SITE SPECIFIC NUTRIENT MANAGEMENT FOR BITTER GOURD
(*Momordica charantia* L.)

by

NEENU, S

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"SITE SPECIFIC NUTRIENT MANAGEMENT FOR BITTER GOURD (*Momordica charantia* L.)"** 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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@	At the rate of
B: C	Benefit Cost ratio
Ca	Calcium
CEC	Cation Exchange Capacity
cm	Centimetre
CD	Critical Difference
cmol kg^{-1}	centi mol per kilogram
cv.	cultivar
Cu	Copper
Dehy	Dehydrogenase
DAP	Days after planting
DAS	Days after sowing
dS m^{-1}	deci Siemens per metre
DTPA	Di Ethylene Tri Amine Penta Acetic Acid
EC	Electrical Conductivity
et al.	And others
Fe	Iron
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
ha	Hectare
HYT	High Yield Target
ISR	Improved State Recommendation
HI	Harvest Index
K	Potassium
KAU	Kerala Agricultural University
kg ha^{-1}	Kilogram per hectare
LCC	Leaf Colour Chart
MYT	Medium Yield Target

m^2	Square metre
mm	Milli metre
mg	Milli gram
Mg	Magnesium
Mg kg^{-1}	Mega gram per kilogram
Mg SO_4	Magnesium sulphate
Mn	Manganese
MOP	Muriate of potash
MSL	Mean Sea Level
μg TPF g^{-1}	Micro gram Tri Phenyl Formazan per gram
N	Nitrogen
Na	Sodium
OM	Omission
P	Phosphorus
POP	Package of Practice
POP +SNMN	Package of Practice with Secondary and Micronutrients
PM	Poultry manure
ppm	parts per million
q ha^{-1}	quintal per hectare
RDF	Recommended Fertilizer Dose
S	Sulphur
SR	State Fertilizer Recommendation
STLR	State Soil Testing Laboratory Recommendation
SSNM	Site Specific Nutrient Management
t	Tonnes
t ha^{-1}	Tonnes per hectare
Zn	Zinc
$ZnSO_4$	Zinc sulphate
VC	Vermi compost
%	Per cent
^{0}C	Degree Celsius

DEDICATED TO MY BELOVED GUIDE

INTRODUCTION

1. INTRODUCTION

The nutritional and mineral profile of a plant ultimately depends on the mineral content of the soil in which it grows. There are reports that nutritional values in food have declined significantly over the past several years consequent to soil mineral depletion which resulted in nutrient imbalance, emergence of secondary and micronutrient deficiencies, decreasing organic carbon content and overall deterioration in soil health (Davis *et al.*, 2004; Thomas, 2007). A healthy soil would ensure proper retention and release of nutrients and water, promote and sustain root growth, maintain soil biotic habitat, respond to management and resist degradation. Indian soils not only show deficiency of primary nutrients but also of secondary and micro nutrients in most parts of the country. Maintenance of soil health depends on selecting appropriate land use and management programs which are best designed at the farm level to suit specific, local soil needs. Site specific nutrient management based on soil testing and resources available with the farmers may play an important role in sustaining higher crop productivity and maintaining better soil health.

Advent of fertiliser as a means of feeding crops has revolutionized crop production and helped in achieving self sufficiency in food production. It is estimated that fertiliser contributes 40 to 60 per cent of total agricultural production (Stewart *et al.*, 2005). The shortage of plant nutrients to meet crop demands, increasing cost of fertilisers, declining profitability and sustainability of agriculture etc call for devising strategies for achieving higher use efficiency of applied nutrients and to get maximum crop yield. Improving nutrient efficiency is a worthy goal and fundamental challenge facing agriculture in general. Opportunities are there and tools are available to accomplish the task of improving efficiency of applied nutrients. However, we must be cautious that improvements in efficiency do not come at the expense of the farmers' economic viability or the environment. Application of fertiliser at right rate, right time and right place have to be followed for targeting both high yields and nutrient efficiency.

To feed the projected population of 1.35 billion in 2025, India needs to produce at least 350 million tonnes of food grains. Fertilisers which contributed 50 per cent towards improved food grain production were the fuel for the green revolution in the country. Contrary to ever increasing demand for food, the rate of response of crops to added fertilisers is declining year after year. The partial factor productivity of fertilisers decreased from 42 kg grain per kg applied NPK to 17 in 1985, 13 in 1995 and to 10 in 2008 (Subba Rao and Sammy Reddy, 2010). Recent studies that compared the mineral content of soils today with soils 100 years ago found that the mineral content of agricultural soils has decreased dramatically (The Rio Earth Summit, 1992). But even now we follow a conventional blanket fertiliser recommendation concentrating only on the major nutrients for all soils without taking into consideration the nutrient management principles, which leads to nutrient antagonism, low fertiliser use efficiency, imbalanced use of fertilisers and declining factor productivity. The secondary and micro nutrient requirement of the crops, which are highly essential for proper growth and functioning of the plant metabolic system are not at all taken care of. As a result of this, secondary and micro nutrient deficiencies have started showing up in almost all the crops cultivated.

Site Specific Nutrient Management (SSNM) is the first and still dominating application of precision agriculture. It is one of the easiest, cheapest and most relevant techniques as far as the Indian farmers are concerned. Due to importance of plant nutrition and its influence on crop yield and quality, it is expected that site specific nutrient management would improve the economic and environmental outcome of crop production. 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, analyze, and manage the spatial and temporal variability of soil and plants for optimum profitability, sustainability and protection of the environment.

SSNM is an approach for need based 'feeding' of crops with nutrients. It aims at increasing farmers' profit by achieving the goal of maximum yield of crops. The salient features of SSNM as a viable approach are to bridge the yield gap and break the stagnation in productivity. The main features of SSNM includes site–specific application of plant essential nutrients based on soil tests, optimal use of existing nutrients, such as from soil, residues and manures, providing guidelines for selection of the most economic combination of nutrients and advocating wise and optimal use of indigenous sources such as crop residues, manures etc.

The SSNM approach was developed to increase mineral fertiliser use efficiency and achieve balanced plant nutrition (Dobermann and White, 1999). 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). The major findings on SSNM experiments in different crops have very clearly been established by Tiwari (2006). The low yield barrier can be broken down and the yield levels can be raised substantially and in cost effective manner. It needs to be stressed that a broad and reliable soil testing system must be in place to make SSNM operational. Apart from optimizing crop nutrition, all other soil and crop management factors must also operate at a high level of efficiency. It was reported that spatial variability of plant nutrients exists at various scales in the cultivated fields. This is mainly attributed to the fertiliser history of individual farmers, diversity of crop types and varieties used (Eghball and Varvel, 1997). Significant correlation has been reported between crop yields and available soil nutrients levels at the corresponding sites in the field (Dobermann *et al.*, 2000). The growth and needs of a crop for supplementary nutrients can vary greatly among fields, seasons and years as a result of differences in crop growing conditions, crop and soil management and climate. Present fertiliser recommendations are not taking care of this variability in the field. These blanket recommendations assume that the need of a crop for nutrients is constant over large areas. The SSNM typically involves applying a definite set of recommendations to different areas in a field based upon a few factors, such as soil test level and yield goals. Hence this new approach aims to achieve efficient fertiliser use and balanced fertilization. The application and management of nutrients are dynamically adjusted to suit crop needs of the location and season.

Bitter gourd (*Momordica charantia* L.) otherwise known as balasam pear or bitter cucumber is a tropical and subtropical vine of the Cucurbitaceae, widely grown in India, South Asia, China, Africa and the Caribbean. The plant is a monoecious annual climber and grown for its bitter tender fruits. The fruits are rich in vitamin A, B, C and are an inexpensive source of proteins and minerals. Bitter gourd fruits are reported to have a lot of medicinal properties like germicidal effect, laxative, curing blood diseases, rheumatism, diabetes, asthma, AIDS etc (Behera *et al.*, 2010). The fruits can be harvested 60-70 days after planting depending upon variety, planting season, soil types, management practices etc. Immature tender fruits are harvested. Regular harvesting at shorter intervals will increase the fruit number. Bitter gourd is a warm season crop and has a wide range of adaptability. The optimum temperature for normal growth and good yield ranges from 25-30°C (Palada and Chang, 2003). The crop can be grown in all types of soils but sandy loam and silt loam soils are most suitable. The optimum soil pH ranges from 6.5 to 7.0.

The soils of southern region of Kerala face severe shortage in essential nutrients. This calls for field-specific, integrated crop management strategies that include site-specific quantitative knowledge of crop nutrient requirements, indigenous nutrient supply and recovery efficiency of applied fertiliser. To create awareness among farmers about the balanced and site specific use of fertiliser nutrients and make use of the indigenous nutrient supply of the soil, this project has been formulated with the following objectives:

1. To formulate a site specific nutrient management system for bitter gourd for medium and high yield targets.
2. To improve the yield and profitability of bitter gourd without degrading soil.

3. To create awareness among the farmers about the importance of site specific and balanced use of fertilisers to bitter gourd.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

An investigation entitled "Site specific nutrient management for bitter gourd (*Momordica charantia* L.)" was conducted in College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing productivity of bitter gourd. The literature pertaining to Site Specific Nutrient Management (SSNM) in various crops have been reviewed and presented in this chapter.

2.1. SITE SPECIFIC NUTRIENT MANAGEMENT

Site specific nutrient management is an important component of precision agriculture. It aims at specific management of nutrients in a particular crop or cropping system to optimize the supply of nutrients according to their differences in cycling through soil plant system. 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. This approach was developed in Asian rice producing countries through partnership of the Irrigated Rice Research Consortium (IRRC). It emphasizes 'feeding' crops with nutrients as and when needed, that enable farmers to dynamically adjust fertiliser use to optimally fill the deficit between the nutrient needs of a high yielding crop and the nutrient supply from 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 (Buresh and Witt, 2007; IRRI, 2007). The SSNM approach advocates sufficient use of fertiliser P and K to overcome P and K deficiencies and to avoid mining of soil P and K. The determination of fertiliser 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). Instead of calculating fertiliser N, P and K requirements individually a linear optimizing procedure, QUEFTS model, was utilised that takes into account interactions between nutrients to achieve an optimal nutritional balance.

SSNM can take into account all nutrient deficiencies to ensure that crop demands are met and soil fertility is improved, which in turn ensures higher nutrient use efficiency, higher crop productivity, and higher economic returns. This strategy was tested in more than 200 farmer fields at six sites in Asia. First, crop recovery efficiencies for fertiliser 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 fertilised and unfertilised omission plots. For all sites, values ranged from 40-60 per cent for N, 20-30 per cent for P and 40-50 per cent for K. Nitrogen recovery efficiency was assumed to be 50 per cent when proper plant based N management strategies are used. The recovery efficiency of N, P and K applied with farmyard manure was similar to values obtained for mineral fertilizer (Witt and Dobermann, 2002).

Low application of rate limits were introduced for fertiliser P (23 kg P_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 fertiliser P and 50 per cent of fertiliser 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 practice in rice (Dobermann *et al.,* 2004).

The experiment conducted by Hatch *et al.* (2007) in rice, where the field is divided into 2 parts, fertiliser management was based on the SSNM method in one part while, in another part, fertiliser management based on the farmer practice called FP. The objectives of the experiment were to compare the effects of two methods of fertiliser management on rice production while, the other cultivation practices are 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^{-1}, then nutrient demand will be 68 kg N, 27 kg P_2O_5 and 81 kg K_2O ha^{-1}. The SSNM recommendations generated were 90-100 kg N ha^{-1}, 33-40 kg P_2O_5 and 44-55 kg K_2O ha^{-1}. Experiment revealed that fertiliser recommendation based on SSNM and leaf colour chart (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 per cent fertiliser. Results of this study also showed that SSNM provided an increase in grain yield about 0.5 t ha^{-1} and gave higher benefit than FFP. Fertiliser rate as estimated by SSNM almost met the requirement of crop; therefore it could save nutrients, especially N which was applied too high by farmers.

2.1.2. Site Specific Nutrient Management in Vegetable Crops

In Tomato, the SSNM treatment of nitrogen (N), phosphorus (P), and potassium (K) @150-120-160 kg ha^{-1}, plus 30 kg sulphur (S) ha^{-1}, 5 kg boron (B) ha^{-1}, and 20 kg zinc (Zn) ha^{-1}, produced a maximum fruit yield of 33 t ha^{-1} (PPI, 2003). The SSNM improved fruit quality parameters such as total soluble solids (4.8 per cent), firmness (1,250 g 0.503 cm^{-2}), and length X breadth (5.0 x 5.5 cm). Number of fruits per plant and fruit weight was also higher compared with other treatments. Net profit under SSNM was US$ 267 ha^{-1} higher compared to standard recommended practice (PPI, 2003). The SSNM practice increased the cabbage yield by 9, 13 and 16 per cent within high, medium, and low fertility plots, respectively. This practice also lowered the fertiliser input costs by 27.6, 28.6 and 16.6 per cent (high, medium and low), and improved income ha^{-1} by 13.1, 18.4 and 20.6 per cent (high, medium and low) (Huang *et al.*, 2007).

In capsicum the SSNM treatment produced a maximum yield of 10.75 t ha^{-1} and a maximum number of fruits per plant (12.5), and also enhanced fruit quality parameters such as fruit weight, fruit size, and colour. Net profit under SSNM was US$ 344 ha^{-1} higher compared to the current state fertiliser recommendation (PPI, 2003). Priya (2011) reported that in chilli the SSNM treatment gave significantly higher yield compared to FP. She also reported that compared to control the SSNM treatments recorded 2.6 - 5.5 times green chilli yield and this was 1.4 - 2.1 times than the recommended practice. The dry matter production and uptake of major and secondary nutrients were also higher for SSNM treatments compared to recommended practice and FP in chilli.

Field trial carried out in Tamil Nadu, India, to evaluate the effect of different levels of macro- and micronutrient fertigation on yield and nutrient uptake of bitter gourd revealed that the application of 100 per cent macro and micronutrients in water soluble fertiliser form significantly increased the nutrient content and uptake of N, P, K and Fe (Meenakshi *et al.*, 2008). Bhunia and Mandai (2009) reported that the treatment comprising 50 per cent inorganic N, 50 per cent organic N and bio-fertilisers were better in comparison to other levels of nutrition for most of the yield contributing characters in bitter gourd. This treatment recorded the highest fruit yield (18.41 t ha^{-1}) also.

