Soil Test Crop Response Based Fertilizer Recommendations for Efficient Fertilizer Use and Enhanced Crop Productivity in Kerala

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FOREWORD

Soil is the most important natural resource known to influence plant growth and biomass production. The deterioration of productive capacity of the soil coupled with imbalanced and inadequate supply of plant nutrients has made most of our production system fragile in the post green revolution era. In this context targeted yield concept on soil testing is inevitable. Soil Test - Crop Response based fertilizer recommendations for targeted yield of crops are the basis for technology transfer in crop production. Soil Test - Crop Response Correlation studies take care of inherent soil fertility status and the quantity of required nutrients through mineral fertilizer. This will also help to reduce the soil degradation and environmental pollution.

The AICRP on Soil Test - Crop Response Correlation Project at the Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara has developed fertilizer prescription equations based on yield target approach for twenty crops of Kerala. The fertilizer application based on this approach increased the crop yields and subsequent improvement in soil fertility, ensures balanced fertilization with enhanced fertilizer use efficiency.

The present bulletin highlights the research efforts on development of fertilizer prescription equations, frontline demonstrations, on farm trials and activities of farmers participation.

I am confident that this bulletin will be of immense use to the students of Soil Science and Agronomy, a reference for research scientists and teachers in the field of plant nutrition, soil fertility and management of cropping systems for balanced use of fertilizer inputs. This bulletin will also serve as a guide to the extension officials of the State Department of Agriculture.

I congratulate the team effort that has gone into the making of this valuable repository of knowledge base and dedicate it to the farming community of the state of Kerala.

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PREFACE

Soil and water forming the basis of sustainable agriculture are under pressure on account of various factors like population growth, urbanization, growing consumerism, intensive agricultural practices, market driven forces, soil degradation etc. Since agriculture became input and capital intensive, efficiency in terms of productivity became a high priority. Soil nutrients play a key role in the productivity of crops for which regular application of fertilizers has become a practice in intensive agriculture. Continued use of imbalanced fertilizers result in accumulation/depletion of specific soil nutrients and consequent decline in fertilizer responses. Soil testing is one of the best scientific means for quick and reliable determination of soil fertility status. Soil test based fertilizer recommendation is a key to improve fertilizer use efficiency and crop productivity.

Now the fertilizer recommendations based on soil test are made by categorizing the soil into low, medium and high categories in respect of the availability of the given essential nutrients. The fertilizer doses is increased or decreased by 24-30 per cent based on the ratings of soils. Soil test data should be correlated with nutrient uptake by crops for making efficient fertilizer recommendations. From this data, fertilizer prescription equations are derived for a particular crop in a particular soil type.

The fertilizer recommendation based on organic/semi quantitative approaches/ methods did not give expected yield response and therefore a need was felt for refinement of fertilizer recommendation for varying soil test values for wide range of crop production practices. The STCR study in the field provides soil test calibration between the level of soil nutrients as determined in the laboratory and crop response to fertilizer as observed in the field for predicting the fertilizer requirements of the crop.

The AICRP(STCP) centre at the College of Horticulture, Kerala Agricultural University, Vellanikkara was started in 1996 and has conducted elaborate and in depth studies on crops like banana, rice, ash gourd, cucumber, salad cucumber, bitter gourd, amaranth, brinjal, bhindi, chilli, tomato, groundnut, ginger, turmeric, cassava, sweet potato and coleus. I hope this publication comprising the entire information so far generated on soil test crop response studies on various crops at KAU will be useful for the farmers, agriculture extension officers, scientists and students.

(T.R. Gopalakrishnan)

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With great pleasure we acknowledge Honourable Vice Chancellor, Dr. P. Rajendran, Kerala Agricultural University, Vellanikkara, Thrissur, for providing the guidance and facilities for carrying out the research activities. We are indebted to ICAR for providing all the financial and technical support for the conduct of the research work. We wish to express our sincere gratitude to Dr. T.R. Gopalakrishnan, Director of Research, Kerala Agricultural University, Vellanikkara, Thrissur for his valuable suggestions, support and guidance given during the project. It is a great privilege for us to extend our sincere gratitude to Dr. P.K.Valsala Kumari, Associate Dean, College of Horticulture, Vellanikkara and Dr.C.T.Abraham, former Associate Dean for their constant encouragement, support and guidance extended to us. With all regards, we acknowledge the sincere efforts taken at each point for the realization of this research programme by late Dr. M.A. Hassan, former Principal Investigator of the AICRP on STCR. We are quite indebted to Dr. P.K. Sushama, Head of Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara for her valuable help and co-operation rendered to us. The good help and support extended to us from all the staff members of the Department of Soil Science and Agricultural Chemistry is gratefully acknowledged. We take this opportunity to place on record our sincere gratitude to Mr. M. Ananthakrishnan, Farm Officer Mr. Vinod, K.A, Lab Assistant and Mr. P.R. Sathian, former Farm Superintendent for their inevitable co-operation and support during the programme. We extend our heartfelt thanks to all the staff members of AICRP on STCR during the conduct of research programme.

Authors

CONTENTS

LIST OF TABLES

LIST OF PLATES

APPENDIX

CHAPTER 1

1.1 Introduction

The present day challenges facing agriculture are food security, soil degradation, environmental safety and diminishing profitability. These natural resources have to be used on the basis of resource management to enhance productivity. Pressure on land is increasing due to variety of uses they are put into. Soil parameters should be well understood to know about the crop production capabilities.

An efficient fertilization means optimization of soil nutrient replacement with minimization of nutrient losses to the environment. Continued use of imbalanced fertilizers results in depletion of soil nutrients provided through fertilizers and consequent decline in fertilizer responses. For improving nutrient use efficiency, nutrient management programmes should be based on soil properties, especially on its inherent capacity to supply nutrients to crop. Soil test data should be correlated with nutrient uptake by crops for making efficient fertilizer recommendation. Balanced nutrition does not mean the application of nitrogen, phosphorus and potassium alone in certain proportions through fertilizers, but it should ensure that the nutrients in available forms are in adequate quantity and in required proportion in the soil to meet the requirement of the crops for obtaining the desired levels of yield. Nutrients available in soil are rarely present in adequate amounts and in balanced proportion to meet the nutrient requirement of the crops. This requires intervention by application of external sources of nutrients *i.e.* fertilizers and manures. Soil test provides the requisite information about the amount of nutrients available in the soil and their imbalances, while fertilizer recommendations aim at correcting the imbalances in nutrients according to crop requirements.

The fertilizer recommendations based on qualitative/semi-quantitative approaches or methods do not give expected yield responses. Therefore, a refined method of fertilizer recommendation for varying soil test values has been developed by Kerala centre of AICRP on Soil Test Crop Response Correlation (STCR) for some crops.

In this methodology, the information on three parameters, i.e. (i) nutrient requirement per unit of grain production, (ii) per cent contribution from soil

available nutrients and (iii) per cent contribution from fertilizer/manure nutrients have been generated for major crops from soil test crop response experiments. From this, fertilizer prescription equations are derived for a particular crop. In order to make the agriculture field viable and profitable, a rational use of fertilizers based on demand of crops and native nutrient supplying capacity of soil need to be worked out.

Large scale cultivation practices using improved technologies including judicious use of fertilizers, manures and chemicals should be done. A fertilizer recommendation on the basis of STCR makes a balance between the production, soil health restoration and judicious management of costly fertilizers. The STCR approach aims at testing of soils, calibration of soil test results with crop recovery and economization of fertilizer levels with optimum yield target to ensure profitable return to the farming community. The AICRP on STCR has developed 20 equations for field crops grown in Kerala. Test verifications trials were done by conducting field level demonstrations, on farm trials etc.

1.2 Objectives

All India Co-ordinated Research Project on Soil Test Crop Response Correlation studies was started at College of Horticulture, Vellanikkara in 1996 with the following objectives.

1. 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.
2. To obtain / derive a basis for fertilizer recommendations for specific yield targets.
3. To evaluate the extent to which fertilizer requirements of the crops can be reduced in relation to conjoint use of organic manures.

1.3 Outcomes and outputs

In this methodology, the information on three parameters is recorded i.e. (i) nutrient requirement per unit of grain production (ii) per cent contribution from soil available nutrients and (iii) per cent contribution from fertilizer/manures. Based on this, fertilizer prescription equations have been developed for a particular crop. This centre has generated equations for the following crops from soil test crop response experiments.

1. Fruit crop – Banana (cv. Nendran)
2. Grain crops – Rice – kharif (cv.Aiswarya) and rabi (cv.Kanakam)
3. Vegetables – Ash gourd (cv. KAU local), cucumber (cv.Mudikode), salad cucumber (cv.Conomon), bitter gourd (cv.Priya), amaranth (cv. Kannara local and Arun)), brinjal (cv. Haritha), bhindi (cv.Arka anamika), chilli (cv. Athulya) and tomato (cv.Anagha)
4. Oil seed crop – Groundnut (cv.TAG 24)
5. Spices – Ginger (cv.Maran) and turmeric (cv. Kanthi)
6. Tuber crops – Cassava (cv. M4), Sweet potato (cv.Varun) and coleus (cv. Nidhi)

CHAPTER 2

General Information about Kerala

2.1 Location and extent

The state of Kerala lies as a narrow strip of land between 8° 18' and 12° 48' north latitude and 74° 52' and 77 ° 22' east longitudes. It is 11 to 124 km wide between the Western Ghats in the east and the Arabian Sea in the west with 560 km long coastal line in the southwestern side of Indian Peninsula. The total geographical area of the state is 38,864 sq. km. The state is endowed with a combination of distinct altitudinal variations resulting from the rise of land mass from 5 metres below mean sea level in the west to the soaring heights of 2695 metres in the east within the short span of 120 km. The large number of lakes and backwaters provide a unique scenic beauty to the land. There are 44 rivers, which are monsoon fed. The total cropped area is about 30, 48000 ha.

2.2 Physiography

The state is divided into three distinct parallel physiographic zones; the highland (above 75m from the mean sea level), the midland (between 7.5 and 75m. above mean sea level) and the lowland above 7.5 m. from the mean sea level). Out of the total geographical area of the state, 10.2 per cent constitutes lowland, 41.8 per cent midland and 48 per cent highland regions.

2.3 Geology

Geologically, Kerala is occupied by four major rock formations namely crystalline rocks of Precambrian age, sedimentary rocks of Tertiary age, laterite capping and the crystalline and sedimentary rocks and recent and sub recent sediments forming the low lying area of river valleys.

2.4 Climate

Kerala state is situated in the humid tropics with two predominant rainy seasons caused by the south-west monsoon and north–east monsoon. On an average, the state receives 3000 mm of annual rainfall. The annual average ambient temperature in Kerala is 27.5^0C. The mean maximum temperature is about 33^0C. Relative humidity varies from 70 to 95 per cent.

2.5 Land use

Out of the total geographical area of 38.86 lakh hectare net sown area is about 53 per cent. The Kerala agriculture is characterized by marginal land and fragmented land holdings. The average size of holding is 0.22 hectare, which is much less than the national average of 1.57 ha. The limited land area accompanied by increased population poses very little scope for increasing area under cultivation. So the effective alternative to increase food production is the adoption of intensive cultivation using scientific technologies.

2.6 Agro-ecological zones

The state has been divided into five agro-ecological zones (AEZ's). Figure 1 present the spatial distribution of the agro-ecological zones in the state (KSPB, 2013).

1. Coastal Plain

The Coastal Plain agro-ecological zone comprises the nearly level to gently sloping lands along the coast at elevation below 30 metres and lying between the sea and the midlands. It includes sandy beaches, sandy plains, coastal laterites, and low-lying areas such as estuaries, backwaters, submerged lands, swamps, marshes, *kayal* lands, and broad valleys. The zone covers 5, 09,246 ha (13.10 per cent) in the state.

2. Midland Laterites

Midland Laterites agro-ecological zone comprises undulating to rolling lands interspersed with narrow valleys between the coastal plain on the west and foothills and hills on the east, extending from the southern end to the northern end of the state. The elevation ranges from 30 to 300 metres. The zone covers 10, 56,385 ha (27.18 per cent) in the state.

3. Foothills

The undulating to rolling lands and low hills between the midland laterite on the west and high hills on the eastern side constitute the Foothills agro-ecological zone. The terrain has only very narrow valleys. The elevation ranges from 300 to 600 metres. The zone covers 4, 60,074 ha (11.84 per cent) in the state.

4. High Hills

The hilly region comprising Western Ghats and plateaus extending from south to north constitute the High Hills agro-ecological unit. The Western Ghats and highland plateaus rise 600 metres above mean sea level, with a number of peaks well over 1800 metres. The Western Ghats comprise Central Sahyadri, the Nilgiris and South Sahyadri. The mountains are essentially plateau remnants of two or three altitudinal zones. Slopes of hill ranges can be as high as 80 per cent. The zone covers 15, 53,225 ha (39.97 per cent) in the state.

5. Palakkad Plain

The Palakkad Gap, resembling an inland plain with low elevation, is a prominent physical feature along the valley of the Bharathapuzha river. The gently sloping lands of Palakkad, east of Kuthiran hills, flanked on the south and north by Nelliyampathy hills and Attappady hills, respectively and merging to Tamil Nadu uplands through the gap in Western Ghats constitute the agro-ecological zone, covering 1,60,006 ha (4.12 per cent) in the state.

