SITE SPECIFIC NUTRIENT MANAGEMENT FOR CHILLI (*Capsicum annuum .L*) IN KALLIYOOR PANCHAYATH OF KERALA

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DECLARATION

I hereby declare that this thesis entitled **"SITE SPECIFIC NUTRIENT MANAGEMENT FOR CHILLI *(Capsicum annuum .L)* IN KALLIYOOR PANCHAYATH OF KERALA"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Certified that this thesis entitled "**SITE SPECIFIC NUTRIENT MANAGEMENT FOR CHILLI** (***Capsicum annuum .L***) **IN KALLIYOOR PANCHAYATH OF KERALA**" ,is record of research work done independently by **PRIYA.U.K (2009-11-118)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree ,fellowship or associateship to her

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LIST OF ABBREVIATIONS

Av – Available

@ - At the rate of

B-Boron

BD- Bulk density

Ca – Calcium

cm- Centimetres

cmol kg^{-1}- Centi Moles per Kilo Gram

Cu-Copper

Dehy - Dehydrogenase

DAP-Days After Planting

DAT-Days after Transplanting

d sm^{-1}-Deci Siemens Per Metre

DTPA-Di Ethylene Tri Amine Penta Acetic Acid

EC – Electrical Conductivity

Fe - Iron

FAO - Food and Agricultural Organisation

FYM -Farm Yard Manure

HYT -High Yield Target

ISR - Improved State recommendation

kg ha^{-1} -Kilogram per Hectare

K - Potassium

MYT – Medium Yield Target

mg kg^{-1}-Milligram Per Kilogram

Mg kg^{-1} - Mega Gram per Metre Cube

Mg - Magnesium

Mn - Manganese

μgTPF g^{-1} - micro grams tri phenyl formazan per gram

N	- Nitrogen
POP	- Package of Practice
POP+SNMN	- Package of Practice Along With Secondary and Micronutrients.
P	- Phosphorus
ppm	- Parts Per Million
q ha^{-1}	- quintals per hectare
RDF	- Recommended Fertilizer Dose
S	- Sulphur
SR	-State fertilizer recommendation
STLR	- State soil testing laboratory recommendation,
SSNM	- Site Specific Nutrient Management
t ha^{-1}	- tons per hectare
Zn	- Zinc
Zn SO_4	- Zinc Sulphate
Mg SO_4	– Magnesium Sulphate
OM	- Omission
VC	Vermi compost

1. INTRODUCTION

Precision agriculture otherwise known as site-specific farming is an agricultural system that has the potential of dramatically changing agriculture in the twenty first century. This technique is environmentally sound and is an integral part in sustaining natural resources. The most important component of Precision Agriculture is Site-Specific Nutrient Management. Site-Specific Nutrient Management (SSNM) is a systematic plant nutrition approach which considers field-scale variability in soil fertility and crop responses to applied nutrients.

It is widely accepted that fertilizers have played a crucial role in attaining self-sufficiency in food grain production in India. Estimates show that 40-60% of the total agricultural production is contributed by these fertilizers (Mahajan *et al.*, 2008). But consequent to intensive cultivation and excessive nutrient mining over the years, the soil has been severely depleted of many of the essential plant nutrients. It is of great concern to learn about the recent reports which show that over half of the world's population is deficient in one or more of calcium, iron, iodine, magnesium, selenium and Zinc (Graham *et al.*,2007: White & Broadley 2009). Most mineral deficiencies are caused by the consumption of plants, directly or via livestock containing insufficient minerals. Of the seventeen elements considered essential for plants, majority of them are essential for animals and humans also. Thus soil becomes the ultimate source of these nutrients. Each nutrient has a specific role to perform in influencing plant growth, development, yield and crop quality. There is a certain critical level and ratio of plant nutrient concentration for their best performance. When this balance is upset, the limiting nutrients exhibit deficiency symptoms and restrict crop yield. In this context, proper and balanced fertilization assumes much importance.

Significant spatial variability of all essential plant nutrients exist in the cultivated fields at various scales. This is mainly attributed to the fertilizer history of individual farmers, diversity of crop types and varieties used (Eghball *et al.*, 1997). Significant correlation has been reported between crop yields and available soil nutrient levels at the corresponding sites in the field (Dobermann *et al.*, 2000). But this variability is not taken care of in the present fertilizer recommendations. The existing fertilizer recommendations for crops often consist of one predetermined rate of nitrogen (N), phosphorus (P), and potassium (K) for vast areas of crop production. Such recommendations assume that the need of a crop for nutrients is constant over time and over large areas. But the growth and needs of a crop for supplemental nutrients can vary greatly among fields, seasons, and years as a result of differences in crop-growing conditions, crop and soil management, and climate. Hence, the management of nutrients for crop requires a new approach, which enables adjustments in applying N, P, and K to accommodate the field-specific needs of the crop for supplemental nutrients.

Site Specific Nutrient Management (SSNM) aims at specific management of nutrients in a particular crop or cropping system to optimize the supply and demand of nutrients according to their differences in cycling through soil plant system. This approach was developed in Asian rice-producing countries through partnerships of the Irrigated Rice Research Consortium (IRRC). It emphasizes 'feeding' crops with nutrients as and when needed. SSNM strives to enable farmers to dynamically adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, organic amendments, crop residues, manures, and irrigation water. This allows farmers to identify, analyze, and manage the spatial and temporal variability of soil and plants for optimum profitability, sustainability and protection of the environment.

The fertilizer consumption pattern in Kerala is skewed, the priorities often fixed merely based on socio economic reasons. Farmers are not aware of the scientific principles behind nutrient dynamics or interactions in soil or/and plant. Multitudes of processes taking place in soil/plant decide the fraction of nutrient absorbed into the plant body. The unabsorbed portion will finally be lost from the rhizosphere by several means. Losses of these kind lead to environmental pollution. The foremost solution for all these is to adopt soil test based balanced fertilization. Farming, now, is considered as another business and hence efficient utilization and maximization of the available resources is inevitable. Since plant nutrition influences the crop yield and quality, it is expected that Site Specific Nutrient Management will improve the environmental and economic outcome of the crop.

Chilli (*Capsicum annuum* L.) is a spice cum vegetable crop grown world wide (Shoemaker and Tesky, 1995). It is the second most important vegetable crop after tomato (Yoon et al., 1989) estimated to be grown over 1.7 million hectares worldwide (FAO, 2008). Chilli belongs to the family solanaceae, genus capsicum with twenty different species. Only four species are commercially cultivated out of. which *Capsicum annum* is the most commonly cultivated. *Capsicum annum* is a warm season crop sensitive to climatic conditions during blossom development and fruiting. They are moderately salt tolerant and comes up well in a wide range of soil types, but best being well drained sandy loam soils. Crop requires a uniform rainfall pattern for production with optimum temperature range being 15-35° C. Under tropical conditions crop prefers an elevation of 150-1800 above MSL (Valenzula, H., 2010). Chillies are indispensable ingredient of Indian diet. They are rich sources of vitamin C, carotene and minerals. Processed chillies and capsaicin extracts have immense diverse use food and pharmaceutical industries. (Bosland and Votava, 2000).

Chillies are indispensable ingredient of Indian diet. They are rich sources of vitamin C, A and minerals. Processed chillies are found in various products including main dishes dairy products, beverages, candies, meat, salad dressings, baked products, hot sauces and even in ice creams. Extracts are also utilized in pharmaceuticals, medicines and in cosmetic products.(Bosland and Votava,2000).

India is a major producer, consumer and exporter of chillies and contributes 25% to the total world production In Kerala chilli is grown in an area of 820 ha with production of 1192 tones. Reports shows that current productivity levels of chilli are far below the satisfactory level to meet domestic demands. Optimum and balanced fertilization is the key for sustained higher production.

Fertilizer doses affect the yield and quality of chillies. This necessitates the remodeling of our approach to the problem of economic and judicious use of fertilizers based on soil test and plant uptake values. In this context, Site Specific Nutrient Management acquires importance. Through this technology it is possible for farmers to attain targeted yield with SSNM recommendations.

With the view of creating awareness among the farmers about the technology of Site Specific Nutrient Management, the present investigation was carried out in farmer's field with following objectives.

1. To formulate a Site Specific Nutrient recommendation for chilli for high and medium yield targets.

2. To increase productivity of chilli grown in Kalliyoor Panchayath without affecting soil health.

3. To increase the profitability of chilli farmers of Kalliyoor Panchayath

2. REVIEW OF LITERATURE

An investigation entitled 'Site specific nutrient management for chilli (*Capsicum annuum L.)* in Kalliyoor Panchayath of Kerala' was conducted in College of Agriculture, Vellayani during 2009-2011 with the objective of formulating a site specific nutrient prescription for enhancing productivity of green chilli in Kalliyoor Panchayath. Site specific nutrient management principles were first applied for rice cultivation and subsequently for other crops. Even though SSNM principles were tested in many vegetables, only a few trials have been conducted in chillies and as a result literature pertaining to chillies is meager. Hence SSNM as applied to crops in general is reviewed in this chapter

2.1 Site specific nutrient management

Site Specific Nutrient Management (SSNM) is one of the important components in precision agriculture. It aims at specific management of nutrients in a particular crop or cropping system to optimize the supply and demand of nutrients according to their differences in cycling through soil plant system. This allows farmers to identify, analyse, and manage the spatial and temporal variability of soil and plants for optimum profitability, sustainability and protection of the environment. SSNM approach was developed in Asian rice-producing countries through partnerships of the Irrigated Rice Research Consortium (IRRC). It emphasizes 'feeding' crops with nutrients as and when needed. SSNM strives to enable farmers to dynamically adjust fertilizer use to optimally fill the deficit between the nutrient needs of a high-yielding crop and the nutrient supply from naturally occurring indigenous sources such as soil, organic amendments, crop residues, manures, and irrigation water.

2.1.1 Site specific nutrient management in rice

The concept was first developed for irrigated rice in Asia and has been well documented at the SSNM web site of the Irrigated Rice Research Consortium including a complete list of publications (IRRI, 2007).

The principles of SSNM are generic and applicable to other crops also. Principles of SSNM developed for rice (Buresh and Witt, 2007; IRRI, 2007) are applicable to other cereal crops in Asia.

The SSNM approach advocates sufficient use of fertilizer P and K to both overcome P and K deficiencies and avoid the mining of soil P and K. The determination of fertilizer P and K requirements for maize follow in essence an approach developed for rice (Witt and Dobermann, 2004), which maintains the scientific principles of the underlying QUEFTS model (Janssen *et al.*, 1990; Witt *et al.*, 1999).

SSNM can take into account all nutrient deficiencies to ensure crop demands are met and soil fertility is improved, which in turn ensures higher nutrient use efficiency, higher crop productivity, and higher economic returns. SSNM strategy was tested in more than 200 farmer fields at six sites in Asia, first-crop recovery efficiencies for fertilizer N, P, and K were estimated in farmer fields within each recommendation domain using the difference method where the uptake of each nutrient is compared in fertilized and unfertilized omission plots. For all sites, values ranged from 40 to 60 percent for N, 20 to 30 percent for P, and 40 to 50 percent for K. Nitrogen recovery efficiency was assumed to be 50 percent when proper plant-based N management strategies are used. The recovery efficiency of N, P, and K applied with farm-yard manure was similar to values obtained for mineral fertilizer.

Instead of calculating fertilizer N, P, and K requirements individually a linear optimization procedure QUEFTS model was utilised that takes into account interactions between nutrients to achieve an optimal nutritional balance.

Low application rate limits were introduced for fertilizer P (23 kgP_2O_5 ha^{-1}) and K (36 kg K_2O ha^{-1}) to ensure that removal from the field in crop products was replenished. All fertilizer P and 50 per cent of fertilizer K were applied early in the season, and remaining K was applied at panicle initiation in line with farmer practice showed the superiority of SSNM practices in rice. (Dobermann *et al.*, 2004).

The experiment conducted by Hach *et al.*, (2007) wherein the rice field is divided in to 2 parts. In one part, fertilizer management is based on the SSNM method while, in another part, fertilizer management is based on the farmer practice called FFP were carried out. The objectives of experiment were to compare the effects of two methods of fertilizer management on rice production while, the other cultivation practice are in the same to both sites. If the target yield in dry season is 7 t ha^{-1}, then nutrient demand will be: 105 kg N, 42 kg P_2O_5 and 126 kg K_2O ha^{-1}. If the target yield in wet season is 4 t/ha, then nutrients demand will be: 68 kg N, 27 kg P_2O_5 and 81 kg K_2O ha $^{-1}$. SSNM recommendations generated were 90-100 kg N ha^{-1}, 33-40 kg $P_2O_5ha^{-1}$ and 44-55 kg K_2O/ha in dry season and in wet season: 73-83 kg N/ha, 40-50 kg P_2O_5 ha^{-1} and 26-33 kg K_2O/ha. Experiment revealed that Fertilizer recommendations based on SSNM and LCC techniques are more flexible and fit to meet the crop demand resulting.in an increment of crop yield up to 0.3-0.5 t ha^{-1} and saving up to 20-30% fertilizer The results of study also showed that SSNM provided an increase in grain yield about 0.5 t ha^{-1} and gave higher benefit than FFP. Fertilizer rate as estimated by SSNM is almost met the requirement of crop, therefore it could save nutrients, especially nitrogen which was applied too high by farmers. SSNM is a simple technique that farmers easily apply.

2.1.2 Site specific nutrient management in other crops

At the Farm surveys conducted by Huang *et al.* (2004) indicated that a close relationship existed between the spatial variability of soil nutrients and the vegetable production history and fertilizer application. Statistical analysis found a close, positive correlation for soil NO3-N, P, and K contents and N, P2O5, and K2O fertilizer application rates, with the corresponding correlation coefficients as high as 0.50, 0.47, and 0.45 ($p<0.01$), respectively. A fertilizer recommendation was made according to production group or plot, and variable fertilization was performed by farmers through hand application. SSNM treatments applied significantly less N and P than FP, and utilized Zn which was omitted under FP.

An experiment conducted in Pacific Northwest and Intermountain West. Total yield was significantly greater under site-specific irrigation management at the 90% confidence level in 2001(King and Stark, 2005).

On-farm experiments were conducted from 2002–03 to 2004–05 on 56 irrigated wheat farms in six key irrigated rice (Oryza sativa L.)-wheat regions of Punjab to evaluate an approach for site-specific nutrient management (SSNM) by Harmandeep *et al.*,(2006) found that when Site-specific N–P–K applications were calculated by accounting for the indigenous nutrient supply, yield targets, and nutrient demand as a function of the interactions between N, P, and K and the performance of SSNM tested for two wheat crops and compared with the current farmers' fertilizer practice (FFP), average grain yield increased from 4.2 to 4.8 Mg ha−1, while plant N, P, and K accumulations increased by 12–20% .

Site-specific nutrient management in maize calls for flexible N management strategies that allow adjustments in N rates according to rainfall events and plant N demand using LCC. The LCC was developed for rice (Balasubramanian *et al.*, 1999; Witt *et al.*, 2005) and is also suitable for maize as indicated by spectral reflectance measurements performed on rice and maize leaves (Witt and Doberman ,2004).

Singh et al., (2011) in a study titled Maximizing Productivity and Profit through Site-SpecificNutrient Management in Rice-Based Cropping Systems revealed the efficiency of site specific nutrient management over farmers practice in different crops the revealed that application of the ISR and SSNM treatments both had a significant influence on mustard productivity. However, significant gains over FFP, the SR, and the STLR were only generated with SSNM. In chickpea, SSNM produced the highest grain yield followed by ISR, STLR, SR, and FFP. The effect of SSNM on garlic was more pronounced than in other crops as about 67% more clove yield was obtained in SSNM than with FFP. Clove yield with ISR was 56% higher than with FFP. Number of cloves/bunch and weight of clove bunch/plant were the important yield contributing parameters, when considering the effect of SSNM on crop growth and development .Use of either the ISR or SSNM not only enhanced potato tuber yield, but also had pronounced effect on total dry matter content, tuber size, and specific gravity Tuber yields resulting from SSNM and the ISR were 54% and 35%, 22% and 7%, and 26% and 11% higher than FFP, the SR, and STLR, respectively. Berseem fodder yield increased up to the third cutting and thereafter it declined with age. Green fodder yield from SSNM, the ISR, the SR, and the STLR were 23%, 17%, 13%, and 7% higher yield than FFP.

Wheat yield under SSNM and the ISR were 24% and 21% higher than FFP. This increase was ascribed to greater head length, higher grains/head, and higher numbers of effective tillers per m^2 Application of fertilizer according to the SR or STLR certainly out yielded FFP, but these treatments generated 0.6 t/ha less grain compared to SSN.

Site-specific nutrient management (SSNM) technology has been developed for cassava and effectively implemented in farmers' fields for field scale nutrient recommendations in major cassava growing regions. Under the SSNM technology, spatial and temporal variability of soil and canopy properties are considered using tools such as simulation models, leaf colour charts and chlorophyll meter for making variable rate fertiliser recommendations (Byju *et al.*, 2011).

2.2 **Effect of soil test on crop yield**

Rao and Subramanian (1994) carried out the Soil Test Crop Response correlation studies on green chillies, tomato, cabbage , brinjal ,okra ,onion and capsicum using fertility gradient and yield goal approach. The results indicated the response to applied N, P and K decreased with increased fertility status of soil for all the vegetable crops.

At Coimbatore high yield achievement (2500 kg ha^{-1}) in cotton was obtained with 50:0:0 NPK /ha based on fertilizer adjustment equation when compared to the blanket recommendation of 90:45:45 kg NPK ha^{-1}. Thus there is possibility of saving in chemical fertilizer of contribution from soil is taken into consideration (Basu., 1995).

In a Soil test crop response (STCR) correlation experiment conducted by Reddy *et al.,* (1999) in a sandy clay loam soil of Nellore with groundnut variety Tirupati -1 revealed that the optimum fertilizer dose required for specific yield targets are decreasing with increasing soil test values. The requirement of nitrogen, phosphate and potassic fertilizer were 'zero' when the available soil N, P and K, test values were 400, 52 and 300 kg ha^{-1}.

Field experiments were conducted with different fertility gradients in Gangetic alluvial soil (Typic Ustochrept) Nilganj series. The study revealed that the yield targets were achieved for jute 25-30 q ha^{-1}, coarse rice 35-50 q ha^{-1} and wheat 340-35q ha^{-1} with +_10 per cent deviation from desired yield targets. Validity of yield targets was tested at farmers' fields through follow up trials as frontline demonstrations which revealed that prescription based on fertilizer application was found profitable as compared to ad hoc recommendation (Ray *et al.,* 2000).

Fertilizer application as per the targeted yield level of 4 tonnes per hectare produced maximum number of pods ,grains, grain weight per plant and thousand grain weight in chickpea ,which were high when compared to recommended fertilizer dose (Shinde *et al.*, 2000).

Patel *et al.*, (2001) conducted an experiment to check the validity of targeted yield relationship for pigeon pea through follow up trials. The study showed that the soil test based yield targets of 10, 12 ,16 and 20 q ha^{-1} were obtained within _+10 per cent variation of targets.

The findings of Meena *et al.*,(2001) in experiments on Soil Test Crop Response calibration in onion in alfisols clearly shows that the fertilizer dose required for attaining a specific target yield of onion was decreased with increase in soil test values. The minimum fertilizer doses required at average soil test value of the fertilizer field experiment {159 kg ha^{-1} N, 63.1 kg ha^{-1} P and 359 kg ha^{-1} K) in the yield maximum method found to be 47, 66 &33 kg ha^{-1} N, P_2O_5 and K_2O respectively for producing 25 t ha^{-1} of onion:

The Field specific fertilizer recommendation calculations by Wang Guanghuo *et al.*,(2001).considering the indigenous nutrient supply, reasonable yield target ,corresponding nutrient demand and nutrient balance consistently improved the plant nutrient uptake, grain yield and profit by about ten to fifteen per cent when compared to farmers fertilizer practice

While considering various methods of fertilizer recommendations, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also the level of yield the farmer can hope if good agronomic practices are followed in raising the crop. For soil plant system this approach is unique because it provides a scientific basis for balanced fertilization not only among the fertilizer nutrient themselves but also the soil available nutrients (Subba Rao & Srivastava, 2001).

Targeted yields of cotton were in close agreement with actual yields of cotton and hence the fertilizer prescription equation is useful to adopt balanced fertilizer dose based on targeted yield concept in cotton (Khandare *et al*, 2002).

In experiments conducted by Verma *et al.* (2002) with wheat, ten with maize and eight with rice at different locations on farmers' fields using fertilizer adjusted equations indicated that on practical basis, the target yield concept not only achieved (50 q ha^{-1}) yield level in rice and (40q ha^{-1}) yield level in maize and wheat but also maintained the soil fertility.

The Soil Test Crop Response correlation studies conducted by Kausadkar *et al.,* (2003) on soybean based on targeted yield at Parbani. The results revealed that 7.8 kgN, 0.92 Kg P_2O_5 and 4.5 kg K_2O were required to produce one quintal of soybean seed yield. The contributions of N, P_2O_5 and K_2O from soil were 86, 46, and 31 per cent and from fertilizer was 90, 15, and 170 percent respectively.

Islam and Milan (2004) developed potassium fertilizer prescription equation for making fertilizer recommendation using data on cotton yield, soil available K and K fertilizer applied for calculated contribution for calculating contribution from soil and applied fertilizers from Central Cotton Research farm , Sreepur and Regional Cotton Research farm Jagdishpur, Bangladesh ,on cotton (Cv.CB-9).

At Coimbatore ,Kalaichelvi and Chinnuswamy (2004) studied the influence of Soil Test Crop Response based on nutrients and potassium humate on cotton productivity , they reported that application of hundred percentage STCR recommended NPK fertilizers recorded more number of sympodial branches ,fruiting points, boll setting percentage over other levels higher seed cotton yield was recorded with 100% STCR recommendation NPK fertilizer combined with soil application of potassium humate either 30 kg or 40 kg ha^{-1}.