2.1.3. Site Specific Nutrient Management in Other Crops

The plant based SSNM approach was evaluated comprehensively for agronomic, economic, and environmental performance in 56 farmers' fields with irrigated wheat and transplanted rice in Punjab during 2002-03 and 2004-05. It was found that when site specific N-P-K applications were calculated by accounting 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 were compared with the current farmer's fertiliser practice (FFP), the average grain yield increased from 4.2 to 4.8 Mg ha^{-1}, while plant N, P and K accumulation increased by 12-20 per cent (Khurana *et al.*, 2008). The results of the study clearly brought out the positive impact of SSNM on grain yields, agronomic recovery and physiological efficiencies of N, profits to farmers under rice-wheat cropping system in Punjab *vis-a-vis* farmer's practice.

In a farm survey 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 fertiliser application. Statistical analysis found a close positive correlation for soil NO_3-N, P and K contents and N, P_2O_5 and K_2O fertiliser application rates, with the corresponding correlation coefficients as high as 0.50, 0.47 and 0.45 ($p< 0.01$), respectively. A fertiliser recommendation was made according to production group or plot, and variable fertilization was performed by farmers through hand application. The SSNM treatments applied significantly lesser N and P than FP and utilized Zn which was omitted under FP.

In pea efficacy of two K sources *viz.* potassium chloride (KCl) and potassium-magnesium sulphate (K, Mg double salt) and two application methods -100 per cent basal and 50 per cent basal : 50 per cent top dress were compared on an early maturing pea cultivar using four K levels: 32.5, 65, 97.5 and 130 kg K_2O ha^{-1}. Both pods per plant and pod yield were maximized at 8.97 pods/plant and 7.28 t ha^{-1}, respectively, with the treatment using 97.5 kg K_2O ha^{-1} split applied using KMg double salt. This treatment also returned the highest net profit and a value-to-cost ratio of 2.14 (IPNI research database, 2003).

Site specific nutrient management in maize calls for flexible N management strategies that allow adjustment 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 also suitable for maize as indicated by spectral reflectance measurements performed on rice and maize leaves (Witt and Doberman, 2004). By adopting the principles of SSNM, Srivastava *et al.* (2006) found that SSNM (1200: 600: 900 kg NPK ha^{-1}) treatment given highest yield of 14.7 t ha^{-1} in mandarin orange.

Singh *et al.* (2011) in a study titled Maximizing Productivity and Profit through Site Specific Nutrient Management in Rice based cropping systems revealed the efficiency of site specific nutrient management over farmers practice in different crops revealed that application of ISR and SSNM treatments both had a significant influence on mustard productivity. However, significant gains over FFP, SR and STCR were only generated with SSNM. In chickpea, SSNM produced the highest grain yield followed by ISR, STCR, SR and FFP. The effect of SSNM on garlic was more pronounced than in other crops as about 67 per cent more clove yield was obtained in SSNM than with FFP. Clove yield with ISR was 56 per cent higher than FFP. Number of clover per bunch and weight of clove bunch per plant were the important yield contributing parameters, when considering the effect of SSNM on crop growth and development. Use of either 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 ISR were 54 and 35 per cent, 22 and 7 per cent and 26 and 11 per cent higher than FFP, SR and STLR respectively. Berseem fodder yield increased up to third cutting and therefore it declined with age. Green fodder yield of SSNM, ISR, SR and STLR were 23, 17, 13 and 7 per cent higher yields respectively than FFP.

Results from on-farm experiments (Dwivedi *et al.*, 2009) comparing soil test-based SSNM with other fertiliser practices in pearl millet-wheat and pearl millet-mustard cropping systems revealed large yield and economic advantages with the adoption of SSNM. Srivastava *et al.* (2009) reported that SSNM increased the yield and improved the quality of sweet orange when compared with state nutrient recommendations and farmer fertiliser practice. Wheat yield under SSNM and ISR were 24 and 21 per cent higher than FFP. This increase was ascribed to greater head length, higher grains per head and higher numbers of effective tillers m^{-2}. Application of fertiliser according to SR or STLR certainly out yielded FFP, but these treatments generated 0.6 t ha^{-1} less grain compared to SSNM (Singh *et al.*, 2011).

The SSNM technology has been developed for cassava and effectively implemented in farmer's 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.*, 2012). According to Biradar and

Alakadi (2005) SSNM supplying 130: 70: 120 kg NPK ha^{-1} plus secondary and micronutrients in cotton produced a yield of 2.3 t ha^{-1} where as the recommended fertiliser practice produced 2 t ha^{-1}.

At Coimbatore, Kalaichelvi and Chinnusamy (2004) studied the influence of soil test crop response based nutrients and potassium humate on cotton productivity. They reported that, application of 100 per cent STCR recommended NPK fertiliser recorded more number of sympodial branches, fruiting points, boll setting percentage over other levels. Higher seed cotton yield was recorded with 100 per cent STCR recommended NPK fertilisers combined with the soil application of potassium humate either 30 kg or 40 kg ha^{-1}.

2.2. EFFECT OF SOIL TEST ON CROP YIELD

Rao and Subramanian (1994) carried out 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. Basu (1995) reported that high yield achievement of 2500 kg ha^{-1} was obtained in cotton by the application of 50: 0: 0 kg NPK ha^{-1} based on soil test, instead of the blanket recommendation of 90: 45: 45 kg NPK ha^{-1}. In another study, based on soil test crop response correlation (STCR) Reddy *et al.* (1999) reported that optimum fertiliser dose required for specific yield targets in groundnut are decreasing with increasing soil test values in sandy clay loam soils of Nellore.

In onion, Meena *et al.* (2001) found that soil test crop correlation (STCR) helps to reduce the fertiliser dose to attain the specific target yield of 25 t ha^{-1} in Alfisol. By considering indigenous nutrient supply, reasonable yield target, corresponding nutrient demand and nutrient balance, the field specific fertiliser recommendation made by Wang *et al.* (2001) consistently improved the plant nutrient uptake, grain yield and profit by about 10-15 per cent compared to the farmer's fertiliser practice. Soil test crop response correlation (STCR) studies were conducted by Santhi *et al.* (2005) with onion under Integrated Plant Nutrition System (STCR-IPNS) in Inceptisols of Tamil Nadu observed that in STCR-IPNS technology, the fertiliser doses were closely related to the requirements of specific yield targets of onion taking into account the contribution from soil, fertilisers, organics and bio fertiliser and therefore there was balanced supply of nutrients coupled with recycling of organic waste avoiding either under or over usage of fertiliser inputs.

Biradar and Aladkatti (2005) reported that in hybrid cotton SSNM (130: 70: 120 kg NPK ha^{-1} along with secondary and micro nutrients) produced a yield of 2.3 t ha^{-1} where as the RDF produced only 2 t ha^{-1} in Karnataka. An experiment conducted at Himachal Pradesh in wheat, rice and maize based on the soil test crop response prescription revealed that fertiliser recommendation based on targeted yield concepts were found more precise and dependable to the target yields of 5 t ha^{-1} for rice and 4 t ha^{-1} for wheat (Verma *et al.*, 2005).

In another experiment Kadam and Sonar (2006) reported that in onion fertiliser application based on targeted yield approach was found superior and resulted the highest yield of 50 t ha^{-1} in Otur and Sawargol soil series. The STCR studies conducted in mustard and rape seed on Typic Haplustept soil at Ludhiana provided high correlation of high predictability between grain yield and soil available nutrients and fertiliser N. The fertiliser application based on targeted yield gave higher yields over farmers' practice and the grain yield of mustard was found between 550 and 1850 kg ha^{-1} and that of rape seed was between 698 and 2720 kg ha^{-1} (Chand *et al.*, 2006).

Targeted yields of cotton were in close agreement with actual yields of cotton. Therefore, the fertiliser prescription equation may be useful to adopt balanced fertiliser dose based on targeted yield concept in cotton (Khandare *et al.*, 2002). 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 that the response to applied N, P and K decreased with increased fertility status of soil for all the vegetable crops.

2.3. EFFECT OF DIFFERENT LEVELS OF CHEMICAL FERTILISERS ON GROWTH, YIELD AND QUALITY OF CROPS

2.3.1. Growth Parameters

In chilli the highest plant height was recorded by the application of 120: 90: 90 kg N, P_2O_5 and K_2O ha^{-1} (Shamima and Islam, 1990). In another experiment Medhi *et al.* (1990) reported that by the application of 100: 50: 50 kg N, P_2O_5 and K_2O ha^{-1} given the highest plant height in chilli. Singh *et al.* (1999) reported that in clay loam soils of Odissa maximum height and number of leaves in chilli was recorded by the application of 120 kg N and 105 kg K_2O ha^{-1} as compared to lower doses of N, K and control (without fertiliser). In bitter gourd Sanap *et al.* (2010) reported a maximum vine length of 11.3 cm with the application of 250: 100: 100 kg NPK ha^{-1}. They also reported that a highest number of branches were recorded by the application of 250: 50: 100 kg NPK ha^{-1}.

Suresh and Pappiah (1992) also reported the beneficial effect of 80 kg N and 30 kg P fertilization on growth of bitter gourd. Singh and Chhonkar (1986) reported the beneficial effect of NPK application in muskmelon. In an experiment Prasad *et al.* (2009) reported that the application of N 20 kg ha^{-1} + PSB + Azotobacter recorded higher number of branches, nodes per vine and length of vine in bitter gourd. Also the same treatment resulted significantly minimum days for first male and female flower appearance compared to control. Malagi (2001) reported that the application of 100 kg N ha^{-1} recorded maximum plant height, number of branches per plant, leaf area index, leaf area duration, total dry matter production and its distribution in different plant parts in chilli as compared to the application of 75, 50 and 25 kg N ha^{-1}.

Majumdar *et al.* (2005) reported that combined application of K and N obviously improved the plant height, branch number, stem diameter, dry weight of shoot, single ginger rhizome weight and yield in ginger. Maya *et al.* (1997) observed that maximum plant height, number of branches per plant and dry matter production (2058 kg ha^{-1}) in sweet pepper (cv. California wonder) was obtained at 150 kg N ha^{-1} along with 100 kg P_2O_5 ha^{-1}. Similarly, Balaraj (1999) noticed that the fertiliser level of 150: 75: 75 kg of N, P_2O_5 and K_2O ha^{-1} recorded significantly higher plant height (97.66 cm) in chilli over lower fertiliser level (100: 50: 50 kg N, P_2O_5 and K_2O ha^{-1}). A field experiment 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 N and 105 kg K_2O ha^{-1} as compared to lower doses of N, K and control (without fertiliser).

2.3.2. Yield Parameters

Beneficial effect of chemical fertiliser application on flowering and fruit yield contributing characters of bitter gourd was reported by Rajput and Gautam (1995). Mahakal *et al.* (1977) also reported the beneficial effect of fertiliser application in bitter gourd. Dhesi *et al.* (1966) reported a fruit yield of 117.317 q ha^{-1} by the application of 250: 50: 100 kg NPK ha^{-1} in bitter gourd. Prasad *et al.* (2009) reported that application of N 20 kg ha^{-1} + PSB + Azotobacter in bitter gourd recorded higher number of fruits per plant, fruit thickness, fruit weight in bitter gourd. The maximum fruit yield (19.9 t ha^{-1}) was also recorded by the same treatment. Bhunia and Mandai (2009) found that the treatment comprising 50 per cent inorganic N, 50 per cent organic N and bio-fertilisers was better in comparison to other levels of nutrition for most of the yield contributing characters in bitter gourd. This treatment also recorded highest fruit yield (18.41 t ha^{-1}). Suresh kumar and Karuppaiah (2008) was found that in bitter gourd the treatment combination of 75 per cent of NPK (60: 30: 20 kg ha^{-1}) + vermicompost at 5 t ha^{-1} + Azospirillum at 2 kg ha^{-1} was the best in the rice fallow condition with the total yield of (1.33 kg $plant^{-1}$) followed by 75 per cent NPK + panchakavya at 3 per cent foliar spray + *Azospirillum* at 2 kg, which was on a par with NPK 100 per cent + vermicompost at 5 t ha^{-1}. Prabhu *et al.* (2006) reported that the treatment with 50 per cent recommended dose of fertiliser + vermicompost @ 2 t

ha^{-1} + biofertilisers resulted in highest yield in terms of yield $plant^{-1}$ and yield ha^{-1} in cucumber. The same treatment also recorded the highest benefit cost ratio of 2.24.

Majumdar *et al.* (2000) reported that increased levels of potassium had significant influence on the fruit yield of tomato and chilli, with highest fruit yield of tomato and chilli (525.33 q ha^{-1} and 168.20 q ha^{-1}, respectively) under 90 kg K_2O ha^{-1}. The application of 90 kg K_2O ha^{-1} resulted in 12.59, 8.67 and 4.75 per cent higher fruit yield of chilli over 0, 30 and 60 kg K_2O ha^{-1} respectively. A field experiment was carried out to know the effect of potassium levels (0, 30, 60 and 90 kg ha^{-1}) on yield and nutrient uptake in paprika under irrigated conditions on red sandy loam soil at Warangal, Andhra Pradesh. The results revealed that, 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 ha^{-1} (Hari *et al.*, 2007). Naveen kumar *et al.* (2012) reported that there was significant increase in yield of bitter gourd due to the application of PGPR.

2.3.3. Quality Parameters

Rajasree and Pillai (2012) reported that at high levels of N increased the crude protein, total P, total K, Fe and ascorbic acid content of bitter gourd fruits. They also reported that N level more than 300 kg ha^{-1} significantly reduced the shelf life of bitter gourd fruits. Significant increase in vitamin C content of chilli fruits (cv. K.2) with increased levels of potassium application was observed by Shibila Mary and Balakrishnan (1990). Highest vitamin C content was obtained with 52.5 kg K_2O ha^{-1} both in green (100.06 mg 100 g^{-1}) and red ripe fruits (115.56 mg 100 g^{-1}). Kaminwar and Rajagopal (1993) reported that significant increase in ascorbic acid content of red ripe chilli fruits (cv. Sindhur) with potassium application and highest ascorbic acid content (40.1 mg 100 g^{-1} fruits) was registered at 100 kg K_2O ha^{-1}, whereas in control the value was (36.9 mg 100 g^{-1} fruits). Application of RDF + VC recorded significantly higher ascorbic acid content (109.56 mg 100 g^{-1} of green chilli) compared to application of RDF or VC alone Sutagundi (2000).