Fig. 1 Agro-ecological zones of Kerala

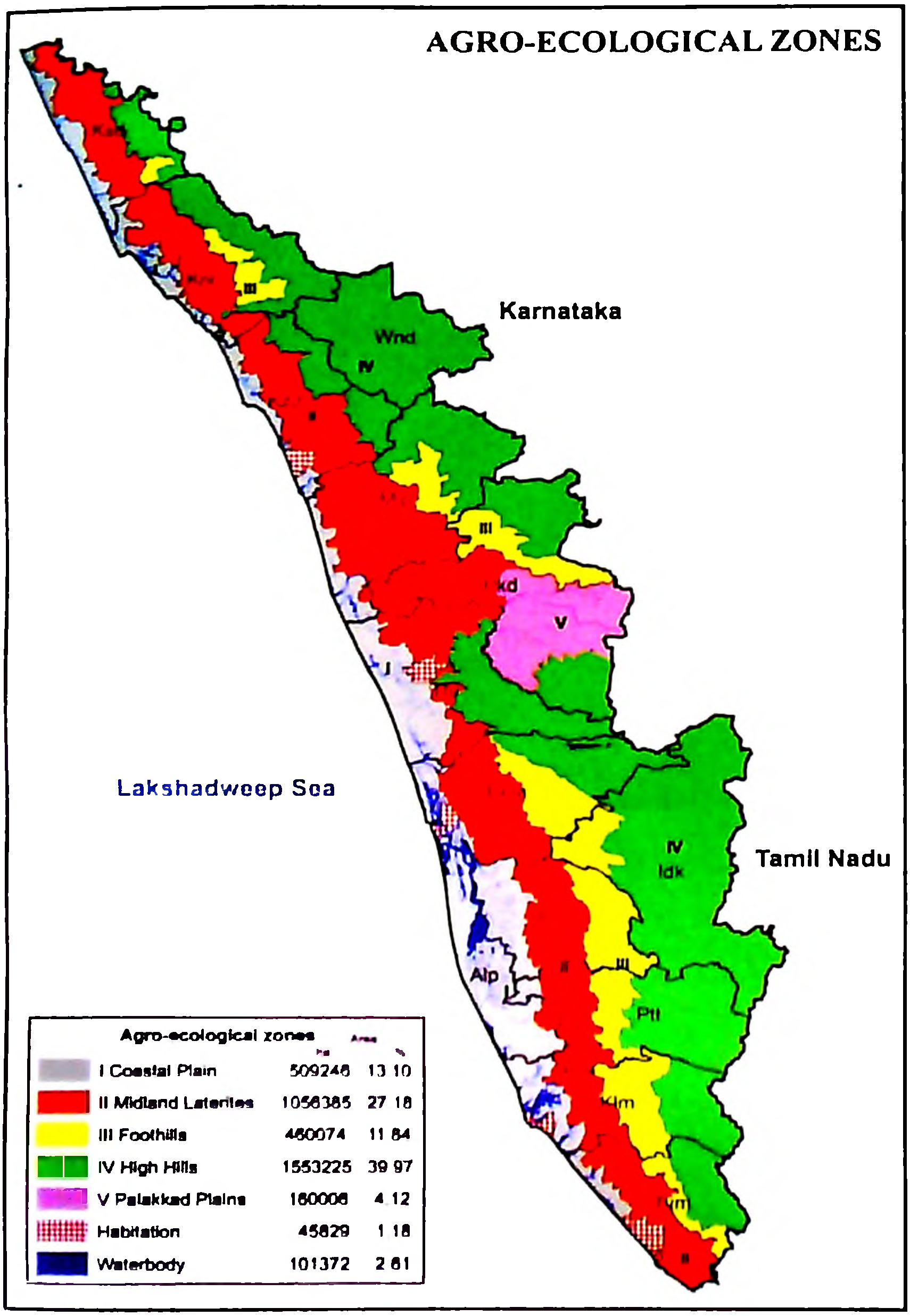
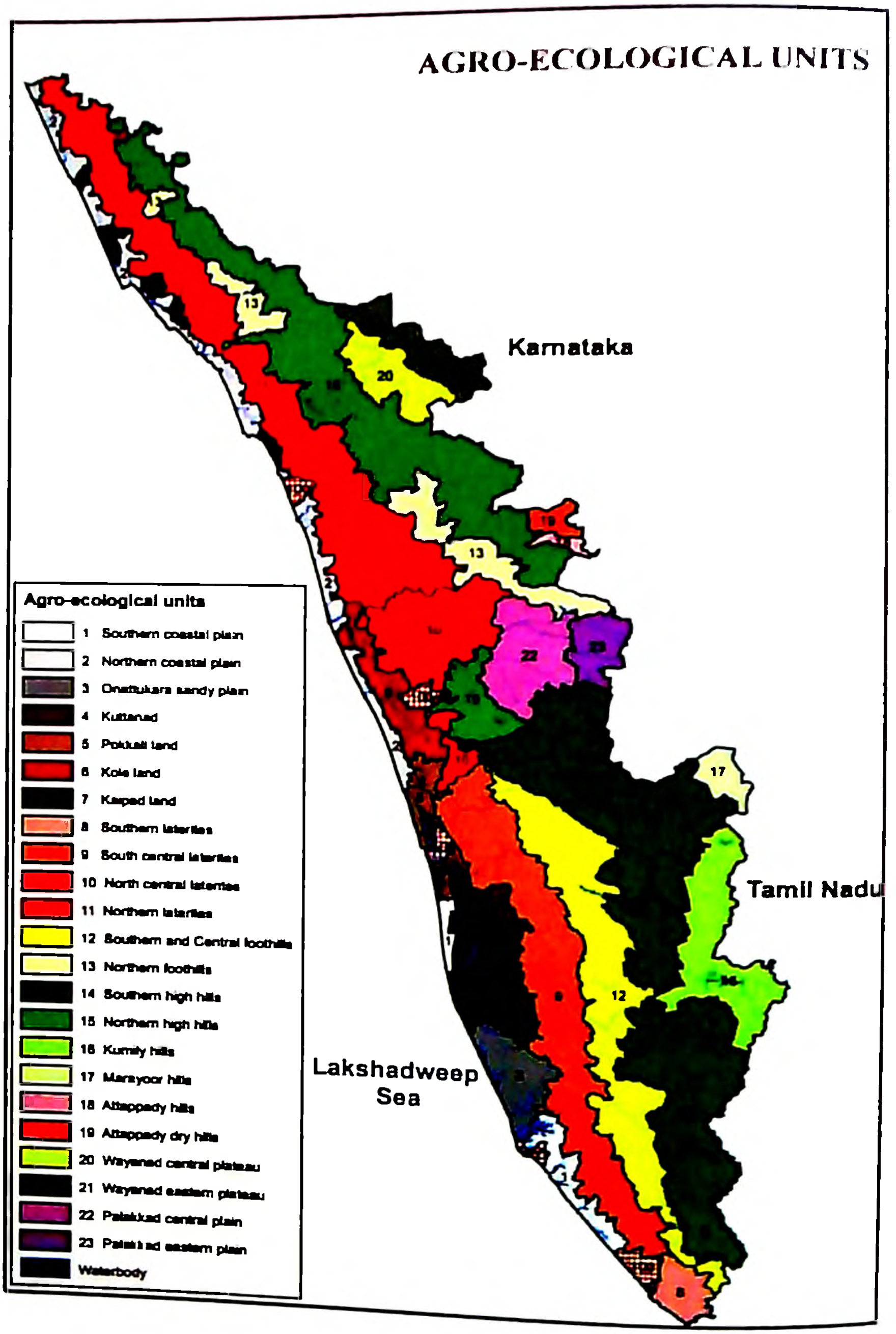


Fig. 2 Agro-ecological units of Kerala.



2.7 Soil Characteristics

Majority of the area under these five zones are extremely acidic to moderately acidic (3.5 to 6.0) with low organic matter content, low cation exchange capacity and with low nutrient and water holding capacity. The exceptions are neutral to slightly alkaline soils of dry hill areas of Idukki, Attappadi and the black cotton soils of Chittur taluk in Palakkad. Laterization is the predominant soil forming process. The process is characterized by the leaching (eluviation) of bases (Na, K, Ca and Mg), silica and organic matter due to high rain fall (3000mm) with subsequent accumulation of sesquioxides of Al, Fe and to some extent Mn (Buol *et al.*, 1998). The net effect is formation of soils with dominance of low activity kaolinitic clay with lowest possible CEC, low organic matter content and high acidity.

The soils in general are low to medium in organic carbon, and hence in nitrogen, high in P due to continuous application of P fertilizers which are being fixed and accumulated and low to medium in K. Severe deficiency of Ca (45 per cent) and Mg (80 per cent) are observed. Sulphur deficiency is seen in about less than 5 per cent. Fe and Mn are abundant in plant available form which is to the tune of toxic levels in wet lands submerged with water. Zn deficiency is to the extent of 15 per cent. Cu deficiency is usually less and its level is sufficient in soils where Cu based fungicides are used especially under plantations like rubber, cardamom, pepper etc. Boron deficiency is severe and wide spread (65 per cent) and symptoms are common in banana, coconut, arecanut, nutmeg, cabbage and cauliflower as well as in rice (KSPB, 2013).

CHAPTER 3

Fertilizer recommendations

3.1 General fertilizer recommendations

Development of these recommendations are based on multi-locational trials conducted with graded doses of N, P and K fertilizers and their economic evaluation to arrive at an optimum dose for a particular crop. The general recommendations hold good under medium soil fertility conditions. In this approach the variation in soil fertility is not taken into consideration and hence, under high or low soil fertility conditions the applied nutrients can become a wasteful expenditure or insufficient. In both the cases, optimum fertilizer use efficiency cannot be achieved. Results of long term fertilizer experiments have shown a considerable build-up of P due to continuous application of even general recommended dose in intensive cropping systems. In few cases the build-up of available P reached a level where no more phosphate application is needed for next few crops (Nambiar, 1994; Singh *et al.*, 1998)

3.2 Fertilizer recommendations based on soil fertility ratings

In this approach medium soil fertility is equated with general recommended dose. In case of low and very low and high and very high fertility categories the fertilizer doses are increased or decreased by 25 to 50 per cent of the general recommended dose as per the situation. At present most of the fertilizer recommendations issued from soil testing laboratories in India are based on this approach. The rating was developed in 1965 for old varieties of crops. Unfortunately, since then these ratings are same irrespective of types of soils and varieties of crops.

Ratings of soil test values for primary nutrients

Nutrient	Rating		
	Low	Medium	High
Organic Carbon (per cent) *	< 0.5	0.50 – 0.75	> 0.75
Alkaline $KMnO_4$-N (kg ha^{-1})	< 280	280 – 560	> 560
Olsen's P (kg ha^{-1})	< 10	10 – 25	> 25
Amm. acetate-K (kg ha^{-1})	< 120	20 – 280	> 280

* As an index of available N

3.3 Fertilizer recommendations based on critical limit of soil available nutrient

Critical level concept of available nutrients was developed by Cate and Nelson (1965). Critical limit is the level of soil available nutrient above which that nutrient is not considered as a primary limiting factor. The probability of getting economic response to fertilizer application in soils having available nutrient above the critical limit is quite low, while in soils below the critical limit the probability of getting economic response is quite high. Critical limit varies, depending on the soil types, crops and varieties, soil test methods used and seasonal variations. This concept separates the soils in responsive and non-responsive groups, but it does not suggest quantification of fertilizer dose for individual situations in responsive group. Hence, this concept may be more useful for fertilizer recommendation of micronutrients.

3.4 Fertilizer recommendations based on nutrient index

In this approach the fertilizer recommendations are given to a particular area after summarizing the overall fertility status with respect to a particular nutrient in that area into low, medium and high categories as per the method given by Parker *et al.* (1951). The Nutrient Index is calculated as:

$$\text{Nutrient Index} = \frac{(NL \times 1) + (NM \times 2) + (NH \times 3)}{NT}$$

where, NL, NM and NH are the number of soil samples falling in low, medium and high categories respectively and NT is the total no of soil samples analyzed. If the nutrient index is < 1.5, the fertility status of that area is categorized as low, a value from 1.5 to 2.5 as medium and > 2.5 as high fertility status. It was felt that these limits attach undue weightage to medium class, hence the limits were modified by Ramamoorthy and Bajaj (1969) as <1.67, 1.67 to 2.33 and > 2.33 for low, medium and high fertility status respectively. In this approach the variation in individual field is not taken into consideration and therefore the fertilizer recommendations are the gross generalization of the situation. In fact, this approach is adopted more for developing soil fertility maps than for fertilizer dose recommendation for a given field.

3.5 Fertilizer recommendations based on Mitscherlich-Bray concept for certain percentage of maximum yields

In this concept an empirical relationship is developed between per cent yield and soil and fertilizer nutrient so that the fertilizer can be recommended for various per centage of maximum yield. Mitscherlich-Bray equation is:

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

where, A is the theoretically calculated maximum yield, Y is the per centage of maximum yield, b is the soil test value, C_1 and C are the efficiency factors for soil and fertilizer nutrient, respectively and X is the fertilizer dose. The limitation of this concept is that the theoretical maximum yield is quite high than the actual yield obtained. Secondly the calculated maximum yield is different for different nutrients, and hence it becomes difficult to predict ultimate achievable yield.

3.6 Multiple regression based fertilizer recommendation for economic yield

The fertilizer dose that gives higher profit per hectare as well as optimum economic return in rupees per rupee invested on fertilizers is called dose for economic yield. Ramamoorthy (1974) established a significant relationship between soil tests, added fertilizers and crop yields by fitting a multiple regression of the quadratic form using linear, quadratic and interaction terms between soil and fertilizer form of nutrients as given below:

$$Y = A + b_1\,SN + b_2\,SP + b_3\,SK + b_4\,FN + b_5\,FN^2 + b_6\,FP + b_7\,FP^2 + b_8\,FK + b_9\,FK^2 + b_{10}\,SN\,FN + b_{11}\,SP\,FP + b_{12}\,SK\,FK$$

where, Y is crop yield (kg ha^{-1}), A is intercept (kg ha^{-1}), b_{1-12} are regression coefficients, SN, SP and SK are soil available N, P and K (kg ha^{-1}) and FN, FP and FK are fertilizer dose of nitrogen, phosphate and potash (kg ha^{-1}), respectively.

Fertilizer recommendations for economic yield include the factors for modifying the fertilizer dose with change in soil test values as well as change in the ratio of cost of fertilizers and cost of produce. Allowance of this ratio makes soil testing recommendations more dynamic and responsive so as to ensure higher profitability from fertilizer investments. The main limitation of this approach is uncertainty of getting curvilinear response type for all the three nutrients N, P and K from the field experiment. In the absence of

curvilinear response type for any nutrient, the fertilizer recommendation for that nutrient cannot be worked out.

3.7 Fertilizer recommendations based on targeted yield approach

The principle behind this concept is the existence of highly significant linear relationship between grain yield and uptake of nutrients (NPK) by crops which means that, for unit production of grain, a definite amount of nutrient is drawn from the soil. This linear relationship forms the basis for fertilizer recommendations for targeted levels of yield production first advocated by Truog (1960). Subsequently, Ramamoorthy *et al.* (1967) established the theoretical basis and experimental proof for its applicability. In this methodology, the information on parameters namely (i) Nutrient requirement (kg q^{-1} of grain/economic produce) (ii) per cent contribution from soil available nutrient and (iii) per cent contribution from fertilizer/manure nutrient are to be derived from the soil test crop response field experiment.

