Table 25 and Fig. 6). Cucumber is not a heavy feeder of K and absorbs K in normal level only. Potassium nutrition had favourable impact on photosynthesis. During the growth period of test crop irrigation was given at frequent intervals. Hence there were chances of leaching loss of K.

5.2.5 Fertilizer Prescription for Targeted Yield

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

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

Based on targeted yield equations, ready reckoners can be prepared for



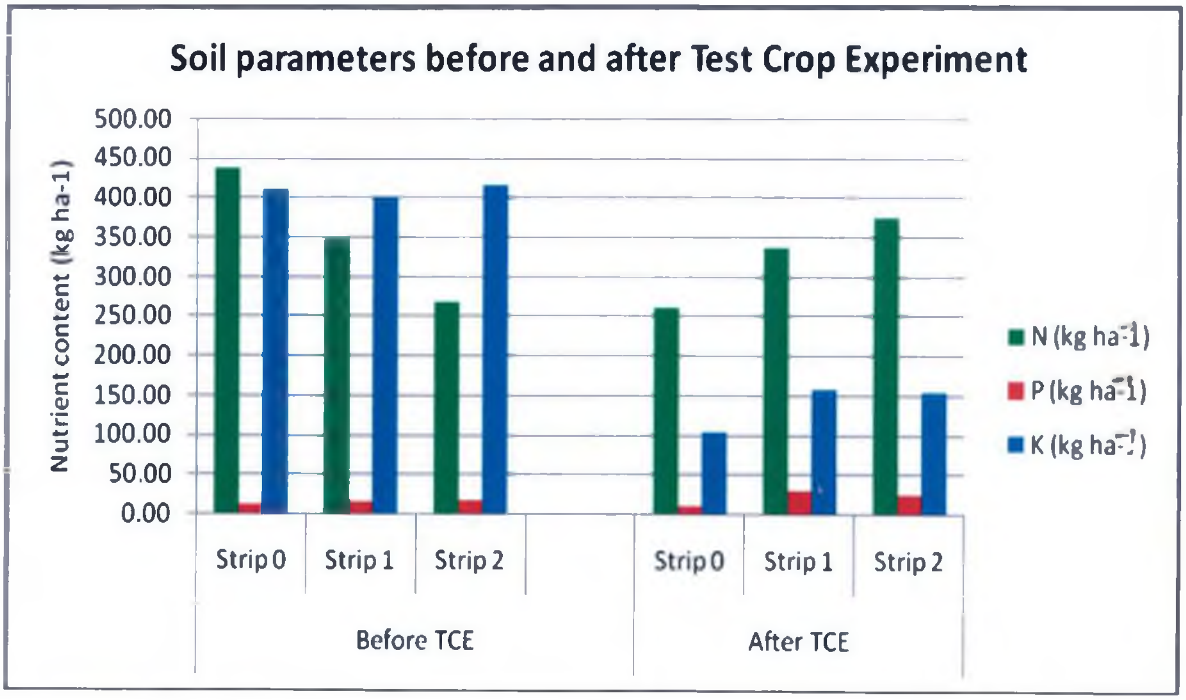


Fig. 6 Soil parameters before and after Test Crop Experiment

recommending fertilizer dose either as inorganic alone or in combination with organics for specific yield targets of the test crop at varying STVs. In the IPNS model developed by IISS, when the soil test values and OM values entered, the ready reckoner is prepared for different soil test values.

The ready reckoner values showed that, increase in the soil test values corresponded to decrease in the fertilizer doses for N, P and K. From the ready reckoner, we could find out the fertilizer doses based on site specific soil test values. Since with STCR approach, we considered the nutrient status of organic manures applied, the quantity of chemical nutrient was less than the quantity of recommendation modified by the soil testing laboratories. Thus fertilizer recommendation based on this approach became meaningful, precise and more quantitative, resulting in reduction in cost of fertilizer for farmers.

5.3 VERIFICATION EXPERIMENT

5.3.1 Analysis on pre-experimental soil sample

The results of soil sample analysis were furnished in the table 26. The necessary data used for preparing prescription equation for target yields of cucumber. The N level in Maraikkal was found to be in medium range and that in other three fields were in low range. It might be due to that fields were continuously using for vegetable crops in all seasons. With regard to P status, all the fields showed high range. The continuous application of P fertilizers might be the reason for the same. As far as K status was concerned, both Pallikkandam and Maraikkal were at high range and Ayiloor and vithanassery were in low range.

5.3.2 Analysis on soil sample at flowering stage

The results of analysis of soil sample at flowering stage were furnished in the table 28. The data were used for path anlaysis and correlation studies.

5.3.3 Analysis on soil sample at harvesting stage

The results of analysis of soil samples at harvest stage were furnished in the table 28. The data were used for path anlaysis and correlation studies.

5.3.4 Analysis on plant sample at flowering stage

The results of analysis of plant samples at flowering stage were furnished in the tables 29. The data were used for path anlaysis and correlation studies.

5.3.5 Analysis on plant sample at harvesting stage

The results of analysis of plant sample at harvest stage were furnished in the tables 29. The data were used for path anlaysis and correlation studies.