Biradar and Alakadi (2005) from Karnataka found out form their studies on hybrid cotton , that yield obtained with SSNM supplying 130 : 70 : 120 NPK kg ha^{-1} plus the secondary and micronutrient produced 2.3 t ha^{-1}. The NPK based on RDF produced 2 t/ha.

Soil Test Crop Response (STCR) Correlation studies were conducted by Santhi *et al.* 2005 with onion (Cv.CO-4) under Integrated Plant Nutrition System (STCR-IPNS) in Inceptisols of Tamil Nadu observed that in STCR-IPNS technology, the fertilizer doses were closely related to the requirements of specific yield targets of onion taking into account the contribution from soil, fertilizers, organics and bio fertilizers and therefore there was balanced supply of nutrients coupled with recycling of organic waste avoiding either under or over usage of fertilizer inputs.

Field experiments conducted by Sharma and Singh ,(2005) on different varieties of wheat in Haplustepts of Delhi ,the results were statistically analysed for multiple regression by taking grain yield of wheat as dependent variable and soil available nutrients (N, P, K) fertilizer nutrients and interaction between soil and fertilizer of 0.88 and 0.91 for multiple regression equation were obtained.

Out of the forty one field verification trials conducted with maize, rice and wheat at farmers field to ascertain the validity of soil test based fertilizer prescription for specific yield targets in wet temperate zone of Himachal Pradesh all of them revealed that the fertilizer recommendation based on targeted yield concept were found more precise and dependable up to the yield targets of 5 tons per hectare for rice and maize and 4 tons per hectare for wheat respectively (Verma *et al*,2005).

Field experiment in maize – chickpea cropping system with integrated use of biogas spent slurry and fertilizer to estimate the fertilizer requirement for specific yield targets of maize and chick pea. The required N, P and K accumulation in the plant for one tinne grain yield 26.6, 4.5 and 2.5 kg in maize and 46.1, 39 and 41.1 kg in chickpea, the suggested N, Pand K ratios in maize and chickpea to be 5.9:1:5.6 and 10.8:1:10.5 respectively. In maize average N, P and K supply from soil19.36%and18% of $KMnO_4$-N olsen P and and NH_4OAc-K respectively, while the values in chickpea were 25,27 and 17% respectively(Singh *et al.*, 2005).

Field experiments were conducted at farmers field to evaluate the validity of fertilizer adjustment equations for different crops (maize ,wheat, green gram, raya and gobhi sarson). The superiority of targeted yield concept over the other practices in farmer's field were clear as it gave higher yields and optimal economic returns. The targets achieved were within reasonable limits when the fertilizers were applied on soil test basis (10 deviation from the target)in majority of crops (Dhillon *et al.*,2006) .

Kadam *et al.* (2006) reported that the results of two follow up trials on onion in Otur (Typic Chromustertts)and Sawargaol series (Vertic Ustropepts) showed that the yield targets of 30, 40, 50 tonnes per hectare was achieved . The highest yield (53.5tonnesper hectare) and profit of (Rs 90,300/ hectare) were observed less than 50 t ha^{-1} yield target of onion followed by 40 t ha^{-1} targeted yield treatment. Fertilizer application based on targeted yield approach was found to be superior to as per soil test treatment.

Soil test crop response correlation studies conducted with mustard and rape seed on Typic Haplustept soil at Ludhiana provided high correlation of high predictability between grain yield and soil available nutrients and fertilizer nitrogen. The fertilizer application based on yield target gave higher yields over farmers practice the grain yield of mustard was found between 550 and 1850kg per hectare with the mean value 1267 kg ha^{-1} and for rapeseed it was between 698and 2720 kg ha^{-1} with mean value of 2108 kg per hectare . (Chand *et al* , 2006).

2.3 Effects of different levels of chemical fertilizers on growth, yield and quality of chilli

2.3.1 Growth parameters

Shamima and Islam (1990) recorded the highest plant height in chilli with application of 120:90:90 kg N, P_2O_5 and K_2O ha^{-1} .

Medhi *et al.* (1990) observed the highest plant height in chilli with the application of 80:80:80 and 100:50:50 kg N, P_2O_5 and K_2O respectively.

The highest plant height of chilli (110.48) was observed at 120 DAT with application of 200% RDF + FYM +VC which was significantly superior over rest of the nutrient levels. He also reported that the highest number of branches of

11.72, 18.00, 19.56 were recorded with application of 200% RDF + FYM +VC at 60, 90, 120 DAT respectively 20 ha $^{-1}$, respectively (Patil,1998) .

A field experiments by conducted by Singh *et al.,* (1999) in clay loam soils of Orissa in chilli resulted in maximum plant height and number of leaves per plant at 120 Kg nitrogen and 105 Kg K_2O ha^{-1} as compared to lower doses of nitrogen, potassium and control i.e. without fertilizers.

Balraj (1999) also observed significantly more number of branches in chilli with fertilizer level of 150:75:75 kg N, P_20_5 and K_20 per hectare than lower fertilizer levels (100:50:50 kg N, P_20_5 and K_20 per hectare.

Suresh (2000) reported that application of 150:50":75 kg N, P_20_5 and K_20 per hectare produced tallest plants in chilli. . The study also revealed that significantly more number of branches was observed in chilli with application of 100:50:75 kg N, P_20_5 and K_20 per hectare.

Malagi, 2001 reported that application of 100 Kg nitrogen per hectare recorded maximum plant height, number of branches per plant, leaf area index, leaf area duration, total dry matter production (102.99 g/plant) and its distribution in different plant parts in chilli as compared to the application of 75, 50, and 25 Kg nitrogen per hectare.

There was a distinct response of K application combined with N on ginger growth, an appropriate K application rate combined with N could obviously enhance plant height, branch number, stem diameter, dry weight of shoot, single ginger rhizome weight and increase yield.(Majumdar *et al.*,2005)

2.3.2 Yield parameters

Jeyaraman and Balasubramanian (1988) conducted a field experiment on sandy clay soil in Madurai to study the effect of graded levels of potassium (035,70 and 105 kg ha^{-1})on chilli (Cv.MDU-1). The results revealed that, highest number of fruits per plant (28.24) was registered at 10 t 5 kg K_2O ha^{-1}.

A field experiment was conducted by Srivastav *et al.*, (1993) on clay loam soil at Jabalpur (M.P) in chilli and they recorded maximum number of fruits per plant (10.60), yield per plant (637.50 g) and yield per hectare (92.95 q ha^{-1}) at medium level of fertilizer tried (200 kg K_2O ha^{-1}).

Srivastava, (1993) noticed that maximum per cent fruit set was (29.5%) with higher dose of nutrients 300:250:250 kg N, P_2O_5 and K_2O in sweet pepper (*Capsicum annuum var Grossum L.*). This might be due to more carbohydrate production and assimilation in fruit. It was also reported that, highest number of fruits per plant were obtained with application of 200 kg K_2O ha^{-1}.

Sharma and Peshin (1996) observed significant increase in fruit length, number of fruits per plant and fruit yield of chilli with an increase in nitrogen levels. The highest was being at 150 kg N ha^{-1}. Similarly Maya et al., (1997) observed highest fruit yield (496.8 g /plant) in sweet pepper at 150 kg nitrogen per hectare.

Palled (1998), reported that, with increased level of nitrogen, number of fruits per plant (96.7), highest dry chilli yield 72.1 g/plant and dry chilli yield 1948 kg ha^{-1} increased up to N application of 200kg ha^{-1}.

Balaraj (1999) who revealed that the total number of fruits per plant in chilli increased from 77.06 to 99.25 with increase in fertilizer level from 100:50:50 to 150:75:75 NPK per hectare.

Srinivasan (1999) revealed that application of P @ 180 kg ha^{-1} significantly produced higher number of fruit per plant an d higher green chilli yield of (52.1 q ha^{-1}) and (80.6 q ha^{-1}) during 1996 and 1998, respectively.

Results obtained by Ananthi *et al.*(2004) who noticed significantly higher number of fruits (115 per plant) and individual fruit weight (0.73 g) in chilli (Cv. PKM 1) at highest level of potassium (75 kg ha^{-1})on sandy clay loam soil at Coimbatore.

Sashidhara (2000) reported that application of 100 per cent RDF (100:50:50 kg NPK ha^{-1}) recorded maximum fruit yield of chilli(629.6 kg ha^{-1})as compared to 50 per cent RDF and control (509.33 kg ha^{-1}).

Srinivas (1983) and Kulvinder Singh and Srivastava (1988) reported that the combined application of N, P (90:80 and 120:60 kg/ha, respectively) recorded significantly higher fruit yield of chilli over control. Similarly Sutagundi (2000) reported that application of RDF+VC gave significantly superior dry chilli yield (11.22q ha-1) over individual application of RDF and VC alone.

Thakur et al. (2000) reported that the application of higher dose of potassium resulted in significantly higher yield of bell pepper. Jayaraj (1999) also recorded significantly higher fruit yield with (5734 kg ha-1) with application of 180:40:40 kg NPK ha^{-1}.

Veeranna *et al.*,(2000) conducted a field experiment at Bangalore to study the effect of potassium fertigation on growth and yield of chilli. The results indicated that application of 150% recommended dose of potassium (112.5 kg per hectare) produced significantly higher dry fruit yield (1132 q ha^{-1}) over control.

Aliyu (2002) noticed that application of 140: 25 kg N and P per hectare produced maximum average weight of fruit in chilli. Similarly Patel (1998) reported that the application of 200% RDF+FYM+VC recorded the dry weight of (36.35 g/plant) and the highest dry fruit yield (19.12 q ha^{-1}) which was significantly superior over other levels of nutrient.

Vandhana`, (2003) revealed that the maximum number of fruits per plant (78.73/plant), highest green chilli yield (175.43 g/plant) and higher fruit-yield (5957 kg ha^{-1}) was recorded in higher fertilizer level (F3 ;250:125:125 NPK ha^{-1}) than fertilizer level (F 1 150:75:75 kg NPK ha^{-1}) (146.76 /plant). Similar results were obtained by Ramakrishna (2002) with the highest fruit weight per plant (45.46 g) which was recorded with highest fertilizer of 150:75:75kg NPK ha^{-1}) compared to other levels and highest chilli fruit yield of 1175 kg per hectare was recorded with application of 150:75:75kg NPK per hectare.

A field experiment carried by Subhani *et al* (1990) on sandy loam soil at Bapatla and reported significant increase in dry fruit yield of chilli (Cv.G-4) with increased application of nitrogen and potassium. The highest yield (90.8 g/ plant) was obtained through 180 kg N/ha and 120 kg K_20 ha^{-1}. Similar results were obtained by Vanangamudi *et al* (1990) with increase in nitrogen level from 125 to 200 kg /ha and Kaminvar and Rajagopal (1993) who reported highest dry pod yield of (15.34 q ha^{-1}) in chilli Cv. Sindhur with highest level of potassium application (100 kg ha^{-1})

Field trials were conducted by Gollifer (1993) in Indian chilli (*Capsicum annuum* cultivar B-16-41) and he reported that application of potash fertilizer 180 kg ha^{-1} increased the fruit yield up to 113 per cent. Linear response was observed by Sharma (1995) in yield and yield attributes of chilli up to the application of 100 kg potassium per hectare, along with 125 and 75 kg N and P_20_5 per hectare respectively. Similar results were also reported by Ram *et al.*, (1996) were the application of 100 kg K_2O per hectare in combination with 125 kg N and 75 kg P_2O_5 per hectare resulted in highest chilli dry fruit yield (26.09 q ha^{-1}).

Increased levels of potassium had significant influence on the fruit yield of tomato and chilli, with highest fruit yield of tomato and chilli (525.33q/ha and 168.20 q ha^{-1}, respectively) under 90 kg K_20 per hectare. The application of 90 kg K_20 per hectare has resulted in 12.59, 8.67 and 4.75 per cent higher fruit yield of chilli over 0, 30 and 60 kg K_20 per hectare respectively (Majumdar *et al.*, 2000).

Ginger rhizome yield and its component increased with the increases of K application rate as applied with no more than 450 kg ha-1 K_2O, and the highest yield was obtained by the treatment N_{450} K_{450} of medium N and medium K this report was revealed in a study conducted by Majumdar *et al.*, 2005

A field experiment was carried out to know the effect of potassium levels (0, 30, 60 and 90 kg /ha) on yield and nutrient uptake in paprika under irrigated conditions on red sandy loam soil at Warangal, Andhra Pradesh. The results revealed that the increased levels of potassium significantly increased the dry pod yield of chilli with highest yield (17.64 q ha^{-1}) at 90 kg K_2O per hectare (Hari *et al.*, 2007).

2.4 Status of micronutrient in soils of India especially Kerala

Micronutrients are essential for the normal growth of plants. Deficiencies of micronutrient drastically affect the growth, metabolism and reproductive phase in plants, animal and human beings. Wide spread deficiencies of micronutrients has been found in Indian soils. About 3 billion people in the world are affected with micronutrient malnutrition.

In India, analysis of 2.52 lakhs surface soil samples collected from different parts of the country revealed the predominance of zinc deficiency in divergent soils. Of these samples 49, 12, 4, 3, 33% and 41% soils are tested to be deficient in available zinc (Zn) Zn, iron (Fe) manganese (Mn), copper (Cu) , boron (B) and sulphur (S), respectively. The magnitude of zinc deficiency varied widely among soil types and within the various states.

Pisharody *et al.*,(1965) noticed that in Kerala the available iron content was high and even reaches toxic limits for paddy soils.

The FAO has estimated that fifty per cent of the world's agricultural lands are deficient in zinc (Mikko Sillanppa, 1990)

Depletion of micronutrients from soil is increasing by adoption of modern technologies in agriculture like use of high analysis fertilizers and use of fertilizer responsive crops. There are records of occurrence of micronutrient deficiency namely deficiency of zinc, copper and manganese in Indian soils at the rates of forty six, five and four per cent respectively (Singh, 2003).

Among micronutrient deficiencies, zinc deficiency is most common in Indian soils. Loses of yield to a tune of forty per cent has been recorded in zinc deficient soil as this results in major economic losses to the farmers due to reduced income (Alloway, 2004).

The highest rate of zinc deficiency of 57 per cent reported from the acid soils of Kerala and Meghalaya followed by Jharkhand, Orissa and West Bengal where the rate of deficiency was reported to be 23-54 per cent (Sarkar and Singh, 2003).

Mathew, 2006 reported that majority of soils in Kerala recorded low content of available zinc.

According to statistics by SSO, (2007), Major soils of Kerala are derived from acid igneous rocks and deficient in B.

A study conducted by Tiwari,*et al.,* (2008) revealed that 49 per cent of Indian soils were found to be deficient in zinc.

2.5 Effect of micronutrients and secondary nutrients application on growth and yield parameters

Among the micronutrients B is one that shows deficiency in soils that results in deficiency of the element in cereals (Elrashidi , 1982).

Hulgar and Dangarwala (1983) recorded the increased uptake of N,Ca,Mg and S in maize due to the application of Zn.

Das (1986) reported that the application of $ZnSO_4.H_2O$ at 20 kg ha^{-1} gave the highest average yield of 4.12 t ha^{-1} for rice in acid lateritic soil.

Application of $ZnSO_4$ @ 5-10 kg ha^{-1} or foliar application of $ZnSO_4$ @1.25 per cent increased he increased the tuber yield and the HCN content in cassava in lateritic soils of Kerala (Nair and Abrol, 1989).

Application of B as foliar spray showed a positive response to deficiency of boron has been reported from more than 80 countries for more than 132 crops over last 60 years (Shorrocks et al., 1997) .

Singh (1999) observed that yield of wet land rice in the soils of Meghalaya showed increase in yield by application of Zn as fertilizer.

Meerabai (2001) reported increase in ginger yield by application of Zn @4 kg ha-1 and increase in turmeric yield, oil content and curcumin content by application of Zn @10 kg ha^{-1}

Reddy and Ahalwat (2002) reported that there is significant increase in yield of lentil when Zn was applied along with P.

Umamaheshwari and Singh(2002) revealed that application of ZnSO4 @ 5 kg ha-1 increased yield aspects of rajmash.

Application of Zn @ 10 kg ha-1significantly increases plant height and green fodder yield in pearl millet.(Dadwhich and Gupta, 2003)

Devi and Rani (2003) reported that application of 25 kg ha^{-1} $ZnSO_4$ .increased the grain yield by 48.2%.

Verma et al (2004) .suggested that the application of foliar spray of 0.5% $ZnSO_4$ increased the quality attributes of pigeon pea.

Jyolsna (2005) reported that the application of Zn @ 5kg ha^{-1} was ideal for economic yield and also Zn influenced the growth, yield and quality of tomato.

Application of Zn 5 Kg ha-1 along with NP and K were found to be suitable for achieving greater productivity in plants (Shivoy and Kumar, 2005).tomato.

Sulphur and zinc when applied along with N, P and K increased the pod yield and number of nodules per plant in ground nut. (Tiwari *et al*, 2006)

Chaube *et al* . (2007) recorded that the application of 1% ZnSO4 increased the plant height, number of leaves, plant height , leaf area and yield in pearl millet.

Application of 2.75 kg ha^{-1} increased the maize grain yield by 25%of total dry matter, number of cobs and cob weight (Haris *et al.*,2007).

Application of 100 g Mg chelate along with 2% foliar spray of MgSO4 proved to be promising treatment in banana , this was revealed by ,Mostafa,(2007) .

In an experiment conducted by Baloch *et al.,* (2008) to study the effect of foliar spray of micro and macro nutrients on the production of green chillies (*Capsicum annuum sp.*L.) wherein application of commercial product Hi Grow a composition of micro and macro nutrients at different rates (4, 5,6 7 and 8 mg/ L) along with nitrogen , phosphorus and potassium (50:50:25 kg NPK /ha)) was studied reported that application of Hi Grow at 8 mg/ L along with nitrogen , phosphorus and potassium recorded the highest plant height(68 cm) 6.93 branches plant^{-1}, 118.86 fruits per plant, 4.19 cm fruit length, 395 g fresh chillies fruit weight per plant and 14.9 t ha $^{-1}$. With decreasing concentrations the yield and growth of chilli got negatively affected.

Application of boron @0.5 kg ha^{-1} to 1.5 kg ha-1 improved the yield and quality attributes of tomato. These results were obtained by Jyolsna and Mathew , (2008).

Application of NPK@ 120:60:40 kg ha^{-1}+FYM 10 t ha^{-1} + Zn @ 10 kg ha^{-1} resulted in increased height in fodder maize (Thankamony, 2010). This study also revealed that the application of foliar spray of 0.75 per cent of zinc sulphate along with NPK@ 120:60:40 kg ha^{-1} +FYM 10 t ha^{-1} showed maximum number of leaf production.

2.6 Effect of different chemical fertilizers doses on nutrient uptake of N, P, K

Application of 200% RDF + FYM +VC recorded the highest N uptake of (122.18 kg/ha) and K uptake of (179.38 kg/ha) which was on par with N uptake (113.94 kg/ha) and K uptake (169.96 kg/ha) noted by application of 150% RDF + FYM +VC. Similarly application of 200% RDF + FYM +VC recorded the highest P uptake of (23.04 kg ha^{-1}) Patil (1998).

The requirement of NPK was 4.5,0 .77 and 3.58 kg/ha respectively to produce one quintal of dry chilli. The yield targets of 25 to 30 q/ha were achievable at these rates of NP-K application (Reddy *et al.*, 1999)

According to Shashidhara (2000) the uptake of nutrients *viz.*, N,P,K, Fe, Cu, M n and Zn (at flowering and harvest) were significantly higher with combined application of organics (farm yard manure /BSS/ red gram stalk) and inorganics (100% RDF/ 50% RDF).

Bidari (2000) studied that irrespective of cultivar and fruits quality, the order of nutrient concentration in whole fruits followed the order K >N >Mg > Ca > P > Fe > M n > Cu, Similarly, Suresh (2000) reported increased uptake of potassium in chilli with increasing levels of potassium. The highest uptake of(108.24 kg ha^{-1}) was obtained at 75 kg K_20 ha^{-1} along with 100:50 kg N and P_20_5 per hectare and it was significantly superior over 25 kg K_20/ha (100.89 kg ha^{-1}).

Increased levels of potassium (0, 30, 60 and 90 kg ha^{-1}) significantly influenced the K content with highest value of 121.5, 216.50 mg per 100g fruit in tomato and chilli respectively at 90 kg K20 ha^{-1}. Application of 90 kg K_20 ha^{-1} has resulted in 2.85, 1.80 and 0.93 per cent more K content in chilli fruits over 0, 30 and 60 kg K_20 ha^{-1} respectively (Majumdar *et al.*, 2000).

Quality attributes had significant positive relation with uptake of all nutrient particularly at 75 and 140 DAT whereas, uptake at 105 DAT had no relation with quality attributes except for nitrogen and sulphur uptake (Bidari ,2000).

Ramakrishna (2002) reported that application of higher fertilizer (F4: 150:75:75 NPK ha^{-1}) in chilli recorded increased N, P and K uptake.

Nitrogen uptake was significantly higher (9.37 and 65.90 kg ha^{-1})at 50% flowering and at harvest respectively. In higher fertilizer level (F3: 250:125:125 kg NPK ha^{-1}) in chilli (*Capsicum annuum* L.) than other lower fertilizer levels.

Similar trends were observed with respect to potassium and phosphorus uptake of chilli (Vadhana, 2003)

The combined application of FYM 10 t per hectare along with 100% RDF recorded significantly higher nutrient uptake (49.4 kg ha $^{-1}$) over rest of the treatments but on par with CS @ 10 t per hectare along with 100% RDF (44.66 kg ha^{-1}) and farmyard manure at the rate of 5t ha^{-1} + CS @ 5 t t ha^{-1}+100% RDF +S&MN +BF (47.56 kg ha^{-1} (kattimani, 2004).

Significantly higher uptake of nitrogen and potassium (99.38 and 171.25 kg ha^{-1}r respectively) by paprika plants was observed at higher level of potassium (90 kg K20 ha^{-1}) whereas the phosphorus uptake was highest (34.58 kg ha^{-1}) at 60 kg K2O ha^{-1} (Hari et al.,2007).