Targeted yield concept is primarily based on balanced prescription of fertilizer nutrients. This procedure provides a scientific basis for balanced prescription of nutrients through fertilizers and manures after considering available nutrients in soil and their actual requirement by crop. Once the actual requirement of nutrients for specific level of production is known, the needed fertilizer dose can be calculated after considering the per cent efficiencies of soil available and fertilizer nutrients. Therefore, it provides the fertilizer dose in balanced and quantitative terms in relation to soil test values and crop requirement which is necessary to optimize the response to added fertilizers, maximize the profit and achieving the desired yield target with ± 10 per cent deviation. Application of fertilizers according to the need of the situation also helps in maintenance of soil fertility and ensures sustainability of crop production.

CHAPTER 4

Soil testing facilities in Kerala

4.1 Soil testing laboratories

There are 23 Soil testing laboratories (STLs) under the State Department of Agriculture. Out of these, 14 are stationary and 9 are mobile. One stationary soil-testing lab is there for each district in the state. There are 7 soil testing labs under the soil survey and conservation department. In addition, 5 STLs are there in 5 Krishi Vigyan Kendras (Kannur, Wayanad, Malappuram, Palakkad and Kottayam) of Kerala Agricultural University. Central government institutions like IISR (Indian Institute of Spices Research), Kozhikode and CPCRI (Central plantation crops research institute) Kasargode also render soil-testing services.

Private agencies as well as NGOs also provide soil-testing services in several districts. They are Mitra Niketan (Thiruvananthapuram), Bapuji KVK (Idukki), Christian Agency for Rural Development (Alappuzha) and A.V. Thomas and Company (Ernakulam).

In addition to the above, Rubber Research Institute of India (Kottayam) has 4 STLs' at Thrissur, Muvattupuzha, Kozhikkode and Taliparamba in our state. Spices Board (Kochi) and FACT (Kochi) also have soil testing laboratories. Altogether the state has approximately 40 soil testing laboratories.

Each soil-testing laboratory of the State Department of Agriculture is under the immediate control of an Assistant Soil Chemist who is assisted by other technical staff. A Central Soil Testing Laboratory is functioning in Thiruvananthapuram since 1978 headed by a Deputy Director of Agriculture (Chief Soil Chemist), who controls and co-ordinates the activities of the District Soil Testing Laboratories in the state. The Chief Soil Chemist is also responsible for the maintenance of quality control of the district laboratories and for imparting training to the staff of different Soil Testing Laboratories.

4.2 Basis of Fertilizer Recommendations of STL's of Kerala

Based on the results obtained in the soil testing laboratories, the soil is first rated and fertility classes are assigned. There are 10 such classes (0-9). The classes 0-2 are considered as low, 3-6 medium and 7-9 high, in fertility status. Soils with average fertility values are given 100 per cent of the general fertilizer recommendation. A soil with 10 kg ha^{-1} of available P is

considered to be average in terms of P content and require 100 per cent of the recommendation. For rating the potassium status as average, the soil should have 115 kg ha^{-1} of exchangeable K. Maximum fertilizer recommendation of 128 per cent is given when P and K are present least in the soil. The average fertility values for total nitrogen differ between soils. For sandy soils, the average total N value is 0.03 per cent (Organic-C 0.3 per cent) and for loamy and clayey soils the average value is 0.05 per cent (Organic-C 0.5 per cent). When the total N is average, 100 per cent of the general fertilizer recommendation is given. The maximum recommendation of 128 per cent is given when the total N content is in traces. The details of fertility classes and the recommendation of N, P and K for each class as percentage to general recommendation currently followed by the state soil testing laboratories are provided in Table 1.

Table 1. Fertilizer recommendation based on soil test values followed in Kerala

Soil fertility class No.	Organic C, per cent		Recommendation of N to general recommendation, per cent	Available P, kg ha^{-1}	Available K, kg ha^{-1}	Recommendation of P and K to general recommendation, per cent
	Sandy	Clayey Loamy				
0	0.00-0.10	0.00-0.16	128	0.0-3.0	0-35	128
1	0.11-0.20	0.17-0.33	117	3.1-6.5	36-75	117
2	0.21-0.30	0.34-0.50	106	6.6-10	76-115	106
3	0.31-0.45	0.51-0.75	97	10.1-13.5	116-155	94
4	0.46-0.60	0.76-1.00	91	13.6-17	156-195	83
5	0.61-0.75	1.01-1.25	84	17.1-20.5	196-235	71
6	0.76-0.90	1.26-1.50	78	20.6-24	236-275	60
7	0.91-1.10	1.51-1.83	71	24.1-27.5	276-315	48
8	1.11-1.30	1.84-2.16	63	27.6-31.0	316-355	37
9	1.11-1.50	2.17-2.50	54	31.1-34.50	356-395	25

Soil samples are analyzed for five parameters viz., pH, EC, Organic carbon, available P_2O_5 and available K_2O by routine procedures and fertilizer recommendations are made for specific crops based on the soil test values. Detailed soil fertility maps are available only for some districts of the state based on soil test summaries.

CHAPTER 5

5.1 Prescription based fertilizer recommendations for Kerala.

The AICRP on STCR project provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. Here prescription equations are formulated based on the assumption that there is a linear relationship between yield and nutrient uptake by the crop and for the obtaining a particular yield a definite amount of nutrients are taken by the plant. Once this requirement is known for a yield level, the fertilizer needed can be estimated taking into consideration the contribution from soil available nutrients. The essential basic data required for formulating fertilizer recommendation based on targeted yield approach are nutrient requirement in kg per tons of produce, percentage contribution of nutrients from the soil and percentage contribution from applied sources. These parameters are used for calibrating crop wise fertilizer adjustment equations for any targeted yield. The validity of these adjustment equations are test verified in farmers fields in different locations and the STCR technology is finally disseminated to the farmers through the soil testing laboratories after conducting front line demonstration trials in many locations. At present we are giving much emphasis for IPNS technology for integrated supply of plant nutrients involving fertilizers and organic manures.

The STCR centre set up in College of Horticulture, Kerala Agricultural University, Vellanikkara during 1996 had been conducting experiments in diversified crops for the last 17 years. List of crops included food crop like rice, fruit crop like banana, vegetables like amaranth, bitter gourd, cucumber, salad cucumber, bhindi, brinjal, chilli and tomato, tuber root crops like coleus, sweet potato, cassava and spices like ginger and turmeric and oil seed crop like groundnut.

So far, targeted yield equations for 20 crops were developed and test verified the equations developed for rice in black soil, cassava, banana, ginger, amaranth, cucumber, salad cucumber, sweet potato, turmeric and groundnut in laterite soil and completed FLD (Front Line Demonstration trials) on banana, cassava, rice 2nd crop (rabi), amaranth, cucumber and salad cucumber.

The conditions under which the targeted yield equations are valid are

1. Laterite soil
2. Humid tropical climate
3. Yield targets chosen should not be neither too low nor too high
4. Target should be within the yield range of the main experiments
5. These equations can be extended to similar soil with almost similar climate

5.2 Soil sampling, soil, plant and water analysis methodologies

For basic soil analysis, soil samples are taken from the entire field from as many locations as possible and composite samples were made. The field was divided in to suitable strips as per the STCR technology. In the strips artificial gradients were created by applying different levels of fertilizers and also by growing exhaustive crop like fodder maize. Each strip will be divided into required number of plots as per the design. From each plot, soil samples will be taken from a depth based on the rooting pattern of the proposed test crop. For example, in banana (cv. Nendran), soil samples were taken from 0-30 cm depth. For all other crops the soil samples were taken from 0-15cm depths.

Table 2. Soil test methodologies

Sl. No.	Parameter	Method
1	Soil reaction (pH)	Glass electrode (1:2.5 soil water suspension)
2	Electrical conductivity (EC)	Conductivity bridge (1:2.5 soil water extract)
4	Available nitrogen	Alkaline permanganate method
5	Organic carbon	Wet oxidation method (Walkley and Black, 1934)
6	Available phosphorus	Bray no. 1 extractant, ascorbic acid reductant, spectrophotometer method
7	Available potassium	Neutral normal ammonium acetate method, flame photometer.

Table 3. Plant analysis methodologies

Sl. No.	Parameter	Method
1	Total nitrogen	Micro kjeldahl digestion and distillation
2	Total phosphorus	Acid digestion and estimation by vanado-molybdophosphoric yellow colour method, spectrophotometry
3	Total potassium	Acid digestion and estimation by flame photometry

5.3 Experimental Methodology

A new technique of field experimentation involving creation of wide soil fertility variation in one and the same field is adopted. Differences due to other factors such as climate and management, which often results in insignificant correlation from data on multiplication trials, are avoided in this system of working. These results are extended as far as possible to soils of similar nature and similar agro climatic conditions without much extrapolation.

5.3.1 Fertility gradient experiment

It is a preparatory experiment to conduct the soil test crop response experiment in the subsequent season. The desired variability in soil fertility is created in this experiment. This is achieved by selecting a large area, which is low/medium in soil fertility. This field is divided into four equal strips, while the first strip receives no fertilizer the second, the third and the fourth strip receive half, one and two times of a standard dose of N, P_2O_5 and K_2O respectively. The standard dose of P_2O_5 and K_2O are fixed taking into account the phosphate and potassium fixing capacities of the soil. However in general the standard NPK doses are as follows.

Fertilizers for gradient experiment	L_0 Strip	$L_{½}$ Strip	L_1 Strip	L_2 Strip
N (kg ha^{-1})	0	75	150	300
P_2O_5 (kg ha^{-1})	0	100	200	400
K_2O (kg ha^{-1})	0	100	200	400

NOTE:

1) For fertility gradient experiment 50 per cent of the N will be added in the form of organics (FYM), which may be incorporated into soil fifteen days in advance and another 50 per cent in the form of inorganic fertilizer.

2) Entire P_2O_5 and K_2O are added in the form of inorganic.

After applying the FYM and fertilizers for each strip an exhaust crop (usually fodder maize) is grown for 60 days so that the fertilizers undergo transformations in the soil with plant and microbial agencies. A comparison of the soil test values for available NPK before and after the fertility gradient experiment indicates the extent to which variation was created in the soil fertility in the four strips.

5.3.2 Main Experiment

This experiment is conducted on the soil where sufficient range in soil fertility in terms of available NPK has already been created through the fertility gradient experiment in the previous season. A factorial experiment (fractional factorial design) best describes the quantitative relationship where more than one production factor (eg. fertilizer NPK) influence the yield and there are interactions among them. Each strip is divided into 27 subplots. The following 21 treatment combinations from 5 levels of N X 4 levels of P_2O_5 X 3 levels of K_2O in addition to 6 controls are randomly allotted to the subplots in each of the four strips and the test crop is grown under irrigation or protective irrigation conditions following all the package of practices except fertilizer doses.

Table 4. The treatment structure

Treatments:								
1 0 0	2 0 0	3 0 0	1 1 0	2 1 0	2 2 0	3 3 0	2 0 1	0 1 1
1 1 1	2 1 1	3 1 1	2 2 1	4 2 1	3 3 1	4 3 1	2 2 2	3 2 2
4 2 2	3 3 2	4 3 2	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0

This experiment is not replicated. Four-fertility gradient strips act as replications even though they are not true replications. Available nutrients before the application of fertilizers and after the harvest of the test crop were estimated from each sub plot. Yields of grain and straw and total uptake of N. P_2O_5 and K_2O are estimated for each sub plot.

The above treatment structure followed in the scheme was modified during the biannual workshop held on January 23-24, 2005. Accordingly during 2005-06 main experiments were conducted in only 3 fertility strips (low (L1), medium (L2) and high (L3)) with 24 treatments in each strip including 3 controls. These changes have not altered the overall objective of the scheme.

Table 5. The new treatment structure adopted from 2005

	F_0	F_1	F_2
FYM-0	000, 331, 122, 222, 322, 212, 232, 220	000, 121, 211, 321, 111, 223, 221, 202	333, 022, 332, 323, 000, 311, 112, 233
FYM-10	000, 121, 211, 111, 202, 223, 221, 321	000, 333, 332, 233, 112, 311, 323, 022	000, 232, 122, 331, 322, 220, 222, 212
FYM-20	000, 333, 332, 323, 311, 112, 233, 022	000, 322, 331, 220, 122, 222, 232, 212	000, 211, 223, 202, 221, 111, 321, 121

5.3.3 Derivation of targeted yield equations

To calculate the fertilizer requirement based on soil test crop response approach, the following parameters are needed.

i) Nutrient requirement (NR) in kg per quintal of produce (grain or economic part)
ii) The per cent contribution from the available nutrient in soils (CS per cent)
iii) The per cent contribution from the applied fertilizers (CF per cent)

From the field data and laboratory analysis the three basic parameters mentioned above are calculated as under:

i) Kg of $N/P_2O_5/K_2O$ required to produce one quintal grain

$$NR = \frac{\text{Uptake of } N/P_2O_5/K_2O \text{ by grain + straw in kg ha}^{-1}}{\text{Grain yield in quintals/ha.}}$$

i) Per cent contribution of $N/P_2O_5/ K_2O$ from soil

$$CS\% = \frac{\text{Uptake of } N/P_2O_5 /K_2O \text{ by grain + straw in control plots in kg/ha}}{\text{Soil test values for avail. } N/P_2O_5/K_2O \text{ from control plots in kg/ha}} \times 100$$

ii) Per cent contribution of $N/P_2O_5/K_2O$ from fertilizer =

$$CF\% = \frac{\left\{\text{Uptake of } N/P_2O_5/K_2O \text{ by grain + straw in kg/ha}\right\} - \left\{\text{Soil Test Value for available } N/P_2O_5/K_2O \text{ in kg/ha}^{-1} \times \frac{\text{per cent contribution of } N/P_2O_5/K_2O \text{ from soil}}{100}\right\}}{\text{Fertilizer } N/P_2O_5/K_2O \text{ applied in kg/ha}^{-1}.} \times 100$$

From these parameters, the fertilizer dose required for specific yield target is calculated as :

$$FN = (NR \times T - \frac{CS}{100} \times SN) \times \frac{100}{CF}$$

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

Like wise

$$FP = \frac{NR}{CF} \times 100 \times T - \frac{CS}{CF} \times S\,P_2O_5$$

$$FK = \frac{NR}{CF} \times 100 \times T - \frac{CS}{CF} \times S\,K_2O$$

Where, NR = Nutrient requirement of $N/P_2O_5/K_2O$ in kg/quintal

CS per cent = Per cent contribution of $N/P_2O_5/K_2O$ from soil

CF per cent = Per cent contribution of $N/P_2O_5/K_2O$ from added fertilizer

SN = Soil test value for available N in kg ha^{-1}

SP = Soil test value for available P_2O_5 in kg ha^{-1}

SK = Soil test value for available K_2O in kg ha^{-1}

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

T = Targeted yield in quintal/ha

The STCR approach of fertilizer prescription is more scientific, fully quantitative and highly situation specific (soil-crop-agro climatic condition). Yield target can be fixed by looking into the genetic potential of the crop/variety. Yield target can be lowered or increased by looking into the economic position of the farmer and availability of fertilizers. Flexibility of fixing the yield target is an added advantage. In this approach the methods most suitable for estimation of available nutrients from the soil are also specified for each crop. The approach of fertilizer recommendations holds well under irrigation/protective irrigation situations.