Shashidhara (2000) found that the combined application of both organics and inorganics with 100 per cent RDF significantly increased the ascorbic acid content as compared to 100 per cent RDF alone. Higher fertiliser level (250: 125: 125 kg NPK ha^{-1}) recorded significantly higher ascorbic acid content (199.19 mg 100 g^{-1} fruits) in chilli than fertiliser level (150: 75: 75 kg NPK ha^{-1}) which observed (184.42 mg 100 g^{-1} fruits) (Vadhana, 2003). Application of 75 kg K_2O ha^{-1} had resulted in highest ascorbic acid content (117.96 mg 100 g^{-1} fruits) in chilli which was significantly superior over 45 kg K_2O ha^{-1} (111.54 mg 100 g^{-1} fruits) but on par with 60 kg K_2O ha^{-1} (117.13 mg 100 g^{-1}) (Ananthi *et al.*, 2004). Priya (2011) found that the uptake of N, P and K was the highest in the SSNM treatment with high yield targets in chilli. Sharma and Peshin (1996) observed significant increase in fruit length, number of fruits per plant and fruit yield of chilli with an increase in N levels. The highest was being at 150 kg N ha^{-1}. Similarly, Maya *et al.* (1997) observed the highest fruit yield (496.8 g $plant^{-1}$) in sweet pepper at 150 kg N ha^{-1}. Thakur *et al.* (2000) reported that application of higher dose of potassium resulted in significantly higher yield of bell pepper. Jayaraj *et al.* (1999) also recorded significantly higher fruit yield (5734 kg ha^{-1}) in chilli with application of 180: 40: 40 kg NPK ha^{-1}.

Bidari (2000) studied that irrespective of cultivar and fruits quality, the order of nutrient concentration in whole fruits followed the order of K> N> Mg> Ca> P> Fe> Mn> Cu. Similarly, Suresh (2000) reported increased uptake of potassium in chilli with increasing levels of K. The highest uptake (108.24 kg ha^{-1}) was obtained at 75 kg K_2O ha^{-1} along with 100: 50 kg N and P_2O_5 ha^{-1} and it was significantly superior over 25 kg K_2O ha^{-1} (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 100 g^{-1} fruit in tomato and chilli respectively, at 90 kg K_2O ha^{-1}. Application of 90 kg K_2O 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_2O ha^{-1} respectively (Majumdar *et al.*, 2000).

2.4. SOIL MICRONUTRIENT STATUS IN INDIA AND KERALA

Micronutrients are essential for the normal growth of plants. Deficiency of micronutrients drastically affects 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 per cent soils are tested to be deficient in available zinc, iron, manganese, copper, boron and sulphur respectively. The magnitude of zinc deficiency varied widely among soil types in various states (Singh, 2009). Boron and zinc deficiencies are increasingly important in Indian soils primarily due to decline in soil fertility, loss of organic matter and non application of deficient nutrients based on soil tests (Katyal and Randhawa, 1983; Tedone, 2009).

Pisharady (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 Sillanappa, 1990). Depletion of micronutrients from soil is increasing by adoption of modern technologies in agriculture like use of high analysis fertilisers and use of fertiliser responsive crops. There are records of occurrence of micronutrient deficiency namely deficiency of zinc, copper and manganese in Indian soils at the rates of 46, 5 and 4 per cent respectively (Singh, 2003).

Among micronutrient deficiencies, zinc deficiency is most common in Indian soils. Losses of yield to a tune of 40 per cent has been recorded in zinc deficient soils 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 Jharkand, Odissa and West Bengal where the rate of deficiency was reported to be 23-54 per cent (Sarkar and Singh, 2003). A study conducted by Tiwari *et al.* (2008) revealed that 49 per cent of Indian soils were found to be deficient in zinc. 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 deficient of boron.

2.5. EFFECT OF SECONDARY AND MICRONUTRIENTS APPLICATION ON GROWTH AND YIELD PARAMETERS

Application of 100 g Mg chelate along with 2 per cent foliar spray of $MgSO_4$ proved to be a promising treatment in banana (Mustafa, 2007). An experiment conducted by Baloch *et al.* (2008) revealed that application of both micro and macronutrients in green chillies increased the plant height, number of branches, fruit weigh plant^{-1} and green chilli yield. Chatterjee *et al.* (2000) reported that the deficiency of sulphur reduced the concentration of chlorophyll, sugars, starch and protein in cotton leaves. Also the activity of the enzyme ribonuclease was decreased due to low sulphur in soil. As a result of sulphur deficiency the quality of cotton seeds deteriorated which was reflected in low content of oil, sugars, starch, proteins and high concentration of phenols.

Studies conducted in farmers' fields revealed that response of about 2 q ha^{-1} and between 2-5 q ha^{-1} in most crops with 5 kg ha^{-1} Mo application in a wide variety of soils across the country (Katyal and Randhawa, 1983). Among the micronutrients boron is one that shows deficiency in soils that result in deficiency of the element in cereals (Elrashidi and O'Connor, 1982). Hulgar and Dangarwala (1983) recorded in increased uptake of N, Ca, Mg and S in maize due to the application of zinc. Application of $ZnSO_4$ @ 5-10 kg ha^{-1} or foliar application of $ZnSO_4$ @1.25 per cent increased the tuber yield and the HCN content in cassava in lateritic soil of Kerala (Nambiar and Abrol, 1989).

Application of boron 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, 1997). Singh *et al.* (1999) observed that yield of wet land rice in the soils of Meghalaya showed increase in yield by application of zinc as fertiliser. Meerabai (2001) reported increase in ginger yield by application of zinc @ 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 zinc was applied along with P. Umamaheswari and Singh (2002) revealed that application of $ZnSO_4$ @ 4 kg ha^{-1} increased yield aspects of rajmah. Devi and Rani (2003) reported that application of 25 kg ha^{-1} $ZnSO_4$ increased the grain yield by 48.2 per cent in rice. Application of Zn @ 10 kg ha^{-1} significantly increases plant height and green fodder yield in pearl millet (Dadwhich and Gupta, 2003).

A number of studies highlighted the benefits of foliar fertilization in improving plant growth, crop yield, nutrient uptake and product quality (Naruka and Singh, 1998; Tumbare *et al.*, 1999; Naruka *et al.*, 2000; Alkaff and Hassan, 2003; Chattopadhyay *et al.*, 2003; El-Aal *et al.*, 2010; Zodape *et al.*, 2011). This technique ensures immediate translocation of nutrients to various plant organs via leaf tissues under various nutrient deficiencies (Fageria *et al.*, 2009). Hence, under the situations of low soil nutrients bioavailability, hard top soil, and decreased root activity during the reproductive growth stage of plants, foliar fertilization is most effective (Naruka *et al.*, 2000; Chattopadhyay *et al.*, 2003; Fageria *et al.*, 2009; Zodape *et al.*, 2011). Foliar fertilization has been recommended as a treatment in the integrated plant production due to its being environmentally safe and since it increases the crop yield and quality (Tumbare *et al.*, 1999; Fageria *et al.*, 2009; El-Aal *et al.*, 2010; Zodape *et al.*, 2011). Recently, Maitlo *et al.* (2006) documented the positive effects of foliar application of urea to the plant growth traits of wheat and its yield. Moreover, nutrient uptake by wheat also increased by the foliar application of urea. Earlier, it has been reported that the foliar fertilization improves nutrient use efficiency and hence it is an environmental friendly technique. Foliar fertilization also improves the use efficiency of applied nutrients (Fageria *et al.*, 2009; El-Aal *et al.*, 2010; Zodape *et al.*, 2011). Despite the fact that the subject of foliar fertilization of various nutrients to supplement crop production under stresses is adequately studied (Naruka *et al.*, 2000; Chattopadhyay *et al.*, 2003; Fageria *et al.*, 2009), many aspects of the nutrient uptake and translocation within a plant in relation to newly introduced foliar fertilisers are still unrevealed.

Verma *et al.* (2004) suggested that the application of foliar spray of 0.5 per cent $ZnSO_4$ increased the quality attributes of pigeon pea. Jyolsna (2005) reported that the application of Zn @ 5 kg ha^{-1} was ideal for economic yield and the element influenced the growth, yield and quality of tomato. According to Shivoy and Kumar (2005) application of Zn @ 5 kg ha^{-1} along with N, P and K were found suitable achieving greater productivity in plants. Tiwari (2006) reported that sulphur and zinc when applied along with N, P and K increased the pod yield and number of nodules per plant in groundnut. Chaube *et al.* (2007) recorded that the application of 1 per cent $ZnSO_4$ increased the plant height, leaf area and yield in pearl millet. Application of 2.75 kg ha^{-1} increased the maize grain yield by 25 per cent of total dry matter, number of cobs and cob weight (Harris *et al.*, 2007).

Jyolsna and Mathew (2008) reported that application of boron @ 0.5 kg ha^{-1} improved the yield and quality attributes of tomato. 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 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 LEVELS OF CHEMICAL FERTILISERS ON DEHYDROGENASE ACTIVITY IN SOIL

Biological and biochemical properties of the soil have often been proposed as early and sensitive indicators of soil ecological stress or other environmental changes (Dick, 1994). Since dehydrogenase activity is only present in viable cells, it is thought to reflect the total range of oxidative activity of soil micro flora and considered to be a good indicator of microbial activity (Nannipieri *et al.*, 1990).

Fertilization greatly increased soil dehydrogenase activity after long-term application. Increased dehydrogenase activity by mineral N fertiliser was also reported in several studies (Serra-Wittling *et al.*, 1995; Cooper and Warman, 1997; Chu *et al.*, 2005; Ebhin Masto *et al.*, 2006). The application of balanced amounts of nutrients and manures improved the organic matter status of soils, which corresponded with higher enzyme activity. It has been reported that the increase in dehydrogenase activity and microbial biomass were proportional to the addition of number and amount of nutrients (Manjaiah and Singh, 2001; Ebhin Masto *et al.*, 2006).

The increased activity by mineral fertilization may be derived from the increased root biomass and exudates because of greater crop yields by fertilization. Chu *et al.* (2007) revealed that dehydrogenase in N- and P-deficiency treatments were significantly ($P<0.05$) lower than that in the NPK treatment, while the activity in the P-deficiency treatment was significantly lower ($P<0.05$) than that in the N-deficiency treatment. According to Pancholy and Rice (1973), dehydrogenase activity was influenced more by the quality than by the quantity of organic matter incorporated into soil. Thus, the stronger effects of FYM or sulphur on dehydrogenase activity might be due to the more easily decomposable components of crop residues on the metabolism of soil microorganisms. The observation that dehydrogenase activity is less influenced by mineral N fertilization is consistent with the studies of Kautz *et al.* (2004) and Marinari *et al.* (2000).

2.7. EFFECT OF DIFFERENT CHEMICAL FERTILISER DOSES ON NUTRIENT UPTAKE OF N, P AND K

Plant N uptake was enhanced under SSNM and SSNM employed lower N application rates, and the contribution from other soil N pools was relatively equal between plots receiving SSNM and FP. Thus, significant improvements in N recovery rate, ranging between 9.8 to 11 per cent, were achieved across soil fertility classifications (Huang *et al.*, 2007). According to Shashidhara (2000) the uptake of nutrients like N, P, K, Fe, Cu, Mn, and Zn (at flowering and harvest) were significantly higher with combined application of organics and inorganics (100 per cent RDF/50 per cent RDF). Bidari (2000) studied that irrespective of cultivars and fruit quality, the order of nutrient concentration in whole fruits followed the order K>N>Mg>Ca>P>Fe>Mn>Cu. Similarly, Suresh (2000) reported increased uptake of potassium in chilli with increasing levels of potassium. The highest uptake (108.24 kg ha^{-1}) was obtained at 75 kg K_2O ha^{-1} along with 100:50 kg N and P_2O_5 ha^{-1} and it was significantly superior over 25 kg K_2O ha^{-1}(100.89 kg ha^{-1}).

Ramakrishna and Palled (2004) reported that application of higher dose of NPK fertilizer in chilli recorded increased N, P and K uptake. Similar result was obtained by Vadhana (2003) in chilli. Hari *et al.* (2007) reported that significantly higher uptake of nitrogen and potassium by paprika plants at higher levels of potassium (90 kg K_2O ha^{-1}) where as phosphorus uptake was highest at 60 kg K_2O ha^{-1}.

2.8. ECONOMICS OF SITE SPECIFIC NUTRIENT MANAGEMENT

Effective and economic nutrient management begins with an understanding of the nutrient requirements of the crops being grown and the nutrient status of the soil. The nutrient requirements may vary with management practices and with type or variety. The SSNM treatments lowered the fertiliser input costs by 27.6, 28.6, and 16.6 per cent (high, medium, and low), and improved income ha^{-1} by 13.1, 18.4, and 20.6 per cent (high, medium, and low) (Huang *et al.*, 2007). A SSNM treatment reduced N rates by 30 per cent, increased P and K rates, and included secondary and micronutrients, increased cane yield by 30 t ha^{-1}. The addition of S, Zn, Fe, and Mn all had a major impact in the SSNM treatment increasing cane yields reported by Phonde *et al.* (2005). A balanced application of macro and micro-nutrients in pulse crops provided 40 per cent increase in both yield and economic benefit to the farmer (Bhattacharya *et al.*, 2004).

Verma *et al.* (2005) reported that the yield obtained from targeted yield of maize, 3 t ha^{-1} was almost equal to state level fertiliser recommendation but benefit cost ratio was (14.9) which was much higher than state level fertiliser recommendation with benefit cost ratio of (6.3) mainly due to higher application of N. According to Khandare *et al.* (2002) the yields 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 fertilisers based on fertiliser adjustment equation developed for cotton at Rahuri. There was increasing trend in monetary returns with increased fertiliser input targeted yields. The higher monetary returns (₹ 38298 ha^{-1}) were observed in the target yield of 20 q ha^{-1} as compared to soil test based fertilization (₹ 35271 ha^{-1}).

Reddy and Ahmed (2000) revealed that the benefit: cost ratio was found to be much higher in Maize (15.6) in case of the treatment based on STCR methodology when compared to either the fertiliser doses based on the general recommended dose (8.9) or farmers Practice (8.8). The higher response ratio (12.31) and net profit (₹ 11014 ha^{-1}) due to application of fertiliser 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 fertiliser used in targeted yield approach (Sharma and Singh, 2000).