2.7 **Economics of site specific nutrient management.**

The economics of fertilizer use on the basis of average yield indicated an additional benefit of Rs. 3163 and 2151 over general recommended dose for 30 q ha^{-1} and 35 q ha^{-1} yield targets of pearl millet and wheat respectively, which was followed by fertilizer application based on soil testing (additional benefit of Rs. 1683 and 2126 ha^{-1} over general recommended dose in pearl millet and wheat, respectively) Tamboli *et al.,(* 1994)

Economics of fertilizer use on the soil test for average yield indicated an additional benefit of Rs. 3163 and 2151, over the general recommended level for 25q ha^{-1} yield target of chickpea (Tamboli et al., 1996).

The findings of Swadija *et al.,(*1998) the Benefit: Cost ratio for yield targets of 20 q ha^{-1}(2.83) and 25 q ha^{-1}(2.82) of cassava were on par and significantly superior to other treatments. The fertilizer dose for targeted yield of 15 q ha^{-1} recorded significantly higher returns per rupee invested on fertilizers than other treatment.

Site-specific nutrient management for maize not only resulted in higher yield but also lower the cost of production (Attanandana et al., 1999, Attanandana and Yost 2003). The results revealed a remarkable change and improvement in the farmers in terms of thinking and working and a better standard of living, greater initiative, ideas and thought, forming the group to share their resources and improvement and maintain their soil and water resources were seen. More effective fertilizer use has resulted in higher yield and profit of maize when farmers followed Site-Specific Nutrient Management technology.

Reddy and Ahmed (2000) revealed that the benefit: cost ratio was found to be much higher in maize (15.6) in case of treatment based on STCCR methodology when compared to either the fertilizer doses based on general recommended dose (8.9) or farmers practice (8.8).

The higher response ratio (12.31) and net profit (Rs. 11014 ha^{-1}) due to application of fertilizer was obtained in targeted yield as compared to economic yield treatment. On the other hand, the benefit cost ratio was lower in targeted yield (6.96) as compared to economic yield treatment(8.59) due to high cost of fertilizer used in targeted yield approach (Sharma and Singh., 2000).

According to Khandare *et al.* (2002) the yield targets of 20, 25 and 30 q ha^{-1} were achieved with +-3 to 8 per cent variation except 30 q ha^{-1} by applying fertilizers based on fertilizer adjustment equation developed for cotton at Rahuri. There was increasing trend in monetary returns with increased fertilizer input targeted yields. The higher monetary returns (Rs.38298 ha^{-1}) were observed in the target yield of 20 q ha^{-1} as compared to soil test based fertilization (Rs. 35271 ha^{-1}).

The yield obtained from targeted yield of maize, 3 t ha^{-1} was almost equal to state level fertilizer recommendation but benefit cost ratio was(14.9) which was much higher than state level fertilizer recommendation with benefit cost ratio of (6.3) mainly due to higher application of nitrogen (Verma *et al.*, (2005).

Higher B: C ratio of wheat (6.2), maize (5.12) and raya (6.19) was reported by Dhillon et al.(2006) and they suggested that target yield concept gave higher yield and hence better economic returns than farmers practices general recommended dose.

The gross return above fertilizer cost (GRF) was about 13% greater with SSNM than with FFP. Improved timing and/or splitting of fertilizer N increased N recovery efficiency from 0.17 kg^{-1} in FFP plots to 0.27 kg^{-1} in SSNM plots (Harmandeep *et al.*,2006).

4. MATERIALS AND METHODS

An investigation entitled "Site Specific Nutrient Management in chilli (*Capsicum annuumL.)* in Kalliyoor panchayath of Kerala" was conducted at college of Agriculture, Vellayani from 2009 to 2011 with the objective of formulating a site specific nutrient prescription for enhancing productivity and profitability of green chilli in Kalliyoor Panchayath of Kerala. The experiment comprised of three parts namely survey of site characteristics, spatial variability studies and field experiments.

3.1. Survey of site characteristics

Field survey covered twenty five chilli growing farmers from different locations of Kalliyoor Panchayath. The major aim of the survey conducted was to find out the field variability in the chilli growing tracts of Kalliyoor panchayath. The survey was carried out using a proforma that provides details on not only the cropping history but also other details important for crop production and of socio economic conditions. The details included in the proforma are listed below

3.1.1 Proforma for Survey

1. Name of farmer
2. Address
3. Survey no
4. Cropping history
   a. Kharif crop
   b. Rabi crop
   c. Variety used
   d. Area cultivating
   e. Irrigated area
   f. Rain fed area
   g. Yield obtained
   h. Previous Crop in field
5. Cultural practices
   a. Ploughing method
   b. Nursery raising / seeding sowing
   c. Thinning and gap filling

- d. Fertilizer application
- e. Fertilizer used
- f. Manure application
- g. Manure application method
- h. Time of application
- i. Spacing followed
- j. Irrigation facility availability
- k. Plantation protection details
- l. Weeding method
- m. Harvesting

6. Weather data
   - a. Details of rain
   - b. Approximate temperature
   - c. Sunlight availability
   - d. Details of drought
   - e. Details of flood
7. Socio economic condition
   - a. Acceptance of the product in area
   - b. Dist. to market
   - c. Type of market
   - d. Mode of transport
   - e. Involvement of middle men
   - f. Whether land is leased in or owned
   - g. Credit facility and amt of credit
   - h. Av g of labour
   - i. Employment generation
   - j. Whether there is support from any society / initiation
   - k. Influence of nearby farmer
   - l. Communities influence
   - m. Whether agricultures is profitable
   - n. Availability of quality input
8. Environmental problem
   - a. Whether there is drainage facility
   - b. Presence of water logged condition
   - c. Detailed water pollution
   - d. Whether there is practices of excess use of chemical fertilizer
   - e. Whether there is mono cropping practiced

f. Details of crop failure due to rain

g. Details of crop failure due to drought

h. Details of a crop failure due to pest and drought

i. Major pest of chilly in the area

j. Major disease of chilly in the area

k. Details of any type of pollution in the area

l. Whether soil in inherently fertile / not

m. The important co friendly practice adopted in the field

n. Availably of indigenous nutrient source

9. Stress such as water ,pest & diseases

a. Whether there is water scarcity

b. Plots receiving low irrigation water

c. Methods of irrigation and facilities area

d. The extent of yield reduction due to water scarcity

e. Major pets in the area

f. Important control measures adopted

g. Whether there is any preference to chemical / biological control measures

h. Important control measure adopted for drainers

i. Whether there is enough water harvesting structure

j. Whether there is the practices of rain water harvesting

k. Whether any physiological disorder in plant identified

l. Whether there is any physical / chemical disorder in soil

3.2 Spatial Variability Studies

Soil and water samples from these twenty five sites were subjected to analysis for various chemical and physical properties like bulk density, water holding capacity, pH, EC soil available nitrogen, phosphorus, and potassium secondary nutrients like calcium, magnesium, sulphur, micronutrients like boron, zinc, iron, manganese and copper.

3.3 Field experiment

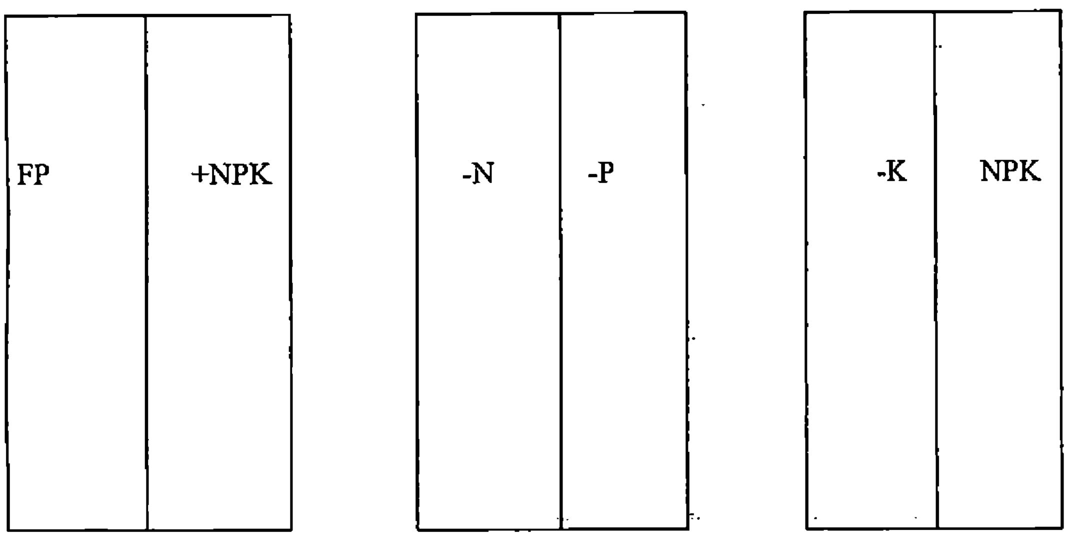
3.3.1 Nutrient omission trials

Nutrient Omission trials were conducted in farmers' fields at four sites of Kalliyoor panchayath namely the Pandara Kari, Vydhyante Kari, Puncha Kari and Palapur. Omission trials were carried out specifically in these four sites since they showed very high variability with respect to the fertility status.

3.2.2 Treatments in omission trial

1. POP recommendation - 75:40:25 kg NPK ha^{-1}
2. Farmers practice - 71 : 31 : 94 kg NPK ha^{-1}
3. Nitrogen omission - 0 :40 : 25 kg NPK ha^{-1}
4. Phosphorus omission trial - 75: 0: 25 kg NPK ha^{-1}
5. Potassium omission trial - 75 :40 : 0 kg NPK ha^{-1}
6. Absolute control - 0:0:0 kg NPK ha^{-1}

Plate .1. LAYOUT OF THE OMISSION TRIAL



3.2.3 Nitrogen omission trial

Nitrogen omission trials were conducted to find out the indigenous supply of nitrogen from the soil. Indigenous nitrogen supply is the cumulative crop uptake of nitrogen from all sources other than fertilizer ie, soil, crop residues, manures, irrigation water, rainfall and atmospheric deposition. It is determined in N omission plot receiving full doses of phosphorus and potassium but no nitrogen. Yield, soil available N, P, K, Ca, Mg ,S ,Cu, Fe ,Mn, Zn, B and nutrient uptake values for N,P,K were recorded initially, 30DAP, 60DAP, 90 DAP. The treatment received 0: 40: 25 kg NPK ha^{-1}

3.2.4 Phosphorus omission trial

Phosphorus omission trials were conducted to find out the indigenous supply of phosphorus from the soil. Indigenous phosphorus supply is the cumulative crop uptake of from all sources other than fertilizer (i.e., soil, crop residues, manures, irrigation water, rainfall and atmospheric deposition. It is determined in P-omission plot receiving full doses of nitrogen and potassium but no phosphorus. Yield, soil available N, P, K, Ca, Mg ,S ,Cu, Fe ,Mn, Zn, B and nutrient uptake values for N,P,K were recorded initially, 30DAP, 60DAP, 90 DAP. The treatment received 75: 0: 25 kg NPK ha^{-1}.

3.2.5 Potassium omission trial

Potassium omission trials were conducted to find out the indigenous supply of potassium from the soil. Indigenous potassium supply is the cumulative crop uptake of potassium from all sources other than fertilizer (i.e., soil, crop residues, manures, irrigation water ,rainfall and atmospheric deposition. It is determined in K-omission plot receiving full doses of phosphorus and nitrogen but no potassium. Yield, soil available N, P, K, Ca, Mg ,S ,Cu, Fe ,Mn, Zn, B and nutrient uptake values for N,P,K were recorded initially, 30DAP, 60DAP, 90 DAP. The treatment received 75:40: 0 kg NPK ha^{-1}.

3.4 Derivation of SSNM recommendations using QUEFT model (Quantitative Evaluation of Fertility of Tropical Soils)

QUEFTS model predicts the crop yields from chemical soil characteristics, as an indicator of soil fertility. Potential yield of the crop recorded was 32t. High yield target was fixed at 50% of potential yield i.e. 16t ha^{-1} and medium yield of 12t ha^{-1}. From the QUEFTS model fertilizer recommendations for medium yield target, high yield target were generated.

A Microsoft excel spread sheet version of QUEFTs in combination with the solver module for the simulation of generic nutrient uptake curves (YN, YP, YK) representing optimal internal efficiencies of N, P and K at different yield level.

3.4.1 Variables utilised for the generation of SSNM fertilizer recommendation

Potential Indigenous N supply (kg/ha) INS = Crop N uptake in a plot without N application but ample P and K supply

Potential indigenous P supply (kg/ha) IPS = crop P uptake in a plot without P application but ample N and K supply

Potential indigenous K supply (kg/ha) IKS = crop K uptake in a plot without K application but ample N and P supply

Recovery fraction

(Total nutrient uptake in the fertilized crop – total nutrient uptake of unfertilized crop)/nutrient applied

Recovery fraction of applied N (RFN)

Recovery fraction of applied P (RFP)
Recovery fraction of applied K (RFK)

Recommended N Fertilizer rate (kg/ha), FN

Recommended P Fertilizer rate (kg/ha), FP

Recommended K Fertilizer rate (kg/ha), FK

Slope of envelope function grain yield vs. N uptake, max. accumulation of N in the plant, aN

Slope of envelope function grain yield vs. N uptake, max. dilution of N in the plant, dN

Slope of envelope function grain yield vs. P uptake, max. accumulation of P in the plant, aK

Slope of envelope function grain yield vs. P uptake, max. dilution of P in the plant , dK

Slope of envelope function grain yield vs. K uptake, max. accumulation of K in the plant,aK

Slope of envelope function grain yield vs. K uptake, max. dilution of K in the plant,dK

Climatic Potential supply of N (kg/ha), SN = INS + RFN x FN

Potential supply of P (kg/ha), SP = IPS + RFP x FP

Potential supply of K (kg/ha), SK = IKS + RFK x FK

Actual N uptake as a function of N and P supply (kg/ha), UN (P)

Actual N uptake as a function of N and K supply (kg/ha), UN (K)

Actual P uptake as a function of P and N supply (kg/ha), UP (N)

Actual P uptake as a function of P and K supply (kg/ha) , UP (K)

Actual K uptake as a function of K and N supply (kg/ha) , UK (N)

Actual K uptake as a function of K and P supply (kg/ha) , UK (P)

Final estimate of actual N uptake (kg/ha), UN = min (UN (P), UN (K))

Final estimate of actual P uptake (kg/ha), UP = min (UP (N), UP (K))

Final estimate of actual K uptake (kg/ha), UK = min (UK (N), UK(P))

Estimated yield for the predicted UN at max. accumulation of N in the plant (kg/ha),

YNA = aN*UN

Estimated yield for the predicted UN at max. dilution of N in the plant (kg/ha),

YND = dN*UN

Estimated yield for the predicted UP at max. accumulation of P in the plant (kg/ha),

YPA = aP*UP

Estimated yield for the predicted UP at max. dilution of P in the plant (kg/ha), YPD = dP*UP

Estimated yield for the predicted UK at max. accumulation of K in the plant (kg/ha),

YKA = aK*UK

Estimated yield for the predicted UK at max. dilution of K in the plant (kg/ha),

YKD = dK*UK

Estimated yield for actual N uptake as limited by yield that can be achieved with the actual P uptake (kg/ha)YNP

Estimated yield for actual N uptake as limited by yield that can be achieved with the actual K uptake (kg/ha), YNK

Estimated yield for actual P uptake as limited by yield that can be achieved with the actual N uptake (kg/ha) , YPN

Estimated yield for actual P uptake as limited by yield that can be achieved with the actual K uptake (kg/ha) , YPK

Estimated yield for actual K uptake as limited by yield that can be achieved with the actual N uptake (kg/ha) , YKN

Estimated yield for actual K uptake as limited by yield that can be achieved with the actual P uptake (kg/ha) , YKP

Final average yield estimate (kg/ha), GY = mean (YNP, YNK, YPN, YPK, YKN, YKP)

Yield-producing uptake efficiency of N, YPUEN = UN/SN

Yield-producing uptake efficiency of P, YPUEP = UP/SP

Yield-producing uptake efficiency of K, YPUEK = UK/SK

Total yield producing uptake efficiency, TYPUE = mean (YPUEN, YPUEP, YPU

3.5. Site Specific Nutrient Management Experiments

3.5.1. Experimental site

The SSNM experiment was conducted in farmer's field at Palapur, Vellayani in Kalliyoor panchayath of Kerala in chilli (*Capsicum annuum L.,).* The experiment was conducted in the planting season from March 2011 to June 2011. The experimental field is located at 8° 28'N latitude and 75° 56'E longitude and altitude of 29 m above mean sea level.

3.5.2 Weather parameters

The major weather parameters during the cropping season were monitored and presented in Fig.1.

The temperature ranged from 30.45°C to 31.45 °C, relative humidity during the period ranged from 87.52% to 90.43% and total rainfall ranged from 0.0 mm to 380.5mm respectively.

3.5.3 Soil parameters

The sol in the experimental site was clayey, kaolinitic, Isohyperthermic, Typic Kandiustults belonging to Vellayani series.

3.5.4 Design and layout of the experiment

Design	:	Randomized Block Design
Plot size	:	$2.74 \times 2.36\ m^2$
Spacing	:	45×45cm
Treatments	:	6
Variety	:	Athulya
Replications	:	4