5.4 Water analysis

As we are using good water for irrigation, we are not resorting to any analysis of water. In Kerala, in certain pockets, higher concentration of iron is noticed in the irrigation water and that too, always less than 1 $\mu g\ ml^{-1}$.

In the coastal area we have saline water. So far we have not conducted any experiments in the saline belt. Now we are mainly concentrating on laterite soils because 65 per cent of the state is occupied by laterite soil.

5.5 How to use STCR equations

From the results obtained from the test crop experiments, the nutrient requirements in kilogram or ton of economic produce, the per cent contribution of available nutrients as measured by soil test and the per cent availability of fertilizer nutrient requirement for the crop in the experiments are calculated. Making use of these three basic parameters, fertilizer adjustment equations for various yield targets are developed. These three basic parameters are converted into simple workable equations of the following type.

$FN = X\ T - Y\ SN$

$FP_2O_5 = X\ T - Y\ SP$

$FK_2O = X\ T - Y\ SK$

Where

FN = Nitrogen dose in kg ha^{-1} which is to be added through fertilizer

FP_2O_5 = P_2O_5 dose in kg ha^{-1} which is to be added through fertilizer

FK_2O = K_2O dose in kg ha^{-1} which is to be added through fertilizer

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

X = A constant derived from nutrient requirement and contribution from fertilizers

Y = A constant derived from contribution of soil and contribution from fertilizers

SN = Soil available nitrogen in kg ha^{-1}

SP = Soil available phosphorus in kg ha^{-1}

SK = Soil available potassium in kg ha^{-1}

For the calculation of IPNS equations, the contribution from organic manure will be also be taken in to account. The targeted yield equations developed are subjected to variation based on soil type, climatic conditions, crops and variety.

5.6 CALCULATION OF FERTILIZER DOSE

The following procedure is adopted for calculating fertilizer doses taking banana as an example.

1. Crop : Banana (cv. Nendran)
2. Yield target fixed : 35 t ha^{-1}
3. Fertilizer adjustment equations :

   FN = 83.49 T – 7.69 SN

   F P_2O_5 = 19.34 T – 34.93 SP

   F K_2O = 121.18 T – 5.38 SK
4. Soil test values

   Available nitrogen (N) = 350 kg ha^{-1}

   Available phosphorus (P) = 18 kg ha^{-1}

   Available potassium (K) = 400 kg ha^{-1}
5. Calculations

   F N (kg ha^{-1}) = 83.49 x 35 – 7.69 x 350

   = 2922.15 – 2691.50

   = 231 kg ha^{-1}

   F P_2O_5 (kg ha^{-1}) = 19.34 x 35 – 34.93 x 18

   = 676.90 – 628.74

   = 48 kg ha^{-1}

   F K_2O (kg ha^{-1}) = 121.18 x 35 – 5.38 x 400

   = 4241.30 – 2152.00

   = 2089 kg ha^{-1}

Thus to produce 35 t ha^{-1} of mature banana we have to apply 231, 48 and 2089 kg ha^{-1} N, P_2O_5 and K_2O respectively. We can convert these figures in to fertilizers in terms of Urea, Rajphos and Muriate of potash.

a) Nitrogen = 231 x 100/46 = 502 kg urea ha^{-1}

b) Phosphorus = 48 x 100/18 = 267 kg rajphos ha^{-1}

c) Potassium = 2089 x 100/60 = 3482 kg muriate of potash ha^{-1}

5.7 The Basic Data, Fertilizer Adjustment Equations and Ready Reckoner of Fertilizer Application Rates for different Crops

5.7.1 BANANA *(Musa spp.)*

Variety - Banana (cv. Nendran)
Season - August - September 1997 to July - August 1998
Irrigation - Irrigation during summer months
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 6. Basic data and fertilizer adjustment equations for targeted yield of banana

Nutrient	Basic data			Fertilizer adjustment equations
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	
N	10.37	95.46	12.42	FN = 83.49T-7.69SN
P_2O_5	1.00	78.87	5.17	FP_2O_5 = 19.34T-34.93SP
K_2O	26.89	98.64	22.19	FK_2O = 121.18T-5.38SK

Table 7. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of banana

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	1318	274	2492	1736	370	3097
150	8	200	933	205	1954	1351	301	2556
200	10	300	549	135	1416	967	231	2021
250	12	400	164	65	878	582	161	1483
300	14	500	0	0	340	195	91	945
350	16	600	0	0	0	0	21	407
400	18	700	0	0	0	0	0	0

5.7.2. GINGER *(Zingiber officinale)*

Variety - *Maran*
Season - April - May to December - January (1999-2000)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 8. Basic data and fertilizer adjustment equations for targeted yield for ginger

Nutrients	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.1	10.1	27.3	30
P_2O_5	0.3	6.9	10.9	7
K_2O	5.6	44	53	60

Fertilizer adjustment equations	
Without FYM	**With FYM**
FN = 7.8T - 0.37SN	F N = 7.8T - 0.37SN – 1.1ON
FP_2O_5 = 2.8T - 0.64SP	F P_2O_5 = 2.8T - 0.64SP – 0.7OP
FK_2O = 10.6T - 0.83SK	F K_2O = 10.6 T - 0.83 SK – 1.13OK

Table 9. Ready reckoner for fertilizer dozes at varying soil test values for specific yield target of fresh ginger rhizome in the rain fed condition

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			20 t ha^{-1}			25 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
140	10	50	104	50	170	143	64	223
160	15	75	97	46	149	135	60	202
180	20	100	89	43	128	128	57	181
200	25	125	82	40	107	121	54	160
220	30	150	75	37	86	114	51	139
240	35	175	67	34	65	106	48	118
260	40	200	60	30	46	99	44	99

5.7.3. TURMERIC *(Curcuma longa)*

Variety	- *Kanthi*
Season	- April - May to December - January (2000-01)
Irrigation	- Rain fed
Soil type	- Laterite
Area of adaptability	- Laterite soils of Kerala

Table 10. Basic data and fertilizer adjustment equations for targeted yield for turmeric

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.43	46.90	59.50	15.38
P_2O_5	0.59	76.19	45.27	2.13
K_2O	9.89	39.81	104.60	59.08

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 4.08T - 0.79SN - 0.26ON	F N = 4.08T - 0.79SN
FP_2O_5 = 1.30T - 3.85SP - 0.11OP	FP_2O_5 = 1.30T - 3.85SP
FK_2O = 9.46T - 0.46SK - 0.68OK	FK_2O = 9.46T - 0.46SK

Table 11. Ready reckoner for fertilizer dozes at varying soil test values for specific yield target of turmeric

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	55	22	217	78	31	270
150	7	200	23	13	172	47	22	225
200	9	300	0	4	127	15	13	180
250	12	400	0	0	82	0	0	135
300	14	500	0	0	37	0	0	90
350	16	600	0	0	0	0	0	45

5.7.4 RICE *(Oryza sativa)* - Kharif

Variety	- *Aiswarya*
Season	- April-May to September-October (2001-02)
Irrigation	- Rain fed
Soil type	- Laterite
Area of adaptability	- Laterite soils of Kerala

Table 12. Basic data and fertilizer adjustment equations for targeted yield for paddy

Nutrient	Basic Data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	26.14	12.06	69.70	21.90
P_2O_5	3.71	37.71	18.4	18.04
K_2O	21.58	46.95	41.50	24.73

Fertilizer Adjustment Equations	
With FYM	Without FYM
F N = 37.5 T – 0.17 SN – 0.31 ON	F N = 37.5 T – 0.17 SN
FP_2O_5 = 20.16 T – 4.69 SP – 2.25 OP	FP_2O_5 = 20.16 T – 4.69 SP
FK_2O = 52.0 T – 1.37 SK – 0.72 OK	FK_2O = 52.0 T – 1.37 SK

Table 13. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of rice under irrigated condition

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			4 t ha^{-1}			5 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	133	53	71	171	73	123
150	8	200	125	43	0	162	63	0
200	10	300	116	34	0	154	54	0
250	12	400	108	25	0	145	45	0
300	14	500	99	15	0	137	35	0
350	16	600	91	6	0	128	26	0
400	18	700	82	0	0	120	17	0

5.7.3. TURMERIC *(Curcuma longa)*

Variety	- *Kanthi*
Season	- April - May to December - January (2000-01)
Irrigation	- Rain fed
Soil type	- Laterite
Area of adaptability	- Laterite soils of Kerala

Table 10. Basic data and fertilizer adjustment equations for targeted yield for turmeric

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.43	46.90	59.50	15.38
P_2O_5	0.59	76.19	45.27	2.13
K_2O	9.89	39.81	104.60	59.08

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 4.08T - 0.79SN - 0.26ON	F N = 4.08T - 0.79SN
FP_2O_5 = 1.30T - 3.85SP - 0.11OP	FP_2O_5 = 1.30T - 3.85SP
FK_2O = 9.46T - 0.46SK - 0.68OK	FK_2O = 9.46T - 0.46SK

Table 11. Ready reckoner for fertilizer dozes at varying soil test values for specific yield target of turmeric

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	55	22	217	78	31	270
150	7	200	23	13	172	47	22	225
200	9	300	0	4	127	15	13	180
250	12	400	0	0	82	0	0	135
300	14	500	0	0	37	0	0	90
350	16	600	0	0	0	0	0	45

5.7.4 RICE *(Oryza sativa)* - Kharif

Variety - *Aiswarya*
Season - April-May to September-October (2001-02)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 12. Basic data and fertilizer adjustment equations for targeted yield for paddy

Nutrient	Basic Data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	26.14	12.06	69.70	21.90
P_2O_5	3.71	37.71	18.4	18.04
K_2O	21.58	46.95	41.50	24.73

Fertilizer Adjustment Equations	
With FYM	Without FYM
F N = 37.5 T – 0.17 SN – 0.31 ON	F N = 37.5 T – 0.17 SN
FP_2O_5 = 20.16 T – 4.69 SP – 2.25 OP	FP_2O_5 = 20.16 T – 4.69 SP
FK_2O = 52.0 T – 1.37 SK – 0.72 OK	FK_2O = 52.0 T – 1.37 SK

Table 13. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of rice under irrigated condition

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			4 t ha^{-1}			5 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	133	53	71	171	73	123
150	8	200	125	43	0	162	63	0
200	10	300	116	34	0	154	54	0
250	12	400	108	25	0	145	45	0
300	14	500	99	15	0	137	35	0
350	16	600	91	6	0	128	26	0
400	18	700	82	0	0	120	17	0

5.7.5. RICE - Rabi

Variety	- *Kanakam*
Season	- Sep - Oct to Dec - Jan (2001-02)
Irrigation	- Irrigated
Soil type	- Laterite
Area of adaptability	- Laterite soils of Kerala

Table 14. Basic data and fertilizer adjustment equations for targeted yield for 2nd crop of paddy

Nutrient	Basic Data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	15.10	9.16	34.72	28.78
P_2O_5	4.47	45.63	10.59	39.01
K_2O	16.25	27.75	34.10	32.19

Fertilizer Adjustment Equations	
With FYM	**Without FYM**
F N = 43.49 T – 0.26 SN – 0.83 ON	F N = 43.49 T – 0.26 SN
FP_2O_5 = 42.21 T – 9.87 SP – 8.44 OP	FP_2O_5 = 42.21 T – 9.87 SP
FK_2O = 47.65 T – 0.99 SK – 1.14 OK	FK_2O = 47.65 T – 0.99 SK

Table 15. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of rice under irrigated condition

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			4 t ha^{-1}			5 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	148	110	93	191	152	140
150	8	200	134	90	0	177	132	41
200	10	300	121	70	0	164	112	0
250	12	400	108	50	0	151	92	0
300	14	500	95	30	0	138	72	0
350	16	600	82	10	0	125	52	0
400	18	700	68	0	0	111	32	0

5.7.6. SWEET POTATO *(Ipomoea batatas)*

Variety - *Varun*
Season - June-July to September-October (2002-03)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 16. Basic data and fertilizer adjustment equations for sweet potato

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.18	19.54	71.85	14.11
P_2O_5	0.87	85.56	68.63	18.55
K_2O	7.67	68.37	89.12	30.77

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 3.04 T – 0.27 SN – 0.20 ON	F N = 3.04 T – 0.27 SN
FP_2O_5 = 1.27 T – 2.85 SP – 0.62 OP	FP_2O_5 = 1.27 T – 2.85 SP
FK_2O = 8.60 T – 0.93 SK – 0.42 OK	FK_2O = 8.60 T – 0.93 SK

Table 17. Ready reckoner for N required for different yield targets of sweet potato

Soil available N (kg ha^{-1})	Fertilizer N to be applied (kg ha^{-1})					
	With 7.5 t ha^{-1} of FYM			With 15 t ha^{-1} of FYM		
	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}
100	56.25	86.65	117.05	48.30	78.70	109.10
150	42.75	73.15	103.55	34.80	65.20	95.60
200	29.25	59.65	90.05	21.30	51.70	82.10
250	15.75	46.15	76.55	7.80	38.20	68.60
300	2.25	32.65	63.05	0.00	24.70	55.10