5.3.6 Yield of Cucumber

The yield of cucumber obtained replication wise in different locations were given table 36. The yield from the plots where farmers' practice was adopted, was found to be lowest in all the locations. This clearly showed the relevance of integrated nutrient management over the practice of indiscriminate use of fertilizers. The plots where blanket recommendation was followed (treatment 2), recorded a B:C ratio of nearly one. That showed the expense made for the cultivation was more or less same as the income obtained from the yield. In the treatment 3, where soil testing laboratory method was adopted, gave a better yield over the farmers' practice and blank recommendation. This result indicated the relevance of the soil test based nutrient management over the blank recommendation. Here the nutrients were applied as per the requirement only by adjusting the quantity of nutritional inputs based on available nutrients in the soil.

The results obtained in the fourth treatment, where the STCR approach was adopted for a targeted yield of 30 t ha $^{-1}$, showed that the target could be achieved in all the locations. Thus the fertilizer prescription equation developed was test verified for the target. From the results, the importance of response of soil nutrients with crop production was clearly evident. In the fifth treatment, where the target was 35 t ha $^{-1}$, the yield targeted was obtained with a B:C ratio of 1.5 (Fig. 11).

5.4 Path coefficient analysis

The direct and indirect contribution of different nutrients on yield can be found out by partitioning the correlation between yield and nutrient components into direct and indirect effects. If the correlation between yield and a character is due to direct effect of a character, it revealed true relationship between them and direct selection of such traits will be rewarding for yield improvement. On the other side, if the correlation is mainly due to indirect effects of the character through another component trait, indirect selection of such trait will be effective in yield improvement.

5.4.1 Path analysis of soil nutrients with yield

The path analysis was done on the data of nutrient contents of soil at flowering stage (Table 32). This showed high direct effect on yield with positive correlation for both organic carbon (0.589) and potassium (0.387). This showed the role of organic matter for improving the yield through making available a major nutrient K (Fig. 12). The pH (0.277), EC (0.265) and N (0.251) had moderate direct effect ensured the low N observed in the plant during the stage. The direct effect of P (0.148) on yield with positive correlation confirmed the essentiality of the nutrient at that stage. The moderate indirect effect of OC, through pH (0.216), EC (0.201), P (0.201) and K (0.293) with positive correlation described its effect on affecting pH and EC for providing better availability of P and K.

It was observed in the data at harvesting stage (Table 33) that N (0.209), K (0.276) and Ca (0.265) had moderate direct effect with moderate correlation with yield (Fig. 13). It showed the importance of N for better yield and K for improving reproductive growth.