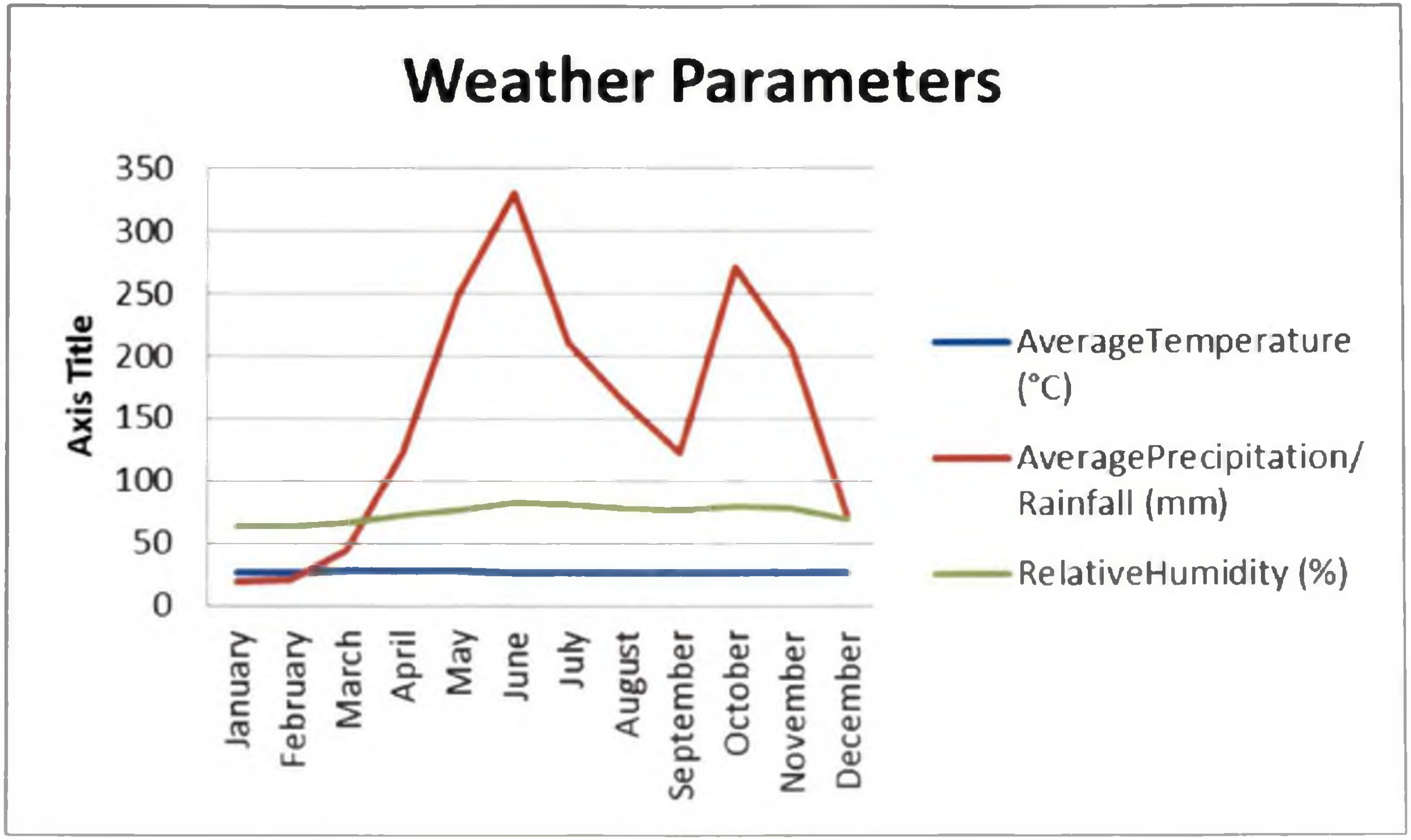


Fig1. WeatherParameters

3.4.5 Treatments of SSNM Trial

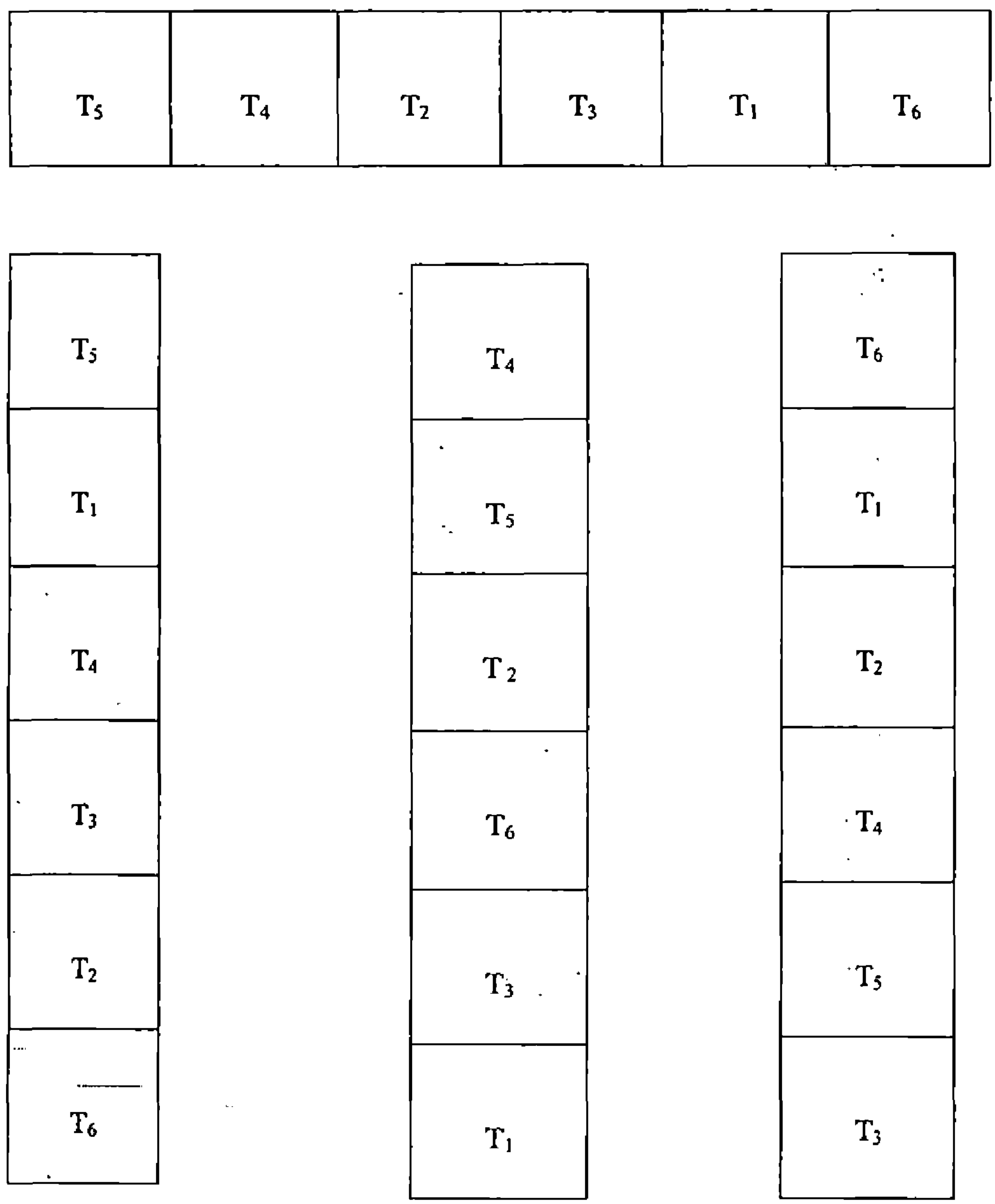
Table1. Treatments of SSNM experiment

Treatments	N : P : K : Ca : Mg : S : Zn :B (kg ha $^{-1}$)
T1. POP Recommendation (POP)	75 : 40 : 25 - -
T2. POP+ micronutrients+ secondary nutrients (POP+SNMN)	75 : 40 : 25 : 30 :7.5 : 30 : 20 : 5
T3. SSNM recommendation for Medium Yield Target (SSNM MYT)	77.28: 8.16: 138 : 30 :7.5 : 30 : 20 : 5
T4. SSNM recommendation for High Yield Target (SSNM HYT)	104.8: 13.6: 201: 30: 7.5 : 30 : 5 + 1 % B foliar
T5. Farmers' Practice (FP)	71 : 31 : 94 - - -
T6. Absolute Control	No fertilizer

Table 2. Analysis of manure

Sl no	Manure	N : P : K %
1.	Cow dung	0.46 0.48 0.63
2.	Poultry manure	0.9 1.2 0.40

Plate. 2. Layout of the SSNM field Trial



3.6. After cultivation practices

3.6.1 Irrigation

The crop was irrigated twice daily at morning and evenings in non-rainy days in order to meet the crop water requirement.

3.6.2 Fertilizer Application

Fertilizer applications were done according to the treatments in the respective plots. The fertilizers were applied in three splits. The first application as a basal dose, second application and the third application 45 DAP and 60 DAP.

3.6.3 Weeding

Weeding was carried out at every 15 days interval so as to reduce weed competition with the plants for nutrients and other resources.

3.7 Biometric Observations

3.7.1 Days to 50% Flowering

Number of days from the date of transplantation required for half of the plant population to reach flowering.

3.7.2 Number of Primary Branches

Number of branches arising from the main stem. The observations were taken at 30, 60 and 90 DAT.

3.8. Yield and quality attributes

3.8.1 Harvesting

Harvesting was carried out after every three days and finally the yields were pooled after every 30 days to obtain the cumulative yield at 30, 60 and 90 DAP.

3.8.2 Fruits per plant

Numbers of fruits per plant were counted at each harvest. The observations were taken at 30 and 60 DAT from four observation plants per plot and the mean was calculated.

3.8.3 Fruit Yield per plant

Weight of fruits per plant was taken at 30 and 60 DAT from four observation plants per plot and the mean was computed.

3.8.3 Fruit Yield per hectare

Weight of fruits per hectare was calculated at 30, 60 and 90 DAT.

3.8.4 Harvest index

Economic yield obtained per unit of dry matter yield

3.8.5 Agronomic efficiency

Yield in SSNM plot –Yield in omissin plot /rate of nutrient added

3.8.6 Partial factor productivity

Units of yield increase per units of nutrient applied

3.9 Soil collection and processing

The soil samples collected from the experimental sites were air dried, processed and passed through 2 mm sieve and stored in polythene bags for analysis. The soil samples were analysed for various physio-chemical parameters

Table 3. Standard analytical methods followed in soil analysis

Sl no	Parameters	Methods	Reference
1.	Mechanical analysis	International pipette method	Piper(1966)
2.	Bulk density	Core sampling	Gupta and Dakshinamurthy(1980)
3.	Water holding capacity	Core sampling	Black (1965)
4.	pH	Direct reading using pH meter in the ratio 1:2.5 soil and water Suspension	Jackson (1973)
5.	EC	Direct reading using conductivity meter	Jackson (1973)
6.	Organic carbon	Walkely and Black rapid titration method	Walkely and Black (1934)
7.	Available nitrogen	Alkaline permanganate method	Subbaiah and Asija (1956)
8.	Available phosphorus	Bray no:1 extraction and spectrophotometry	Jackson (1973)
9.	Available potassium	Neutral normal ammonium acetate extraction and flame photometry	Jackson (1973)
10.	Exchangeable calcium and magnesium	Versenate titration method	Hesse (1971)
11.	Available sulphur	Turbidimetry - Barium chloride method	Chesnin and Yien (1950)
12.	Available micronutrient	DTPA extraction and AAS	Lindsay and Norvel (1978)
13.	Boron content	Hot water soluble boron	Gupta (1966)
14.	Dehydrogenase	extraction with ethanol and spectrophotometry	Lenhard (1956)

3.9 Plant **sample collection and processing**

Plant samples were collected after each harvest namely at 30DAP, 60DAP, 90 DAP before application of split doses of fertilizers. Collected plant samples were washed free of sand and dust and subjected to drying in a hot air oven at temperature of 60-70°C till it attains a constant weight. The dried plants were then powdered in a grinder with steel blades. Wrapped in a clean butter paper cover and stored for analysis. The powdered samples were then analysed for their nutrient content.

Table: 4 Standard analytical methods followed in plant analysis

Sl no	Parameters	Methods	Reference
1.	N	Microkjeldahl digestion with H_2SO_4	Jackson (1973)
2.	P	Di acid digestion using nitric –Perchloric acid (9:4) and colorimetry using vanadomolybdate yellow colour method.	Jackson (1973)
3.	K	Di acid digestion using nitric –Perchloric acid (9:4) and flame photometry	Jackson (1973)
4.	Ca and Mg	Di acid digestion using nitric –Perchloric acid (9:4)and Versenate titration	Piper(1966)
5.	S	Turbidimetry - Barium chloride method	Chesnin and Yien (1950)
6.	Fe,Mn,Zn & Cu	Di acid digestion and atomic absorption spectrophotometry	Lindsay and Norvel (1978)
7.	B	Estimation of hot water soluble boron	Gupta,1966
8.	Capsaicin	Extraction with ethyl acetate and colorimetry	S.Sadasivam and A.Manikam(1973)

3.10 Economic analysis

The economics of fertilizer application was worked out for different treatments after calculating the benefit: cost ratio.

Benefit: cost Ratio = Cost of cultivation / Returns in terms of Rs.

3.11 Statistical analysis

The data generated from the experiments were subjected to various statistical analyses. The data collected from SSNM field experiments were analysed using ANOVA in RBD. Where ever there are significant differences between treatments detected through ANOVA critical differences (CD) are provided for their effective comparison. Correlations with different factors were also done to get an idea about the effect of different treatments.

5. RESULTS

A study titled 'Site specific nutrient management for chilli (*Capsicum annuum* L.) in Kalliyoor Panchayath of Kerala' was conducted at College of Agriculture, Vellayani during 2009-2011 with the objective of formulating a site specific nutrient prescription for enhancing productivity and profitability of green chilli in Kalliyoor Panchayath of Kerala. The results of the study are presented in this chapter

4.1. Survey of site characteristics

A survey, using a specially designed proforma was conducted among the chilli farmers of Kalliyoor panchayath to collect information on cropping history, cultural practices, weather data, environmental problems and stresses such as water, pests or mineral disorders.

Kalliyoor Panchayath is located in the Nemom block of Thiruvananthapuram district, with 21 wards distributed in an area of 17.23 sq.km. It is bordered by the Vellayani fresh water lake. Agriculture has been the primary occupation of the people of the panchayath. It is one of the major vegetable growing tracts of Thiruvananthapuram district. Vegetables are grown in the garden lands and reclaimed wet lands. Coconut, rice, banana, cassava and vegetables are the main crops. Cow pea, bitter gourd, chilli, cucumber, amaranths, snake gourd *etc.* are the vegetables grown in this area.

The survey revealed that the cultivation practices for chilli among the different farmers of the area were not uniform. Farmers' preferences varied in different aspects like variety of the crop cultivated, spacing followed, manures added, fertilizers used and number and interval of pickings. Vegetables were raised mainly by using organic manure without much application of chemical fertilizers. The soils of the area were heterogeneous. The main source of irrigation was the Vellayani Lake and the network of neighboring channels, though some of the farmers preferred their own sources. Occasional inundation of fields through flash floods was pointed out to be the major weather constraint of the area. Soil and water samples were collected from several locations of the panchayath and tested in the laboratory. The results are presented below.

4.2. Spatial variability studies

In order to assess the spatial variability, soil samples were collected from 25 different locations of the Panchayath. Water used for irrigation was also collected from the available sources. Various parameters that determine their properties were studied in the laboratory. The results of such analyses are presented in the following pages.

4.2.1. Soil analysis:

The soil samples collected from 25 different locations of the Panchayath were analyzed for physical, chemical and biological properties. The results are presented in Table.5

Wide variation was noticed in the soil properties of the Panchayath. The pH values recorded by different samples indicated that soils in the Panchayath were acidic to slightly acidic in soil reaction. EC values of the samples revealed that there was not any threat from soluble salts. The range of organic carbon content from 0.34 – 4.90 % clearly pointed out the variation in organic matter status of soils in different locations of the panchayath. Soil texture varied from sandy loam to clay. Wide variation was also observed in the available major nutrient content in different locations. The values for available P and K showed huge variation, but exchangeable Ca was more or less uniform in distribution. The exchangeable Mg values showed variation from 1.0 to 9.5. However, much variation was not observed for the available micronutrient status.

Table 5. Status of physical, chemical and biological properties of soil in Kalliyoor Panchayath.

Sl No.	Parameters	Range of Values
1.	pH	4.16 – 6.3
2.	EC (dSm^{-1})	0.183 – 0.211
3.	OC (%)	0.34 – 4.90
4.	Texture	Sandy loam – clay
5.	Available P ($kg\ ha^{-1}$)	11.4 – 270.9
6.	Available K ($kg\ ha^{-1}$)	18.0 -176
7.	Exchangeble Ca ($cmol\ kg^{-1}$)	1.5 – 6.0
8.	Exchangeble Mg ($cmol\ kg^{-1}$)	1.0 – 9.5
9.	Dehydrogenase activity ($\mu g\ g^{-1}$)	0.015 – 0.48
10.	AvailableZn ($mg\ kg^{-1}$)	0.6 – 1.6
11.	AvailableMn ($mg\ kg^{-1}$)	1.63 – 5.19
12.	AvailableFe ($mg\ kg^{-1}$)	12.5 – 14.12
13.	HWS B ($mg\ kg^{-1}$)	0.03 – 0.6
14.	Available Cu ($mg\ kg^{-1}$)	Traces – 0.86

4.2.2. Irrigation water analysis:

The resulst of irrigation water analysis is given in Table.6. The data revealed that the water in different locations of the Panchayath was slightly acidic in reaction, but safe for irrigation and contained only insignificant quantities of plant nutrients.

Table 6. Analysis of irrigation water from different locations.

Parameters assessed	Range of values
pH	6.2 – 6.5
EC (dSm-1)	0. 108 – 0.212
N (ppm)	2.3- 6.5
P (ppm)	0.098 -0.150
K (ppm)	2.3-5.8
Ca (ppm)	2.9 – 5.1
Mg (ppm)	4.2 - 6.0
Fe (ppm)	0.02 – 0.08
Mn (ppm)	0.10 – 0.13
Zn (ppm)	0.02 – 0.04
Cu	Traces

4.2.3. Field experiments

The Key components of SSNM are measurement of grain yield in nutrient omission plots to obtain field-specific estimates of the indigenous supply of N, P and K (Dobermann et al., 2003). Hence Nutrient Omission Trials were conducted to arrive at fertilizer doses for the Site Specific Nutrient Management Experiment.

4.2.3.1. Nutrient Omission Trials

Because of the wide heterogeneity recorded in soil properties, the soils of the Panchayath were grouped into four classes on the basis of soil fertility (Table.7) and Nutrient Omission Trials were laid out in farmers' fields at four locations representing each class. The treatments were -NPK, -N, -P,-K, +NPK and FP. The yields obtained in these locations are given in Table.8

Table 7. Grouping chart of soils based on fertility status.

Parameter	Classes and No. of locations falling in each class			
	Lower extreme	middle	Middle	Higher extreme
pH	<4.2	4.2-5	5-6	>6
No.	2	11	11	1
EC(dSm^{-1})	Values at all locations fall below 0.2 dSm^{-1}			
No.				
OC (%)	<1	1-2.5	2.5-5	>5
No.	3	6	16	Nil
Av.P(kg ha^{-1})	<60	60-120	120-180	>180
No.	2	6	14	3
Av.K(kg ha^{-1})	<68	68-140	140-180	>180
No.	3	13	8	1
Ca(cmol kg^{-1})	<2	2-3.5	>3.5	-
No.	2	21	2	-
Mg(cmol kg^{-1})	<2	2-3.5	3.5-5	>5
No.	2	12	7	4

Chilli Yield:

The heterogeneity exhibited by the soils of the Panchayath reflected in the variations in yield. Location I and III were having medium fertility status, location II, low fertility status and location IV, high fertility status. In all the locations, NPK omission plots recorded the lowest yield and application of full dose of NPK, the highest. The yields in full NPK plots were approximately twice that of FP. However the yield reduction in (-)P plots was not much pronounced.

Table 8. Effect of nutrient omission on chilli yield in different locations of Kalliyoor panchayath

Treatments	Location I	Location II	Location III	Location IV
FP	2.7	1.41	3.3	6.2
NPK	4.02	2.67	5.9	8.5
(-) N	3.28	2.21	4.6	6.9
(-) P	3.90	2.82	5.8	8.2
(-) K	3.29	2.47	4.2	7.5
(-) NPK	2.26	1.30	2.2	5.1

Yield components.

Observations on yield components recorded at Location I are presented in Tables 9 & 10. Data revealed that omission of any one of the primary major nutrients severely restricted number of primary branches in chilli. N omission had the most severe effect when compared to P and K. (+) NPK plots had the highest number of primary branches.

Table 9. Effect nutrient omission on number of primary branches in chilli

Treatment	30 DAP	60 DAP	90 DAP
FP	4.7	6	6
+NPK	6	8.25	9.75
-N	4.75	5	5
-P	6	8	8..25
-K	5.2	7.5	8
-NPK	5.5	6.5	6.5

Table 10, Shows that nutrient omission had a depressive effect on the number of fruits formed. Application of full N,P and K stimulated fruit production in chilli as evident from the data. Complete omission of the three primary major nutrients severely curtailed fruit production. However, omission of P did not seriously affect the number of fruits formed in this soil.

Table.10 Effect nutrient omission on number of fruits in chilli

Treatment	30 DAP	60 DAP	90 DAP
FP	3.75	13.5	13.75
+NPK	11.25	17.25	22
-N	5.5	11.5	14
-P	8.5	16	20.25
-K	6.25	14.25	18.25
-NPK	7.75	9	7

Dry matter yield:

The plant dry matter was highest for plants receiving full NPK doses followed by phosphors omission plot, followed by – N and –K plots.

Table.11 Effect of nutrient omission trials on the dry matter yield of chilli g ha^{-1}

Treatment	First harvest	Second harvest	Third Harvest
- NPK	1089.3	2061.1	2456
-N	1642.4	2962.9	4444.6
-P	1123.4	3209.83	4938.3
-K	1139.2	2716.01	3456.7
+NPK	1668.6	3703.6	5432.1
FP	1502.2	3209.8	2922.7

Plant nutrient concentration:

The data on plant nutrient concentration after I harvest at 45 DAP are given in Table 12. The lowest values of plant nutrient concentration was recorded by the treatment (-) NPK and the highest by (+) NPK.

Table 12. Effect of nutrient omission on the major nutrient concentration of plants 45 DAP

Treatment	N(%)	P(%)	K(%)	Ca(ppm)	Mg(ppm)
- NPK	0.62	0.16	5.0	1.20	2.1
-N	0.53	0.17	6.3	0.88	1.9
-P	0.84	0.15	7.3	1.28	2.2
-K	0.67	0.16	5.9	1.12	2.3
+NPK	0.95	0.18	7.4	1.44	2.1
FP	0.90	0.16	6.1	1.22	2.1

The data on plant nutrient concentration after II harvests at 60 DAP are given in Table. 13 The same trend in plant nutrient concentration was exhibited at 60 DAP also.

Table 13. Effect of nutrient omission on the major nutrient concentration of plants 60 DAP

Treatment	N(%)	P(%)	K(%)	Ca(ppm)	Mg(ppm)
- NPK	0.71	0.13	1.5	1.20	1.3
-N	0.45	0.23	2.6	1.52	1.2
-P	0.67	0.14	2.5	0.96	1.0
-K	0.64	0.22	1.2	1.44	1.1
+NPK	0.88	0.26	2.5	1.84	1.2
FP	0.81	0.28	2.9	1.08	1.1

Table 14. Effect of omission trial on the nutrient uptake 45DAP

Treatment	N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})	Ca(g ha^{-1})	Mg(g ha^{-1})
- NPK	6.75.366	1.74	5.44	1.36	2.28
-N	8.70	2.79	103.47.12	1.44	3.15
-P	9.43	1.68	82.00.82	1.43	2.47
-K	7.63	1.82	67.1.28	1.27	2.62
+NPK	15.85	3.00	123.47.64	2.40	3.50
FP	13.5	2.40	91.63.42	1.83	3.15

Table 15. Effect of omission trial on the nutrient uptake 60 DAP

Treatment	N kg ha^{-1})	P kg ha^{-1}	K kg ha^{-1})	Ca g ha^{-1})	Mg g ha^{-1}
- NPK	14.63	2.67	30.91	24.73	26.79
-N	13.33	6.81	77.03	45.03	35.55
-P	21.50	4.49	80.24.	30.81	32.09
-K	17.38	5.97	32.59	39.11	29.87
+NPK	32.59	9.62	92.59	68.14	44.44
FP	25.99	8.98	93.08	34.66	35.30

4.2.3.1.1.2. Soil properties

The initial analyses of soil are given in Table. 16 and 17. The data revealed that the soil was acidic in reaction with a high status of organic carbon. The status of available nitrogen was medium, which of P high and K, low. Secondary nutrients also registered a low status.

Table 16. Initial physical and chemical properties of soil during omission trial

Treatments	pH	EC dSm^{-1}	WHC (%)	BD ($Mg\ m^{-3}$)	OC (%)	DH ($\mu gTPF\ g^{-1}$)
-NPK	5.1	0.230	28.2	1.016	2.9	0.185
-N	5.0	0.296	30.1	1.018	3.1	0.214
-P	5.0	0.230	30.3	1.018	3.4	0.235
-K	5.1	0.232	29.8	1.018	3.2	0.289
+NPK	5.1	0.242	30.2	1.016	3.1	0.246
FP	5.0	0.236	30.2	1.016	3.4	0.232

Table 17. Initially available major nutrient concentration in soil during omission trial

Treatments	Av.N $kg\ ha^{-1}$	Av.P $kg\ ha^{-1}$	Av.K $kg\ ha^{-1}$	Ex.Ca ($cmol\ kg^{-1}$)	Ex.Mg ($cmol\ kg^{-1}$)	Av.S $kg\ ha^{-1}$
-NPK	231.2	82.3	68	1.5	2	32.7
-N	268.5	79.8	78	2.5	1.5	26.5
-P	358.3	82.4	84	2.5	2	25.2
-K	360.4	74.1	66	2.5	3	28.6
+NPK	365.4	76.3	68	2.0	3	32.6
FP	342.5	80.2	66	2.0	2.5	29.5

Data on available micro nutrient concentration is given in Table.18 Fe, Mn and Cu recorded sufficiency values whereas Zn and B were deficient.