Table 18. Ready reckoner for P required for different yield targets of sweet potato

Soil available P (kg ha^{-1})	Fertilizer P_2O_5 to be applied (kg ha^{-1})					
	with 7.5 t ha^{-1} of FYM			with 15 t ha^{-1} of FYM		
	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}
5	0.00	12.37	25.07	0.00	0.00	0.89
10	0.00	0.00	10.82	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00

Table 19. Ready reckoner for K required for different yield targets of sweet potato

Soil available K (kg ha^{-1})	Fertilizer K_2O to be applied (kg ha^{-1})					
	with 7.5 t ha^{-1} of FYM			with 15 t ha^{-1} of FYM		
	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}	30 t ha^{-1}	40 t ha^{-1}	50 t ha^{-1}
100	142.95	228.95	314.95	120.90	206.90	292.90
150	96.45	182.45	268.45	74.40	160.40	246.40
200	49.95	135.95	221.95	27.90	113.90	199.90
250	3.45	89.45	175.45	0.00	67.40	153.40
300	0.00	42.95	128.95	0.00	20.90	106.90

5.7.7. ASH GOURD *(Benincasa hispida)*

Variety - *KAU local*
Season - May-June to August-September (2002-03)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 20. Basic data and fertilizer adjustment equations for ash gourd

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	1.55	1.57	9.83	3.22
P_2O_5	0.43	4.45	11.31	0.50
K_2O	5.20	1.25	62.56	5.59

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 15.79 T – 0.16 SN – 0.33 ON	F N = 15.79 T – 0.16 SN
FP_2O_5 = 3.77 T – 0.90 SP – 0.10 OP	FP_2O_5 = 3.77 T – 0.90 SP
FK_2O = 8.31 T – 0.024 SK – 0.11 OK	FK_2O = 8.31 T – 0.024 SK

Table 21. Ready reckoner for N required for different yield targets of ash gourd

Soil available N (kg ha^{-1})	Fertilizer N to be applied (kg ha^{-1})					
	with 15 t ha^{-1} of FYM			with 30 t ha^{-1} of FYM		
	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}
100	115.67	194.62	273.57	89.43	168.38	247.33
150	107.67	186.62	265.57	81.43	160.38	239.33
200	99.67	178.62	257.57	73.43	152.38	231.33
250	91.67	170.62	249.57	65.43	144.38	223.33
300	83.67	162.62	241.57	57.43	136.38	215.33

Table 22. Ready reckoner for P required for different yield targets of ash gourd

Soil available P (kg ha^{-1})	Fertilizer P_2O_5 to be applied (kg ha^{-1})					
	with 15 t ha^{-1} of FYM			with 30 t ha^{-1} of FYM		
	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}
5	25.40	44.25	63.10	17.60	36.45	55.30
10	20.90	39.75	58.60	13.10	31.95	50.80
15	16.40	35.25	54.10	8.60	27.45	46.30
20	11.90	30.75	49.60	4.10	22.95	41.80
25	7.40	26.25	45.10	0.00	18.45	37.30

Table 23. Ready reckoner for K required for different yield targets of ash gourd

Soil available K (kg ha^{-1})	Fertilizer K_2O to be applied (kg ha^{-1})					
	with 15 t ha^{-1} of FYM			with 30 t ha^{-1} of FYM		
	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	10 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}
100	69.15	110.70	152.25	57.60	99.15	140.70
150	67.95	109.50	151.05	56.40	97.95	139.50
200	66.75	108.30	149.85	55.20	96.75	138.30
250	65.55	107.10	148.65	54.00	95.55	137.10
300	64.35	105.90	147.45	52.80	94.35	135.90

5.7.8. COLEUS - Chinese potato *(Solenostemon rotundifolius)*

Variety - *Nidhi*
Season - May-June to September-October (2002-03)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 24. Basic data and fertilizer adjustment equations for coleus

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM per cent
N	9.15	21.00	61.60	21.05
P_2O_5	1.38	46.85	9.57	13.59
K_2O	16.38	40.85	56.60	57.23

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 14.85 T – 0.34 SN – 0.34 ON	F N = 14.85 T – 0.34 SN
FP_2O_5 = 14.42 T – 11.21 SP – 3.25 OP	FP_2O_5 = 14.42 T – 11.21 SP
FK_2O = 28.93 T – 0.87 SK – 1.22 OK	FK_2O = 28.93 T – 0.87 SK

Table 25. Ready reckoner for N required for different yield targets of coleus

Soil available N (Kg ha^{-1})	Fertilizer N to be applied (kg ha^{-1})					
	with 7.5 t ha^{-1} of FYM			with 15 t ha^{-1} of FYM		
	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}
100	175.24	249.49	323.74	161.72	235.97	310.22
150	158.24	232.49	306.74	144.72	218.97	293.22
200	141.24	215.49	289.74	127.72	201.97	276.22
250	124.24	198.49	272.74	110.72	184.97	259.22
300	107.24	181.49	255.74	93.72	167.97	242.22

Table 26. Ready reckoner for P required for different yield targets of coleus

Soil available P (kg ha^{-1})	Fertilizer P_2O_5 to be applied(kg ha^{-1})					
	with 7.5 t ha^{-1} of FYM			with 15 t ha^{-1} of FYM		
	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}
5	33.50	105.60	177.70	0.00	0.00	50.95
10	0.00	49.55	121.65	0.00	0.00	0.00
15	0.00	0.00	65.60	0.00	0.00	0.00
20	0.00	0.00	9.55	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00

Table 27. Ready reckoner for K required for different yield targets of coleus.

Soil available K (kg ha^{-1})	Fertilizer K_2O to be applied (kg ha^{-1})					
	with 7.5 t ha^{-1} of FYM			with 15 t ha^{-1} of FYM		
	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}	15 t ha^{-1}	20 t ha^{-1}	25 t ha^{-1}
100	282.90	427.55	572.20	218.85	363.50	508.15
150	239.40	384.05	528.70	175.35	320.00	464.65
200	195.90	340.55	485.20	131.85	276.50	421.15
250	152.40	297.05	441.70	88.35	233.00	377.65
300	108.90	253.55	398.20	44.85	189.50	334.15

5.7.9. GROUNDNUT *(Arachis hypogeaea)*

Variety - *TAG-24*
Season - January to May (2002-03)
Irrigation - Irrigated
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 28. Basic data and fertilizer adjustment equations for groundnut

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	49.46	28.11	45.61	71.20
P_2O_5	4.25	7.70	11.18	9.13
K_2O	19.52	6.88	27.33	41.86

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 108.44 T – 0.616 SN – 1.561 ON	F N = 108.44 T – 0.616 SN
FP_2O_5 = 38.01 T – 1.577 SP – 1.87 OP	FP_2O_5 = 38.01 T – 1.577 SP
FK_2O = 71.43 T – 0.305 SK – 1.853 OK	FK_2O = 71.43 T – 0.305 SK

Table 29. Ready reckoner for N required for different yield targets of groundnut

Soil available N (kg ha^{-1})	Fertilizer N to be applied (kg ha^{-1})					
	with 2 t ha^{-1} of FYM			with 4 t ha^{-1} of FYM		
	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
100	138.73	192.95	247.17	122.19	176.41	230.63
150	107.93	162.15	216.37	91.39	145.61	199.83
200	77.13	131.35	185.57	60.59	114.81	169.03
250	46.33	100.55	154.77	29.79	84.01	138.23
300	15.53	69.75	123.97	0	53.21	107.43

Table 30. Ready reckoner for P required for different yield targets of groundnut

Soil available P (kg ha^{-1})	Fertilizer P_2O_5 to be applied (kg ha^{-1})					
	with 2 t ha^{-1} of FYM			with 4 t ha^{-1} of FYM		
	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
5	48.70	67.69	86.70	29.24	48.24	67.25
10	40.80	59.81	78.81	21.35	40.36	59.36
15	32.91	51.92	70.93	13.47	32.47	51.48
20	25.03	44.04	63.04	5.58	24.59	43.59
25	17.15	36.15	55.16	0.00	16.70	35.71

Table 31. Ready reckoner for K required for different yield targets of groundnut

Soil available K (kg ha^{-1})	Fertilizer K_2O to be applied (kg ha^{-1})					
	with 2 t ha^{-1} of FYM			with 4 t ha^{-1} of FYM		
	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}	2 t ha^{-1}	2.5 t ha^{-1}	3 t ha^{-1}
100	86.42	122.13	157.85	60.48	96.19	131.91
150	71.17	106.88	142.60	45.23	80.94	116.66
200	55.92	91.63	127.35	29.98	65.69	101.41
250	40.68	76.38	112.10	14.73	50.44	86.16
300	25.42	61.13	96.85	0.00	35.19	70.91

5.7.10. CUCUMBER *(Cucumis melo)*

Variety - *Mudicode local*
Season - January to March (2003-04)
Irrigation - Irrigated
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 32. Basic data and fertilizer adjustment equations for targeted yield of cucumber

Nutrient	Basic Data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	0.79	2.32	24.42	2.06
P_2O_5	0.17	5.91	10.16	1.00
K_2O	2.95	5.26	93.36	10.32

Fertilizer Adjustment Equations	
With FYM	**Without FYM**
F N = 3.24T – 0.095 SN – 0.084 ON	F N = 3.24 T – 0.095 SN
FP_2O_5 = 1.64T – 1.332 SP – 0.226 OP	FP_2O_5 = 1.64 T – 1.332 SP
FK_2O = 3.16T – 0.068 SK – 0.134 OK	FK_2O = 3.16 T – 0.068 SK

Table 33. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of cucumber

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	71.50	34.42	72.20	87.70	42.63	88.00
150	7	200	66.75	31.75	65.40	82.95	39.97	81.20
200	9	300	62.00	29.09	58.60	78.20	37.30	74.40
250	12	400	57.25	25.09	51.80	73.45	33.31	67.60
300	14	500	52.50	22.43	45.00	68.70	30.64	60.80
350	16	600	47.75	19.76	38.20	63.95	27.98	54.00
400	18	700	43.00	17.10	31.40	59.20	25.31	47.20

5.7.11. BITTER GOURD *(Momordica charantia)*

Variety - *Priya*
Season - May-June to August-September (2003-04)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 34. Basic data and fertilizer adjustment equations for targeted yield for bitter gourd

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.98	23.31	32.18	11.14
P_2O_5	0.31	4.71	7.67	2.28
K_2O	2.70	13.98	136.97	23.16

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 9.26 T – 0.724 SN – 0.346 ON	F N = 9.26 T – 0.724 SN
FP_2O_5 = 4.04 T – 1.406 SP – 0.680 OP	FP_2O_5 = 4.04 T – 1.406 SP
FK_2O = 1.97 T – 0.124 SK – 0.205 OK	FK_2O = 1.97 T – 0.124 SK

Table 35. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of bitter gourd

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	159.10	93.97	36.85	205.40	114.17	46.70
150	7	200	122.90	91.16	24.45	169.20	111.36	34.30
200	9	300	86.70	88.35	12.05	133.00	108.55	21.90
250	12	400	50.50	84.13	0.00	96.80	104.33	9.50
300	14	500	14.30	81.32	0.00	60.60	101.52	0.00
350	16	600	0.00	78.50	0.00	24.40	98.70	0.00
400	18	700	0.00	75.69	0.00	0.00	95.89	0.00

5.7.12. AMARANTH - 1st crop *(Amaranthus spp.)*

Variety - *Kannara local*
Season - May-June to August-September (2005-06)
Irrigation - Rain fed
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 36. Basic data and fertilizer adjustment equations for targeted yield for amaranth (1st experiment)

Nutrient	Basic Data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.804	12.40	41.85	22.92
P_2O_5	0.227	12.59	12.89	3.87
K_2O	4.313	5.81	215.74	41.54

Fertilizer adjustment equations	
With FYM	**Without FYM**
$FN = 6.70\ T - 0.30\ SN - 0.55\ ON$	$FN = 6.70\ T - 0.30\ SN$
$FP_2O_5 = 1.76\ T - 2.24\ SP - 0.69\ OP$	$FP_2O_5 = 1.76\ T - 2.24\ SP$
$FK_2O = 2.00\ T - 0.033\ SK - 0.23\ OK$	$FK_2O = 2.00\ T - 0.033\ SK$

Table 37. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of amaranth 1st crop

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			20 t ha^{-1}			25 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	104	24.00	36.70	137.50	32.8	46.70
150	7	200	89	19.52	33.40	122.50	28.32	43.40
200	9	300	74	15.04	30.10	107.50	23.84	40.10
250	12	400	59	8.32	26.80	92.50	17.12	36.80
300	14	500	44	3.84	23.50	77.50	12.64	33.50
350	16	600	29	0	20.20	62.50	8.16	30.20
400	18	700	14	0	16.90	47.50	3.68	26.90

5.7.13. AMARANTH 2nd crop *(Amaranthus spp.)*

Variety - *Arun*
Season - Oct - Nov to Dec - Jan (2005-06)
Irrigation - Irrigated
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 38. Basic data and fertilizer adjustment equations for targeted yield for amaranth (2nd experiment)

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	2.022	5.83	57.76	11.12
P_2O_5	0.095	7.45	6.61	0.86
K_2O	3.191	11.62	236.30	25.13

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 3.50 T – 0.10 SN – 0.19 ON	F N = 3.50 T – 0.10 SN
FP_2O_5 = 1.44 T – 2.58 SP – 0.30 OP	FP_2O_5 = 1.44 T – 2.58 SP
FK_2O = 1.35 T – 0.06 SK – 0.13 OK	FK_2O = 1.35 T – 0.06 SK

Table 39. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of amaranth (2nd experiment)

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			20t ha^{-1}			25t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	60	15.90	21	77.50	23.1	27.75
150	7	200	55	10.74	15	72.50	17.94	21.75
200	9	300	50	5.58	9	67.50	12.78	15.75
250	12	400	45	0	3	62.50	5.04	9.75
300	14	500	40	0	0	57.50	0	3.75
350	16	600	35	0	0	52.50	0	0
400	18	700	30	0	0	47.50	0	0

5.7.14. BHINDI - 1st crop (Okra) *(Abelmoschus esculentus)*

Variety - *Arka anamika*
Soil type - Laterite
Season - August to November (2006-07)
Irrigation - Irrigated
Area of adaptability - Laterite soils of Kerala