As per the findings of Swadija *et al.* (1998), the BCR (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 fertiliser dose for targeted yield of 15 q ha^{-1} recorded significantly higher returns per rupee invested on fertilisers than other treatment. Economics of fertiliser use on the soil test for average yield (27.4 q ha^{-1}) indicated an additional benefit (₹ 3480 ha^{-1}) over the general recommended level for 25 q ha^{-1} yield target of chickpea (Tamboli *et al.*, 1996). The economics of fertiliser use on the basis of average yield indicated an additional benefit of ₹ 3163 and 2151, over the 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 fertiliser application based on soil testing (additional benefit of ₹

1683 and 2126 ha^{-1} over general recommended dose in pearl millet and wheat, respectively) (Tamboli *et al.*, 1994).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The experiment titled "Site specific nutrient management for bitter gourd (*Momordica charantia* L.)" comprised of three parts namely survey of site characteristics, spatial variability studies and field experiments.

3.1. SURVEY OF SITE CHARACTERISTICS

A field survey was conducted to collect information from the farmers about the variability in field, weather, and availability of inputs and yield of bitter gourd in the bitter gourd cultivating areas of Vellayani. A total of 50 soil samples were collected from the entire area and analyzed to get the overall nutrient composition of the soil. A pre designed proforma was used for the survey, the details of which are given in Appendix - III.

3.2. SPATIAL VARIABILITY STUDIES

Soil and water samples from the bitter gourd areas of Kalliyur village were collected and subjected to analysis for various physical, chemical and biological properties like bulk density, water holding capacity, pH, EC, available major and micronutrients namely N, P, K, Ca, Mg, S, B, Zn, Fe, Mn, Cu and dehydrogenase and microbial count.

3.3. FIELD EXPERIMENTS

Field experiments were conducted in three steps.

1. Nutrient Omission Trial
2. The SSNM experiment
3. Validation trial

3.3.1. Nutrient Omission Trial

In order to assess the indigenous nutrient supplying capacity of the soil, an omission trial was conducted during January to March 2009 in a selected farmer's field at Palappur, in Kalliyur village by omitting the particular nutrients in study.

Nutrient omission trial helped to reveal the native fertility status as well as the productivity of bitter gourd in the area.

3.3.1.1. Treatments in Omission Trial

Omission trial was conducted with Preethi, which is the most popular bitter gourd variety in Kalliyur village as per the field survey. There were 10 pits in each plot with two plants per pit. The treatment details are as follows:

T1. Nitrogen Omission (-N)	- 0: 25: 25 kg NPK ha^{-1}
T2. Phosphorus Omission (-P)	- 70: 0: 25 kg NPK ha^{-1}
T3. Potassium Omission (-K)	- 70: 25: 0 kg NPK ha^{-1}
T4. POP recommandation (+NPK)	- 70: 25: 25 kg NPK ha^{-1}
T5. Absolute Control (-NPK)	- 0: 0: 0 kg NPK ha^{-1}

The source of N was urea (46 per cent N), that of P was single super phosphate (18 per cent P_2O_5) and of K was MOP (60 per cent K_2O). The package of practices recommendation for bitter gourd is 70: 25: 25 kg NPK ha^{-1} (KAU, 2007).

3.3.1.2. Weather Parameters

The major weather parameters during the omission trial were monitored and are presented in Fig. 1 and Appendix – I.

3.3.1.3. Nitrogen Omission Trial (0: 25: 25 kg ha^{-1})

Nitrogen omission trial was conducted to find out the indigenous supply of nitrogen from the unfertilized soil. Indigenous nitrogen supply accounts for the cumulative crop uptake of nitrogen from all sources other than fertiliser *i.e.* soil, crop residue, manures, irrigation water, rainfall and atmosphere deposition. It is determined in N omission plots receiving 100 per cent dose of phosphorus and potassium but no nitrogen. Yield, soil available N, P, K, Ca, Mg, S, Mn, Fe, Zn,

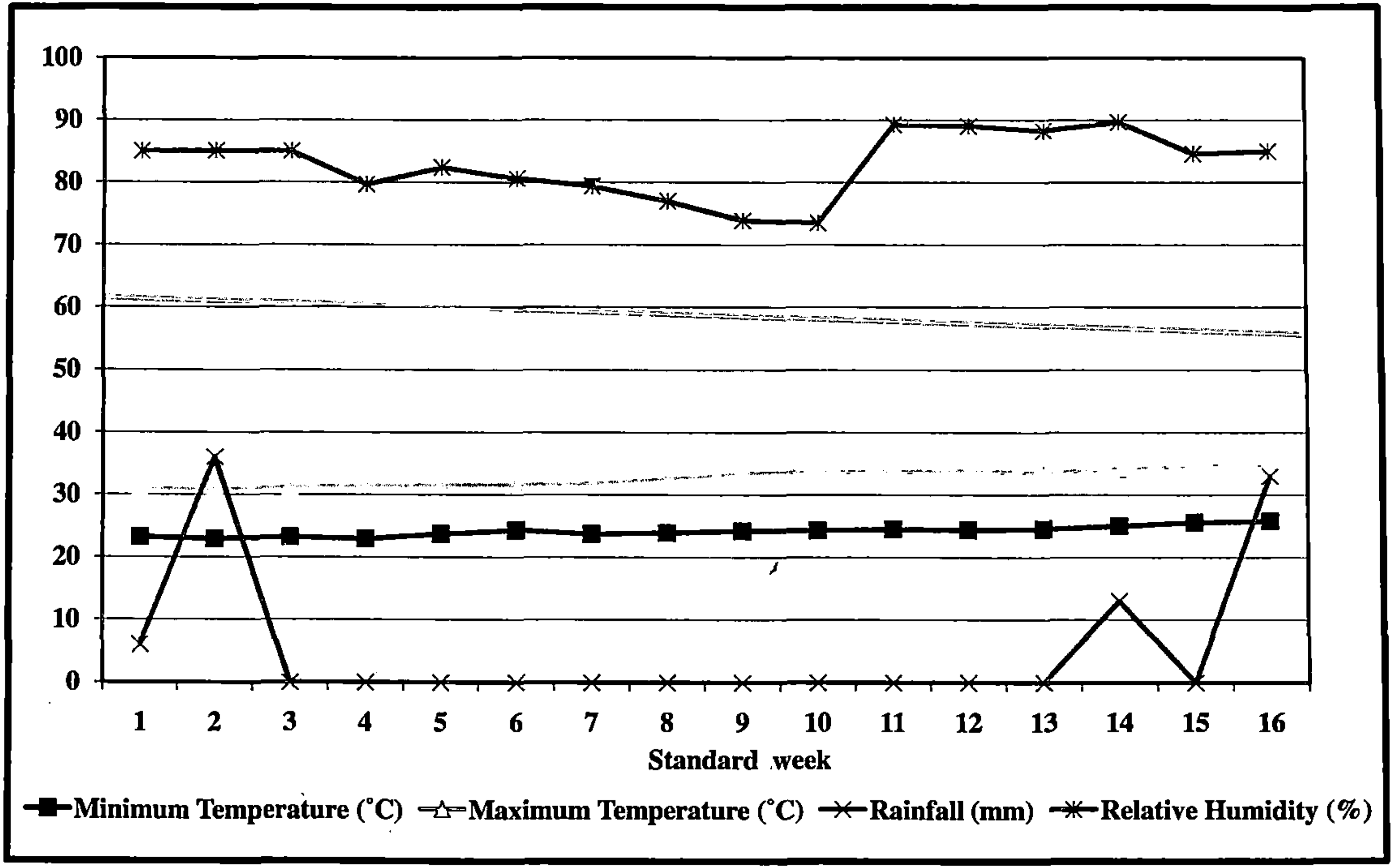

Fig. 1. Weather parameters during omission trial

B, Cu status and nutrient content in plant and fruits were analyzed and their uptake values were computed to get the indigenous fertility status of soil.

3.3.1.4. Phosphorus Omission Trial (70: 0: 25 kg ha^{-1})

Phosphorus omission trial was conducted to find out the indigenous supply of phosphorus from the soil in the area. Indigenous phosphorus supply is the cumulative crop uptake of P from all sources other than fertiliser as in the case of nitrogen. It is determined from P omission plot receiving 100 per cent dose of nitrogen and potassium. Yield, soil available N, P, K, Ca, Mg, S, Mn, Fe, Zn, B, Cu status and nutrient content in plant and fruits were analyzed and their uptake values were computed to get the indigenous fertility status of soil.

3.3.1.5. Potassium Omission Trial (70: 25: 0 kg ha^{-1})

Potassium omission trial was conducted to find out the indigenous supply of potassium from the soil. Yield, soil available N, P, K, Ca, Mg, S, Mn, Fe, Zn, B, Cu status and nutrient content in plant and fruits were analyzed and their uptake values were computed to get the indigenous fertility status of soil.

3.3.2. Derivation of SSNM Recommendations Using QUEFTS Model (Quantitative Evaluation of Fertility of Tropical Soils)

QUEFTS model predicts the crop yields from soil chemical characteristics which is an indicator of soil fertility. In bitter gourd the maximum yield recorded was 34 t ha^{-1}, the high yield target was fixed at 27 t and the medium yield fixed was 16 t ha^{-1}. From the QUEFTS model fertiliser recommendations for medium yield target and high yield target were generated. The dose of secondary and micronutrients were fixed based on the published works done in vegetable nutrition in similar soil types. A Microsoft excel sheet version of QUEFTS in combination with the solver module was used for the simulation of generic nutrient uptake curves representing optimal internal efficiencies of N, P and K at different yield level.

3.3.2.1. The Excel View of the QUEFT Table

3.3.2.1.1. Variables:

Variables used for calculating the amount of N, P, and K needed for the target yield

Model input data and parameters		**Source**
INS	Potential indigenous N supply (kg/ha)	Field-specific
	= crop N uptake in a plot without N application but ample P and K supply	1. Measured directly as N uptake in a 0N plot, INS = UN_0N, or
		2. Estimated from grain yield measured in a 0N plot, INS = UN_0N = f(GY_0N), or
		3. Estimated from a soil test (x) using a boundary line model, INS = a (1-exp(-x/b)) + c (1-exp(-x/d))
IPS	Potential indigenous P supply (kg/ha)	Field-specific
	= crop P uptake in a plot without P application but ample N and K supply	1. Measured directly as P uptake in a NK plot, IPS = UP_NK, or
		2. Estimated from grain yield measured in a NK plot, IPS = UP_NK = f(GY_NK), or
		3. Estimated from a soil test (x) using a boundary line model, IPS = a (1-exp(-x/b)) + c (1-exp(-x/d)), or
		4. Estimated from P uptake (GY) measured in a farmers fertilizer plot assuming a constant RFP, IPS = UP_FFP - RFP * FP
		5. Estimated from the initial IPS and the change in IPS (dIPS) resulting from the P balance of the preceding crop
IKS	Potential indigenous K supply (kg/ha)	Field-specific
	= crop K uptake in a plot without K application but ample N and P supply	1. Measured directly as K uptake in a NP plot, IKS = UK_NP, or
		2. Estimated from grain yield measured in a NP plot, IKS = UK_NP = f(GY_NP), or
		3. Estimated from a soil test (x) using a boundary line model, IKS = a (1-exp(-x/b)) + c (1-exp(-x/d)), or
		4. Estimated from K uptake (or GY) measured in a farmers fertilizer plot assuming a constant RFK, IKS = UK_FFP - RFK * FK
		5. Estimated from the initial IKS and the change in IKS (dIKS) resulting from the K balance of the preceding crop
RFN	Recovery fraction of applied N	Soil-specific, target value for plant-based N management
RFP	Recovery fraction of applied P	Soil-specific, obtained from previous fertilizer trials
RFK	Recovery fraction of applied K	Soil-specific, obtained from previous fertilizer trials
FN	Recommended N fertilizer rate (kg/ha)	Initial value = 0, Optimized by model
FP	Recommended P fertilizer rate (kg/ha)	Initial value = 0, Optimized by model
FK	Recommended K fertilizer rate (kg/ha)	Initial value = 0, Optimized by model
aN	Slope of envelope function grain yield vs. N uptake, max. accumulation of N in the plant	Generic model
dN	Slope of envelope function grain yield vs. N uptake, max. dilution of N in the plant	
aP	Slope of envelope function grain yield vs. P uptake, max. accumulation of P in the plant	Generic model
dP	Slope of envelope function grain yield vs. P uptake, max. dilution of P in the plant	
aK	Slope of envelope function grain yield vs. K uptake, max. accumulation of K in the plant	Generic model
dK	Slope of envelope function grain yield vs. K uptake, max. dilution of K in the plant	
Ymax	Climatic + genetic yield potential (kg/ha)	Region and season-specific, obtained from crop simulation models or expertise
Model-calculated variables	after Janssen et al., 1990 and Witt et al., 1999	
SN	Potential supply of N (kg/ha), SN = INS + RFN x FN	
SP	Potential supply of P (kg/ha), SP = IPS + RFP x FP	
SK	Potential supply of K (kg/ha), SK = IKS + RFK x FK	
UN(P)	Actual N uptake as a function of N and P supply (kg/ha)	
UN(K)	Actual N uptake as a function of N and K supply (kg/ha)	
UP(N)	Actual P uptake as a function of P and N supply (kg/ha)	
UP(K)	Actual P uptake as a function of P and K supply (kg/ha)	
UK(N)	Actual K uptake as a function of K and N supply (kg/ha)	
UK(P)	Actual K uptake as a function of K and P supply (kg/ha)	
UN	Final estimate of actual N uptake (kg/ha), UN = min (UN(P),UN(K))	
UP	Final estimate of actual P uptake (kg/ha), UP = min (UP(N),UP(K))	
UK	Final estimate of actual K uptake (kg/ha), UK = min (UK(N),UK(P))	
YNA	Estimated yield for the predicted UN at max. accumulation of N in the plant (kg/ha), YNA = aN*UN	
YND	Estimated yield for the predicted UN at max. dilution of N in the plant (kg/ha), YND = dN*UN	
YPA	Estimated yield for the predicted UP at max. accumulation of P in the plant (kg/ha), YPA = aP*UP	
YPD	Estimated yield for the predicted UP at max. dilution of P in the plant (kg/ha), YPD = dP*UP	
YKA	Estimated yield for the predicted UK at max. accumulation of K in the plant (kg/ha), YKA = aK*UK	
YKD	Estimated yield for the predicted UK at max. dilution of K in the plant (kg/ha), YKD = dK*UK	
YNP	Estimated yield for actual N uptake as limited by yield that can be achieved with the actual P uptake (kg/ha)	
YNK	Estimated yield for actual N uptake as limited by yield that can be achieved with the actual K uptake (kg/ha)	
YPN	Estimated yield for actual P uptake as limited by yield that can be achieved with the actual N uptake (kg/ha)	
YPK	Estimated yield for actual P uptake as limited by yield that can be achieved with the actual K uptake (kg/ha)	
YKN	Estimated yield for actual K uptake as limited by yield that can be achieved with the actual N uptake (kg/ha)	
YKP	Estimated yield for actual K uptake as limited by yield that can be achieved with the actual P uptake (kg/ha)	
Grain Yield	Final average yield estimate (kg/ha), GY = mean (YNP,YNK,YPN,YPK,YKN,YKP)	
YPUEN	Yield-producing uptake efficiency of N, YPUEN = UN/SN	
YPUEP	Yield-producing uptake efficiency of P, YPUEP = UP/SP	
YPUEK	Yield-producing uptake efficiency of K, YPUEK = UK/SK	
TYPUE	Total yield producing uptake efficiency, TYPUE = mean (YPUEN,YPUEP,YPUEK)	Maximized by model

The model maximizes TYPUE by changing FN, FP, and FK under a set of constraints.