Table 18. Initially available micro nutrient concentration in soil during omission trial, mg kg^{-1}

Treat	Fe	Mn	Zn	Cu	B
-NPK	12.1	2.8	1.02	0.48	0.014
-N	12.5	2.5	1.10	0.50	0.0160
-P	13.1	2.7	1.06	0.45	0.0152
-K	12.4	2.7	1.12	0.46	0.0135
+NPK	12.8	2.6	1.10	0.50	0.0140
FP	12.4	2.5	1.08	0.46	0.0152

After first harvest (45 DAP)

The soil properties after I harvest at 45 DAP are given in Table. 19 and available major nutrient content in Table 20. After 45 days of planting, there were not any distinct changes in important soil properties like pH, EC, WHC or BD. However organic carbon content of soil increased in (-) NPK and (-) N plots and decreased in all others. The status of major nutrients N,P and K showed a decrease in all the plots whereas that of secondary nutrients showed an increasing trend except S. But even after the first harvest, the availability of nutrients was the highest in the plot where full recommended dose of NP and K was applied.

Table 19. Effect of omission trial on physical and chemical properties of soil after first harvest

Treatments	pH	EC dSm^{-1}	WHC (%)	BD (Mg m^{-3})	OC (%)	DH (μgTPF g^{-1})
-NPK	5.1	0.270	30.2	1.015	1.25	0.071
-N	5.1	0.234	31.3	1.014	2.30	0.078
-P	5.0	0.276	33.5	1.016	3.58	0.232
-K	5.0	0.096	32.1	1.015	3.45	0.213
+NPK	4.9	0.091	31.8	1.014	4.26	0.309
FP	4.9	0.260	30.6	1.015	3.61	0.211

Table20. Effect of omission trials on available major nutrient concentration in soil after first harvest

Treatments	Av.N kg ha^{-1}	Av.P kg ha^{-1}	Av.K kg ha^{-1}	Ex.Ca (cmol kg^{-1})	Ex.Mg (cmol kg^{-1})	Av.S kg ha^{-1}
-NPK	182.1	58.2	62	3.0	2.0	28.2
-N	190.5	68.8	88	3.0	3.0	22.3
-P	269.4	56.5	87	3.0	2.5	20.6
-K	284.3	54.3	20	3.0	2.5	25.6
+NPK	302.9	68.2	93	2.5	1.5	22.1
FP	265.1	65.2	76	2.5	2.0	20.3

After second harvest (60 DAP)

The chemical analyses of soil after second harvest at 60 DAPS are given in Table.21 and available nutrient content in Table 22. The data revealed that the general fertility status of the soil decreased as the crop was raised. There was a decrease in pH and organic carbon content of the soil. The availability of nutrients also showed a decreasing trend. But, even after 60 DAP, the availability of nutrients was the highest in full NPK plot. (-) NPK plot registered the lowest available nutrients except Mg and S.

Table 21. Effect of omission trial on physical and chemical properties of soil after second Harvest

Treatments	pH	EC dSm^{-1}	WHC (%)	BD ($Mg\ m^{-3}$)	OC (%)	DH ($\mu g TPF\ g^{-1}$)
-NPK	5.1	0.323	29.2	1.016	1.45	0.058
-N	4.9	0.330	29.3	1.014	1.87	0.074
-P	4.8	0.469	30.5	1.016	2.01	0.081
-K	4.8	0.248	30.1	1.015	2.01	0.082
+NPK	4.7	0.360	31.8	1.014	3.16	0.204
FP	4.5	0.322	32.6	1.014	3.56	0.093

Table.22 Effect of omission trial on available major nutrient concentration in soil after second harvest

Treatments	Av.N	Av.P	Av.K	Ex.Ca	Ex.Mg	Av.S
	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}	(cmol kg^{-1})	(cmol kg^{-1})	kg ha^{-1}
-NPK	122.1	52.0	36	1.5	3.0	24.6
-N	108.5	58.4	74	3.0	1.5	22.1
-P	169.4	56.2	86	1.5	3.5	20.0
-K	198.3	46.3	26	2.5	2.0	22.3
+NPK	223.4	52.6	88	1.5	2.0	23.8
FP	160.5	56.8	58	1.5	2.0	21.6

4.2.3.1.1.3. Irrigation water analysis

Irrigation water from the site was collected twice and analyzed for pH, EC and major, secondary and micro nutrient concentration. The results of the analyses are given in Table 23 and 24 .The values revealed that the water was practically neutral in reaction with low values of EC. Nutrients like N,K, Ca and Mg were present in very low amounts. Only traces of micronutrients were present in this water.

Table 23. Results of irrigation water analysis at first sampling during omission trials

Parameters assessed	Sample I	Sample II
pH	6.9	6.8
EC (dSm-1)	0.292	0.278
N (ppm)	4.5	5.1
P (ppm)	0.10	0.11
K (ppm)	4.7	5.2
Ca (ppm)	4.0	3.5
Mg (ppm)	5.2	5.8
Fe (ppm)	0.04	0.04
Mn (ppm)	0.10	0.10
Zn (ppm)	0.04	0.03
Cu (ppm)	Traces	Traces

Table 24. Results of irrigation water analysis at second sampling during omission trial

Parameters assessed	Sample I	Sample II
pH	6.2	6.4
EC (dSm-1)	0. 328	0.282
N (ppm)	5.6	6.2
P (ppm)	0.128	0.142
K (ppm)	5.2	5.8
Ca (ppm)	4.2	3.6
Mg (ppm)	4.8	5.2
Fe (ppm)	0.06	0.08
Mn (ppm)	0.12	0.10
Zn (ppm)	0.04	0.03
Cu (ppm)	Traces	Traces

Fig.2 . Yield (t ha^{-1}) vs N Uptake (kg ha^{-1})

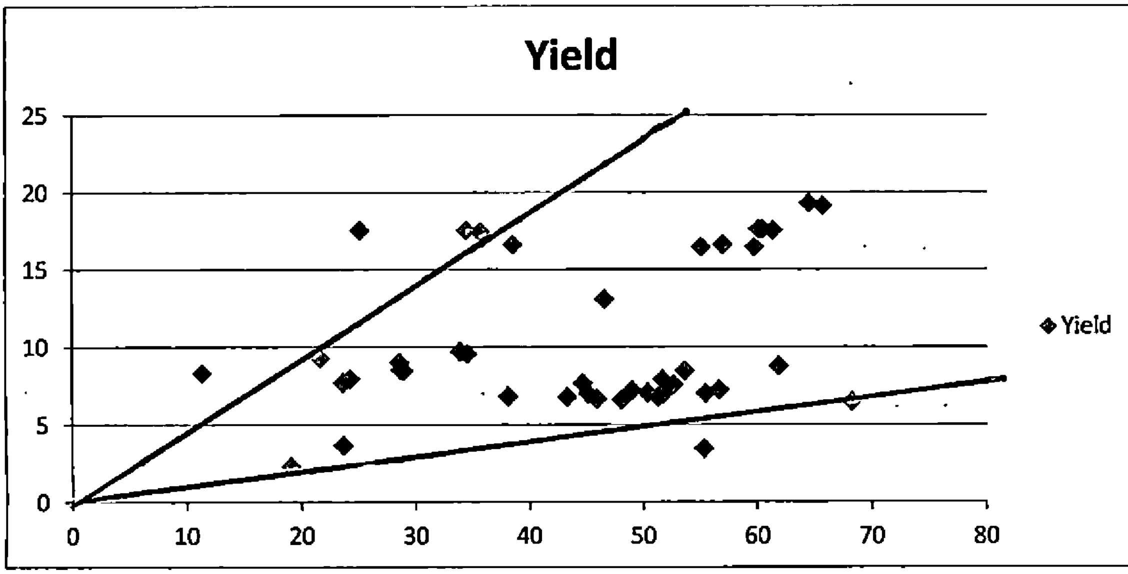


Fig.3 . Yield (t ha^{-1}) vs P Uptake (kg ha^{-1})

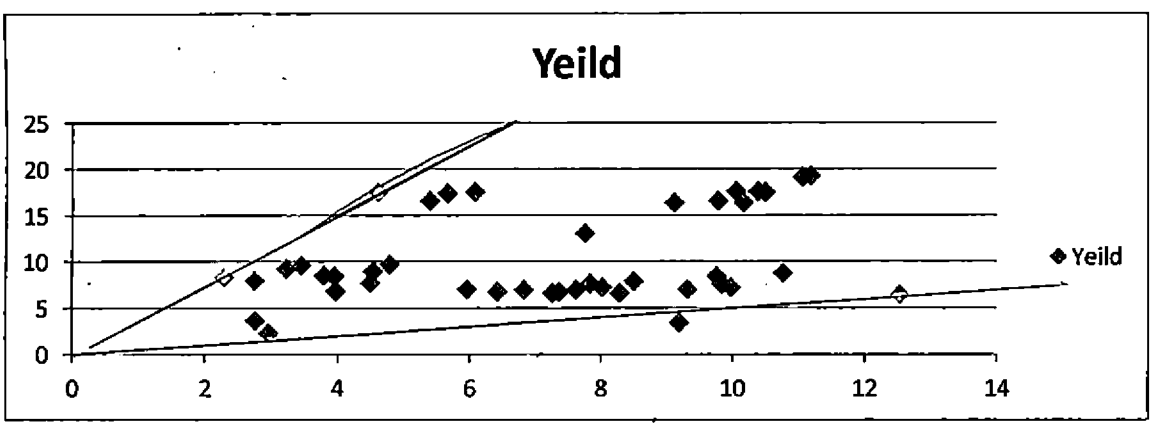
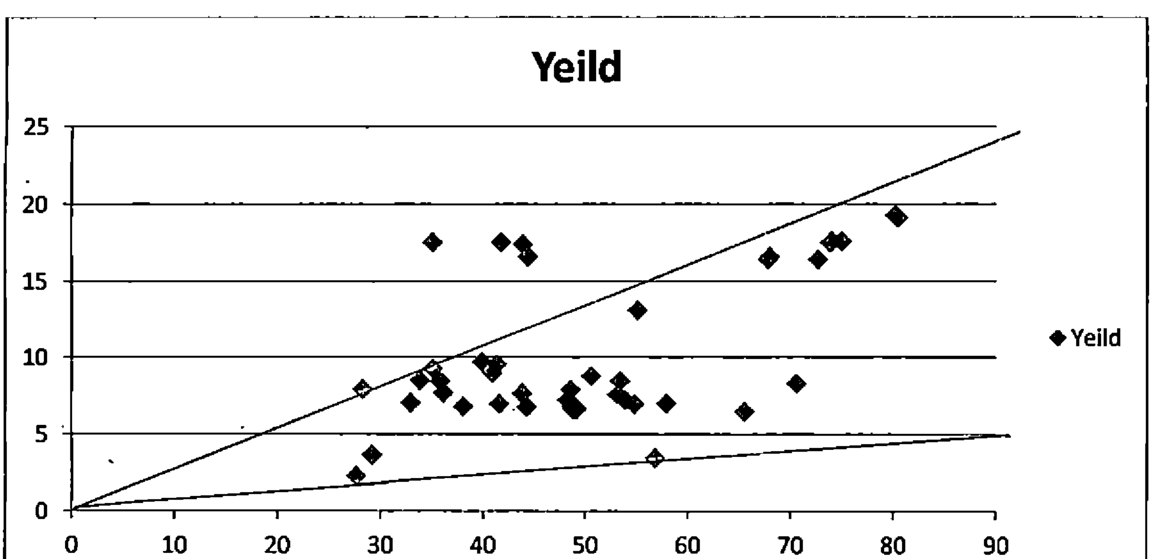


Fig. 4. Yield (t ha^{-1}) vs K Uptake (kg ha^{-1})



Based on the data collected from the literature , a graph with yield on the Y-axis and uptake on the X axis was plotted to obtain the values of minimum and maximum dilution for the three nutrients namely N,P,K that was 88 and 305.3 for N, 558 and 1666.6 for P and 30.7 and 103.4 for K. the indigenous nutrient supply was obtained from the omission trial as INS 5.8, IPS 6.66, IKS 32.6 and the recovery efficiency were 0.45 for nitrogen,0.13 for phosphorus and 0.37 for potassium. These parameters were utilized for formulating the QUEFT recommendation. Graphical representation is presented in fig 2, 3 &4.

4.2.3.2. SSNM Experiment

The data obtained from the nutrient omission trial at Palapor and the information collected through survey and from literature were utilized for working out the site-specific nutrient recommendations for two yield targets,*viz*. Medium Yield (12 t ha^{-1}) and High yield (16 t ha^{-1}). These recommendations were compared with the Package of Practices recommendation of KAU, with and without secondary and micro nutrient addition. FP and control were also included for comparison. The observations of the experiment are detailed in the following pages.

4.2.3.2.1. Yield parameters and yield

45 DAP:

The observations recorded on 45 DAP on yield parameters of chilli are presented in Table. 25 Number of primary branches per plant was the highest for the SSNM (MYT) at 45 DAP. The lowest was recorded by control plot. SSNM (MYT) recorded double the number of primary branches in control plot. No. of fruits per plant was three times higher in SSNM (MYT) when compared to the FP.

Table 25. Effect of treatments on yield parameters of chilli

Treatments	No. of primary branches		No. of fruits plant $^{-1}$		Fruit yield plant $^{-1}$ g / plant	
	45DAP	60 DAP	45 DAP	60 DAP	45 DAP	60 DAP
1. POP	7.8	12.4	3	7.9	27.11	63.99
2. POP + SNMN	9.8	14.7	4.4	11.2	49.42	136.64
3. MYT (12 t ha^{-1})	10.6	14.7	6.1	12.3	61.74	131.04
4. HYT (16 t ha^{-1})	10.4	15.1	5.4	13.2	39.32	90.155
5. FP	6.6	10.0	2.4	5.6	14.19	33.9
6. Absolute control	5.3	6.9	1.9	4.1	12.78	24.07
7.CD	1.759	2.001	0.654	3.216	7.604	26.755

60 DAP:

The observations recorded on 60 DAP on yield parameters of chilli are presented in Table 26. Number of primary branches per plant was the highest for the SSNM (HYT) at 60 DAP. The lowest was recorded by control plot. Number of primary branches and number of fruits per plant in all the plots which received the right amount of chemical fertilizers, were twice that of the control plot.

Chilli yield:

The chilli yield obtained in three harvests *i.e.* 45, 60 and 90 DAP and the cumulative yields are presented in Table. 26 & 27. There was significant difference between treatments in each harvest. Cumulative yield also registered significant difference. The treatments in which fertilizers were added registered 2.6 to 5.5 times yield compared to the control plot. The highest yield was recorded by SSNM treatment (HYT). The yield targeted in this case was 16 t ha^{-1}. The treatment where medium yield of 12 t ha^{-1} was targeted, 11.75 tons could be obtained. The yield in MYT and HYT plots were 1.4 and 2.1 times more than that of the POP treatment.

Table 26 . Effect of treatment on yield of chilli in each harvest(t ha^{-1})

Treatment	First harvest	Second harvest	Third Harvest	Total
POP	1.3375	1.49	5.48	8.3
POP + SNMN	1.55	1.875	6.4	9.83
MYT (12 t ha^{-1})	1.85	2.075	7.85	11.75
HYT (16 t ha^{-1})	2.95	3.15	11.275	17.32
FP	0.6	0.8125	3.775	5.2
Absolute control	0.675	1.2	1.275	3.14
CD	26.75	0.895	1.018	1.902

4.2.3.2.2. Dry matter yield:

The plant dry matter yield recorded significant difference between treatments after second and third harvest. The highest dry matter was recorded by the SSNM treatment where HY was targeted. This was followed by SSNM (MYT).

Table 27. Effect of treatments on dry matter yield of chilli g ha^{-1}

Treatments	First harvest	Second harvest	Third Harvest
POP	2924.6	3054.7	7587.0
POP + SNMN	2862.8	3378.8	8601.8
MYT (12 t ha^{-1})	3078.4	3840.4	9448.9
HYT (16 t ha^{-1})	3811.5	4594.3	10678.9
FP	1089.5	1236.2	5175.1
Absolute control	998.2	1570.1	2922.7
CD	NS	233.021	253.628

4.2.3.2.3. Plant nutrient concentration:

The plant nutrient concentration in whole plant was determined after every harvest. Data on nutrient concentration after first harvest are presented in Tables 28 and 29. All the nutrients varied significantly in plant tissue as a result of different nutrient management practices. It is evident from the Table. That the concentration of all the nutrients was highest in SSNM (HYT). The SSNM (MYT) closely followed. The data show the effect of secondary and micronutrient application in the absorption of nutrients. Absorption of all nutrients were more in POP treatment which received secondary and micronutrients in addition to NP and K.

Table.28 Effect of treatments on major nutrient concentration of plants after first harvest

Treatments	N(%)	P(%)	K(%)	Ca(ppm)	Mg(ppm)	S(%)
POP	1.3	0.40	1.18	1.03	0.87	0.12
POP + SNMN	1.5	0.44	2.61	1.08	0.98	0.15
MYT (12 t ha^{-1})	1.68.	0.48	3.84	1.51	1.14	0.17
HYT (16 t ha^{-1})	1.85	0.56	4.88	1.62	1.17	0.20
FP	0.90	0.36	1.12	0.98	0.99	0.13
Absolute control	0.78	0.24	0.94	0.36	0.33	0.12
CD	0.080	0.017	0.143	0.139	0.325	0.015

Table 29. Effect of treatments on micronutrient concentration of plants after, first harvest, ppm

Treatments	Fe	Mn	Zn	Cu
POP	21.77	0.08	1.05	0
POP + SNMN	17.44	0.52	1.15	0
MYT (12 t ha^{-1})	9.68	0.29	2.20	0
HYT (16 t ha^{-1})	8.88	1.24	3.67	0
FP	14.89	0.83	0.65	0
Absolute control	17.65	0.005	0.75	0
CD	1.021	NS	0.723	

After second harvest

Data on nutrient concentration after second harvest are presented in Tables 30&31. The nutrient content was the highest in plants where SSNM (HYT) was applied. This was followed by SSNM (MYT) and POP +SNMN. The trend obtained revealed the necessity of secondary and micronutrient application in chilli cultivation. Among the micronutrients, Cu could not be detected in plants.

Table 30. Effect of treatments on major nutrient concentration of plants after second harvest

Treatments	N(%)	P(%)	K(%)	Ca(ppm)	Mg (ppm)	S(%)
POP	0.905	0.40	2.22	1.23	1.12	0.11
POP +SN MN	1.07	0.46	3.28	1.33	1.18	0.19
MYT (12 t ha^{-1})	1.09	0.56	4.74	1.91	1.56	0.23
HYT (16 t ha^{-1})	1.205	0.54	5.72	1.92	1.72	0.24
FP	0.77	0.30	2.12	1.09	0.98	0.16
Absolute control	0.74	0.28	1.32	0.63	0.35	0.13
CD	0.130	0.101	0.202	0.114	0.084	0.120

Table 31. Effect of treatments on micro nutrient concentration of plants after second harvest g ha^{-1}

Treatments	Fe	Mn	Zn	Cu
POP	20.19	0.084	1.33	0
POP + SNMN	17.78	0.183	1.62	0
MYT (12 t ha^{-1})	9.54	0.197	2.37	0
HYT (16 t ha^{-1})	9.01	0.753	3.98	0
FP	13.38	0.003	0.58	0
Absolute control	19.17	0.0007	0.61	0
CD	1.457	0.062	1.120	

After third harvest

Data on nutrient concentration after III harvest are presented in Tables 32, 33. A similar trend as at II harvest was observed for N and P at third harvest also. The highest concentrations were recorded for SSNM (HYT), followed by SSNM (MYT) and POP +SNMN. But K concentration was the highest for POP + SNMN treatment. Concentration of secondary and micronutrients was also high in HYT. Among the micronutrients, Cu could not be detected in plants.

Table 32. Effect of treatments on major nutrient concentration of plants after third harvest

Treatments	N (%)	P (%)	K (%)	Ca(ppm)	Mg(ppm)	S %
1. POP	0.65	0.14	1.25	1.16	1.03	0.10
2. POP +SN MN	0.76	0.15	5.23	1.22	1.12	0.12
3. MYT (12 t ha^{-1})	0.90	0.17	4.15	1.74	1.43	0.14
4. HYT (16 t ha^{-1})	1.09	0.18	4.53	1.81	1.63	0.16
5. FP	0.58	0.11	1.9	0.91	0.97	0.11
6. Absolute control	0.44	0.09	1.0	0.51	0.23	0.10
7.CD	0.121	0.100	3.073	0.083	0.068	0.102

Table 33. Effect of treatments on micro nutrient concentration of plants after third harvest ,ppm

Treatments	Fe	Mn	Zn	Cu
1.POP	20.92	0.06	0.57	0
2.POP + SNMN	17.02	0.15	1.14	0
3. MYT (12 t.ha^{-1})	7.59	0.22	2.18	0
4. HYT (16 t ha^{-1})	7.39	0.30	3.75	0
5. FP	14.28	0.74	0.65	0
6. Absolute control	17.06	0.00	0.53	0
7.CD	1.873	0.016	0.736	NS

4.2.3.2.4. Nutrient uptake

Uptake of nutrients was calculated from the plant nutrient concentration and dry matter yield. Even though higher values of nutrient uptake were obtained in SSNM treatments and POP +SNMN treatment after first harvest, they were not statistically significant (Table. 34). Similar was the case with micro nutrients (Table.35).

Table 34. Effect of treatments on uptake of major nutrients after first harvest

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg ha^{-1})	Mg (mg ha^{-1})	S (kg ha^{-1})
POP	38.01	11.68	34.51	30.12	25.44	3.50
POP + SNMN	42.94	12.58	74.71	30.91	28.05	4.29
MYT (12 t ha^{-1})	51.71	14.76	118.21	46.48	35.09	5.23
HYT (16 t ha^{-1})	70.51	21.34	186.00	61.74	44.59	7.62
FP	9.80	3.92	12.20	10.67	10.78	1.41
Absolute control	7.78	2.38	9.38	3.59	3.29	1.19
CD	NS	NS	NS	NS	NS	NS

Table 35. Effect of treatments on uptake of micro nutrients after first harvest, g ha^{-1}

Treatments	Fe	Mn	Zn	Cu
1. POP	63.66	0.23	3.07	0
2. POP + MN	49.92	1.49	3.29	0
3. MYT (12 t ha^{-1})	29.79	0.89	6.77	0
4. HYT (16 t ha^{-1})	33.84	4.73	13.98	0
5. FP	16.22	0.90	0.70	0
6. Control	17.61	0.004	0.75	0
CD	NS	NS	NS	

But after second harvest, the effect due to treatments became apparent. The plots which received secondary and micro nutrients in addition to N, P and K, exhibited significantly higher values for uptake of major, secondary and micro nutrients Tables(36,37). However, uptake of Fe was the highest in POP treatment.