Table 40. Basic data and fertilizer adjustment equations for targeted yield of bhindi (1st experiment)

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	0.33	3.98	30.66	0.05
P_2O_5	0.05	8.73	93.16	0.04
K_2O	0.36	2.85	103.49	0.04

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 1.08 T – 0.13 SN – 1.56 ON	F N = 1.08 T – 0.13 SN
FP_2O_5 = 0.06 T – 0.09 SP – 0.44 OP	FP_2O_5 = 0.06 T – 0.09 SP
FK_2O = 0.35 T – 0.03 SK – 0.42 OK	FK_2O = 0.35 T – 0.03 SK

Chemical analysis of organics		
N (per cent)	P (per cent)	K (per cent)
0.77	0.14	0.85

Table 41. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of bhindi 1st crop

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			20t ha^{-1}			25t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	8.60	0.66	4.00	14.00	0.96	5.75
150	8	200	2.10	0.48	1.00	7.50	0.78	2.75
200	10	300	0.00	0.30	0.00	1.00	0.60	0.00
250	12	400	0.00	0.12	0.00	0.00	0.42	0.00
300	14	500	0.00	0.00	0.00	0.00	0.24	0.00
350	16	600	0.00	0.00	0.00	0.00	0.06	0.00
400	18	700	0.00	0.00	0.00	0.00	0.00	0.00

5.7.15. BHINDI (2nd crop)

Variety - *Arka anamika*
Soil type - Laterite
Season - February to May (2006-07)
Irrigation - Irrigated
Area of adaptability - Laterite soils of Kerala

Table 42. Basic data and fertilizer adjustment equations for targeted yield for bhindi (2nd experiment)

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	0.38	3.12	53.15	0.04
P_2O_5	0.08	11.95	171.55	0.04
K_2O	0.36	3.69	100.94	0.05

Fertilizer adjustment equations	
With FYM	Without FYM
F N = 0.72 T – 0.06 SN – 0.78 ON	F N = 0.72 T – 0.06 SN
FP_2O_5 = 0.05 T – 0.07 SP – 0.25 OP	FP_2O_5 = 0.05 T – 0.07 SP
FK_2O = 0.36 T – 0.04 SK – 0.47 OK	FK_2O = 0.36 T – 0.04 SK

Chemical analysis of organics		
N (%)	P (%)	K (%)
0.75	0.16	0.76

Table 43. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of bhindi (2nd experiment)

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			20 t ha^{-1}			25 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	8.40	0.58	5.20	12.00	0.83	7.00
150	8	200	5.40	0.44	3.20	9.00	0.69	5.00
200	10	300	2.40	0.30	1.20	6.00	0.55	3.00
250	12	400	0.00	0.16	0.00	3.00	0.41	1.00
300	14	500	0.00	0.02	0.00	0.00	0.27	0.00
350	16	600	0.00	0.00	0.00	0.00	0.13	0.00
400	18	700	0.00	0.00	0.00	0.00	0.00	0.00

5.7.16. BRINJAL (Normal crop) *(Solanum melongena)*

Variety	- *Haritha*
Season	- August - March (2007-08)
Irrigation	- Irrigated
Soil type	- Laterite
Area of adaptability	- Laterite soils of Kerala

Table 44. The basic data used for making the targeted yield equations for brinjal (normal crop)

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	0.30	5.10	8.51	0.02
P_2O_5	0.03	20.39	6.18	0.02
K_2O	0.30	[illegible]	[illegible]	[illegible]

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 3.56 T – 0.60 SN – 2.82 ON	F N = 3.56 T – 0.60 SN
FP_2O_5 = 0.51 T – 3.30 SP – 2.88 OP	FP_2O_5 = 0.51 T – 3.30 SP
FK_2O = 0.71 T – 0.12 SK – 1.81 OK	FK_2O = 0.71 T – 0.12 SK

Chemical analysis of organics		
N (per cent)	P (per cent)	K (per cent)
0.56	0.15	0.35

Table 45. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of brinjal normal crop

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	29.00	0.00	5.75	46.80	0.00	9.30
150	8	200	0.00	0.00	0.00	16.80	0.00	0.00
200	10	300	0.00	0.00	0.00	0.00	0.00	0.00
250	12	400	0.00	0.00	0.00	0.00	0.00	0.00

5.7.17. BRINJAL (Ratoon crop)

Variety - *Haritha*
Season (Period) - March 2007 to Sep 2007
Soil type - Laterite
Irrigation - Irrigated
Area of adaptability - Laterite soils of Kerala

Table 46. The basic data used for making the targeted yield equations for ratoon crop of brinjal

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	0.44	6.90	28.10	0.07
P_2O_5	0.04	21.80	17.47	0.02
K_2O	0.61	10.20	211.43	0.10

Fertilizer adjustment equations	
With FYM	**Without FYM**
F N = 1.56 T – 0.25 SN – 2.60 ON	F N = 1.56 T – 0.25 SN
FP_2O_5 = 0.25 T – 1.25 SP – 0.97 OP	FP_2O_5 = 0.25 T – 1.25 SP
FK_2O = 0.29 T – 0.05 SK – 0.46 OK	FK_2O = 0.29 T – 0.05 SK

Chemical analysis of organics		
N (per cent)	P (per cent)	K (per cent)
0.51	0.17	0.42

Table 47. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of brinjal (ratoon crop)

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	14.00	0.00	2.25	21.80	0.00	3.70
150	8	200	1.50	0.00	0.00	9.30	0.00	0.00
200	10	300	0.00	0.00	0.00	0.00	0.00	0.00
250	12	400	0.00	0.00	0.00	0.00	0.00	0.00
300	14	500	0.00	0.00	0.00	0.00	0.00	0.00

5.7.18. CHILLI *(Capsicum annum)*

Variety - *Athulya*
Soil type - Laterite
Season - July 2012 to September 2012
Irrigation - Irrigated
Area of adaptability - The laterite area of the state

Table 48. The basic data used for making the targeted yield equations for chilli

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM (per cent)
N	11.85	7.32	152.47	15.59
P_2O_5	0.60	11.19	17.63	2.85
K_2O	14.03	3.28	70.71	9.06

Fertilizer adjustment equations	
With FYM	**Without FYM**
7.77 T – 0.048 SN – 0.10 ON	7.77 T – 0.048 SN
3.41 T – 0.635 SP – 0.16 OP	3.41 T – 0.635 SP
19.84 T – 0.046 SK – 0.13 OK	19.84 T – 0.046 SK

Chemical analysis of organics		
N (per cent)	P (per cent)	K (per cent)
1.17	0.54	1.31

Table 49. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of chilli

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			10 t ha^{-1}			15 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	5	100	72.92	30.94	193.74	111.77	47.99	292.92
150	7	200	70.52	29.67	189.11	109.37	46.72	288.29
200	9	300	68.12	28.40	184.47	106.97	45.45	283.66
250	12	400	65.72	26.49	179.84	104.57	43.55	279.03
300	14	500	63.32	25.22	175.21	102.18	42.28	274.40
350	16	600	60.92	23.95	170.58	99.78	41.01	269.76
400	18	700	58.52	22.68	165.95	97.38	39.74	265.13

5.7.19. CASSAVA *(Manihot esculenta)*

Variety - M4
Season - August - September to June - July (2000-01)
Soil type - Laterite
Irrigation - Irrigated
Area of adaptability - The laterite soils of Kerala

Targeted yield equations for cassava

FN	= 12.10 T – 0.74 SN
FP_2O_5	= 05.04 T – 2.02 SP
FK_2O	= 11.93 T – 1.10 SK

Table 50. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of cassava

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of					
			30 t ha^{-1}			35 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	289.00	139.08	247.90	349.50	164.28	307.55
150	8	200	252.00	135.04	137.90	312.50	160.24	197.55
200	10	300	215.00	131.00	27.90	275.50	156.20	87.55
250	12	400	178.00	126.96	0.00	238.50	152.16	0.00
300	14	500	141.00	122.92	0.00	201.50	148.12	0.00
350	16	600	104.00	118.88	0.00	164.50	144.08	0.00
400	18	700	67.00	114.84	0.00	127.50	140.04	0.00

5.7.20. TOMATO *(Solanum lycopersicum)*

Variety - *Anagha*
Season - October – February (2010-11)
Irrigation - Irrigated
Soil type - Laterite
Area of adaptability - Laterite soils of Kerala

Table 51. Basic data and fertilizer adjustment equations for targeted yield for tomato

Nutrient	Basic data			
	NR (kg t^{-1})	CS (per cent)	CF (per cent)	COM per cent
N	1.63	4.89	19.87	4.89
P_2O_5	0.20	15.22	4.13	0.83
K_2O	3.04	10.96	30.20	5.81

Fertilizer adjustment equations	
With FYM	Without FYM
FN = 8.21 T – 0.246 SN – 0.25 ON	FN = 8.21 T – 0.246 SN
FP_2O_5 = 4.92 T – 8.437 SP – 0.46 OP	FP_2O_5 = 4.92 T – 8.437 SP
FK_2O =10.07 T – 0.439 SK – 0.23 OK	FK_2O =10.07 T – 0.439 SK

Table 52. Ready reckoner for fertilizer doses at varying soil test values for specific yield target of tomato

Soil available nutrients (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of (without FYM)					
			25 t ha^{-1}			30 t ha^{-1}		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	6	100	180.65	72.38	229.80	221.70	96.98	280.15
150	8	200	168.35	55.50	207.85	209.40	80.10	258.20
200	10	300	156.05	38.63	185.90	197.10	63.23	236.25
250	12	400	143.75	21.76	163.95	184.80	46.36	214.30
300	14	500	131.45	4.88	142.00	172.50	29.48	192.35
350	16	600	119.15	0.00	120.05	160.20	12.61	170.40
400	18	700	106.85	0.00	98.10	147.90	0.00	148.45

5.8 FRONT LINE DEMONSTRATION (FLD)

5.8.1. Banana

We have conducted front line demonstration trials on banana (cv. Nendran) at 8 locations, cassava at 4 locations, rice 2nd crop (rabi season) salad cucumber, cucumber (oriental pickling melon) and amaranth and the results obtained are given below.

Table 53. Benefit cost ratio analysis of different treatments of FLD on Nendran banana at different locations in Palakkad and Thrissur districts

Name and address of farmer	Treat ment	Yield (t/ha)	Cost of fertilizer (Rs./ha)	Total cultivation cost (Rs./ha)	Total benefit (Rs./ha)	B/C ratio
Krishnankutty. P Kundradkalam Chemmanthode Chatahamangalam Nemmara. Palakkad- 678 508	T1	18.67	58782	233782	224046	0.96
	T2	19.83	18031	193031	237924	1.23
	T3	18.30	15977	190977	219621	1.15
	T4	22.85	38479	213479	274167	1.28
	T5	20.02	43630	218630	240189	1.10
Kaladharan Thanneerankadu, Kuzhalmannam(P.O.) Palakkad-678 702	T1	16.46	61563	236563	197550	0.84
	T2	17.62	18031	193031	211476	1.10
	T3	16.57	18503	193503	198792	1.03
	T4	22.06	41783	216783	264778	1.22
	T5	19.28	53597	228597	231365	1.01
Chandran.P.V Perumbarathu veedu Marakkal. Kannara(P.O.) Thrissur	T1	30.46	14881	189881	365500	1.92
	T2	29.92	18031	193031	359000	1.86
	T3	30.85	17872	192872	370222	1.92
	T4	36.55	40536	215536	438636	2.04
	T5	33.21	52408	227408	398500	1.75
Seetha. K.K Kundoli veedu Kannara (P.O.) Thrissur	T1	30.25	14881	189881	363000	1.91
	T2	29.63	18031	193031	355500	1.84
	T3	30.81	18343	193343	369722	1.91
	T4	36.79	48360	223360	441500	1.98
	T5	34.54	60044	235044	414500	1.76

The treatments consisted of the following:

T1 - Farmers' practices

T2 - General recommendation (POP of KAU)

T3 - STL recommendation

T4 - STCR-1 targeted yield recommendations for a target of 35t ha^{-1}

T5 - STCR-2 targeted yield recommendations for a target of 40t ha^{-1}

Results

In all the locations the STCR treatments gave the highest benefit cost ratio. Among the STCR treatments, the treatment T4 (STCR recommendation for 35 t ha^{-1}) was superior.