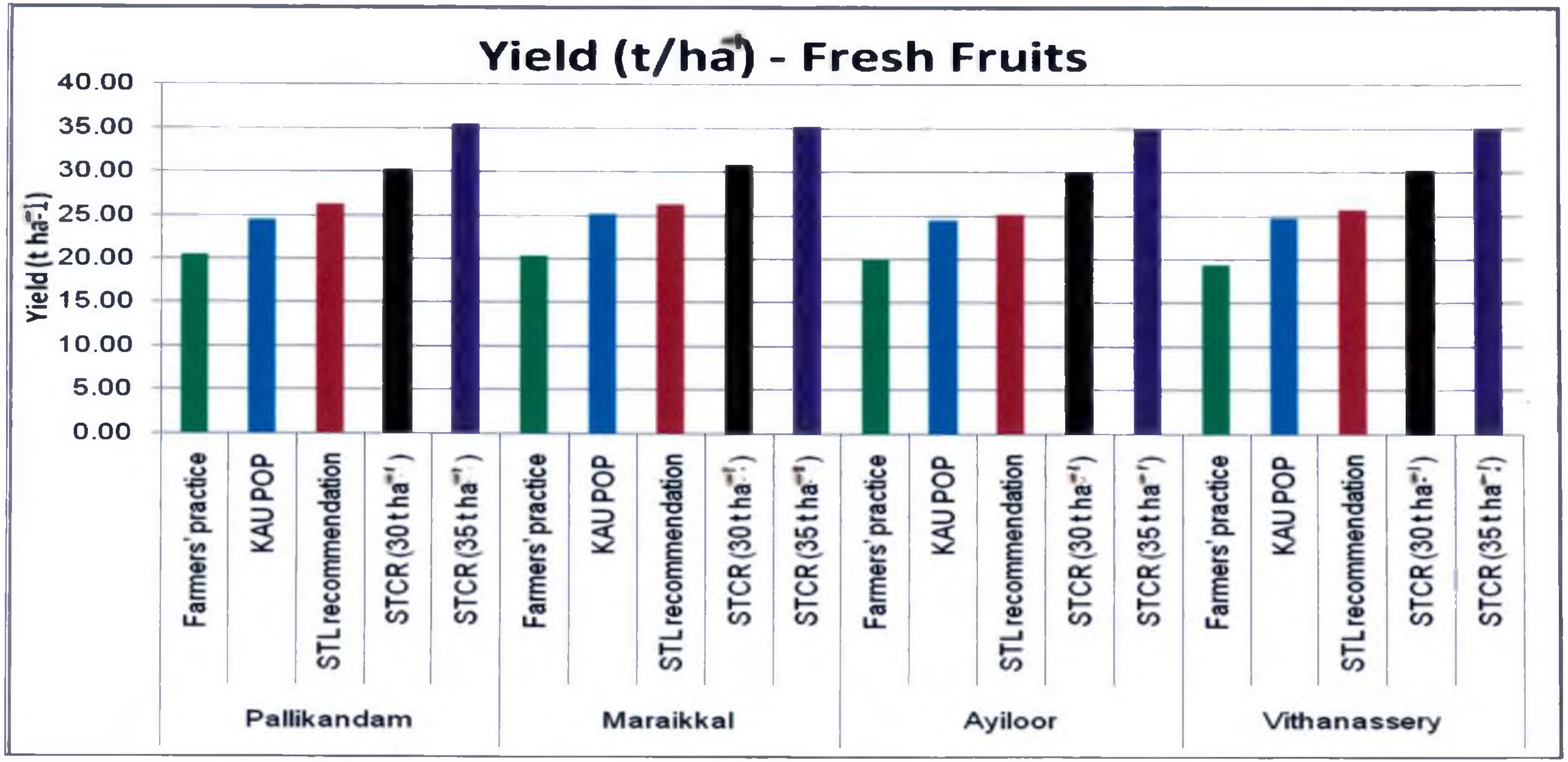


Fig. 11 Treatment wise yield (fresh fruits) obtained from four fields

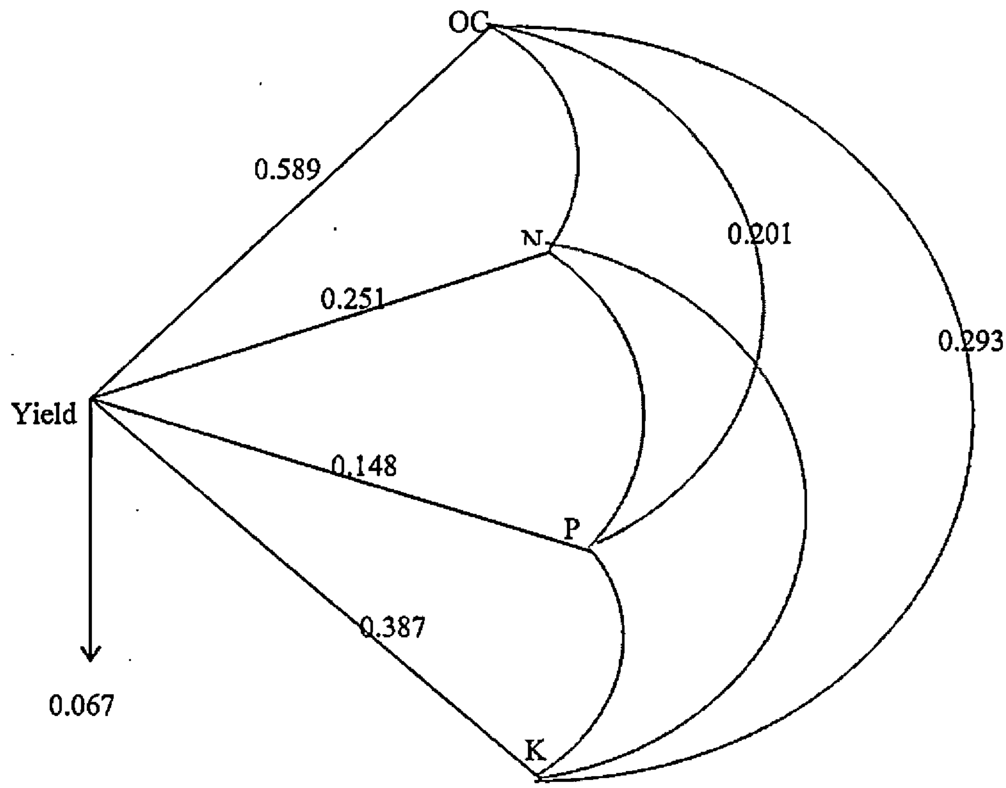


Fig. 12 Direct and indirect effect of soil nutrients at flowering stage on yield

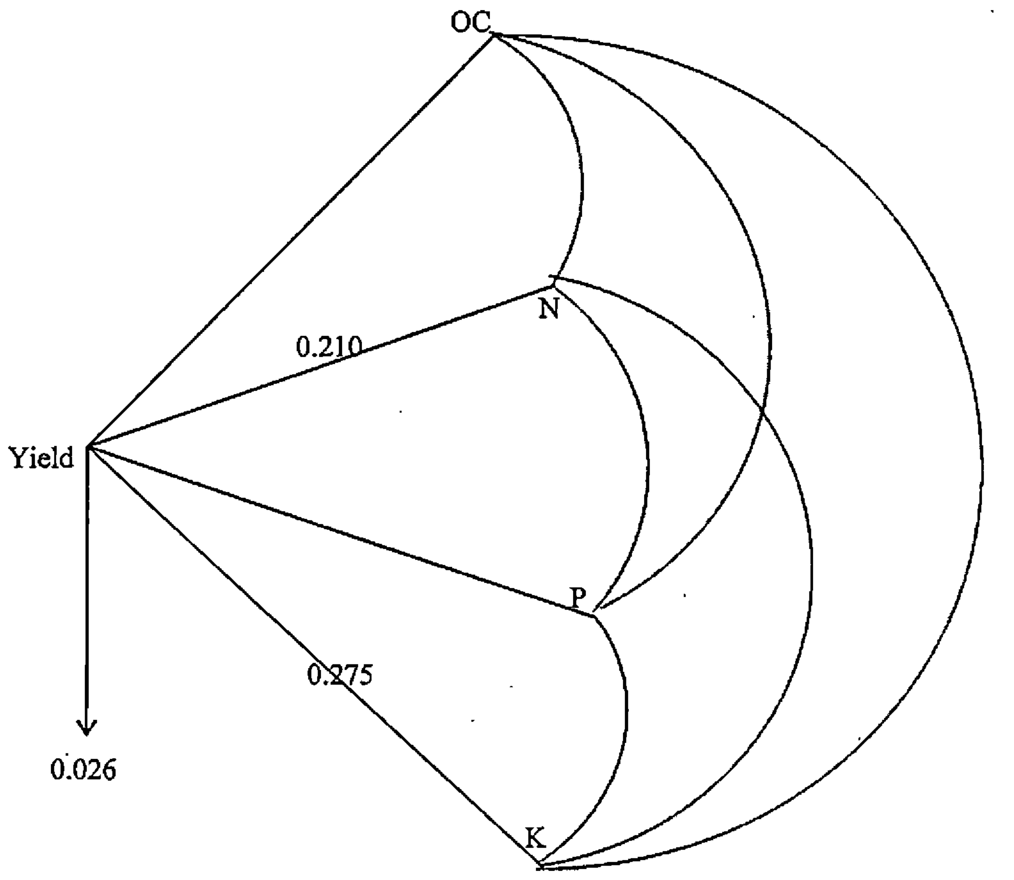


Fig. 13 Direct and indirect effect of soil nutrients at harvest on yield

5.4.2 Path analysis of plant nutrients with yield

Path analysis was carried out with the yield and plant nutrients. The data obtained on plant analysis at flowering stage (Table 34) showed the direct and indirect effects of nutrients of vegetative plant parts on the fruit yield (Fig. 14). High direct effect on yield was observed for P (0.397), K (0.812) and Mn (0.568) in plant whereas N (0.1) had low direct effect. The positive high correlation with yield for P and K showed the relevance of the nutrients in the growing stage. The high indirect effect of K through N (0.732), P (0.494) and Ca (0.441) revealed the complementary effect of the nutrients.

From the table 35, it was observed in the data at harvesting stage that, Ca in plant had high (0.334) direct effect on yield with high correlation (0.798) whereas N (0.232), P (0.267) and K (0.242) had moderate direct effect with high correlation (Fig. 15). The improvement occurred in the case of N showed the importance at the fruiting stage for better yield. The moderate indirect effect of P through Ca and that of K through N with high correlation showed the additive effect. The Ca was having high indirect effect on yield through P (0.308) with high correlation revealed the potential of Ca for making P available to plant.

5.5 Nutrient interactions

The simple correlations were carried out to study the interactions of nutrients in both soil and plant at flowering and harvesting stage. Since the quantity of fertilizers applied in different treatments is of varying nature, the availability of one nutrient might have affected by the sufficiency and deficiency of another one.

At flowering stage, the availability of N and K in soil was positively correlated with organic carbon in the soil. In the growing stage, the availability of N and K was essential and the same was ensured by the organic carbon. In the same way, the level of organic carbon, P and K in soil was positively correlated with yield also.