Table 36. Effect of treatments on uptake of major nutrients after second harvest, kg ha^{-1}

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (mg ha^{-1})	Mg (mg ha^{-1})	S (kg ha^{-1})
1. POP	27.64	6.10	67.81	37.57	34.21	3.36
2. POP + MN	36.15	7.77	110.82	44.93	39.86	6.41
3. MYT (12 t ha^{-1})	41.86	10.75	182.03	73.35	59.91	8.83
4. HYT (16 t ha^{-1})	55.36	12.40	262.79	88.21	79.02	11.02
5. FP	9.51	1.85	26.20	13.47	12.11	1.97
6. Absolute control	11.61	2.19	20.72	9.89	5.49	2.04
CD	7.843	4.789	17.391	7.097	7.146	3.521

Table 37. Effect of treatments on uptake of micro nutrients after second harvest, g ha^{-1}

Treatments	Fe	Mn	Zn	Cu
1. POP	61.67	0.25	4.06	0
2. POP + MN	60.07	0.61	5.47	0
3. MYT (12 t ha^{-1})	36.63	0.75	9.10	0
4. HYT (16 t ha^{-1})	41.39	3.45	18.28	0
5. FP	16.54	0.003	0.71	0
6. Absolute control	30.09	0.001	0.95	0
CD	116.87	4.64	70.76	-

A similar trend as that of second harvest was observed after third harvest also. Here again, the POP treatment registered the highest uptake of micronutrient iron (Fe).

Table 38 . Effect of treatments on uptake of major nutrients after third harvest kg ha^{-1}

Treatments	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}	Ca (g/ha)	Mg (g/ha)	S kg ha^{-1}
1. POP	49.31	21.24	94.83.	88.00	78.14	7.58
2. POP + MN	65.37	25.80	449.87	104.94	96.34	10.32
3. MYT (12 t ha^{-1})	85.04	38.44	392.12	164.41	135.11	13.22
4. HYT (16 t ha^{-1})	116.40	38.44	483.75	193.28	174.06	17.08
5. FP	30.01	11.38	98.32	47.09	50.19	5.69
6. Absolute control	12.85	5.26	29.22	14.90	6.72	2.92

Table 39 . Effect of treatments on uptake of micro nutrients after third harvest g ha^{-1}

Treatments	Fe	Mn	Zn	Cu
1. POP	158.72	0.45	4.32	0
2. POP + MN	146.40	1.29	9.80	0
3. MYT (12 t ha-1)	71.71	2.07	20.59	0
4. HYT (16 t ha-1)	78.91	3.20	40.04	0
5. FP	73.90	3.82	3.36	0
6. Absolute control	49.86	0	1.54	0
CD	124.59	1.607	61.441	

4.2.3.2.5. Soil Properties and Nutrient Availability:

The initial analysis of soil showed that the soil was acidic in reaction with a high level of organic carbon content. Among the plant nutrients, Ca, Mg, S, Zn and B were found deficient, but that of the primary major nutrients was medium to high.

Table 40. Initial physical and chemical properties of soil during SSNM treatments

Treatments	pH	EC dSm^{-1}	WHC (%)	BD (Mg m^{-3})	OC (%)	DH (µgTPF g^{-1})
POP	5.0	0.091	30.6	1.29	1.81	0.883
POP + SNMN	5.1	0.091	30.2	1.20	1.82	0.797
MYT (12 t ha^{-1})	5.2	0.090	30.5	1.26	1.90	0.862
HYT (16 t ha-1)	5.0	0.088	30.6	1.23	1.60	0.8 32
FP	5.0	0.086	30.6	1.20	1.81	0.736
Absolute control	5.1	0.089	30.8	1.24	1.71	0.452
CD	0.215	NS	NS	NS	NS	NS

Table. 41 Initially available major nutrient concentrations in soil during SSNM

Treatments	Av.N kg ha^{-1}	Av.P kg ha^{-1}	Av.K kg ha^{-1}	Ex.Ca (cmol kg^{-1})	Ex.Mg (cmol kg^{-1})	Av.S kg ha^{-1}
1. POP	304.5	80.8	131.2	2.3	2.3	25.7
2. POP + SNMN	315.2	82.9	162.8	2.3	2.1	27.3
3. MYT (12 t ha-1)	311.2	73.4	179.6	1.9	1.8	32.0
4. HYT (16 t ha-1)	335.5	68.1	132.8	2.3	1.8	28.2
5. FP	341.8	66.3	171.2	2.0	2.5	29.3
6. Absolute control	330.8	77.5	181.6	1.9	1.8	29.5
CD	NS	NS	NS	1.111	NS	NS

Table 42. Initially available micro nutrient concentration in soil, mg ha^{-1}

Treatments	Fe	Mn	Zn	Cu	B
1. POP	12.76	3.19	0.34	0.60	0.03
2. POP + SNMN	13.14	2.67	0.42	0.60	0.02
3. MYT (12 t ha-1)	13.29	2.78	0.45	0.61	0.04
4. HYT (16 t ha-1)	12.96	2.79	0.39	0.60	0.02
5. FP	13.17	2.97	0.38	0.63	0.02
6. Absolute control	12.46	2.47	0.44	0.63	0.03
CD	NS	NS	NS	NS	NS

After First Harvest:

Soil properties after first harvest showed significant variation in several properties like pH, EC, BD, organic carbon content, P, K, Ca and B concentration. The plot which received SSNM recommendation for medium yield target recorded the highest values for soil physical properties and organic carbon. The lowest organic carbon content was recorded in the control plot. Available nutrient content was the lowest in control plots and the highest in SSNM recommendation for high yield target.

Table. 43 Effect of treatments on Physical and chemical properties of soil after first harvest

Treatment	pH	EC dSm^{-1}	WHC (%)	BD (Mg m^{-3})	OC (%)	DH (µgTPF g^{-1})
1. POP	4.8	0.092	21.03	1.20	1.81	0.983
2. POP + SNMN	5.2	0.092	21.09	1.10	1.82	0.967
3. MYT (12 t ha^{-1})	5.0	0.095	26.03	1.23	1.91	0.942
4. HYT (16 t ha^{-1})	4.8	0.097	24.58	1.22	1.80	0.532
5. FP	4.7	0.083	23.33	1.18	1.80	0.936
6. Absolute control	4.8	0.086	24.32	1.23	1.50	0.466
CD	0.18	0.011	NS	0.03	0.474	NS

Table 44. Effect of treatments on available major nutrient concentration in soil after first harvest, kg ha^{-1}

Treatments	Av.N (kg ha^{-1})	Av.P (kg ha^{-1})	Av.K (kg ha^{-1})	Ex.Ca (cmol kg^{-1})	Ex.Mg (cmol kg^{-1})	Av.S (kg ha^{-1})
POP	232.04	115.75	182.0	1.63	1.63	45.20
POP + SNMN	243.91	112.96	203.8	2.9	3.0	57.94
MYT (12 t ha^{-1})	232.87	98.95	225.8	2.9	2.5	69.44
HYT (16 t ha^{-1})	252.81	110.61	308.4	3.7	2.5	75.25
FP	264.68	76.27	89.1	1.8	1.98	47.42
Absolute control	241.95	31.54	60.4	1.47	2.75	26.42
CD	NS	18.474	242.388	1.023	NS	NS

Table 45. Effect of treatments available micro nutrient concentration in soil after first harvest, mg kg^{-1}

Treat	Fe	Mn	Zn	Cu	B
1. POP	12.76	3.15	1.14	0.59	0.39
2. POP + SN&MN	13.15	2.70	1.18	0.58	0.4 2
3. MYT (12 t ha-1)	13.29	2.73	1.26	0.59	0.44
4. HYT (16 t ha-1)	12.96	2.76	1.26	0.60	0.53
5. FP	13.17	3.43	1.26	0.67	0.02
6. Absolute control	12.46	2.51	1.57	0.69	0.30
CD	NS	NS	NS	NS	2.343

After Second Harvest:

The physical and chemical properties of the soil after II harvest did not record significant variation except for pH and EC, but the available nutrient content differed significantly between treatments. Available N was highest in plot receiving FP , available P in POP+SNMN, K, Ca and S in HYT and Mg,,B in MYT.

Table. 46 Effect of treatments on physical and chemical properties of soil after second harvest

Treatments	pH	EC dSm^{-1}	WHC (%)	BD (Mg m^{-3})	OC (%)	DH (μgTPF g^{-1})
POP	5.12	0.089	20.88	1.203	1.20	0.963
POP + SN&MN	5.23	0.092	21.24	1.24	0.75	0.937
MYT (12 t ha-1)	5.23	0.094	28.06	1.28	1.19	0.912
HYT (16 t ha-1)	4.85	0.094	27.77	1.303	1.21	0.522
FP	4.55	0.089	30.2	1.269	1.25	0.946
Absolute control	4.5	0.906	28.6	1.248	1.15	0.5 66
CD	0.18	0.032	NS	NS	NS	NS

Table 47. Effect of treatments on available major nutrient concentration in soil after second harvest

Treatments	Av.N kg ha^{-1}	Av.P kg ha^{-1}	Av.K kg ha^{-1}	Ex.Ca cmol kg^{-1}	Ex.Mg cmol kg^{-1}	Av.S kg ha^{-1}
POP	195.03	105.67	167.15	1.4	1.25	34.59
POP + SN&MN	211.40	93.157	130.8	3.15	3.05	31.44
MYT (12 t ha^{-1})	198.12	86.45	202.35	3.12	3.17	48.65
HYT (16 t ha^{-1})	222.27	90.36	224.65	3.65	2.75	55.71
FP	230.80	61.3	85.07	1.42	1.5	42.12
Absolute control	205.05	28.585	54.2	1.325	1.25	23.53
CD	NS	15.895	218.767	0.656	NS	NS

Table.48. Effect of treatments on available micro nutrient concentration in soil (mg kg^{-1}) after second harvest

Treatments	Fe	Mn	Zn	Cu	B
POP	12.85	3.20	1.05	0.58	0.36
POP + SN&MN	12.71	2.07	1.09	0.54	0.48
MYT (12 t ha^{-1})	13.32	2.69	1.24	0.52	0.54
HYT (16 t ha^{-1})	13.19	2.79	1.12	0.59	0.52
FP	13.02	2.79	1.26	0.67	0.017
Absolute control	12.13	3.02	1.57	0.68	0.003
CD	NS	NS	NS	0.11	2.96

After third harvest:

Among the soil properties pH and organic carbon content differed significantly after III harvest. There was generally a rise in pH values in all the plots. The values of organic carbon and nutrient content showed a decrease in all the treatments. The plot on SSNM (HYT) became more acidic after third harvest. The EC value in this plot was also high, even though not significant. Table. 50 Shows the data on major nutrient concentration after third harvest. Available P, K and exchangeable calcium registered significant difference between treatments

Table 49. Physical and chemical properties of soil after third harvest

Treatments	pH	EC dSm-1	WHC (%)	BD (Mg m^{-3})	OC (%)	DH (µgTPF g^{-1})
POP	5.22	0.091	20.5 8	1.23	1.09	0.922
POP + SN&MN	5.22	0.091	21.64	1.27	0.57	0.926
MYT (12 t ha^{-1})	5.25	0.089	25.06	1.309	1.03	0.902
HYT (16 t ha^{-1})	4.52	0.092	27.59	1.302	0.90	0.528
FP	5.02	0.09	29.12	1.269	1.12	0.943
Absolute control	4.72	0.091	27.5	1.244	0.76	0.5 32
CD	0.338	NS	NS	NS	0.381	NS

Table 50. Effect of treatments on major nutrient concentration after third harvest.

Treatments	Av.N kg ha^{-1}	Av.P kg ha^{-1}	Av.K kg ha^{-1}	Ex.Ca cmol kg^{-1}	Ex.Mg cmol kg^{-1}	Av.S kg ha^{-1}
1. POP	174.38	96.17	107.9	1.05	1.15	32.59
2. POP + SN&MN	199.40	78.15	121.75	2.6	2.1 5	29.44
3. MYT (12 t ha^{-1})	175.35	71.35	169.55	2.15	3.075	46.65
4. HYT (16 t ha^{-1})	191.24	85.32	163.5	2.75	2.175	48.71
5. FP	197.62	57.99	74.26	1.2	2.5	38.12
6. Absolute control	199.53	58.78	45.4	1.1	1.25	23.15
CD	NS	12.672	218.72	0.888	NS	NS

None of the micronutrients exhibited significant difference after third harvest.

Table 51. Effect of treatments on available micro nutrient concentrations in soil after third harvest,mg kg-[1]

Treatments	Fe	Mn	Zn	Cu	B
1. POP	12.72	3.10	0.96	0.68	0.21
2. POP + SN&MN	12.75	2.05	0.98	0.68	0.34
3. MYT (12 t ha-1)	13.16	2.39	1.08	0.65	0.43
4. HYT (16 t ha-1)	13.04	2.35	1.13	0.64	0.45
5. FP	12.85	2.75	1.09	0.62	0.01
6. Absolute control	11.57	3.32	1.29	0.61	0.01
CD	NS	NS	NS	NS	NS

Partial Factor Productivity for nitrogen was highest for POP+SNMN followed by POP practices. Among the SSNM treatments HYT registered the maximum. The same trend was followed in case of phosphorus and potassium. Agronomic efficiency also follows the same trend as that of partial factor productivity (Table 53).

Table 52. Effect of treatments on Partial Factor Productivity

Treatments	N	P	K
POP	110.6	207.50	332.0
POP+SNMN	131.06	245.70	393.2
SSNM(MYT)	69.9	220.03	51.08
SSNM(HYT)	75.9	203.70	51.70
FP	73.2	167.70	55.30

Table 53. Agronomic efficiency of N, P, K in different nutrient management practice

Treatments	N	P	K
POP	68	129	206.4
POP+SNMN	89.2	167.2	267.6
SSNM(MYT)	51.2	168.8	37.4
SSNM(HYT)	62.1	166.8	42.3
FP	29.01	66.4	21.9

Capsaicin content did not show any significant changes with the different treatments. Capsaicin content of chillies for different treatments are given in Table 54.

Table 54 . Capsaicin content (%)

Treatment	First harvest	Second harvest
1. POP	0.70	0.69
2. POP + SN&MN	0.71	0.70
3. MYT (12 t ha^{-1})	0.74	0.73
4. HYT (16 t ha^{-1})	0.76	0.72
5. FP	0.70	0.74
6. Absolute control	0.60	0.65

Economic analysis of SSNM practices:

The economics of the different nutrient management practices were worked out and the B: C ratio is presented in Table 55. Additional expenditure in terms of chemical fertilizer application in different treatments varied from Rs.1500 /- in FP to Rs.10755 in SSNM treatment (HYT). But the benefit to farmers by adopting to the SSNM treatment with HYT was three times that of FP and two times that of the POP. From this it is evident that though the cost of production is higher in HYT, it is more profitable to farmers since the treatment gave very high yield.

Table 55. Benefit: Cost Ratio of the different nutrient management practices

Treatment	Benefit Rs	Cost Rs	B:C Ratio
POP	166000	63000	2.63
POP+MN	196600	65000	3.02
MYT	235000	68430	3.43
HYT	346400	70755	4.89
FP	104000	61500	1.69
OM	62800	60000	1.05

Correlation studies:

Cumulative yield showed a positive correlation with nitrogen concentration,(0.59), phosphorus concentration (0.53), potassium concentration (0.1654),S concentration in (0.085) calcium and magnesium concentration . Yield showed negative correlation with iron and manganese concentration in the plant sample. Positive correlation was noted in case of zinc concentration in the plant sample. Copper concentration in plant sample showed zero correlation.

Yield and uptake were positively correlated in the case of major nutrients. Number of primary branches and dry matter showed positive correlation with cumulative yield of chilli

Plate .3. Omission trial field view

Plate .4. N Omission Field

Plate .5. N Omission Yield

Plate . 6 . K Omission Field

Plate .7. K Omission Yield

Plate .8. P Omission Field

Plate. 9. P Omission Yield

Plate .10. NPK Field

Plate .11. NPK Yield

Plate .12 . Farmers Practice Field

Plate .13. Farmers Practice Yield

Plate .14. Absolute Control Field

Plate .15. Absolute Control Yield

Plate .16 . POP Practice

Plate .17 . POP +SNMN

Plate No18 High Yield Target

Plate No19 Medium Yield Target

Plate .20 . Farmers Practice

Plate .21. Absolute Control

5. DISCUSSION

Significant spatial variability of all essential plant nutrients exists in the cultivated fields at various scales. But this variability is not taken care of in the present fertilizer recommendations. Site specific nutrient management approach that evolved as a solution to this, aims at specific management of nutrients in a particular crop or cropping system to optimize the supply and demand of nutrients in accordance with their differences in cycling through soil plant system. SSNM principles had been successfully implemented in rice based cropping systems. But reports on application of SSNM in vegetables are meager. Therefore a study entitled 'Site specific nutrient management for chilli (*Capsicum annuum* L.) in Kalliyoor Panchayath of Kerala' was taken up at College of Agriculture, Vellayani during 2009-2011 with the objective of formulating a site specific nutrient prescription for enhancing productivity of green chilli in Kalliyoor Panchayath. The salient findings of the study are discussed in this chapter.

5.1. Survey of site characteristics

Kalliyoor Panchayath is located in the Nemom block of Thiruvananthapuram district. It is one of the major vegetable growing tracts of Thiruvananthapuram district. Vegetables are grown in the garden lands and reclaimed wet lands. The survey conducted in the Panchayath as part of the study revealed that farmers' preferences varied in different aspects of crop production like variety of the crop cultivated, spacing followed, manures added, fertilizers used and number and interval of pickings. Occasional inundation through flash floods was pointed out as the main weather constraint of the area.

5.2. Spatial variability studies

The data recorded on soil properties (Table. 5) revealed that wide variation in fertility status existed in the soils of the Panchayath. The Panchayath, which extends over 21 wards of entirely differing physiographical conditions, consists of wet lands, reclaimed lands and garden lands. The variation in the lie of the land modifies the inherent soil properties in different locations of the Panchayath. However, the soils, in general, were acidic in reaction and did not contain any amount of salts which could pose threat to crop production. Since vegetables are grown extensively, farmers resort to all types of manure addition as available, which was reflected in the higher values of organic carbon content of the soil. The available P content of the majority of soil samples ranged from medium to high status. This may be due to the over application of Factamphos, which is the most popular fertilizer in the locality. Even otherwise, high P fixation is a problem in these soils. Similar cases of P build-up in soil have been reported in many parts of India due to continuous application of phosphatic fertilizers coupled with low phosphate use efficiency (Vasuki,2010). Available K in various locations ranged from low to medium and the micronutrients Zn and B were found deficient in these soils. A possibility for phosphorus-induced zinc deficiency in soil has been reported by Vasuki (2010). The data on irrigation water analysis revealed that the water in different locations of the Panchayath was slightly acidic in reaction, but safe for irrigation and contained only insignificant quantities of plant nutrients. The main source of irrigation is the Vellayani lake which is a fresh water lake.

5.3 Nutrient omission trials

5.3.1. Yield components and yield

The four Nutrient Omission Trials laid out in different locations exhibited variations in yield owing to the gradation in soil fertility (Fig 5). In all the locations, NPK omission plots recorded the lowest yield and (+) NPK, the highest. N, P and K are the primary major nutrients which are vital for the metabolic activities of all plants. Non availability of any of these nutrients will affect the normal functioning of plant cells. However, the inherent P content in the soil safeguarded the plants from serious yield reductions in (-)P plots. The yield components in high yield plots registered a high value as is evident from Table.10

Khurana et al. (2008) also reported similarly while working with irrigated wheat in North West India.

5.3.1. Plant nutrient concentration:

Data on plant nutrient concentration recorded at different intervals clearly indicated that omission of nutrients hampered absorption by the plants. The treatment receiving full dose of NPK registered the highest nutrient content in plants. NPK omission plots recorded the lowest concentrations. For plants to absorb nutrients, they must be present in soil in available forms. The soil availability of nutrients (Table.14, 15, 16, 17& 18) was the lowest in (-) NPK plots which reduced the plant uptake. The Recovery efficiency of the major nutrients (Fig.6) in Palapur soil was very low. This throws light on the limitations of the present soil and nutrient management practices of the area. (Lakshmi et al .,(2003). Garabet, (1995) and Harmsen,(2003)).