Table 54. Benefit cost ratio analysis of different treatments of FLD on Nendran banana at different locations in Malappuram and Thrissur districts

Name and address of farmers	Treatments	Yield t/ha	Fertilizer cost/ha Rs.	Total Cultivation costs/ha Rs.	Total Benefit / ha. Rs.	B/C ratio
Ali,K., Kottilil House, Vattamkulam, Edappal, Malappuaram Dt	T1	26.29	17625	312625	657125	2.10
	T2	29.47	17758	302758	736675	2.43
	T3	30.29	13875	298875	757150	2.53
	T4	32.45	19948	304948	811350	2.66
	T5	28.05	31663	316663	701150	2.21
Nafeesa Ali, Tharayil Havai House, Vattamkulam, Edappal, Malappuaram Dt.	T1	27.12	17625	312625	677975	2.17
	T2	28.25	17758	302758	706300	2.33
	T3	31.21	13520	298520	780250	2.61
	T4	32.86	36294	321294	821600	2.56
	T5	32.28	45860	330860	806900	2.44
Rama Aiyer.S., Pottayilthopu, Mapranam, Irinjalakkuda, Thrissur (Dt)	T1	21.17	11252	312502	529275	1.69
	T2	22.86	17758	302758	571500	1.89
	T3	21.34	14846	299846	533575	1.78
	T4	23.97	37844	322844	599325	1.86
	T5	24.22	47410	332410	605450	1.82
Jhony, Pullakkaran, Muriyad, Irinjalakkuda, Thrissur (Dt)	T1	26.33	18543	321043	658250	2.05
	T2	27.33	17758	302758	683125	2.26
	T3	27.57	13875	298875	689225	2.31
	T4	29.34	27382	312382	733600	2.35
	T5	30.21	36948	321948	755300	2.35

The treatments consisted of the following:

T1 - Farmer's practices
T2 - General recommendations (POP of KAU)
T3 - Fertilizer recommendations by Soil testing laboratory (STL)
T4 - STCR-1 targeted yield recommendations for a target of 30t ha^{-1}
T5 - STCR-2 targeted yield recommendations for a target of 35t ha^{-1}

5.8.2. Cassava (Variety: M4)

Table 55. Benefit cost ratio analysis of different treatments of FLD on cassava at different locations in Palakkad and Thrissur districts

Name and address of farmers	Treatments	Yield t ha^{-1}	Fertilizer cost/ha Rs.	Total cultivation costs/ha Rs.	Total Benefit / ha. Rs.	B/C ratio
Suneesh, P.C. Perumpurath Marakkal, Kannara Thrissur	T1	33	439	89939	133440.00	1.48
	T2	35	2196	84196	141240.00	1.68
	T3	36	876	82876	142360.00	1.72
	T4	41	2272	84272	165320.00	1.96
	T5	43	3572	85572	171760.00	2.01
Wilson Chalampadam Kannara, Thrissur	T1	31	1097	83097	125720.00	1.51
	T2	31	2196	84196	125520.00	1.49
	T3	31	1382	83382	122640.00	1.47
	T4	32	4524	86524	129800.00	1.50
	T5	39	6292	88292	156360.00	1.77
Rajan, C.C. Aalumpurathu House Cheramangalam Nemmara, Palakkad	T1	31	3827	85827	124120.00	1.45
	T2	32	2196	84196	128360.00	1.52
	T3	30	2288	84288	119760.00	1.42
	T4	30	6093	88093	118120.00	1.34
	T5	41	7860	89860	164080.00	1.83
Sheeju, K.V. Kombankallu House, Chathamangalam Nemmara, Palakkad	T1	37	4317	86317	147840.00	1.71
	T2	34	2196	84196	136600.00	1.62
	T3	29	1526	83526	115080.00	1.38
	T4	25	4022	86022	100720.00	1.17
	T5	42	4949	86949	167240.00	1.92

The treatments consisted of the following:

T1 - Farmers' practices
T2 - General recommendation (POP of KAU)
T3 - Fertilizer recommendations by Soil Testing Laboratory (STL)
T4 - STCR-1 targeted yield recommendations for a target of 25t ha^{-1}
T5 - STCR-2 targeted yield recommendations for a target of 30t ha^{-1}

5.8.3. Salad cucumber

Table 56. Benefit cost ratio analysis of different treatments of FLD on salad cucumber at different locations in Palakkad and Thrissur districts

Name and address of farmers	Treatments	Yield t ha^{-1}	Fertilizer cost/ha Rs.	Total Cultivation costs/ha Rs.	Total Benefit / ha. Rs.	B/C ratio
Mr. K.R. Viswanathan, Kombankkallu Veedu Chathamangalam (PO) Nemmara, Palakkad.	T1	22.66	1270	96270	226563	2.35
	T2	23.03	1547	96547	230313	2.39
	T3	20.59	1428	96428	205938	2.14
	T4	24.53	1363	96363	245313	2.55
	T5	28.59	1826	96826	285938	2.95
Mr. C. Vasu, Kalathil House, Thittumpuram, Thiruvazhiyad, Nemmara, Palakkad	T1	22.21	1370	96370	222083	2.30
	T2	22.13	1538	96538	221250	2.29
	T3	20.29	1468	96468	202917	2.10
	T4	24.67	1612	96612	246667	2.55
	T5	26.88	2010	97010	268750	2.77
Mr. Deepu, T.S., Thengamoochiveedu, Karippakkunnu, Pattikkad (PO), Thrissur.	T1	22.00	1560	96560	220000	2.28
	T2	22.98	1855	96855	229750	2.37
	T3	29.50	1833	96833	295000	3.05
	T4	33.00	1290	96290	330000	3.43
	T5	36.75	1846	96846	367500	3.79
Mr. Krihsnan Warier Keerankulangara Wariam Edappalam, Pattikkad (PO) Thrissur.	T1	17.88	680	95680	178750	1.87
	T2	21.06	773	95773	210625	2.20
	T3	23.44	551	95551	234375	2.45
	T4	25.00	698	95698	250000	2.61
	T5	26.25	896	95896	262500	2.74

The treatments consisted of the following:

T1 - Farmers' practices
T2 - General recommendation (POP of KAU)
T3 - Soil testing laboratory recommendation (STL)
T4 - STCR-1 targeted yield recommendations for a target of 30t ha^{-1}
T5 - STCR-2 targeted yield recommendations for a target of 35t ha^{-1}

5.8.4. Rice (rabi)

Table 57. Benefit cost ratio analysis of different treatments of FLD on rice at different locations in Palakkad district

Name and address of farmers	Treatments	Yield t/ha	Straw yield t ha^{-1}	Fertilizer cost/ha Rs.	Total Cultivation costs/ha Rs.	Total Benefit / ha. Rs.	B/C ratio
Mr. Velandy Master, Nelliyamkunnam, Aalathur, Palakkad	T1	3.38	5.89	0	39000	48900	1.25
	T2	5.68	9.10	12315	52315	80625	1.54
	T3	6.63	9.86	2377	47377	92600	1.95
	T4	7.10	9.69	10513	50513	97475	1.93
	T5	7.96	10.78	8004	55504	109138	1.97
Mrs. Sudha Rajan, Kunduparambathu, Coyalmannam, Palakkad	T1	3.41	9.04	0	39000	55613	1.43
	T2	6.20	11.25	8700	48700	90700	1.86
	T3	6.31	11.60	2377	47377	92638	1.96
	T4	6.48	11.09	9244	49244	93400	1.90
	T5	7.45	12.74	5854	53354	107425	2.01
Mr. K.C. Prabakaran, Perungotukavu Nemmara, Palakkad	T1	3.25	7.71	0	39000	51175	1.31
	T2	4.26	9.83	2075	47075	66538	1.41
	T3	4.89	11.28	2377	47377	76313	1.61
	T4	5.68	11.66	7970	47970	85750	1.79
	T5	6.59	13.73	5457	52957	99913	1.89

The treatments consisted of the following:

T1 - Control
T2 - Farmers practices
T3 - General recommendation (POP of KAU)
T4 - STCR 2 - 7.5t ha^{-1}
T5 - IPNS 2 - 7.5t ha^{-1}

5.8.5 Amaranth

Table 58. Benefit cost ratio analysis of different treatments of FLD on amaranth at different locations in Palakkad district

Name and Address of farmers	Treatments	Yield t ha^{-1}	Fertilizer cost/ha Rs	Total Cultivation costs/ha Rs	Total Benefit / ha Rs	B/C ratio
C. Muralidharan Thekkevvedu, Edakkampadam Vithanasserry	T1	0.73	0	59940	10938	0.00
	T2	20.08	4484	124414	301250	2.42
	T3	18.58	3710	122308	278750	2.28
	T4	19.17	2668	120600	287500	2.38
	T5	17.75	2015	68615	266250	3.88
	T6	19.33	1855	109121	290000	2.66
Narayanan Thekkevvedu, Edakkampadam Vithanasserry	T1	2.19	0	61260	32875	0.00
	T2	20.50	4204	125604	307500	2.45
	T3	19.67	3710	123750	295000	2.38
	T4	18.08	3580	122940	271250	2.21
	T5	18.17	1208	69208	272500	3.94
	T6	19.58	1516	110196	293750	2.67
Ramakrishnan A. S Ambekkat House, Puzhakkalthara Nemmara, Palakkad	T1	2.20	0	61560	33000	0.00
	T2	22.00	4258	126078	330000	2.62
	T3	21.25	3710	124162	318750	2.57
	T4	20.50	3627	123395	307500	2.49
	T5	20.17	1838	70238	302500	4.31
	T6	19.67	1275	110359	295000	2.67
K. Narayanankutty Thekkinkadu veedu Vithanasserry Nemmara, Palakkad	T1	2.15	0	59760	32250	0.00
	T2	22.00	4484	124204	330000	2.66
	T3	20.46	3710	122102	306875	2.51
	T4	19.38	2425	120153	290625	2.42
	T5	18.42	1620	68020	276250	4.06
	T6	19.33	1407	108471	290000	2.67
Ramadas. M Thekkinkadu House Vithanasserry Nemmara, Palakkad	T1	2.27	0	59400	34000	0.00
	T2	21.54	4484	123784	323125	2.61
	T3	20.25	3710	121690	303750	2.50
	T4	19.38	3804	121124	290625	2.40
	T5	18.25	1472	67472	273750	4.06
	T6	19.33	2036	108696	290000	2.67

The treatments consisted of the following:

T1 - Absolute Control
T2 - Farmer's Practices
T3 - GRD
T4 - STL
T5 - STCR – 25t ha^{-1}
T6 - STCR + IPNS 20t ha^{-1}

5.8.6. Cucumber

Table 59. Benefit cost ratio analysis of different treatments of FLD on cucumber at different locations in Palakkad district.

Name and Address of farmers	Treatments	Yield t ha^{-1}	Fertilizer cost/ha Rs.	Total Cultivation costs/ha Rs.	Total Benefit / ha. Rs.	B/C ratio
C. Muralidharan Thekkeveedu, Edakkampadam Vithanasserry, Palakkad	T1	1.46	0	53190	11667	0.00
	T2	26.25	4776	86831	210000	2.42
	T3	24.92	2098	82971	199333	2.40
	T4	23.17	1500	81782	185333	2.27
	T5	23.58	3056	62156	188667	3.04
	T6	28.67	1705	81396	229333	2.82
K. Narayanan Thekkeveedu, Edakkampadam Vithanasserry Palakkad	T1	2.01	0	52290	16067	0.00
	T2	29.67	5168	96173	237333	2.47
	T3	24.92	2098	81941	199333	2.43
	T4	23.17	2015	81277	185333	2.28
	T5	24.58	3988	62088	196667	3.17
	T6	30.08	2162	80843	240667	2.98
Ramakrishnan A. S Ambekkat House, Puzhakkalthara Nemmara, Palakkad	T1	2.13	0	51390	17067	0.00
	T2	29.83	5223	95178	238667	2.51
	T3	28.00	2098	80911	224000	2.77
	T4	26.58	2140	80382	212667	2.65
	T5	23.75	4154	61254	190000	3.10
	T6	30.08	2328	79999	240667	3.01
R. Sethumadhavan Thekkinkadu veedu Vithanasserry Nemmara, Palakkad	T1	2.07	0	52380	16533	0.00
	T2	26.67	4496	83606	213333	2.55
	T3	26.00	2098	82044	208000	2.54
	T4	24.17	1448	80812	193333	2.39
	T5	21.83	2248	60448	174667	2.89
	T6	24.92	1152	79934	199333	2.49
P. C. Viswanathan Pulikkal veedu, Vithanasserry, Nemmara, Palakkad	T1	2.18	0	53460	17467	0.00
	T2	28.92	4496	86866	231333	2.66
	T3	25.08	2098	83280	200667	2.41
	T4	23.83	1516	82104	190667	2.32
	T5	24.00	2874	62274	192000	3.08
	T6	29.17	1820	81814	233333	2.85

The treatments consisted of the following:

T1 - Absolute Control
T2 - Farmer's Practices
T3 - GRD
T4 - STL
T5 - STCR – 35 t ha^{-1}
T6 - STCR – IPNS – 35 t ha^{-1}

In STCR treatments, when the soil is excessively high in a particular nutrient, which requires no further additional fertilizers, we generally apply half the quantity of GRD of that particular nutrient (maintenance dose).

Conclusion

For optimum utilization of renewable and nonrenewable resources with more concern on soil quality, research on balanced fertilization in crop production has already been realized. However, the economic, judicious and profitable use of costlier input like fertilizer is the need of day. Soil test crop response correlation approach of yield target plays a key role in making judicious and profitable fertilizer use. The fertilizer application based on this approach optimises the crop yield along with improvement in the soil fertility, ensures balanced and enhanced fertilizer use efficiency. Still there is scope to improve these aspects for improvement of soil fertility and sustained crop productivity. From STCR experiments and field level demonstrations, it is evident that fertilizer recommendations based on targeted yield approach resulted in higher yield and higher benefit:cost ratio compared to GRD and STL recommendations.

Soil testing approaches needs re-orientation. Future concerns in soil test crop response studies are

1. Soil test crop response studies on cropping sequence should be done. Prediction equations or rates of build up in soil test values due to addition of fertilizers will help in predicting the nutrient content in soil after harvest. This will help in precise fertilizer application to the succeeding crop.
2. Work on integrated nutrient management through soil testing involving organic manures, chemical and bio fertilizers should be continued.

3. In different agro- ecological zones prescription equations should be verified
4. Prescription equations on bench mark soil series has to be established for transfer of technology.

Furthermore the following points are to be considered in the future

1. Evaluation of causes of decline in fertilizer response
2. Comparison of sub soil nutrient management and yield target approach of STCR.
3. Performance of bio-fertilizers in low and high fertility conditions.
4. Use of geo-referenced fertility maps and application of remote sensing and geographical information system for large scale fertilizer use.
5. Fertilizer prescription equations for best economically viable intercropping system needs to be developed.
6. IPNS based STCR equations needs to be developed for plantation crops. Methods of elemental analysis should be improved.

APPENDIX I

Fertilizer recommendations followed for the various crops grown in Kerala as per package of practices of Kerala Agricultural University

1. Rice

Kind of land / region	Variety	N	P_2O_5	K_2O
		kg ha^{-1}		
Up lands	PTB 28, 29, 30.	40	20	30
-do-	High yielding short duration varieties	60	30	30
Wet lands (all regions)	-do-	70	35	35
-do-	High yielding medium duration varieties	90	45	45
-do-	Local varieties	40	20	20
-do-	H4	70	45	45
-do-	Mashuri	50	25	25
Kole lands	Annapurna	90	35	45
-do-	Medium duration high yielding varieties	110	45	45
Kattukampal and Ponnani kole lands	Medium duration high yielding varieties	110	45	55

Organic matter in the form of farmyard manure/compost/green leaves at the rate of 5t ha^{-1} will be applied and incorporated into the soil while ploughing. The entire quantity of phosphatic fertilizers will be applied along with the organic manure.