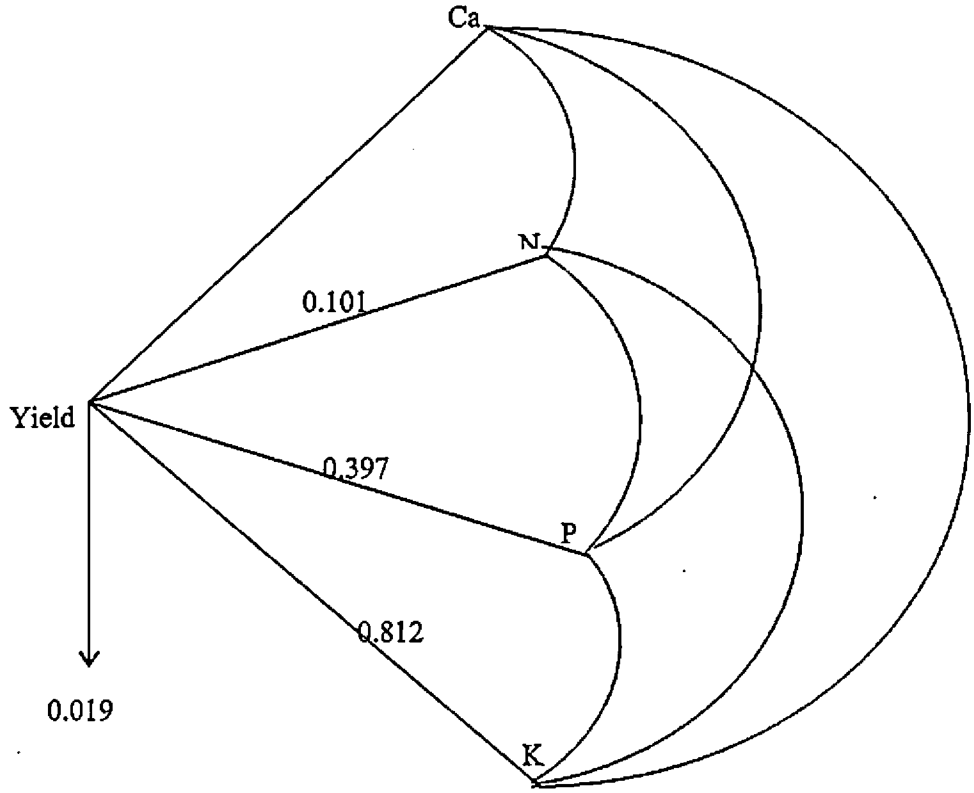


Fig. 14 Direct and indirect effect of plant nutrients at flowering stage on yield

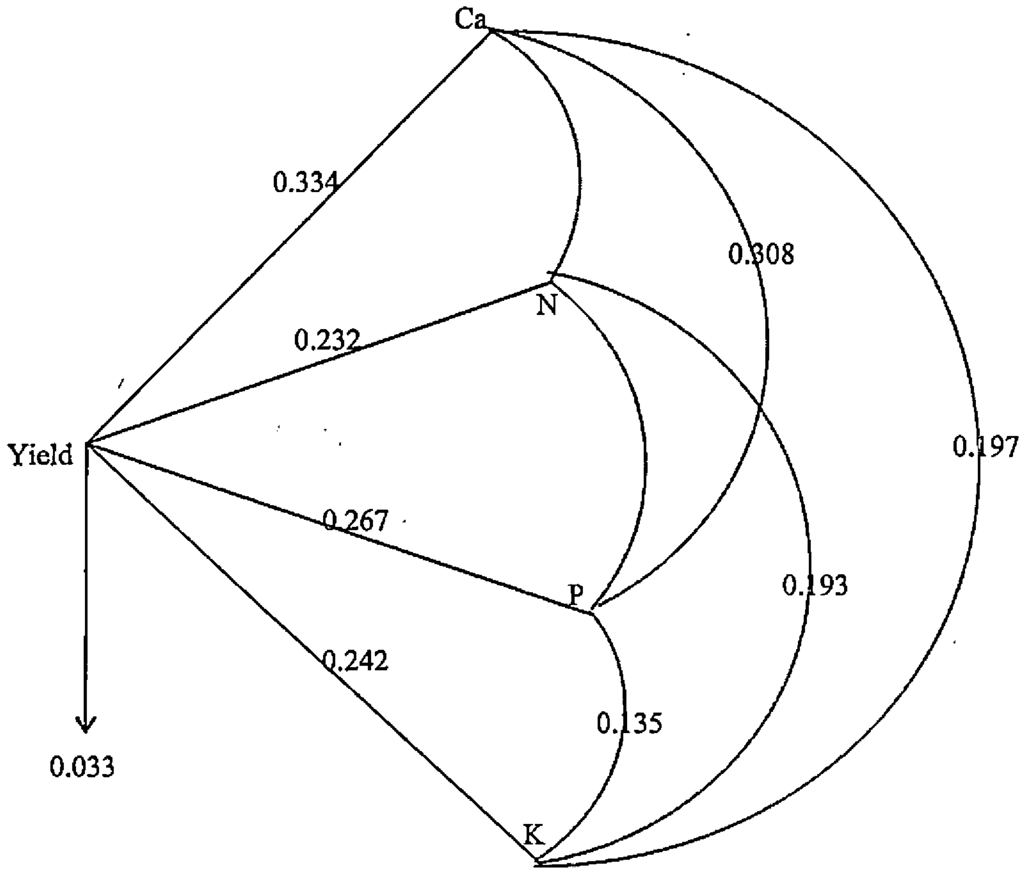


Fig. 15 Direct and indirect effect of plant nutrients at harvest on yield

At the harvesting stage, level of N, P and K in soil was positively correlated with yield. The P in soil was correlated with pH level of soil means when the pH increases the availability of P also increases. The Zn in soil was negatively correlated with Fe content in the soil.

In the case of plant nutrients at flowering stage, level of N, P and K in soil was positively correlated with yield. This ensured the importance of the primary nutrient status for plant growth in this stage.

In the case of plant nutrients at harvesting stage, K in plant had positive correlation with N and P in plant. The Ca content in plant had positive correlation with P and K in the plant. As far as the correlation with yield was considered, level of N, P and K in plant was positively correlated.

When correlation studies between soil and plant nutrients (Table 37) showed that the N and K in plant was positively correlated with soil P. The P content was necessary for root growth and hence it led to greater absorption of N and K by the plant. The Fe in the soil was positively correlated with Mn content in plant. The Fe in soil was negatively correlated with P in plant means the content of Fe in soil restricted the absorption of P by the crop by fixing the same in the soil.