Constraints usually include:
- a yield target (minimum yield to be achieved)
- maximum values for FN, FP, FK
- (YPUEN+YPUEP+YPUEK)>=0.95 to ensure that internal nutrient use efficiencies are equally high
- Constraints for internal efficiencies

3.3.2.1.2. Explanations:

To run a fertilizer rate calculation:									
1. Copy input data for farmer into the second row of the worksheet 'MODEL' (cells A2:H2)									
2. Set values for FN, FP, and FK to 0 (cells D17:F17)									
3. Check constraints and if necessary change the settings:									
				Subject to constraints		Cell			
	Maximum yield potential			Ymax = 10000		A17	depending on site and season		
	Grain yield target					B17	depending on site and season		
	Fertilizer sources					E6:G6			
	N recovery efficiency			RFN		D14	depending on site and season		
	P recovery efficiency			RFP		E14	depending on site and season		
	K recovery efficiency			RFK		F14	depending on site and season		
	Maximum FN			FN<=150		I6	depending on site and season		
	Minimum FP			FP>=10		H7	depending on site and season		
	Maximum FP			FP<=40		I7	depending on site and season		
	Minimum FK			FK>=30		H8	depending on site and season		
	Maximum FK			FK<=150		I8	depending on site and season		
	Internal N efficiency			IEN >= 60		H10	RECOMMENDED		
	Internal P efficiency			IEP >=340		H11	RECOMMENDED		
	Internal K efficiency			IEK >= 60		H12	RECOMMENDED		
	Yield producing uptake efficiency			UN/SN>=0.95		H14	RECOMMENDED		
	Yield producing uptake efficiency			UP/SP>=0.95		H15	RECOMMENDED		
	Yield producing uptake efficiency			UK/SK>=0.95		H16	RECOMMENDED		
3. Open menu Tools and choose option Solver									
4. Check the settings:									
	Set Target Cell			TYPUE					
	Equal to			Max					
	By changing cells			$D$17:$F$17					
	under the constraint			UN/SN=UP/SP			RECOMMENDED		
	under the constraint			UP/SP=UK/SK			RECOMMENDED		
5. Click on Solve									
6. After solution has been found: click ok and inspect the result									
7. Print the results from the worksheet 'MODEL OUTPUT'									
8. Keep records									
Example:									
				1998	1998	1999			
Model constraints				DS	WS	DS			
	FN			<=160					
	FP			>=10					
	FP			<=45					
	FK			>=30					
	FK			<=150					
Fertilizer management 98 DS									
		Basal			20 kg N/ha				
		20-25 DAT			40 kg N/ha				
		28-35 DAT (MT)			30-40 kg N/ha		Date: if SPAD<35		
		40-50 DAT (PI)			40-50 kg N/ha		Date: if SPAD<35		
		55-65 DAT (H-F)			20 kg N/ha		Date: if SPAD<35		
	continue SPAD readings until about 2 wk after flowering								
	P and K management								
		apply all P basal		K: 25% basal, 25% 20-25 DAT and 50% before PI					
N source	prilled urea								
P source	SSP		**K source**	KCl (60)					
Recovery fractions of applied fertilizer					1998				
					DS				
			Location A	N	0.50				
				P	0.20				
				K	0.40				
			Location B	N	0.50				
				P	0.25				
				K	0.50				
			Location C	N	0.45				
				P	0.25				
				K	0.60				
Estimation of INS, IPS, IKS 1998 DS									
INS	INS measured in 1997DS (N uptake in +PK plots)								
IPS	IPS measured in 1997DS (P uptake in +NK plots)								
IKS	IKS measured in 1997DS (K uptake in +NP plots)								
Yield targets			1998	1998	1999				
			DS	WS	DS				
Location A	average FFP		6880						
	max FFP		9933						
	average SSNM								
	max SSNM								
	yield target SSNM			7000					
Location B	average FFP		5872						
	max FFP		6443						
	average SSNM								
	max SSNM								
	yield target SSNM			7000					
Location C	average FFP		5259						
	max FFP		5965						
	average SSNM								
	max SSNM								
	yield target SSNM			6500					
Potential yield (Ymax)			DS	WS					
	Location A		10000	8000					
	Location B		9000	7000					
	Location C		8000	6000					

3.3.2.1.3. Model:

Village	Farmer	Farm No.	Plot size	INS	IPS	IKS
Thanh Van	N.V. Ti	312	160	41.5	9.8	64.5

Fertilizer sources			kg nutrient/kg
N	Urea	46% N	0.460
P	SSP	7.2% P (16.5% P2O5)	0.072
K	MOP	50% K (60% K2O)	0.500

Constraints	>	<
FN	-	200
FP	0	200
FK	0	200

Model parameters	a	d
N	125	279
P	400	1111
K	79	242

Ymax	GYTARGET
34000	22000

Supply & recovery		
INS	IPS	IKS
41.5	9.8	64.5
RFN	RFP	RFK
0.34	0.23	0.30
FN	FP	FK
123	59	160

IE (N)	300
IE (P)	1100
IE (K)	250
UN/SN	0.95
UP/SP	0.95
UK/SK	0.95
UN/SN=UP/SP=UK/SK:	yes

Estimates (all kg/ha):	N	P	K	Grain yield target
Fertilizer rate	123	59	160	16038 kg /ha
Estimated nutrient uptake:	79.6	22.3	107.7	
Internal efficiency (IE, kg grain / kg nut	201	719	149	Grain yield target =
Standard IE target	160	1350	180	47 % of Ymax
Reciprocal IE (RIE, kg nutrient / 1 t gra	5.0	1.4	6.7	80% of Ymax =
Standard RIE target	6.0	0.8	5.0	27200 kg /ha

Nutritional optimum parameters	UN/SN	UP/SP	UK/SK	TYPUE
Yield-producing uptake efficiencies	0.957	0.957	0.957	0.957

Fertilizer recommendation for 1998 spring rice		Total	Basal	DAT 20-25	DAT 45	DAT
N	kg N/ha	122.5	20	30		
	kg urea/SSM plot	4.26	0.70	1.04	0.00	0.00
P	kg P/ha	58.7	58.7			
	kg SSP/SSM plot	13.04	13.04			
K	kg K/ha	160.0	40.0	40.0	80.0	
	kg MOP/SSM plot	5.12	1.28	1.28	2.56	

* apply basal doses of N, P, K shortly before land preparation so that it is well incorporated
** determine best date of N application at MT (28-35 DAT) and PI (40-50 DAT) based on SPAD
*** use SPAD for decision about need for late N application (30 N at 65-70 DAT)

Village	Farmer	Farm No.	Plot size	INS	IPS	IKS	GY PK
kalliyur	N.V. Ti	312	160	41.5	9.8	64.5	0.0

Detailed Calculations:

Step 1: Potential N, P, and K supply from soil or soil+fertilizer (= yield producing supplies)

SN	SP	SK
83.2	23.3	112.5

Step 2: Estimation of actual uptake as a function of pot. supply of nutrient pairs (= yield producing uptake)

Points in the uptake vs. supply curve

Point S1	33.4	31.9	9.4	8.0	43.0	38.5
Point S2	380.7	403.7	106.7	128.1	544.4	616.7

UN(P)	UN(K)	UP(N)	UP(K)	UK(N)	UK(P)
79.6	79.6	22.3	22.3	107.7	107.8

Final uptake estimates

UN	UP	UK
79.6	22.3	107.7

Step 3: Estimation of yield ranges for actual nutrient uptake

YNA	YND	YPA	YPD	YKA	YKD
9949	22207	8919	24773	8507	26058

Step 4: Combination of possible yield ranges into one yield estimate

Estimation of yield for pairwise interactions of nutrients

YNP	YNK	YPN	YPK	YKN	YKP
16703	16038	15968	15607	15806	15508

Grain Yield

16038

Nutritional optimum parameters

Yield-producing uptake efficiencies

UN/SN	UP/SP	UK/SK
0.957	0.957	0.957

Total yield-producing uptake efficiency:

0.957

Nutrient supply equivalent:

SN/SP	SN/SK	SK/SP
3.57	0.74	4.83

Weighted nutrient supplies:

SNw	SPw	SKw
83.16	83.16	83.16

3.3.2.1.4. Model Output:

Village	Farmer	Farm No.	Plot size	INS	IPS	IKS
Thanh Van	N.V. Ti	312	160	41.5	9.8	64.5

Fertilizer sources			kg nutrient/kg
N	Urea	46% N	0.460
P	SSP	7.2% P (16.5% P2O5)	0.072
K	MOP	50% K (60% K2O)	0.500

Model parameters	a	d	Ymax	INS	IPS	IKS
				Supply & recovery		
N	125	279	34000	41.5	9.8	64.5
P	400	1111	GY_{TARGET}	RFN	RFP	RFK
K	79	242	22000	0.34	0.23	0.30

Constraints	>	<		>		>
FN	-	200	IE (N)	300	UN/SN	0.95
FP	0	200	IE (P)	1100	UP/SP	0.95
FK	0	200	IE (K)	250	UK/SK	0.95

Potential maximum yield (Ymax)	34000 kg ha^{-1}
Grain yield target	16038 kg ha^{-1}
Grain yield target in % of Ymax	47 %
Maximum economic yield target (80% of Ymax)	27200 kg ha^{-1}

Estimates (all kg/ha):	N	P	K	
Fertilizer rate	123	59	160	
Estimated nutrient uptake:	80	22	108	
Internal efficiency (IE, kg grain/kg nutrient)	201	719	149	
Standard IE target	160	1350	180	
Reciprocal IE (RIE, kg nutrient/1 t grain)	5.0	1.4	6.7	
Standard RIE target	6.0	0.8	5.0	TYPUE
Yield-producing uptake efficiencies	0.957	0.957	0.957	0.957

<u>Fertilizer recommendation for 1998 spring rice</u>

		Total	Basal	DAT 20-25	DAT 45	DAT 0
N	kg N/ha	122.5	20	30	0	0
	kg urea/SSM plot	4.26	0.70	1.04	0.00	0.00
P	kg P/ha	58.7	58.7			
	kg SSP/SSM plot	13.04	13.04			
K	kg K/ha	160.0	40.0	40.0	80.0	
	kg MOP/SSM plot	5.12	1.28	1.28	2.56	

Comments:

* apply basal doses of N, P, K shortly before land preparation so that it is well incorporated

** determine best date of N application at MT (28-35 DAT) and PI (40-50 DAT) based on SPAD

*** use SPAD for decision about need for late N application (30 N at 65-70 DAT)

3.3.2.2. Variables Utilized for the Generation of SSNM Fertiliser Recommendation

The details of variables used are included in Appendix V.

3.3.3. Site Specific Nutrient Management Trial

The details of the SSNM trial are presented below.

3.3.3.1. Experimental Site and Season

The experiment was conducted in a farmer's field at Palapur, Vellayani in Trivandrum district of Kerala in bitter gourd (*Momordica charantia* L.) variety Preethi. The SSNM experiment was conducted in the season January to March, 2011.

3.3.3.2. Location

The experimental field is located at 8° 28' N latitude and 75° 56' E longitude and the altitude of the site is 29 m above mean level.

3.3.3.3. Weather Parameters

The average temperature of the location ranged from 30.45-31.45°C, relative humidity during the period ranged from 87.52 per cent to 90.43 per cent and total rainfall ranged from 0-35 mm.

The weather parameters during the cropping season were monitored and are presented in Fig. 2 and Appendix - I.

3.3.3.4. Soil Parameters

The soil in the experimental site was fine Kaolinitic Isohyperthermic Typic Kandiustult belonging to Vellayani series.