2. Groundnut

Name of Crop	Organic Manure	Lime	N	P_2O_5	K_2O
Ground nut	2 t ha^{-1}	1-1.5 t ha^{-1}	10 kg ha^{-1}	75 kg ha^{-1}	75 kg ha^{-1}

3. Ginger

Apply manures and fertilizers at the following rates:

FYM : 30 t ha^{-1}

N: P_2O_5: K_2O : 75:50:50 kg/ha/year

Full dose of P_2O_5 and 50 per cent of K_2O may be applied as basal dose and half the quantity of N may be applied 60 days after planting. The remaining quantity of N and K_2O may be applied 120 days after planting

4. Turmeric

Apply cattle manure or compost as basal dose at 40 t ha^{-1} at the time of land preparation or by spreading over the beds after planting. Apply N, P_2O_5 and K_2O fertilizers at the rate of 30: 30: 60 kg ha^{-1}. Full dose of P_2O_5 and half dose of K_2O may be applied as basal, 2/3 N may be applied at 30 days after planting and 1/3 N and remaining K_2O may be applied 60 days after planting

5. Cassava

Cattle manure or compost may be applied @ 12.5 t ha^{-1} during the preparation of land or while filling up the pits so as to provide about 1kg of organic manure/plant. Apply fertilizers at the rates shown below in kg ha^{-1}

Sl. No	Crop varieties	Fertilizer kg ha^{-1}		
		N	P_2O_5	K_2O
1.	H-97 and H-226	75	75	75
2.	H-165, Sree Visakham, Sree Sahya	100	100	100
3.	M-4 and local	50	50	50

6. Sweet potato

Apply cattle manure/compost at 10 t ha^{-1} at the time of preparation of ridges. The recommended N, P_2O_5 and K_2O dosage for sweet potato is 75: 50: 75 kg ha^{-1}. For the reclaimed alluvial soils of Kuttanad the N, P_2O_5 and K_2O recommendation is 50: 25: 50 kg ha^{-1}. Apply N in two equal split doses, the first at the time of planting and the second 4-5 weeks after planting. Apply full dose of P_2O_5 and K_2O at planting time.

7. Cucurbitaceous vegetables

Apply FYM @ 20-25 t ha^{-1} as basal dose along with half dose of N (35 kg ha^{-1}) and full dose of P_2O_5 (25 kg ha^{-1}) and K_2O (25 kg ha^{-1}). The remaining dose of N (35 kg ha^{-1}) can be applied in two equal split doses at the time of vining and at the time of full blooming. For bitter gourd and snake gourd, top dressing may be done in several split doses at fortnightly intervals.

8. Solanaceous vegetables

Apply FYM/compost at the rate of 20-25 t ha^{-1} at the time of land preparation. A fertilizer dose of 75:40:25 kg ha^{-1} of N, P_2O_5 and K_2O may be given. Half of nitrogen, full phosphorus and half of potash may be applied as basal dose first before transplanting. One fourth of nitrogen and half potash may be applied 20-30 days after transplanting. The remaining quantities may be applied two months after planting.

9. Amaranth

Apply 50 t ha^{-1} of FYM as basal dose before planting. After preparing trenches, apply N, P_2O_5 and K_2O fertilizers @ 50:50:50 kg ha^{-1}. Another 50 kg of N can be applied at regular intervals as top dressing. Spraying 1 per cent urea immediately after each harvest will increase the yield in amaranth.

10. Okra (Bhindi)

Apply FYM as basal dose @ 12 t ha^{-1}. At the time of sowing apply N, P_2O_5 and K_2O fertilizers @ 25, 8 and 25kg ha^{-1}. Another 25 kg N ha^{-1} may be applied one month after sowing.

11. Banana

Apply organic manure 10 kg/plant at the time of planting. Apply fertilizers at the following dose (g/plant/year).

Sl No	Varieties	Fertilizers (g/plant/year).			No of splits
		N	P_2O_5	K_2O	
1.	Nendran (irrigated).	190	115	300	6
2.	Palayankodan (rain fed)	100	200	400	2
3.	Others	160-200	160-200	320-400	–

APPENDIX II

Predominantly Available Organic Materials in Kerala State

The predominantly available organic material in Kerala state includes farmyard manure, cow dung. poultry manure, goat manure and other crop residues. The rice farmers of Kerala usually use dried cow dung before transplanting of the seedlings. However fresh cow dung as well as dilute solution of cow dung slurry is used for vegetable cultivation. Cattle penning is a regular practice in Palakkad district. This is the practice of keeping the cattle over night on the cultivated land, which facilitates absorption the dung and urine into soil. Coir pith is available in plenty in Kerala. But the potential of this waste is not exploited fully.

Green manuring with thick leaves of mango, jack etc. is also followed. Industrial products like sawdust, wood scrap and oil cakes of different types and fish wastes are also used.

Farmers cultivate leguminous crops like cowpea and blackgram in summer fallows. After harvest of the crops, stubbles are incorporated in to the soil. Glyricidia *(Glyricidia maculata)* is the best source of green manure as it decomposes rapidly.

The STCR project is helping for a productive and sustainable agriculture in Kerala by the efficient management of the organic manures along with chemical fertilizers.

Commonly used organic manure in Kerala

Sl No	Materials	Nutrient content (per cent)		
		N	P_2O_5	K_20
1	Bone meal	3.5	21	--
2	Fish meal	4.1	3.9	0.3 – 1.5
3	Poultry manure	1.2 –1.5	1.4 – 1.8	0.8 – 0.9
4	Sheep manure	0.8 – 1.6	0.3 – 0.4	0.3 - 0.4
5	FYM	1.0	0.5	1.0
6	Compost	0.5	0.4	0.8
7	Ground nut cake	7.0	1.5	1.5
8	Castor cake	4.3	2.0	1.3
9	Neem cake	5.0	1.0	1.5
10	Gingelly cake	6.2	2.0	1.2
11	Coconut cake	3.0	1.9	1.8

12	Vermi compost	1.5	0.4	1.8
13	Vermi wash	200mg	70mg	1000mg
14	Coirpith	0.61	0.07	0.06
15	Coirpith compost	0.94	0.50	1.02
16	Poultry manure compost	1.2	1.4	0.8
17	Goat manure	1.93	0.96	2.9
18	Cow dung	1.57	0.25	0.18
19	Glyricidia	2.1	0.5	1.2
20	Water Hyacinth	1.4	0.3	3.8
21	Banana pseudo stem	0.45	0.021	5.4
22	Banana leaves	2.28	0.074	2.61
22	Cow's urine	0.07	0.004	0.25
23	Bio gas slurry	0.005	0.065	0.33

APPENDIX III

STAFF PATTERN

List of office in charge and scientific staff worked in the AICRP on STCR project, Department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara from 1997 to 2014

Office in charge

Sl No	Post sanctioned	No. of Posts	Name of the incumbent	Date of joining	Date of leaving
1	Soil Chemist / Professor		Dr. M.A. Hassan	1-2-97	20-08-10
2	Soil Chemist / Professor		Dr. Betty Bastin	20-8-10	30-5-13
3	Soil Chemist/ Assistant Professor	1	Dr. Sreelatha, A.K	9-7-13	Continuing

Sl No	Post sanctioned	No. of Posts	Name of the incumbent	Date of joining	Date of leaving
1	Assistant Soil Chemist / Assistant Professor		Dr. P. Suresh Kumar	1-2-97	30-06-02
2	Assistant Soil Chemist / Assistant Professor		Dr. Betty Bastin	1-7-02	19-8-10
3	Assistant Soil Chemist / Assistant Professor	1	Dr. Beena. V.I.	21-5-11	Continuing
4	Technicians (Agri.)	2	Mr. M. Anantha Krishnan	29-1-97	Continuing
			Mr. P. Ajithkumar	6-2-97	23-05-97
			Mr. Biju Kuruvilla	26-5-97	03-05-99
			Mr. P.R. Sathian	19-5-99	30-11-13
5	Lab Assistant	1	Mrs. P.K. Kamalakshy	1-1-97	15-06-99
			Mr. P.B. Sivadasan	16-6-99	05-04-00
			Mrs. P.K. Kamalakshy	6-4-00	29-04-04
			Mr. M.S. Moni	22-6-04	20-05-05
			Mr. K.A. Vinod	27-12-05	Continuing

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Plate: 1 Dr. A. Subba Rao, Director, IISS visiting STCR field

Plate: 2 Fully grown crop of ginger

Plate: 3 Paddy crop at harvest stage

Plate: 4 Fully grown crop of turmeric

Plate:5 Harvest of sweet potato

Plate: 6 Coleus crop In the fleld

Plate:7 Groundnut crop in field

Plate: 8 Harvest of cucumber

Plate: 9 Bitter gourd in full bloom

Plate: 10 Amaranthus at harvest stage

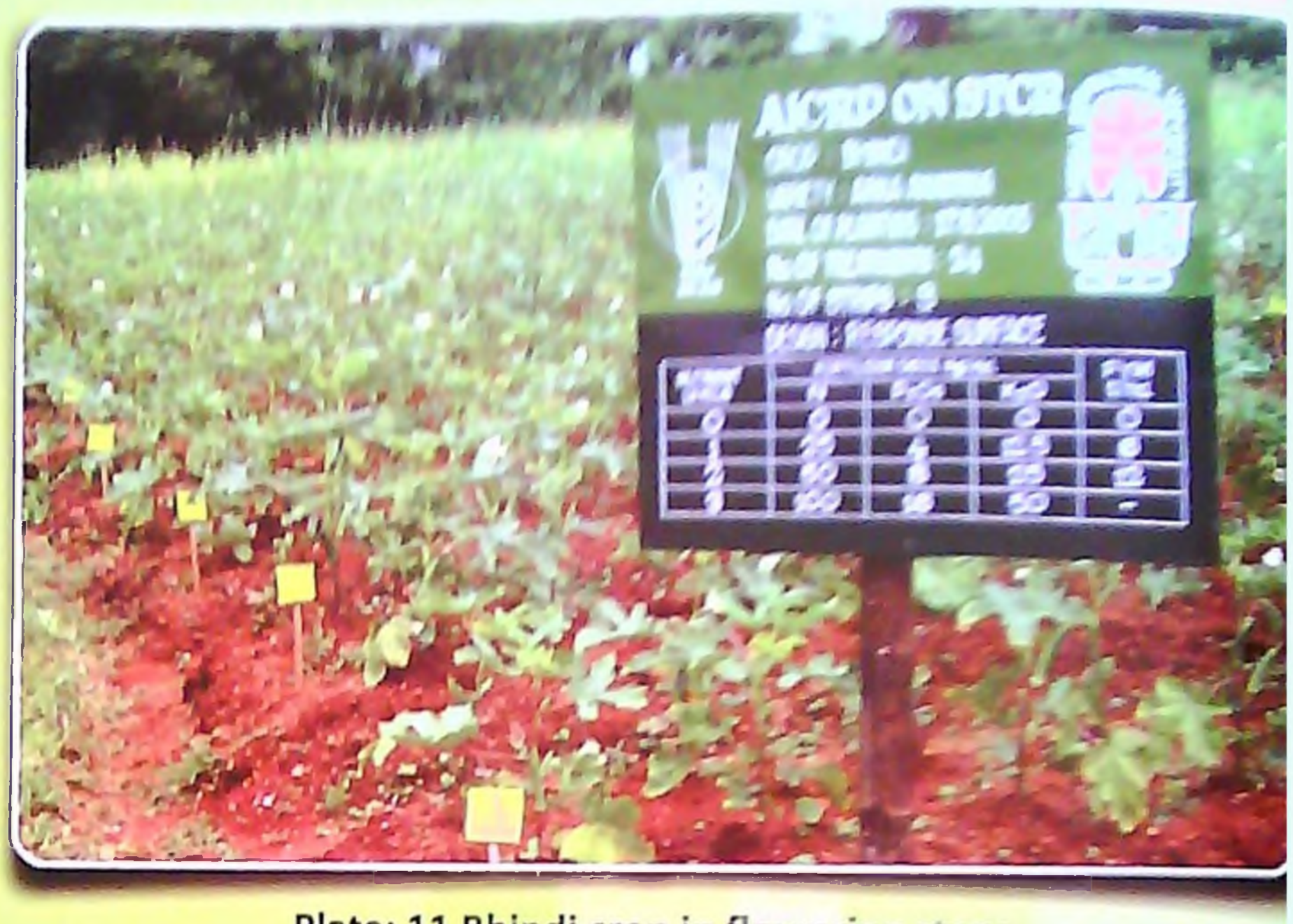

Plate: 11 Bhindi crop in flowering stage

Plate: 12 Brinjal crop in flowering stage

Plate: 13 Chilli crop in initial stage

Plate: 14 Salad cucumber in full bloom stage

Plate: 15 Tomato in fruit maturity stage

Plate: 16 Test verification trials on chilli

Plate: 17 Test verification trials on bhindi at Kombankkallu

Plate: 18 Test verification trials on sweet potato at Mathur

Plate: 19 Test verification trials on groundnut at Pattikulam

Plate: 20 FLD on Nendranbanana at Maraikkal

Plate: 21 FLD on Nendran banana conducted through
the State Department of Agriculture,
Soil Testing Laboratories at Edappal in Malappuram (2008 –2009)

Plate : 22 Agricultural Officer, Vattamkulam Krishi Bhavan along with STCR team in the FLD on Nendran Banana at Vattamkulam, Malappuram (2008-09)

Plate : 23 FLD on Nendran Banana conducted through the State Department of Agriculture, Soil Testing Laboratories at Muriyad in Thrissur (2008–2009)

Plate : 24 FLD on Nendran Banana conducted through the State Department of Agriculture, Soil Testing Laboratories at Mapranam in Thrissur (2008 –2009)

Plate: 25 FLD on cassava at Kombankkallu

Plate: 26 FLD on salad cucumber at Chathamangalam, Nemmara

Plate: 27 Dr. Y. Muralidharudu,
former PC visiting the FLD on rice at Alathur

Plate: 28 FLD on amaranthus at Vithanassery

Plate: 29 FLD on Amaranthus at Vithanassery

Plate : 30 Dr. P. Rajendran, VC, KAU visiting the AICRP (STCR) analytical laboratory

Plate: 31 . Dr. T.R. Gopalakrishnan, Director of Research addressing the Southern Regional Workshop at College of Horticulture, Vellanikkara, Thrissur, Kerala

Plate: 32 . Dr.Pradip Dey, PC, AICRP(STCR) delivering the inaugural address at the Southern Regional Workshop at College of Horticulture, Vellanikkara, Thrissur, Kerala