Future line of work

As per the pattern of soil test crop response correlation studies, the next step is to carry out the frontline demonstrations in various farmers' field in different parts of the state where there is similar soil and agro-climatic conditions to validate the results obtained. Since there is distinct difference between the POP package with a better B:C ratio, the methodology can be recommended through soil testing laboratory, if it is found satisfactory after the frontline demonstrations. The equation can be utilized for fertilizer recommendation for other varieties of cucumber prevalent in Kerala. The available soil test values in the soil testing laboratories regarding their own areas can be utilized for recommendation to a particular area for obtaining a

Table 37. Interaction of soil and plant nutrient contents at harvest

[N,P,K,Ca,Mg,Fe, Mn, Cu,Zn : content in plant, N (s), P (s), K (s), Ca (s), Mg (s), Fe (s), Mn (s), Cu (s), Zn (s): content in soil]

	P	K	Ca	Mg	Fe	Mn	Cu	Zn	N (s)	P (s)	K (s)	Ca (s)	Mg (s)	Fe (s)	Mn (s)	Cu (s)	Zn (s)
N	0.377	.831**	0.338	-.557*	-0.152	-0.285	-0.031	0.44	-0.006	.628**	-0.024	0.27	-0.258	-0.024	-0.331	-0.305	-0.36
P		.507*	.920**	0.245	0.154	-0.07	-0.128	0.436	0.377	0.082	0.025	0.338	0.29	-.494*	-0.339	-0.268	-0.154
K			.536*	-.673**	0.118	-0.271	-0.098	0.301	0.08	.693**	0.229	0.028	-0.026	-0.094	-0.258	-0.213	-0.214
Ca				0.112	0.256	0.088	-0.057	0.382	0.184	0.024	0.265	0.316	0.399	-0.114	-0.31	-0.155	-0.145
Mg					0.036	0.227	0.041	0.008	0.124	-.661**	-0.367	0.229	0.22	-0.062	-0.075	-0.08	0.004
Fe						-0.024	-0.434	-0.221	-0.204	0.153	0.189	-0.067	-0.026	0.065	-0.218	-0.034	-0.026
Mn							0.271	0.049	-0.159	-.472*	-0.01	0.022	0.079	.548*	0.286	0.317	-0.29
Cu								-0.105	0.053	-0.404	0.356	-0.276	0.095	0.21	0.009	-0.074	-0.226
Zn									0.047	-.557*	-0.015	0.234	0.05	0.207	0.125	-0.08	-0.411
N (s)										0.052	-0.043	-0.221	0.09	-0.418	0.082	-0.121	0.049
P (s)											-0.14	-0.016	-0.437	-0.272	-0.367	-0.076	0.032
K (s)												-0.149	0.279	0.057	0.131	-0.067	0.118
Ca (s)													0.017	-0.097	-0.284	0.014	-0.041
Mg (s)														-0.02	0.326	-0.015	0.144
Fe (s)															0.376	0.279	-.514*
Mn (s)																0.256	-0.052
Cu (s)																	0.054

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

targeted yield. Then only the implementation of the project result will become fruitful in the field level and reach farmers who are the ultimate beneficiaries of research results.

SUMMARY

SUMMARY

Other than the influence of climate, the important factors affecting the agricultural production are its inputs meant for plant protection and crop growth improvement. Fertilizer application is one of the most efficient means of increasing agricultural profitability. Without the prior knowledge of soil fertility status and nutrient requirements of crops, application of fertilizers by the farmers might result into adverse effect on soil as well as on crops both in terms of nutrient deficiency and toxicity either by inadequate use or over use. So the emphasis on soil test based fertilization has become much more relevant in the present scenario of high fertilizer costs and yield maximisation programmes.

A research programme entitled 'Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala' was conducted during 2006-2008 in the experimental field of AICRP on STCR associated with College of Horticulture, Vellanikkara and farmers' fileds.

The field experiments consist of (i) fertility gradient experiment (FGE), test crop experiment (TCE) and verification experiment (VE). The FGE and TCE experiment are using fertilizers and organic manure. The FGE was conducted during November 2006 – January 2007 in the experimental field. The objective of this experiment was to create a fertility gradient by applying graded doses of N, P and K fertilizer and raising exhaustive crop, fodder maize variety Co-1 in one and the same field. The soil nutrient status before and after the experiment were analysed for both FGE and TCE. The soil nutrient status, fodder yield and nutrient uptake by the gradient crop showed an increasing trend by strip 0 to 2. The fertility gradient was developed after the crop. In the same field, a test crop experiment was laid out.

The TCE experiment was conducted during January to April 2007 with test crop cucumber variety AAUC-2. The treatment structure consisted of four levels of nitrogen (0, 35, 70 and 140 kg ha^{-1}), four levels of phosphorus (0, 12.5, 25 and 50 kg

ha^{-1}) and four levels of potassium (0, 12.5, 25 and 50 kg ha^{-1}) along with three levels of FYM (0, 12.5 and 25 t ha^{-1}). The results of the experiment are summarized below:

The soil samples were collected before, at flowering and harvest stages. The plant samples were collected at flowering and harvest stages. The fruit samples were collected for analysis. The total dry matter productions of various treatments were found out. The soil, plant and fruit samples were analysed for different parameters. The data obtained from the test crop experiment were utilized for determining parameters necessary for deriving an fertilizer prescription equation. The data on yield, uptake of nutrients, nutrient status, nutrient requirement, quantity of farm yard manure applied were used for formulating the fertilizer prescription equations for cucumber.