5.3.2. Soil properties and nutrient availability:

The important soil properties like pH, EC ,WHC or BD did not show any marked change after I harvest. However organic carbon content in (-)N and (-)NPK plots decreased while in all others it increased. This could be attributed to the mineralization of native organic matter which is the only N source for the plants in these plots. But after second harvest, there was a general decrease in organic carbon and plant nutrients in all the plots. Simultaneously the pH values also decreased and reached the acidic condition inherent to the soil. But, it is noteworthy that even after the final harvest of the crop, the availability of nutrients was the highest in full NPK plot. This situation suggests that the crop could be kept for longer duration instead of

Fig. 5. Effect of nutrient omission on chilli yield in different locations

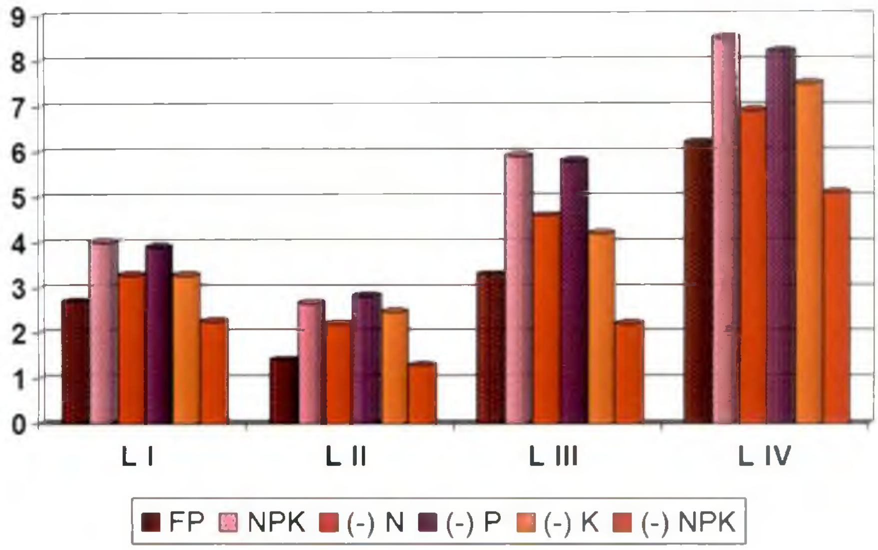
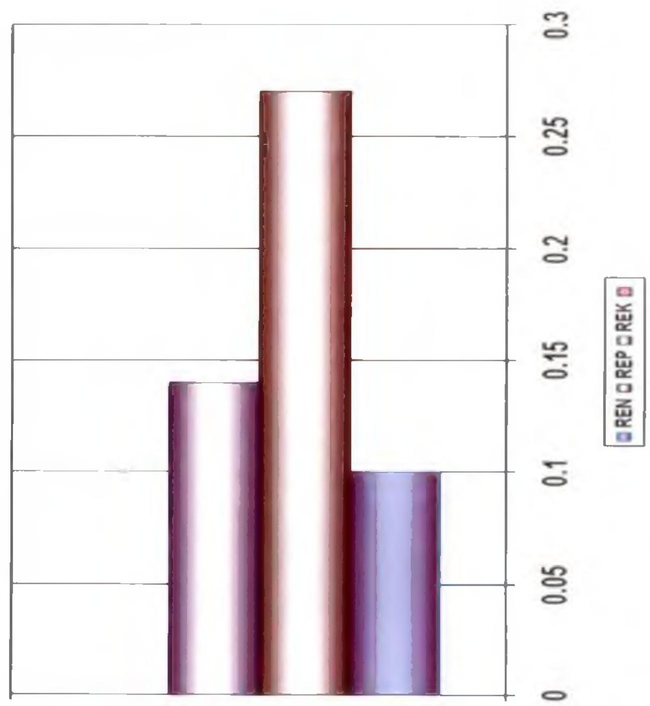


Fig .6. Recovery NPK in Palapur of Kalliyoor panchayath



limiting to three months as done in the experiment. This result is in accordance with the finding of Deshmukh (2008).

5.4. SSNM Experiment:

The data obtained from the nutrient omission trial at Palapur and the information collected through survey and from literature were utilized for working out the site-specific nutrient recommendations for two yield targets,viz. Medium Yield (12 t ha^{-1}) and High yield (16 t ha^{-1}). The tool used for deriving nutrient recommendations was the Microsoft version of QUEFTS Model. Even though QUEFTS was originally developed as a tool for land evaluation, it was later applied by many scientists (Janssen et al.1995; Mulder,2000) for quantitative estimation of the overall fertility level and to predict anticipated yields. QUEFTS calculates the potential availability of the three major nutrients and deals with the interaction among them. The recommendations arrived at in this manner were compared with the Package of Practices recommendation of KAU, with and without secondary and micro nutrient addition. FP and control were also included for comparison.

5.4.1. Yield parameters and yield

The observations recorded on yield parameters of chilli (Table 25) showed that the yield components were highest in SSNM treatments. At first harvest the number of fruits per plant was three times higher in SSNM (MYT) when compared to the FP. Moreover, the number of primary branches and number of fruits per plant in all the plots which received the right amount of chemical fertilizers were twice that of the control plot in each harvest. The nutrients K,Ca and B are known to have specific roles in reproductive functions of plants. It should be noted that the treatments which recorded high yields received these nutrients at proper rates. These results are in agreement with the findings of Suresh (2000), Kattimani (2004) and Thimma Naik (2006).

Significant difference between treatments was observed in the total yield of green chilli (Table.26). The treatments in which fertilizers were added registered 2.6 to 5.5 times yield compared to the control plot. The highest yield was recorded by SSNM treatment (HYT). The yield targeted in this case was 16 t ha^{-1} . The treatment where medium yield of 12 t ha^{-1} was targeted, 11.75 tons could be obtained. The yield in MYT and HYT plots were 1.4 and 2.1 times more than that of the POP treatment. Deshmukh (2008) reported significant yield increase in chilli with increase in the targeted yield level treatments.

The results throw light into the importance of application of secondary and micro nutrients along with the right quantities of primary nutrients so as to enable the plants to absorb the nutrients in an efficient manner and utilize them for higher production. The chilli variety 'Athulya' which was grown in this experiment has a potential yield of 32 tons ha-1. The findings of the present study indicate the scope of aiming at yield maximization by efficiently managing the resources, incorporating all components, tools and techniques of precision farming.

5.4.2. Plant nutrient concentration and uptake:

Data on nutrient concentration (Fig. 8 .) show that all the nutrients varied significantly in plant tissue as a result of different nutrient management practices. The concentration of all the nutrients were highest in SSNM (HYT), followed by SSNM(MYT). As a result, uptake of nutrients was also the highest in SSNM treatments. Significant difference in nutrient uptake by chilli plants was also observed by Deshmukh (2008). In his work, SSNM treatments on high yield targets recorded significantly higher uptake of nutrients. The higher uptake of nutrients in SSNM treatments in the present study was well reflected in the final yield of chilli (Fig. 4). The P content of plants was generally high indicating a possibility of inclusion of disproportionately high content of chilli fruits in the analytical sample prepared, though whole plant analysis was resorted to.

It was observed that the plant nutrient concentration of secondary and micro nutrients was the highest in the treatments which received application of these nutrients as chemical fertilizer. The fact that yields were also higher in these treatments, indicate the potential of chilli plants to utilize these nutrients very efficiently, if supplied. Absorption of all nutrients was found to be more when secondary and micronutrients were also applied along with N,P and K. This finding is in conformity with the report of Malawadi et al. (2004) in chilli. Thus the results revealed the significance of secondary and micronutrient application in the absorption of nutrients. But, among the micronutrients, Cu could not be detected in plants.

Fig.7. Effect different nutrient management practices on chilli yield

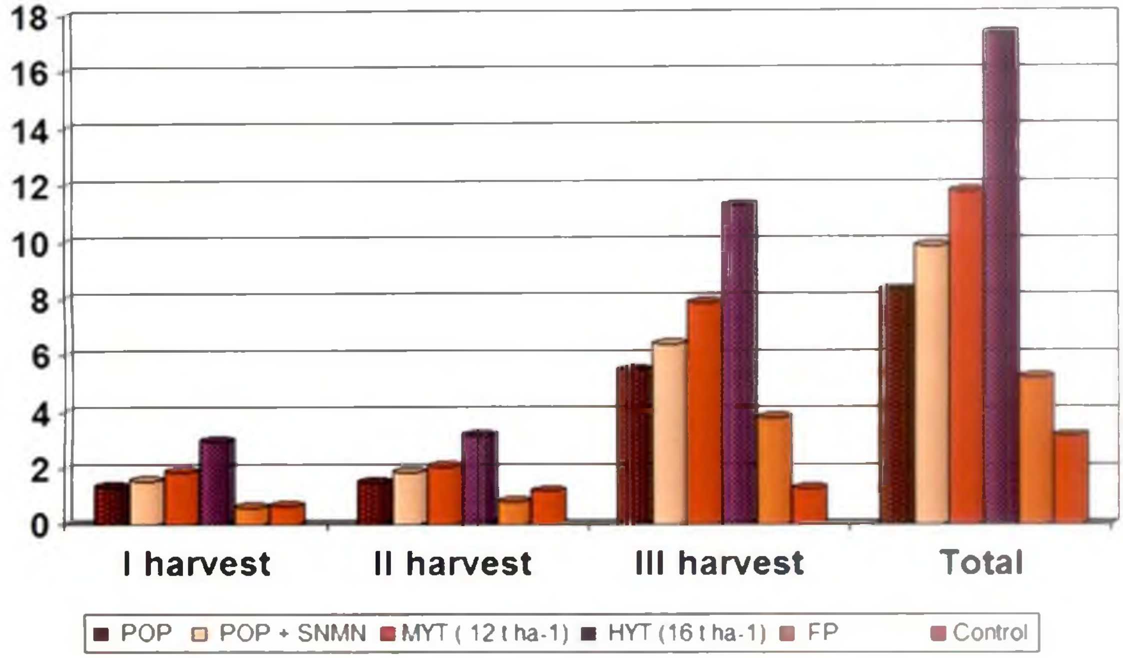


Fig. 8. Effect of treatments on major nutrient concentration of chilli at I harvest

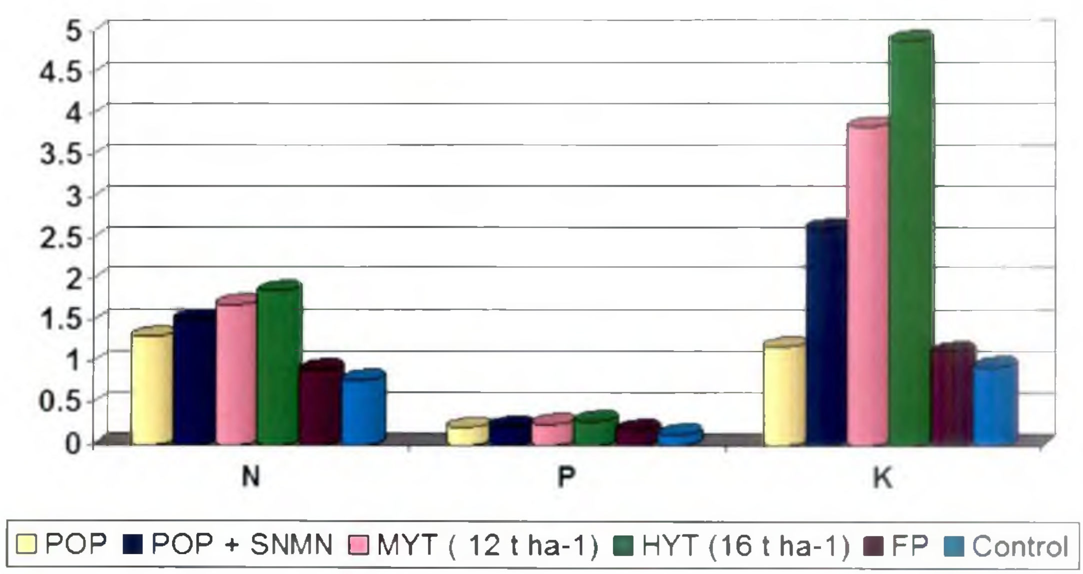


Fig. 9. Effect of treatments on major nutrient concentration in chilli at II harvest

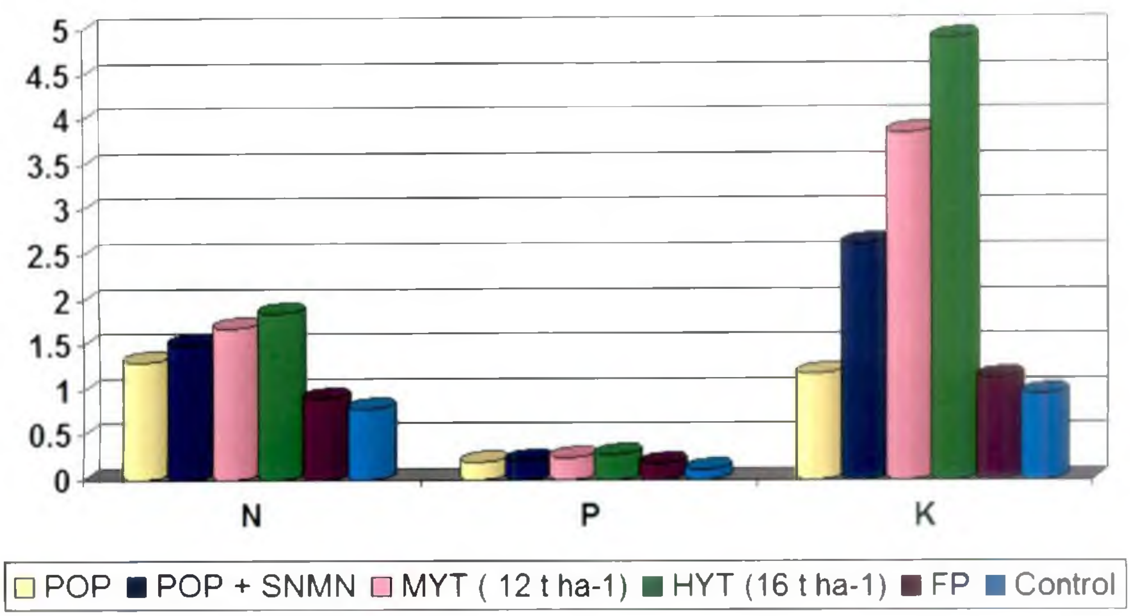


Fig. 10. Effect of treatments on major nutrient concentration in chilli at III Harvest

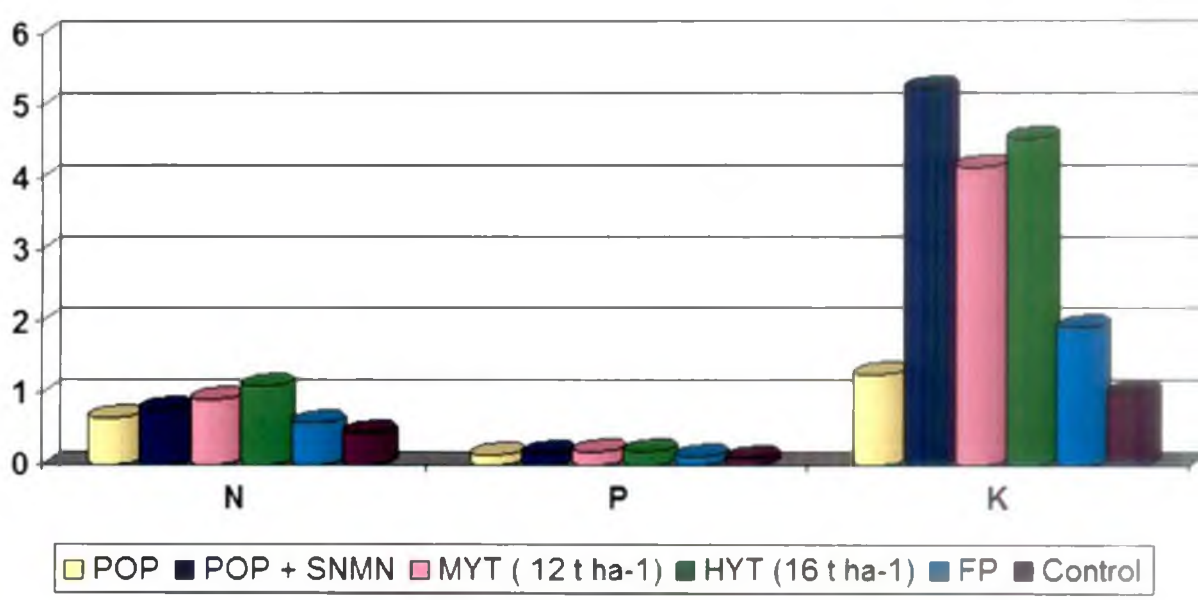


FIG. 11. Effect of treatments on plant concentration of secondary nutrients in chilli

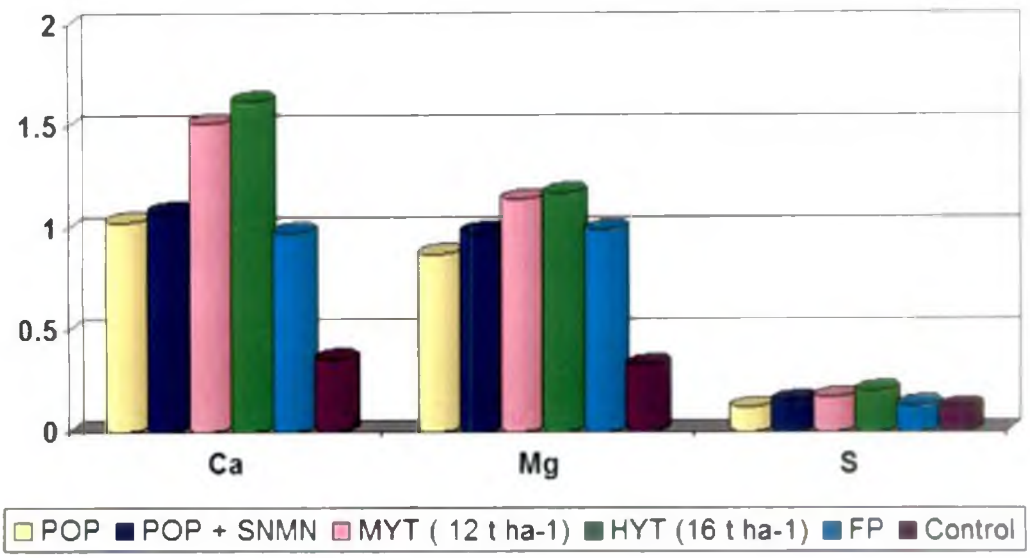


Fig . 12. Effect of treatments on plant concentration of secondary nutrients in chilli at second harvest

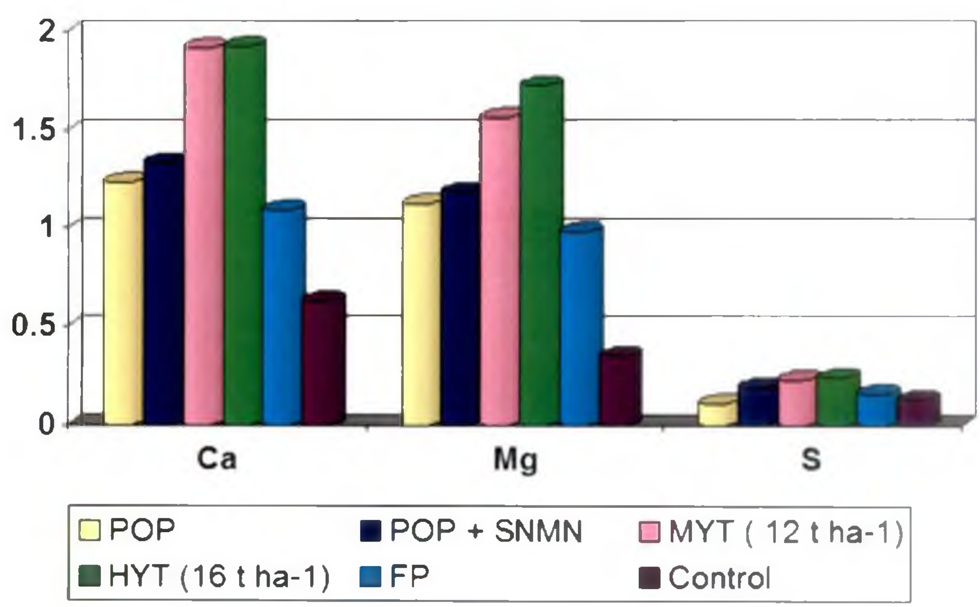


Fig. 13. Effect of treatments on plant concentration of secondary nutrients in chilli at III harvest

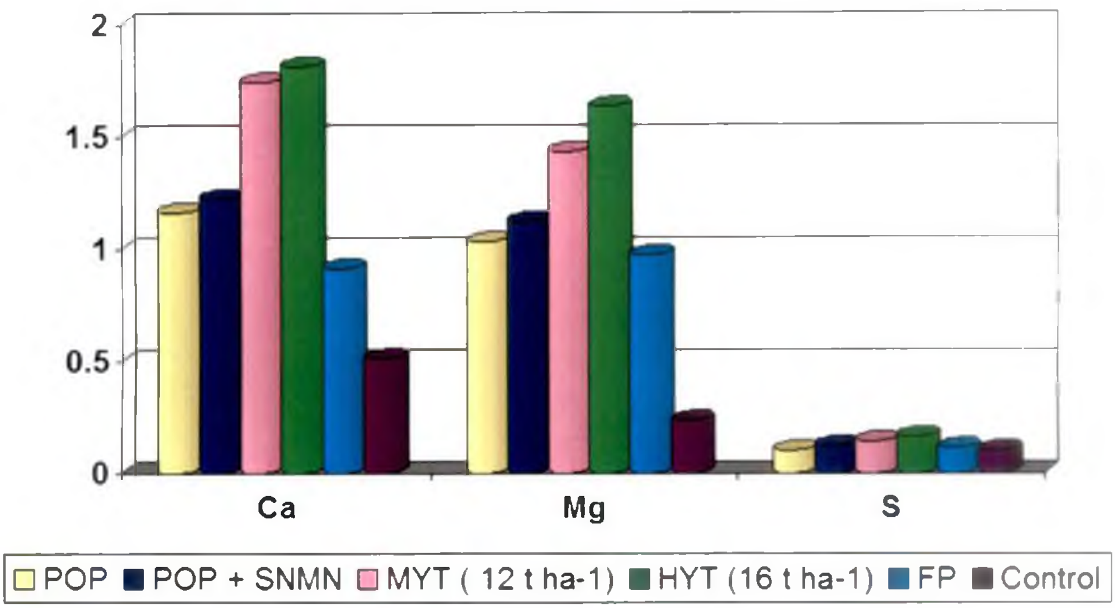
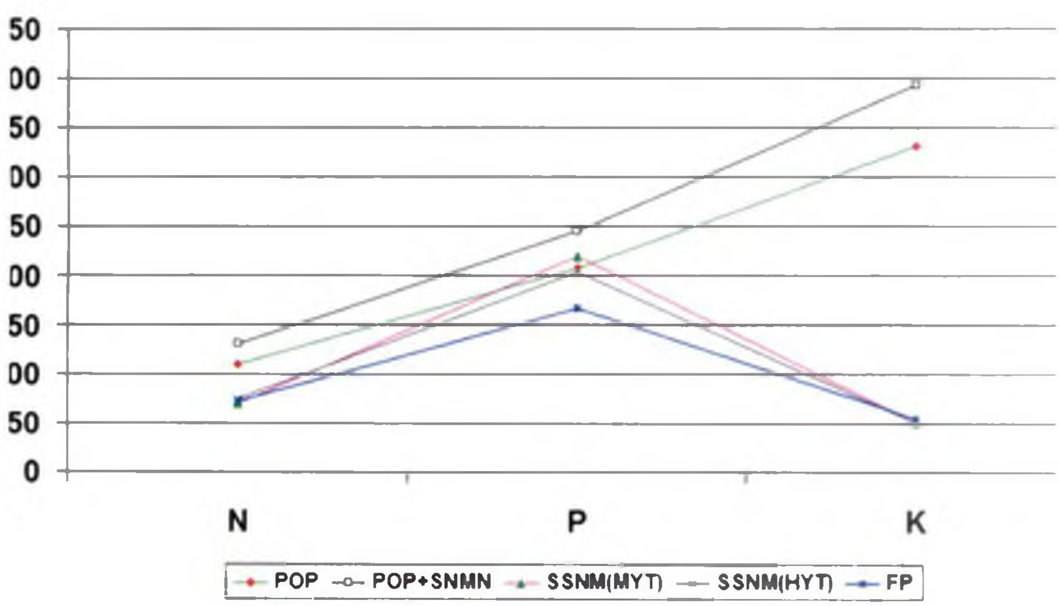


Fig.14. Partial Factor Productivity of N, P, K in different nutrient management practices



5.4.3. Soil properties and nutrient availability:

The soil of the experimental site was inherently acidic in reaction with a high level of organic carbon content. Among the plant nutrients, Ca, Mg, S, Zn and B were found to be deficient, but the status of the primary major nutrients was medium to high. Soil properties after first harvest showed significant variation in several properties like pH, EC, BD, organic carbon content, P, K, Ca and B concentration. This could be expected in view of the fertilizer and manure addition for the crop, both basal and top dressing.