3.3.3.5. Design and Layout of the Experiment

Design : Randomized Block Design

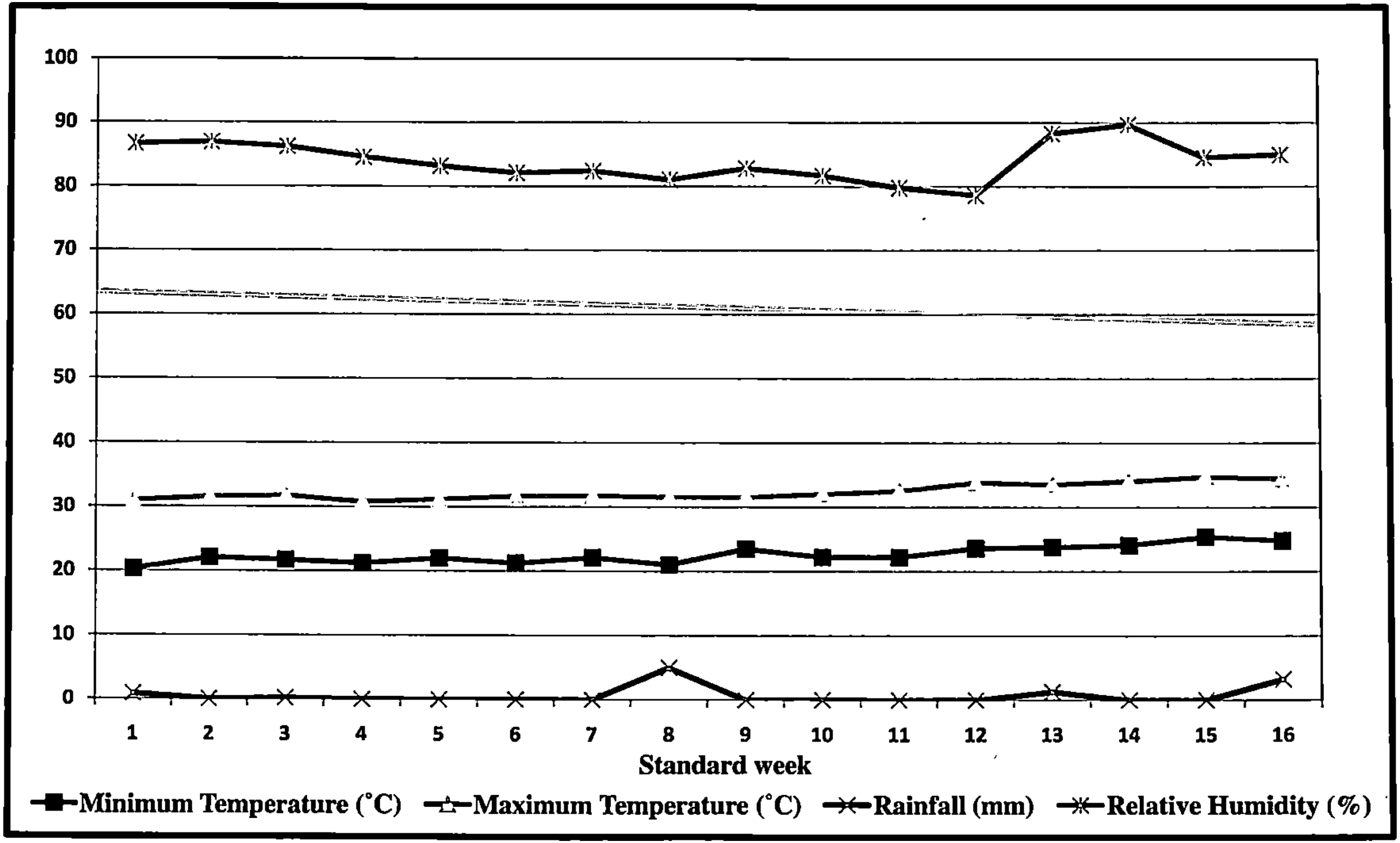

Fig. 2. Weather parameters during SSNM experiment

Plot Size : 40 m^2

Spacing : 2 x 2 m

Treatments : 10

Variety : Preethi

Replication : 3

Layout of the experiment is given in Fig 3.

3.3.3.6. Treatment Details of SSNM Trial

T_1. POP Recommendation

T_2. T_1 + suggested soil doses of secondary and micro nutrients

T_3. T_1 + suggested foliar doses of secondary and micro micronutrients

T_4. Site specific nutrient recommendations for medium yield target (Soil application of micronutrients)

T_5. Site specific nutrient recommendations for high yield target (Soil application of micronutrients)

T_6. Site specific nutrient recommendations for medium yield target (Foliar application of micronutrients)

T_7. Site specific nutrient recommendations for high yield target (Foliar application of micronutrients)

T_8. Farmers' Practice (I)

T_9. Farmers' Practice (II)

T_{10}. Absolute control

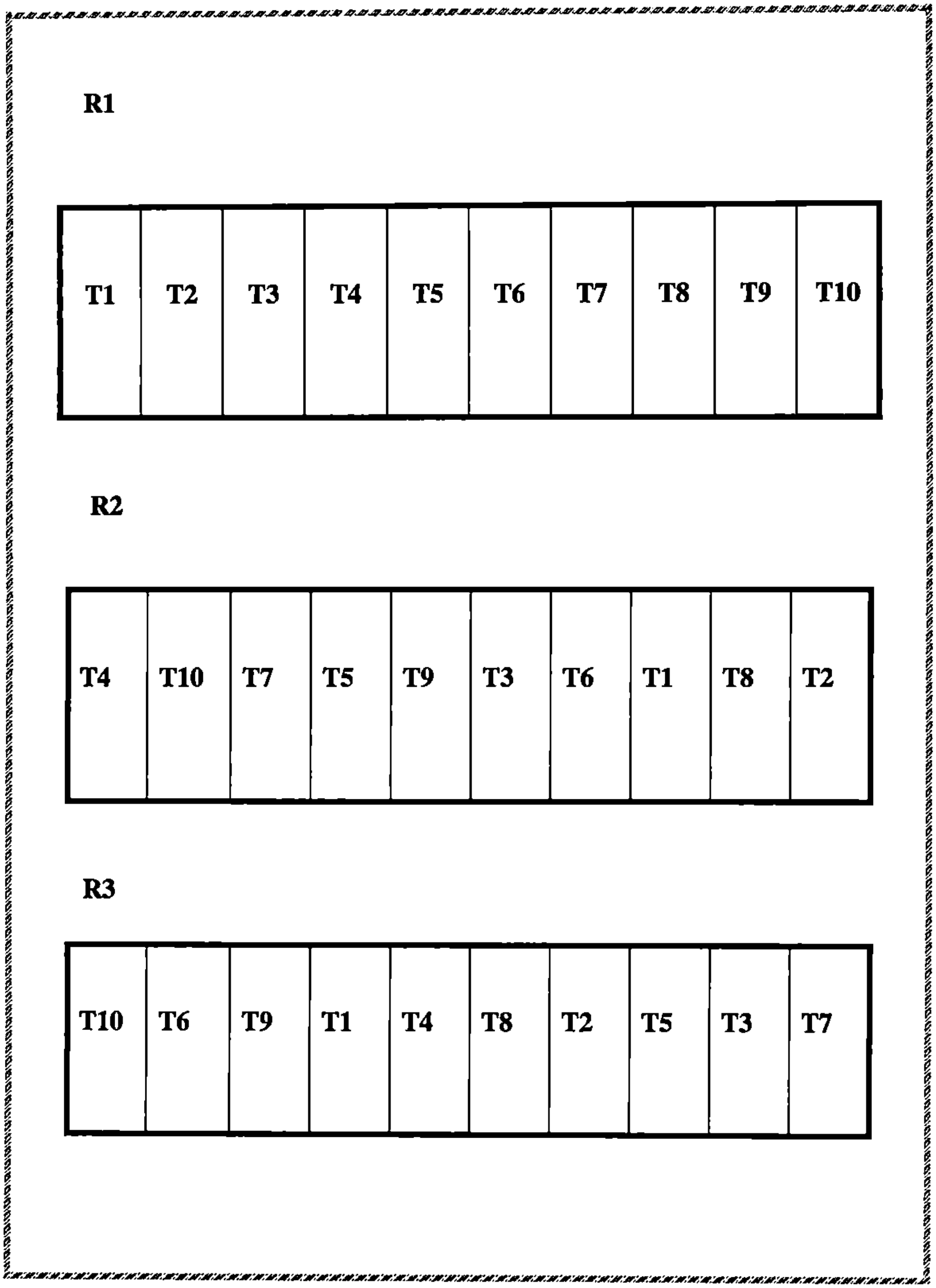

Fig. 3. Lay out of SSNM field experiment

The field survey revealed that farmers in the area were using different kinds of organic manures. It was found that about 46 per cent of the total vegetable growing farmers were using FYM as the source of nutrients, 51 per cent were using poultry manure as the source of nutrients and the rest were using composted materials and green manures. Hence we categorized the farmers in two groups, as FYM using group and poultry manure using group and included two farmers' practices as two treatments, farmers' practice-1 and farmers' practice-2. The actual doses of the fertiliser materials are given in Table 1a. The analysis details of the manures used in the farmers' practices are presented in Table 1b.

3.3.4. Materials

3.3.4.1. Planting Material

The Preethi variety of bitter gourd, which was used in omission trial, was used for the SSNM experiment. The seeds were collected from the sales counter, College of Agriculture, Vellayani. The fruits are white, medium, and spiny with white tinge at stylar end. The yield potential of the variety is 30 t ha^{-1}.

3.3.4.2. Manures and Fertilisers

Cattle manure was applied @ 25 t ha^{-1} as basal dose to all treatments except farmer's practices. Nitrogen was applied as urea (46 per cent N), phosphorus source was rock phosphate (20 per cent P_2O_5), potassium was applied as muriate of potash (50 per cent K_2O), Ca as $CaSO_4$ (22 per cent Ca), Mg as $MgSO_4$ (9.8 per cent Mg), Zn as $ZnSO_4$ (21 per cent Zn) and B as borax (10.5 per cent B). In farmer's practice -I, cow dung (2.5 t ha^{-1}), factamfos (187.5 kg ha^{-1}) where as in farmer's practice –II, poultry manure (5t ha^{-1}), factamfos (125 kg ha^{-1}) were applied along with 2.5 t ha^{-1} ash. The quantity of nutrients applied were calculated and presented in Table 1a. The analysis details of cow dung and poultry manures used are presented in Table 1b.

Table 1a. Treatment details of SSNM experiment

Treatment	N: P: K: Ca: Mg: Zn: B (kg ha^{-1})
T_1	70: 25: 25:0:0:0:0
T_2	70: 25: 25: 30: 40: 25: 10
T_3	70: 25: 25: 30: 40: 1% Zn foliar spray + 0.5% B foliar spray
T_4	52: 30: 52: 30: 40: 25: 10
T_5	123: 59: 160: 30: 40: 25: 10
T_6	52: 30: 52: 30: 40: 1% Zn foliar spray + 0.5% B foliar spray
T_7	123: 59: 160: 30: 40 + 1% Zn foliar spray + 0.5% B foliar spray
T_8	35: 37: 90: 0: 0:0 (as FYM, Factamfos and Ash)
T_9	82: 97: 95: 0: 0: 0 (as PM, Factamfos and Ash)
T_{10}	No fertilizer

Table 1b. Analysis of manures

Sl. No.	Manure	N- P- K (%)
1.	Cow dung	0.46- 0.48- 0.63
2.	Poultry manure	0.90- 1.2- 0.40

3.3.5. After Cultivation Practices

3.3.5.1. Fertiliser Application

The fertiliser applications were done according to treatments in respective plots. Application of 1/3rd N, ½ K and 100 per cent P were done as basal, remaining dose of K and 100 per cent dose of Ca, Mg and micronutrients were applied 30 days after sowing and N in 4-5 split doses at fortnightly intervals. In the case of foliar application, the micronutrients were applied just before flowering.

3.3.5.2. Trailing of Vines

Thin bamboo splits were fixed in each pit and vines were allowed to trail on them and tied from time to time since one week after germination till they reached the pandal height.

3.3.5.3. Pandal Making

After 15 days of sowing a pandal with casuarina poles and coir was erected at the experimental area. The pandal was firmly secured by metal wire from all the four sides.

3.3.5.4. Nipping of Lateral Buds

Lateral buds were nipped off from time to time to avoid lateral branching till the central vine reached the pandal height.

3.3.5.5. Weeding and Irrigation

Weeding was done at the time of fertiliser application. During the initial stages of growth the crop was irrigated at an interval of 3-4 days. Alternate day irrigation was given during flowering and fruiting periods.

3.3.5.6. Plant Protection

Furadan traps were set up for catching the fruit flies immediately after flowering. After fruit set the fruits were covered with paper for protection from fruit fly attack.

3.3.6. Biometric Observations

Four plants per treatment per replication were selected for observations and the mean were worked out for each replication as per standard procedure. Four fruits per treatment per replication were selected for taking observations of fruit characters. The following observations of the plant under different treatments were recorded at different growth stages.

3.3.6.1. Number of Days to Fruit Harvest

Number of days taken from sowing to the harvest of the fruit.

3.3.6.2. Node at which First Male Flower Appears

Number of nodes from the base of the plant to the node where the first male flower appeared.

3.3.6.3. Node at which First Female Flower Appears

Number of nodes from the base of the plant to the node where the first female flower appeared.

3.3.6.4. Length of Vine (cm)

Total length of the vine was measured from the collar region to the tip of the main vine using the measurement tape after pulling out the vine at the time of last harvest.

3.3.6.5. Dry Matter Content (g plant^{-1})

At final harvest 4 sample plants were uprooted from each plot, first dried in shade and then dried in hot air oven at 70°C. Dry weights were recorded and mean values worked out and expressed as g plant^{-1}. In the case of fruit dry matter production, one fruit from each plant per treatment were collected in each harvest, were cleaned, made into small pieces, first dried in shade and then dried in hot air oven at 70°C and recorded the average weight of single fruit per plant per treatment. The total number of fruits per plant per treatment was counted and the average number of fruits was multiplied with the average dry weight of single fruit to get the fruit dry matter production per plant.

3.3.7. Yield Components

3.3.7.1. Number of Fruits per Plant

Fruits were harvested at 65 days after planting in weekly intervals. There were 4-5 pickings. At each harvest number of harvested fruits per plant per treatment per replication was recorded and after final harvest the total number of fruits harvested per plant was counted and the average was expressed as the total number of fruits per plant.

3.3.7.2. Average Fruit Weight (kg)

Weight of four fruits from each treatment from each replication was taken and average was worked out.

3.3.7.3. Yield per Plant (kg)

Weight of whole fruits from each plant from each treatment from each replication was recorded and average was worked out.

3.3.7.4. Fruit Length (cm)

The length of the fruit measured from the stalk end to the blossom end.

3.3.7.5. Fruit Girth (cm)

The girth at the middle of the same fruit used for the length measurement.

3.3.7.6. Pest and Disease Scoring

The disease (mosaic) scoring was done 60-75 days after sowing at 0-5 scale where minimum score is 0 and maximum score is 5. Pest scoring was recorded during the fruiting stage at 1-5 scale, where minimum score is 1 and maximum score is 5 (Nath, 1966).

3.3.8. Quality Parameters

3.3.8.1. Keeping Quality

To determine the number of days the fruits can be stored without damage for culinary purpose, 1 kg fruit samples with fruits having uniform maturity representing each plot was kept at room temperature. Keeping quality of each lot was assessed by duration of time from harvest to the development of visual symptoms of yellowing and rotting of fruit and was recorded as the storage life or the keeping quality of the fruits at room temperature (Veenakumari *et al.*, 1994). The scoring details of keeping quality are presented in Appendix VII.