The basic parameters like nutrient requirement, percent contribution of nutrient from soil, percent contribution of nutrient from fertilizer, percent contribution of nutrient from farmyard manure, soil test values and treatments were used for preparation of equation. Using the programme developed by IISS, Bhopal, fertilizer prescription equation for cucumber was derived.

The derived equation was verified in farmers' fields. In Thrissur district, the selected fields were at Pallikandam and Maraikkal. The fields selected in Palakkad district were at Ayiloor and Vithanassery. The total area taken for experiment was 0.10 acre in each location. The experiment was carried out during December 2007 - May 2008.

Treatment details of the experiment were T_1 (Farmers' practices), T_2 (POP recommendation of KAU), T_3 (STL recommendation of Kerala), T_4 (STCR recommendation for target of 30 t ha^{-1}) and T_5 (STCR recommendation for target 35 t ha^{-1}) with four replications. The FYM was applied in all the fields at 25 t ha^{-1} .

The soil samples were collected before, at flowering and harvest stages. The plant samples were collected at flowering and harvest stages. The fruit samples were collected for analysis. The total dry matter productions of various treatments were found out. The soil, plant and fruit samples were analysed for different parameters. The data obtained were utilized for statistical analysis.

The results obtained from different fields showed that fertilizer application based on yield target gave higher yields, net benefit and B/C ratio over the farmers' practice. The target yield approach was also found superior to fertilizer doses prescribed by the soil testing laboratories. The targets fixed as T_4 and T_5 could be achieved in the verification experiment in all the locations with a better B:C ratio. The percent achievement of targets aimed at different level was almost 100%, indicating soil test based fertilizer recommendation approach was economically viable within the agroecological zone with relatively uniform cropping practices and socio-economic conditions.

The results can be verified by conducting frontline demonstrations in more number of fields. The application of this method should be widespread through soil testing laboratories all over the state. This approach can be utilized for the planning and motivating the cultivating practices and thus attain the maximum output with available resources.

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ABSTRACT

Nutrient interactions in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala

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ABSTRACT OF THE THESIS
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ABSTRACT

A comprehensive approach has to be adopted for efficient fertilizer use, incorporating soil test, field research and economic evaluation of the results for providing a scientific basis for the process of enhancing and sustaining food production as well as soil productivity with minimum environmental degradation, it needs more. Soil testing is one of the best scientific means for quick and reliable determination of soil fertility status. Soil test crop response study in the field provides soil test calibration between the level of soil nutrients as determined in the laboratory and the crop response to fertilizers as observed in the field for predicting the fertilizer requirements of the crop. In Kerala, many studies have been conducted to get a fertilizer prescription equation for targeted yield in various crops like rice, banana etc.

A programme was formulated to investigate the nutrient interaction in soil test crop response studies on cucumber (*Cucumis sativus* L.) in the laterite soils of Kerala. In this, the field works were conducted as per the pattern of soil test crop response correlation studies.

A gradient crop experiment was conducted in the experimental field of AICRP on STCR using maize. The purpose is to create a fertility gradient in the field by applying different doses of fertilizers. The area was divided into three strips and the doses of nutrients were applied as per STCR pattern of fertilization for maize. The crop was harvested and the plant samples were taken for analysis. The pre and post experimental soil samples were analysed. It was found that fertility gradients were developed in the field. Using the data on dry matter production in various strips, the nutrient uptake was also determined.

A test crop experiment was designed in the same field where the gradient crop was raised. There were 24 treatments with three control plots. The treatments included four levels of nutrients and three levels of farm yard manure. The crop, cucumber (Var.: AAUC-2), popularly known as salad cucumber, was raised and managed as per package of practices of KAU. The soil samples were collected before,

at flowering and harvest stages during the experiment. The plant samples were collected at flowering and harvesting stages. The total dry matter production and yield were taken treatment wise at the harvest. The soil samples were analysed for various chemical parameters.

The data on yield, uptake of nutrients, nutrient status, nutrient requirement, quantity of farm yard manure applied were used for formulating the fertilizer prescription equations for cucumber. Using these equations, the quantity of fertilizers to be used to get a target of yield can be calculated if the available nutrient status is known.

The equations thus developed were verified in farmers' field at four locations; Pallikandam, Maraikkal, Ayiloor and Vithanassery. The fields were laid out with five treatments and four replications. The treatments were (i) farmers' practice, (ii) KAU package, (iii) soil testing laboratory method, (iv) STCR method with a target of 30 t ha^{-1} and (v) STCR method with a target of 35 t ha^{-1}. The soil samples were analysed before raising the crop and the quantities of fertilizers to be applied were computed for various treatments. The plant and soil samples at flowering and harvest stages were analysed for pH, EC, CEC, Organic Carbon, available N, P, K, Ca, Mg, and micronutrients such as Fe, Mn, Cu and Zn. The total dry matter production and yield were taken treatment wise at the harvest.