After the final harvest, there was generally a rise in pH values in all the plots. But the plot on SSNM (HYT) became more acidic after third harvest. The EC value in this plot was also high, even though not significant. This could be due to the residual effect of any fertilizer added in the plot. The values of organic carbon and nutrient content showed a decrease in all the treatments. This shows that the applied nutrients could be used properly to a certain extent by the crop. The quantities of available nutrients were higher in the SSNM treatments even after third harvest. This shows that not only the present crop, but the succeeding crop also will be benefited by this fertilizer practice. The nutrient balance sheet for major nutrients (N, P and K) revealed that the available nutrient status was increased with increasing targeted yield levels (Deshmukh, 2008)

Fig. 15. Harvest Index as influenced by nutrient management practices

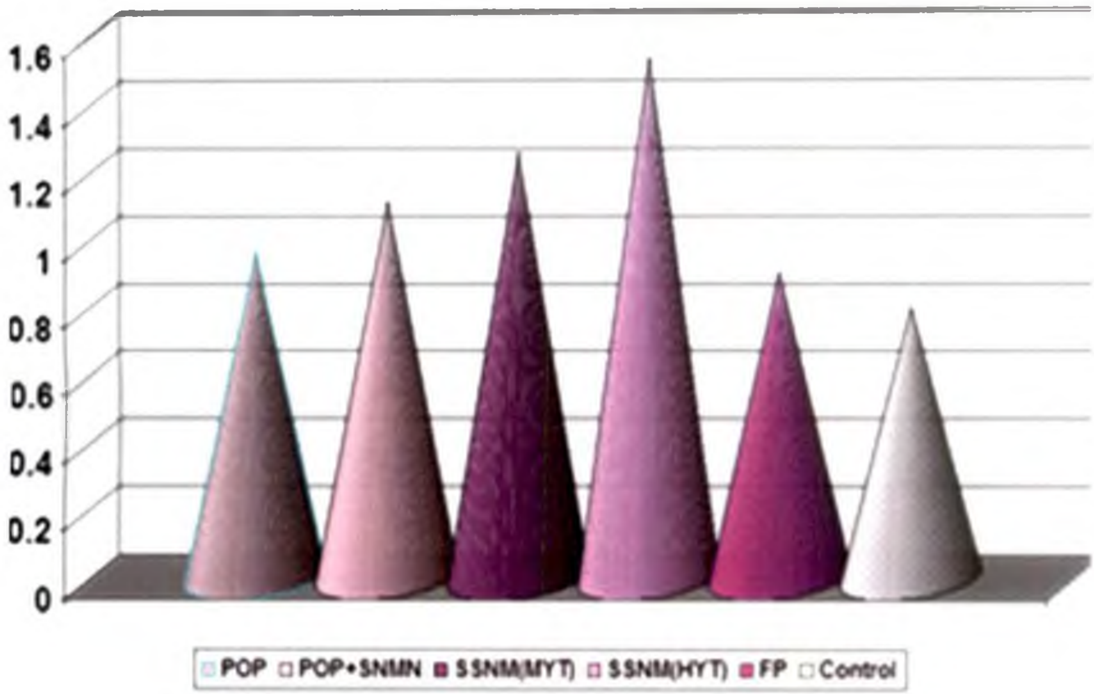
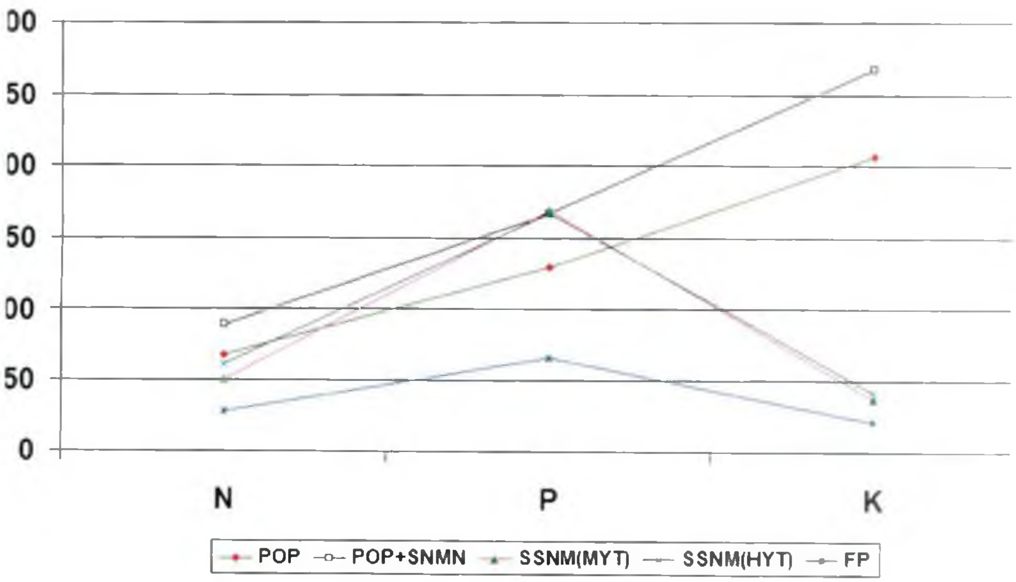


Fig.16. Agronomic efficiency of N, P, and K in different nutrient management practices



5.4.4. Economic analysis:

The B:C ratio worked out (Table.53) explains that the benefit to farmers by adopting tothe SSNM treatment with HYT was three times that of FP and two times that of the POP. Harvest Index (Fig.12) in the various plots shows that the highest HI was obtained for the SSNM treatment with a high yield target followed by MYT. Agronomic efficiency is aso highest for SSNM treatments as it is evident for figure 13. From these it is evident that though the cost of production is higher in HYT, it is more profitable to farmers since the treatment gave very high economic yield. (Biradar, D.P. and Aladkatti, Y.R., (2005), Harmandeep *et al.*, 2006).

Hence it could be concluded that the SSNM prescriptions were found to increase the productivity of green chillies in Kalliyoor Panchayat by 2.25 times in MYT and 3.3 times in HYT. The profit of the farmer could be increased 2.8 times that of current profit attained. The study also stressed the need for application of secondary and micronutrient in chilli cultivation for attaining maximum productivity. The study thus confirmed the superiority of SSNM treatments over POP recommendations and farmers' practice.

6. SUMMARY

A study entitled 'Site specific nutrient management for chilli (Capsicum annuum L.) in Kalliyoor Panchayath of Kerala' was conducted at College of Agriculture, Vellayani during 2009-2011 with the objective of formulating a site specific nutrient prescription for enhancing productivity and profitability of green chilli in Kalliyoor Panchayath of Kerala. The experiment consisted three parts – Survey of site characteristics, Spatial variability studies and Field experiments.

Kalliyoor Panchayath is located in the Nemom block of Thiruvananthapuram district, with 21 wards distributed in an area of 17.23 sq.km. Agriculture has been the primary occupation of the people of the panchayath. It is one of the major vegetable growing tracts of Thiruvananthapuram district.

1. From the survey it was revealed that vegetables are cultivated in the reclaimed wet lands and garden lands of the panchayath. The productivity of green chillies varied from one to thirty two tons. Vegetables were raised mainly by using organic manure without much application of chemical fertilizers.

2. The spatial variability studies indicated wide variation in soil properties of the Panchayath. The soils were acidic to slightly acidic in reaction with no threat of soluble salts. Organic carbon content ranged from 0.34 – 4.90 % in different locations of the panchayath. Soil texture varied from sandy loam to clay. Wide variation was also observed in the available major nutrient content in different locations. Exchangeable Ca was more or less uniform in distribution. However, much variation was not observed for the available micronutrient status.

3. The results of irrigation water analysis revealed that the water in different locations of the Panchayath was slightly acidic in reaction, but safe for irrigation and contained only insignificant quantities of plant nutrients.

4. Based on the heterogeneity recorded in soil properties, the soils of the Panchayath were grouped into four classes on the basis of soil fertility and a grouping chart was prepared. The majority of soils fell into the two middle classes of medium fertility.

5. The nutrient omission trials conducted in different locations proved the inevitability of major nutrient addition for enhancing the productivity of chili crop. In all the locations, NPK omission plots recorded the lowest yield and application of full dose of NPK, the highest. The yield in full NPK plots was approximately twice that of FP. However the yield reduction in (-)P plots was not much pronounced owing to the medium to high indigenous P content of the soils.

6. Data on yield components revealed that omission of any one of the primary major nutrients severely restricted number of primary branches in chilli. N omission had the most severe effect when compared to P and K. (+) NPK plots had the highest number of primary branches.

7. Nutrient omission had a depressive effect on the number of fruits formed. Application of full N, P and K stimulated fruit production in chilli. Complete omission of the three primary major nutrients severely curtailed fruit production.

8. The data on plant nutrient concentration after I harvest showed that the lowest value of plant nutrient concentration was recorded by the treatment (-) NPK and the highest by (+) NPK. The same trend in plant nutrient concentration was exhibited at second harvest also.

9. The initial analyses of soil in the SSNM experimental site revealed that the soil was acidic in reaction with a high status of organic carbon. The status of

available nitrogen was medium that of P high and K, low. Secondary nutrients also registered a low status. Fe, Mn and Cu recorded sufficiency values whereas Zn and B were deficient.

10. The soil properties after I harvest did not show any distinct changes in important soil properties like pH, EC, WHC or BD. However organic carbon content of soil increased in (-) NPK and (-) N plots and decreased in all others. The status of major nutrients N, P and K showed a decrease in all the plots whereas that of secondary nutrients showed an increasing trend except S. But even after the I harvest, the availability of nutrients was the highest in the plot where full recommended dose of NP and K was applied.

11. The chemical analyses of soil after II harvest revealed that the general fertility status of the soil decreased as the crop was raised. There was a decrease in pH and organic carbon content of the soil. The availability of nutrients also showed a decreasing trend. But, even after 60 DAP, the availability of nutrients was the highest in full NPK plot. (-) NPK plot registered the lowest available nutrients except Mg and S.

12. Analysis of the irrigation water from the site at two intervals revealed that the water was practically neutral in reaction with low values of EC. Nutrients like N, K, Ca and Mg were present in very low amounts. Only traces of micronutrients were present in this water.

13. Among the different treatments in the SSNM experiment conducted at Palapur MYT recorded the highest number of primary branches at 45 DAP .No. of fruits per plant was three times higher in SSNM (MYT) when compared to the FP.

14. At 60 DAP; high yield target recorded the highest number of primary branches and number of fruits.

15. There was significant difference between treatments at each harvest in chilli yield. Cumulative yield also registered significant difference. The treatments in which fertilizers were added registered 2.6 to 5.5 times yield compared to the control plot. The highest yield was recorded by SSNM treatment (HYT). The yield targeted in this case was 16 t ha-1. The treatment where medium yield of 12 t ha-1 was targeted, 11.75 tons could be obtained. The yield in MYT and HYT plots were 1.4 and 2.1 times more than that of the POP treatment.

16. The plant dry matter yield recorded significant difference between treatments after second and third harvest. The highest dry matter was recorded by the SSNM treatment where HY was targeted. This was followed by SSNM (MYT).

17. The plant nutrient concentration in whole plant after I harvest varied significantly as a result of different nutrient management practices. The concentrations of all the nutrients were highest in SSNM (HYT), closely followed by SSNM (MYT). The data showed the effect of secondary and micronutrient application in the absorption of nutrients. Absorption of all nutrients was more in POP treatment which received secondary and micronutrients in addition to N, P and K.

18. The nutrient content after second harvest was the highest in plants where SSNM (HYT) was applied. This was followed by SSNM (MYT) and POP +SNMN. The trend obtained revealed the necessity of secondary and micronutrient application in chilli cultivation. Among the micronutrients, Cu could not be detected in plants. A similar trend as at second harvest was observed at third harvest also.

19. The initial analysis of soil at the experimental site showed that the soil was acidic in reaction with a high level of organic carbon content. Among the plant nutrients, Ca, Mg, S, Zn and B were found deficient, but that of the primary major nutrients was medium to high.

20. Soil properties after I harvest showed significant variation in several properties like pH, EC, BD, organic carbon content, P,K ,Ca and B concentration. The plot which received SSNM recommendation for medium yield target recorded the highest values for soil physical properties and organic carbon. The lowest organic carbon content was recorded in the control plot. Available nutrient content was the lowest in control plots and the highest in SSNM recommendation for high yield target.

21. The physical and chemical properties of the soil after II harvest did not record significant variation except for pH and EC, but the available nutrient content differed significantly between treatments. Available N was highest in plot receiving FP, available P in POP+SNMN, K, Ca and S in HYT and Mg, B in MYT.

22. Among the soil properties pH and organic carbon content differed significantly after III harvest. There was generally a rise in pH values in all the plots. The values of organic carbon and nutrient content showed a decrease in all the treatments. The plot on SSNM (HYT) became more acidic after III harvest. The EC value in this plot was also high, even though not significant.

23. Economic Analysis of SSNM Practices showed that the benefit to farmers by adopting the SSNM treatment with HYT was three times that of FP and two times that of the POP. From this it is evident that though the cost of production is higher in HYT, it is more profitable to farmers since the treatment gave very high yield.

CONCLUSION

The study confirmed the superiority of SSNM treatments over POP recommendations and farmers practice. The nutrient prescription for attaining a yield target of 12 tons per hectare, the nutrients to be applied are 77.28: 8.16: 138 : 30 :7.5 : 30 : 20 : 5 N : P : K : Ca : Mg : S : Zn :B(kg ha $^{-1}$) and for a yield target of 16 tons per hectare, the nutrients to be applied are 104.8: 13.6: 201 30: 7.5 : 30 : 5 N :

P : K : Ca : Mg : S : Zn :B (kg ha $^{-1}$) + 1 % B foliar. These prescriptions were found to increase the productivity of green chillies in Kalliyoor Panchayath by 2.25 times in MYT and 3.3 in HYT. The profit of the farmer could be increased 2.8 times of current profit attained. The study clearly proved the necessity of secondary and micronutrient application at the required doses for achieving higher levels of productivity with the full utilization of plant nutrients.

Future line of work:

1. From the present study, it could be suggested that Site-Specific Nutrient Management practices should be evolved for a cropping system as a whole, considering the nutrient availability after the crop and their residual action.

2. SSNM principles should be extended to other vegetable crops, since it has proved profitable in chillies.

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APPENDIX –I

Weather data during cropping period (2010-2011)

	Average Temp (°C)	Average Precipitation Rainfall (mm)	Relative Humidity (%)
January	27	19	63
February	27	21	63
March	28	44	66
April	28	122	73
May	28	249	77
June	26	331	82
July	26	211	81
August	26	164	78
September	27	123	77
October	27	271	80
November	27	207	78
December	27	73	69

APPENDIX –II

Input Cost and Market Price Of Produce

1 Kg Urea .... 10 Rs
1kg of Rock Phosphate ....8 Rs
1 Kg of Murate of Potash..........................10 Rs
1kg of $ZnSO_4$ ....30 Rs
1 Kg of Borax ....25 Rs
1kg of Calcium Sulphate ....30 Rs
1kg of Magnesium Sulphate.......................30 Rs
Labour Charge......................................300 Rs

APPENDIX III

LIST OF FARMERS

SL NO	LIST OF FARMERS
1.	Satheeshan ,KaliparambiL Veedu , Punchakari
2.	Soman Nada Kari Palapuru
3.	Manmadan Kalliyoor Palapur
4.	Shashi Punaghattuvila Kaghiram villa
.5.	Gopan Kaniykavila

	Palapur
6.	Ananthan Kumali Palapur
7.	Shivanandhan Ottakyathamoodu Palapur
8.	Sukumaran Perakuzhi,thenghu vila Puncha kari Palapur
9.	Sadashivan Kootikari Palapuru
10	Shobhitharajan Panara kari
11	Vijayan

	Thenghu vila Kumali
12	Sajikumaran Puncha kari
13	Manmohanan Vydhyante kari
14	Krishnan kutty Nadar kalliyoor
15	Raju,Nediyan nada ,kakamoola
16	Appu kulangara veedu Kakamoola
17	Raghuvaran Vatta vila Palapur
18	Shashi

	Kidaghu vila Palapur
19	Vincent Nediyan nada Kalliyoor
20	Rajan Kalliyoor
21	Saji kumar Nediyan ela Kallitoor
22	Soman Nediyan ela Kalliyoor
23	Manoharan Nediyan vila Kalliyoor
24	Shashi nediyan ela Kalliyoor
25	Gopalan kalliyoor

SITE SPECIFIC NUTRIENT MANAGEMENT FOR CHILLI *(Capsicum annuum .L)* IN KALLIYOOR PANCHAYATH OF KERALA

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Site Specific Nutrient management is a technology in precision farming that offers chance for farmers to achieve the targeted yield taking into consideration the potential yield of the crop by application of apt amount of fertilizers. The technology is farmers' friendly, eco-friendly and also consumer friendly.

In Indian scenario wherein farmers are suffering from yield losses up to 40% due to micronutrient deficiency of soils mainly zinc and boron deficiencies are the yield limiting factors of production. Kerala the soils are low in basic ions that are posing serious threat to crop production. The Judicious application of chemical fertilizers along with micronutrients is necessary for sustainable crop production.

The present study "Site Specific Nutrient Management in Chilli (*Capsicum annuum.L.*) in Kalliyoor Panchayath Of Kerala" was carried out to satisfy the objectives viz. study the spatial variability of area, to find out the indigenous nutrient supply via omission trials, fix a target yield based on the potential yield of the crop and formulate a site specific nutrient recommendation to obtain the targeted yield.

In order to understand the spatial variability survey was conducted at 25 sites of Kalliyoor panchayath. The results of survey showed that the soils showed wide variation in terms of soil physical and chemical properties. Soil phosphorus status was high in all cases other nutrient concentration ranged from low to high.

The spatial variability necessitated carrying out the omission trials at four different sites that were ranked according to the nutrient status into high, medium first level, medium second level and low fertility soils. From the omission trials the recovery fraction and, indigenous nutrient supply were calculated. Utilising all these parameters in QUEFT model SSNM treatments were fixed.

The high yield target was fixed at 16 t ha that was 50% of the potential yield. The nutrient recommendation generated for HYT was 104.8: 13.6: 201 kg N, P_2O_5 and K_2O ha^{-1}. Medium yield target was fixed at 168:51: 230 kg N, P_2O_5 and K_2O ha^{-1}. Taking into account micronutrient and secondary nutrient deficiencies in the soil. In high yield target soil application of micronutrients and secondary nutrients along with application of 1% foliar spray of boron was recommended. Micronutrients for soil application were boron @ 5 kg ha^{-1} in form of borax, zinc @ 20 kg ha^{-1} in form of zinc sulphate. Secondary nutrients applied were calcium @ 30 kg ha^{-1} in form of CaSO4, magnesium @ 7.5 kg ha^{-1} in form of MgSO4. The requirement of sulphur was met from soil applied zinc sulphate, calcium sulphate and magnesium sulphate. In medium yield target only soil application of micro and secondary nutrients along with the application of QUEFT generated recommendations for the crop; POP + micronutrient recommendations were evaluated. Simultaneously an absolute control was also carried out.

Soil analysis was carried out for all the physical and chemical properties of the soil initially before the crop was raised, and after each harvest. So that change in soil properties as a result of application of treatments could be evaluated, since the application of fertilizer coincided with each harvest.

The results derived from the experiment proved the superiority of SSNM over other treatments with respect to the yield major nutrient and micronutrient uptake. Where high yield target registered a cumulative yield of 17. 32 tons, medium yield target registered a cumulative yield of 11.75 tons this was much superior to POP+SNMN that registered an yield of 9.83 tons, or the package of practice recommendation that registered an yield of only 8.3 tons . Farmers practice registered inferior yield data of only 5.2 tons. The study revealed that the site specific nutrient management is an efficient technology to increase the yield of crops and hence provide additional income to the farmers; this technique also provides a scope of increasing the yield without over application of fertilizers that would result in deterioration of the soil physical and chemical properties in long run.