3.3.8.2. Organoleptic Tests

The organoleptic quality and acceptability of fruits were done at maturity stage (fully developed but green) using a scoring method proposed by Jijiamma (1989). The fruits were thoroughly washed in water and cut into pieces. 100g fruits were boiled in 100 mL water and 1g salt for 7 minutes. The prepared sample was used for organoleptic quality scoring. The panel members were selected from a group of healthy adults in the age group of 25-35. They were requested to taste each sample and score it. Each quality was assessed by the panel members after testing the same sample several times if needed. The organoleptic scoring details are presented in Appendix VII.

3.3.8.3. Beta Carotene

Beta carotene content of fruit was estimated by following the method proposed by Srivastava and Kumar (1998).

3.3.8.4. Vitamin C

Ascorbic acid/Vitamin C content was estimated by 2, 6- dichlorophenol indophenol dye method (Sadasivam and Manikkam, 1996).

3.3.8.5. Iron

Fruit samples were taken from each plot from each harvest, dried and powdered. Iron content of the fruit samples were estimated by atomic absorption spectrophotometry after wet digestion of the samples using di-acid mixture.

3.4. SOIL ANALYSIS

3.4.1. Physical and Chemical Analysis

The soil samples from different sites of the village were collected during the crop growing season and at two times (initial and final) from the experimental sites. The samples were air dried, processed and passed through 2 mm sieve and stored in polythene bags for analysis. The soil samples were analysed for various physico-chemical parameters using standard procedures (Table 2a & 2b).

3.4.2. Microbial Analysis

3.4.2.1. Microbial Count

The number of bacteria, fungi and actinomycetes in soil was determined by serial dilution plate method (Timonin, 1940). The media used for isolation of different groups of microorganisms are given in Appendix-VIII.

3.4.2.2. Dehydrogenase Activity

Dehydrogenase activity in soil was determined by monitoring the rate of production of tri-phenyl formazon (TPF) from tri-phenyl tetrazolium chloride (TTC), using the method of Klein *et al.* (1971).

3.5. IRRIGATION WATER ANALYSIS

Irrigation water samples were collected along with the soil samples collection from different sites of the village as well as the water samples used for the field experiments were analyzed using standard procedures (Dewis and Freitas, 1970).

3.6. PLANT SAMPLE ANALYSIS

Plant samples were collected after harvest, cleaned and subjected to drying in a hot air oven at 70°C. The dried samples were powdered, wrapped in clean butter paper cover and stored for analysis. In the case of fruit samples, mature fruits from each treatment in each harvest were collected, made into pieces, dried in shade and then subjected to drying in hot air oven at 70°C and powdered, wrapped in clean butter paper cover. The powdered samples then analyzed for various nutrients content using standard procedures (Table 3). The plant and fruit uptake of nutrients were calculated by multiplying the plant/ cumulative fruit dry weight by nutrient concentration in the respective plant part.

3.7. VALIDATION TRIAL

The validation trial was carried out by selecting the best treatments from the SSNM field experiment. An unreplicated trail was conducted in selected farmer's field in Kalliyur village.

3.8. ECONOMIC ANALYSIS

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

Benefit: Cost ratio = Return in terms of rupee / Cost of cultivation

3.9. STATISTICAL ANALYSIS

The data generated from the experiment were subjected to various statistical analyses. The data on soil properties were subjected to analysis using descriptive statistics. The data collected from SSNM field experiments were analyzed using ANOVA in RBD. Correlation analysis was done to find out the effect of treatments on yield. The results were interpreted and tabulated.

Table 2a. Standard analytical methods followed in soil analysis

Sl. No.	Parameter	Method	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 1:2.5 ratio of soil and water suspension	Jackson (1973)
5	EC	Direct reading using conductivity meter 1:2.5 ratio of soil and water suspension	Jackson (1973)
6	Organic Carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
7	Available N	Alkaline permanganate method	Subbaiah and Asija (1956)
8	Available P	Bray No.1 extraction and spectrophotometry	Jackson (1973)

Table 2b. Standard analytical methods followed in soil analysis

Sl. No.	Parameter	Method	Reference
1	Available K	Neutral Normal ammonium acetate extraction and flame photometry	Jackson (1973)
2	Exchangeable Ca & Mg	Versenate titration method (N 1N Ammonium acetate extraction)	Hesse (1971)
3	Available S	Turbidimetry – Barium chloride method	Chesnin and Yien (1950)
4	Available Fe, Mn, Zn & Cu	DTPA extraction and AAS	Lindsay and Norvel (1978)
5	Boron	Hot water soluble boron	Wolf (1971)
6	Molybdenum	Griggs method	Grigg (1953)
7	Aluminium	1N KCl extraction method	Cottenie *et al.* (1982)
8	Dehydrogenase	Extraction with ethanol and spectrophotometry	Klein *et al.* (1971)

Table 3. Standard analytical methods followed in plant analysis

Sl. No.	Parameter	Method	Reference
1	N	Micro-kjeldahl 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 & Mg	Di-acid digestion using nitric-perchloric acid (9:4) and versenate titration	Piper (1966)
5	S	Turbidimetry–$BaCl_2$ method (0.15% $CaCl_2$ extraction)	Chesnin and Yien (1951)
6	Fe, Mn, Zn & Cu	Di-acid digestion using nitric-perchloric acid (9:4) and atomic absorption spectrophotometry	Lindsay & Norvel (1978)
7	B	Colorimetry	Wolf (1971)
8	Mo	Ammonium oxalate method	Johnson and Arkley (1954)
9	Vitamin C	2,6-dichlorophenol indophenol dye method	Sadasivam and Manikkam (1996)
10	Beta carotene	Colorimetric method	Sadasivam and Manikkam (1996)

RESULTS

4. RESULTS

An investigation entitled "Site specific nutrient management for bitter gourd (*Momordica charantia* L.)" was conducted in College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing productivity of bitter gourd. The results of the study are presented in this chapter.

4.1. SURVEY OF SITE CHARACTERISTICS

A questionnaire was prepared and the field survey was conducted among the bitter gourd farmers to collect information on cropping history, cultural practices, weather data, socio economic conditions, environmental problems and stresses such as water, pests or mineral disorders.

The survey covered the entire area of Kalliyur Village. The area of the village is 17.23 km^2 and belongs to Nemom block of Thiruvananthapuram district. Physiography of the village consists of wet lands, reclaimed lands and garden lands. More than 60 per cent of the people are engaged in agriculture. Kalliyur village is one of the major vegetable growing tracts of the district. The main vegetables grown in this area are bitter gourd, amaranthus, chilli, snake gourd, cow pea, banana, cucumber etc. Vegetables are cultivated in garden and reclaimed wet land. The main water source for the village is the Vellayani fresh water lake.

The list of farmers and site characteristics recorded during the survey are presented in the Appendix IV.

4.2. SPATIAL VARIABILITY STUDIES

In order to study the spatial variability of soil fertility, soil samples were collected from 50 different locations of the village. Along with soil the water samples used for irrigation were also collected and analyzed. The soil and water collected were analyzed for various physical, chemical and biological parameters.

4.2.1. Soil Analysis

The soil samples collected from 50 different locations of bitter gourd growing areas were analyzed for various physical, chemical and biological parameters. The physical and chemical analysis results are presented in Table 4 and Appendix VI. Wide variation was observed in the soil fertility parameters of the samples collected. The pH values ranged from 3.2-6.3 in different sites of the village. Electrical conductivity values varied from 0.01 to 0.36 dS m^{-1} and organic carbon from 4.0 to 38.3 g kg^{-1}. The available nutrients like available N varied between 225.5 to 394.2 kg ha^{-1}, available P from 11.4 to 270.9 kg ha^{-1} and available K from 18 to 176 kg ha^{-1}. Secondary nutrients like exchangeable Ca ranged from1.5 to 6.0 cmol kg^{-1}, exchangeable Mg from 1.0 to 9.5 cmol kg^{-1} and available sulphur from 5 to 35 kg ha^{-1}. The micronutrients like available Zn varied between 0.22 and 1.42 mg kg^{-1}, available Fe between 12.5 and 14.12 mg kg^{-1}, available Mn between 1.63 and 5.19 mg kg^{-1}, available Cu from traces to 0.86 mg kg^{-1}, hot water soluble boron from 0.01 to 0.8 mg kg^{-1}, and exchangeable Al varied between 10-19 mg kg^{-1}. Available Mo was found only in traces in all the samples collected (Table 4).

Descriptive statistics of the chemical analysis data of soil samples from the entire village is presented in Table 5. The standard deviation values of available N, P and K indicated that high variation occurred in these parameters from site to site. Available potassium in various locations ranged from low to medium. The table shows that the exchangeable Ca, Mg and Zn values are highly skewed whereas all the other parameters are moderately skewed. Available Fe was not deficient but available Zn was deficient in majority of the sites. The data for the individual samples are presented in Appendix VI. The dehydrogenase activity varied between 10-90 μg TPF g^{-1}soil 24 h^{-1}, the bacterial count of the samples between 7-20 X 10^6 CFU g^{-1}soil, fungal count between 6 -8 X 10^4 CFU g^{-1}soil and the actinomycetes between 3-6 X 10^8 CFU g^{-1}soil. The results of biological analyses of soil samples from the village are presented in Table 6.

Table 4. Physical and chemical analysis details of soil samples from Kalliyur village

Sl. No	Parameter	Range of Values
1	Texture	Sandy loam-clay loam
2	Bulk Density (Mg m^{-3})	1.01-1.2
3	Water Holding Capacity (%)	28-32
4	CEC (cmols kg^{-1})	5-32
5	pH	3.2- 6.3
6	EC (dS m^{-1})	0.01-0.36
7	OC (g kg^{-1})	4.0-38.3
8	Available N (kg ha^{-1})	225.5-394.2
9	Available P (kg ha^{-1})	11.4-270.9
10	Available K (kg ha^{-1})	18-176
11	Exchangeable Ca (cmol kg^{-1})	1.5-6.0
12	Exchangeable Mg (cmol kg^{-1})	1.0-9.5
13	Available Sulphur (kg ha^{-1})	5-35
14	Available Zn (mg kg^{-1})	0.20-1.42
15	Available Mn (mg kg^{-1})	1.63-5.19
16	Available Fe (mg kg^{-1})	87.50-133.84
17	Available Cu (mg kg^{-1})	Traces-0.86
18	Hot Water Soluble Boron (mg kg^{-1})	0.01-0.8
19	Available Mo (mg kg^{-1})	Traces
20	Exchangeable Aluminium (mg kg^{-1})	10-19

Table 5. Descriptive statistics of soil chemical properties in Kalliyur village

Sl. No.	Soil properties	Min.	Max.	Mean	Median	SD	Kurtosis	Skewness
1	pH	3.20	6.30	4.75	4.80	0.66	0.48	-0.05
2	EC (dS m^{-1})	0.01	0.36	0.15	0.17	0.10	-0.54	0.26
3	OC (g kg^{-1})	4.0	38.30	14.8	9.5	1.7	-0.42	0.98
4.	Available N (kg ha^{-1})	225.50	394.20	288.05	278.30	57.42	-0.57	0.83
5	Available P (kg ha^{-1})	11.40	270.90	148.20	161.87	87.74	-0.13	0.14
6	Available K (kg ha^{-1})	18.00	176.00	112.32	106.00	52.87	-0.71	-0.34
7	Exchangeable Ca (cmol kg^{-1})	1.50	6.00	3.20	3.00	1.38	1.20	1.13
8	Exchangeable Mg (cmol kg^{-1})	1.00	9.50	4.00	3.50	2.42	0.90	1.18
9	Available Zn (mg kg^{-1})	0.22	1.42	0.60	0.60	0.28	2.21	1.30
10	Available Mn (mg kg^{-1})	1.63	5.19	3.67	4.08	1.11	-1.02	-0.46
11	Available Fe (mg kg^{-1})	87.50	133.84	97.73	94.89	12.58	2.77	1.97

4.2.2. Irrigation Water Analysis

The chemical analysis data of irrigation water samples collected from the village is presented in Table 7. The water source was the Vellayani Lake near to the fields. The water sample was slightly acidic in reaction with an acceptable limit of soluble salts. The chemical analysis revealed that there were very low concentrations of plant nutrients and aluminium in the sample.

4.3. FIELD EXPERIMENTS

The key component of SSNM experiment was measurement of economic 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 fertiliser doses for the Site Specific Nutrient Management Experiment.

For eliminating the locations giving extreme values, the results were arbitrarily grouped into three as given in the grouping chart (Table 8). The grouping chart showed that a number of samples fell into the two extreme groups thus that stressing the heterogeneity of the samples in the village. The sites which gave extreme values were eliminated and a location in the middle group (Group II) was selected for conducting omission trial.

4.3.1. Nutrient Omission Trial

Omission trial was laid out in a selected location of the village which came under Group II of the grouping chart. The treatments were (-) N, (-) P, (-) K, (+) NPK and (-) NPK. Before the omission trial, soil and water samples were collected and analyzed to get the initial fertility status of the site and quality of water. The initial physical and chemical analysis data are presented in the Table 9. Initial analysis showed that the soil of the experimental area was acidic in reaction and EC value was found safe. The initial WHC value was 29.18 per cent, bulk density was 1.31Mg m^{-3} and organic carbon was 7.16 g kg^{-1}. The initial available N status was medium (255.94 kg ha^{-1}), phosphorus was high (75.7 kg

Table 6. Microbial analysis of soil samples from the village

Sl. No.	Parameter	Range of values
1	Bacterial count	7-20 X 10^6 CFU g^{-1}soil
2	Fungal count	6 -8 X 10^4 CFU g^{-1}soil
3	Actinomycetes count	3-6 X 10^8 CFU g^{-1}soil
4	Dehydrogenase activity (μg TPF g^{-1}soil 24 h^{-1})	10-90

Table 7. Chemical analysis of the water samples from the village

Sl. No.	Parameter	Range of values
1	pH	6.1-6.5
2	EC (dS m^{-1})	0.100-0.215
3	N (mg kg^{-1})	2.1-6.9
4	P (mg kg^{-1})	0.092-0.160
5	K (mg kg^{-1})	2.1-6.1
6	Ca (mg kg^{-1})	2.2-6.2
7	Mg (mg kg^{-1})	4.0-6.1
8	Fe (mg kg^{-1})	0.01-0.09
9	Mn (mg kg^{-1})	0.10-0.15
10	Zn (mg kg^{-1})	0.01-0.04
11	Cu (mg kg^{-1})	Traces
12	Mo (mg kg^{-1})	Traces
13	Al (mg kg^{-1})	Traces

Table 8. Grouping chart of soils based on fertility status

Parameter	Classes and number of locations falling in each class		
	Group I	Group II	Group III
pH	<4	4-7	>7
No	2	48	Nil
EC No	All values below 0.36 dS m^{-1}		
OC ($g\ kg^{-1}$)	≤5.0	5.1-25	>25
No	2	42	6
Avail N ($kg\ ha^{-1}$)	<280	280-560	>560
No	27	23	Nil
Avail P ($kg\ ha^{-1}$)	<25	25-50	>50
No	4	Nil	46
Avail K ($kg\ ha^{-1}$)	<120	120-180	>180
No	12	38	Nil
Ca ($cmol\ kg^{-1}$)	<2	2-3.5	>3.5
No	4	34	12
Mg ($cmol\ kg^{-1}$)	<1.5	1.5-3.5	>5
No	5	29	16

ha^{-1}) and potassium was low (100 kg ha^{-1}). The exchangeable Ca was 2.2 cmol kg^{-1}, Mg was 1.22 cmol kg^{-1}, S was 28.14 kg ha^{-1}, the micronutrients like Fe showed high value (89.71 mg kg^{-1}), available Mn recorded medium status (2.36 mg kg^{-1}), Zn, B and Mo showed low status. The Al status was found high owing to the parent material. The initial microbial status revealed that the bacteria were predominant over fungi and actinomycetes. The dehydrogenase activity value was 21μgTPF g^{-1}soil 24h^{-1}.