The data were used for statistical analysis for assessing direct and indirect effect of nutrients on yield and nutrient interactions. A positive correlation was observed between organic carbon and soil parameters at flowering stage. At the harvesting stage, there was a positive correlation was found between yield and major nutrients. The interaction between available P in the soil and N and K in the plant was observed. The availability of P in plant was negatively correlated with Fe in the soil.

The targeted yield equations for cucumber could produce the yields of 30 and 35 t ha^{-1} from the verification experiments conducted at the different locations. The B:C ratio also was higher in the STCR methods over the farmers' practices, blanket recommendations and STL recommendations. The information generated in the project will help in making the soil testing programme scientifically sound in terms of achieving predicted yields, maintaining soil fertility and helping the extension agencies in ensuring balanced fertilizer use according to the soil fertility status and crop requirement.

APPENDICES

APPENDIX - I

MONTHLY AVERAGE WEATHER PARAMETERS OF VELLANIKKARA
(Location for Fertility Gradient & Test Crop Experiments)
(Jan 2006 – Dec 2007)

2006	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Max. Temperature	33.5	34.9	36	34.8	31.5	29.7	28.4	29	30.7	31.9	31.2	32.3
Min. Temperature	20.8	21.9	23.8	25.4	24.1	23.3	22.5	23	23.4	23.2	22.6	23.1
Rainfall (mm)	2.5	0	4.4	38.8	583.9	477.3	759.3	356.4	37.5	313.3	69.8	1.8
Rainy days	0	0	1	2	18	25	28	22	8	12	3	0
R H (am)	65	80	81	83	92	93	94	94	91	92	87	72
R H (pm)	34	36	46	53	72	76	82	75	65	69	62	45
Sunshine (hrs)	9	10	9.7	8.3	4.5	3.4	2.4	3.5	6.2	6.5	6	10.2
Wind speed (Km/hr)	10	8.4	5.4	5.2	4.4	4.4	3.9	3.8	2.8	2.4	4.2	9.5
2007												
Max. Temperature	33.6	35.9	36.4	35.6	35.1	29.7	29.1	29	31.5	30.5	31.5	31.9
Min. Temperature	22.2	21.7	24.9	24.5	25.5	23.8	22.8	22.7	23.7	23.2	23	21.7
Rainfall (mm)	3.9	0	1.8	83.3	86.1	993.1	975.6	583.2	61.5	281.7	191.3	0.2
Rainy days	1	0	0	4	5	28	27	24	7	14	9	0
R H (am)	74	74	84	83	85	94	94	95	91	90	87	78
R H (pm)	41	28	47	53	55	82	79	78	64	74	63	49
Sunshine (hrs)	10.9	4.1	8.7	8.9	7.5	4.8	2.5	2.8	7.3	4.3	7.1	8.6
Wind speed (Km/hr)	4.5	4.5	4.9	4.7	4.5	4.8	4.6	3.6	4.2	3.7	6.1	9.8

APPENDIX - II

MONTHLY AVERAGE WEATHER PARAMETERS OF THRISSUR (Location for Verification Experiment)

(July 2007 – Jun 2008)

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max. Temperature	28.8	28.9	30.1	30.7	31	31.1	32.6	35.5	36.9	36.3	33.8	30.5
Min. Temperature	22.7	23.3	23.1	22.1	23.1	22.3	28.9	21.8	22.8	24.4	24.8	23.7
Rainfall (mm)	874.5	563.9	302.9	386.7	377.5	2	0	0	0	48.6	90.6	979.8
Rainy days	26	25	17	14	12	0	0	0	0	3	6	22
R H (am)	95	94	91	92	86	72	69	87	84	82	85	92
R H (pm)	80	81	73	72	68	49	36	42	38	48	61	77
Sunshine (hrs)	2.1	2.7	4.1	4.6	5.5	8.9	9	9.2	9.2	8.8	7.4	3.3
Wind speed (Km/hr)	4.3	4.3	3.8	3.2	5.8	13.7	11.7	5	5	4.8	4.4	5.3

MONTHLY AVERAGE WEATHER PARAMETERS OF PALAKKAD (Location for Verification Experiment)

(July 2007 – Jun 2008)

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Max. Temperature	29.4	29.1	31.7	31.8	30.2	31.3	32.5	33.9	35	33.8	31.8	29.9
Min. Temperature	23.8	23.1	23.9	23.1	24.6	22.1	21.8	21.6	23.6	25.3	24.5	22.3
Rainfall (mm)	769.3	346.4	37.9	314.3	68.8	1.9	2.6	0	4.7	38.6	573.9	478.3
Rainy days	29	23	9	14	4	0	0	1	1	2	17	26
R H (am)	98	96	92	91	88	73	67	81	80	84	93	92
R H (pm)	89	77	66	67	63	46	35	37	47	54	71	74
Sunshine (hrs)	2.9	3.9	6.2	6.9	6.4	10.1	9.3	10	9.8	8.1	4.6	3.5
Wind speed (Km/hr)	3.4	3.7	2.8	2.7	4.4	9.1	10.1	8.6	5.3	5.4	4.8	4.5

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