The results of initial analysis of irrigation water used for omission trial are presented in Table 10. The initial analysis revealed that the water was slightly acidic but had safe limit of electrical conductivity. The mineral content of the irrigation water was very low.

4.3.1.1. Omission Trial on Growth Parameters

The growth parameters are shown in the Table 11. The omission trial on growth parameters revealed that the number of days to fruit harvest varied 2-3 days between treatments. The treatment (+) NPK took more time for harvest compared to control and other treatments. The P omission treatment took lowest time for harvest. Male flowers appeared first in the treatment T_5 (-NPK), followed by (–) K. The treatment (+) NPK showed the highest node number in case of male flower appearance. At the same time, in the case of female flower appearance the treatment T_4 (+NPK) recorded the lowest node number followed by treatment T_2 (-P) indicating that P omission had no effect in this growth parameter. In the case of length of vine the (+) NPK treatment recorded highest value followed by the P omission treatment. The lowest value was recorded by the absolute control. The N omission treatment also recorded low value compared to P and K omission treatments.

4.3.1.2. Omission Trial on Yield Parameters

The yield and yield attributes of bitter gourd is shown in Table 12. The number of fruits per plant was highest for the treatment T_4 (100 per cent NPK)

Table 9. Initial physical, chemical and biological properties of soil during omission trial

Sl. No.	Parameter	Range of values
1	Texture	Clay loam
2	Bulk Density (Mg m^{-3})	1.31
3	Water Holding Capacity (%)	29.18
4	CEC (cmols kg^{-1})	8.00
5	pH	5.71
6	EC (dS m^{-1})	0.025
7	OC (g kg^{-1})	7.16
8	Available N (kg ha^{-1})	255.94
9	Available P (kg ha^{-1})	75.70
10	Available K (kg ha^{-1})	100.00
11	Exchangeable Ca (cmol kg^{-1})	2.20
12	Exchangeable Mg (cmol kg^{-1})	1.22
13	Available Sulphur (kg ha^{-1})	28.14
14	Available Fe (mg kg^{-1})	89.71
15	Available Mn (mg kg^{-1})	2.36
16	Available Zn (mg kg^{-1})	0.49
17	Available Cu (mg kg^{-1})	0.46
18	Hot Water Soluble Boron (mg kg^{-1})	0.15
19	Available Mo (mg kg^{-1})	0.08
20	Exchangeable Aluminium (mg kg^{-1})	15.08
21	Bacterial count (10^6 CFU g^{-1}soil)	8
22	Fungal count (10^6 CFU g^{-1}soil)	6
23	Actinomycetes count (10^6 CFU g^{-1}soil)	4
24	Dehydrogenase activity (μgTPF g^{-1}soil $24h^{-1}$)	21

Table 10. Initial analysis of water sample used in omission trial

Parameter	Sample
pH	6.80
EC (dS m^{-1})	0.312
N (mg L^{-1})	4.70
P (mg L^{-1})	0.115
K (mg L^{-1})	5.10
Ca (mg L^{-1})	4.20
Mg (mg L^{-1})	3.70
Fe (mg L^{-1})	0.10
Mn (mg L^{-1})	0.14
Zn (mg L^{-1})	0.035
Cu (mg L^{-1})	Traces

followed by the treatment (-) P treatment. The lowest value was recorded by the absolute control. Average fruit weight was highest for the treatment (+) NPK, followed by P omission treatment. The fruit weight in K omission treatment was lower when compared to P omission but higher than N omission. The yield per plant was also the highest for the treatment T_4 followed by P omission trial. The N omission recorded lower values compared to the other omission treatments. The lowest value was recorded by the absolute control. The fruit length was the highest for the treatment T_4 followed by (-) P treatment. Here also the K omission treatment recorded a lower value compared to (-) N and (-) P. The lowest value was recorded by absolute control. The fruit girth also followed the same trend as that of fruit length. The highest value was recorded by the 100 per cent NPK (18.33 cm) treatment and the lowest value was registered by the absolute control (9.67 cm). The highest value was double the value of absolute control value.

4.3.1.3. Omission Trial on Quality Parameters

The quality attributes of bitter gourd fruits after omission trial are shown in the Table 13. The keeping quality of the fruits was found to be highest in the treatment T_1 followed by T_3. The beta carotene content was the highest for the treatment 100 per cent NPK (T_4) followed by the P omission treatment. The lowest value was recorded by absolute control. The vitamin C content also was the highest for the treatment T_4 followed by P omission treatment. The N omission treatment recorded lower value compared to other treatments. The lowest value was recorded by the treatment T_5 (absolute control). The highest value for iron content on fresh weight basis was recorded by the treatment T_4 followed by the P omission treatment. N omission recorded a lower value among the omission treatments but the lowest value was recorded by the absolute control. The crude protein content also was the highest for the 100 per cent NPK treatment followed by P omission. The lowest value was recorded by the absolute control.

Table 11. Omission trial on growth parameters of bitter gourd

Treatment	Number of days to fruit harvest	Node at which first male flower appears	Node at which first female flower appears	Length of vine (cm)
T_1	64.33	18.67	25.33	253.33
T_2	63.33	17.67	20.67	286.67
T_3	65.67	16.67	23.33	271.67
T_4	66.00	19.67	18.67	370.00
T_5	64.00	13.67	25.67	216.67
δ Values	δN_{max}	δN_{max}	δN_{max}	δL_{max}
T_1	1.7	1.0	6.7	116.7
T_2	2.7	2.0	2.0	83.3
T_3	0.3	3.0	4.7	98.3
T_5	2.0	6.0	7.0	153.3

δN_{max}, δL_{max} = deviation from maximum values

Table 12. Omission trial on yield and yield attributes of bitter gourd

Treatment	Number of fruits/plant	Average fruit weight (g)	Yield per plant (kg)	Fruit length (cm)	Fruit girth (cm)
T_1	13	180.00	2.43	18.67	14.67
T_2	14	213.33	3.77	19.00	16.67
T_3	12	208.33	2.52	17.67	13.67
T_4	17	281.67	4.73	22.67	18.33
T_5	11	140.00	1.37	15.00	9.67
δ Values	δN_{max}	δW_{max}	δY_{max}	δL_{max}	δG_{max}
T_1	4	101.7	2.3	4.0	3.7
T_2	3	68.3	1.0	3.7	1.7
T_3	5	73.3	2.2	5.0	4.7
T_5	6	141.7	3.4	7.7	8.7

δN_{max}, δW_{max}, δY_{max}, δL_{max}, δG_{max} = deviation from maximum values

Table 13. Omission trial on quality attributes of bitter gourd

Treatment	Keeping quality (Shelf Life in days)	Organoleptic Tests	Beta Carotene (μg 100 g^{-1})	Vitamin C (mg 100 g^{-1})	Iron (mg 100 g^{-1})	Crude protein content (%)
T_1	3.17	1.60	67.00	70.00	2.5	7.33
T_2	2.83	1.93	80.00	77.67	2.8	8.33
T_3	2.95	1.77	74.00	75.33	2.7	7.88
T_4	2.67	2.33	91.00	84.67	3.4	9.58
T_5	3.00	1.87	57.67	62.33	2.3	7.29

4.3.1.4. Omission Trial on Pests and Disease Scores

The results of pests and diseases scoring during omission trial are presented in Table 14. All other treatment recorded a same score of pest attack in omission trial experiment. The disease scoring revealed that the N omission trial and absolute control recorded lower values compared to other treatments.

4.3.1.5. Omission Trial on Dry Matter Production

The plant and fruit dry matter production in omission trial is presented in Table 15. In the case of per plant dry matter production, the highest value was recorded by the treatment T_4 followed by T_2 (P omission). The N omission trial recorded a lower value compared to 100 per cent NPK and P and K omission treatments. The lowest value was recorded by the treatment T_5. The plant dry matter production calculated on per hectare basis also showed the same trend as in the case of per plant DMP. The fruit dry matter production showed that the treatment T_4 produced highest amount of DM followed by P omission. The K and N omission treatments recorded a tremendous decrease in fruit dry matter production. The lowest value of fruit dry matter production was recorded by absolute control.

4.3.1.6. Omission Trial on Major and Secondary Nutrient Concentration in Plant Samples

The major and secondary nutrient content of the plant samples are presented in the table 16. The N content was highest in the 100 per cent NPK treated plants and lowest in the absolute control. The N omission trial also recorded a low value of plant N content. In the case of P content of plant tissue, the lowest value was recorded by absolute control followed by P omission. The highest value was recorded by the treatment 100 per cent NPK. The K, Ca, Mg

Table 14. Omission trial on pests and diseases of bitter gourd

Treatment	Pest scoring (Fruit fly)	Disease scoring(Mosaic)
T_1	3	1.0
T_2	3	1.3
T_3	3	1.3
T_4	4	1.3
T_5	3	1.0

Table 15. Omission trial on dry matter production in bitter gourd

Treatment	Fruit Dry matter production (g $plant^{-1}$)	Fruit Dry matter production (kg ha^{-1})	Plant dry matter production (g $plant^{-1}$)	Plant Dry matter production (kg ha^{-1})
T_1	152.08	380.21	250.50	626.25
T_2	235.42	588.54	305.03	762.58
T_3	157.29	393.23	254.00	635.00
T_4	295.83	739.58	365.67	914.17
T_5	85.42	213.54	188.00	470.00
δD_{max} values				
T_1	143.75	359.37	115.17	287.92
T_2	60.41	151.04	60.64	151.59
T_3	138.54	346.35	111.67	279.17
T_5	210.41	526.04	177.67	444.17

δD_{max}= deviation from maximum and S content of the plant tissue was highest for the treatment 100 per cent NPK. In the case of K the lowest value was recorded by the absolute control followed by K omission trial. Lowest contents of Ca, Mg and S were recorded by absolute control followed by N omission trial. In the case of all nutrients the absolute control recorded values lower than the plant critical values indicating the lower absorption of these nutrients.

4.3.1.7. Omission Trial on Micronutrient Concentration in Plant Samples

In the case of micronutrients in the plant tissues the treatment 100 per cent NPK recorded the highest values of all micronutrients. The Fe Mn, Zn and Mo contents of plant tissue were lowest in absolute control followed by N omission. In the case of Cu and B the lowest value was recorded by absolute control followed by P omission trial (Table 17).

4.3.1.8. Omission Trial on Major and Secondary Nutrient Concentration in Fruit Samples

The fruit sample analysis revealed that the N content was the highest in the treatment T_4 followed by (-) P treatment. The (-) NPK recorded the lowest value followed by N omission. The P content also was the highest in 100 per cent NPK treatment followed by K omission treatment. The lowest value was recorded by the treatment (-) NPK followed by P omission treatment. The K content was the highest in T_4 followed by N omission. The lowest value was recorded by T_5 followed by K omission treatment. The Ca, Mg and S content were the highest in the treatment T_4 and the lowest in absolute control. In the case of Ca and S content the K omission recorded a lower value than other omission treatments. In the case of Mg the N omission treatment recorded a lower value than other omission treatments (Table 18).

Table 16. Omission trial on major and secondary nutrients content in plant samples of bitter gourd, per cent

Treatment	N	P	K	Ca	Mg	S
T_1	2.05	0.16	2.47	2.13	0.82	0.16
T_2	2.35	0.14	2.40	2.30	0.79	0.18
T_3	2.42	0.18	1.93	2.13	0.85	0.17
T_4	2.62	0.20	2.70	2.37	0.93	0.20
T_5	1.73	0.12	1.67	1.95	0.73	0.11

Table 17. Omission trial on micronutrients concentration in plant samples of bitter gourd, mg kg^{-1}

Treatment	Fe	Mn	Zn	Cu	B	Mo
T_1	846.7	213.67	52.00	5.60	20.33	0.23
T_2	867.3	221.67	52.00	5.50	18.33	0.26
T_3	873.3	223.00	53.32	5.73	18.67	0.33
T_4	929.3	226.67	61.32	5.87	21.67	0.37
T_5	830.7	211.67	41.32	5.30	16.67	0.21

Table 18. Omission trial on major and secondary nutrients content in fruit samples of bitter gourd, per cent

Treatment	N	P	K	Ca	Mg	S
T_1	1.17	0.69	4.20	0.65	0.37	0.22
T_2	1.26	0.66	4.17	0.62	0.39	0.21
T_3	1.33	0.72	3.57	0.58	0.42	0.19
T_4	1.53	0.74	4.27	0.78	0.47	0.26
T_5	1.17	0.57	3.53	0.48	0.24	0.17

Table 19. Omission trial on micronutrient concentration in fruit samples of bitter gourd, mg kg^{-1}

Treatment	Fe	Mn	Zn	Cu	B	Mo
T_1	1016.00	23.74	26.00	4.60	15.33	0.08
T_2	1040.80	24.63	26.00	4.50	13.33	0.11
T_3	1048.00	24.78	26.67	4.73	13.67	0.18
T_4	1115.20	25.19	30.67	4.87	16.67	0.22
T_5	996.80	23.52	20.67	4.30	11.67	0.06

4.3.1.9. Omission Trial on Micronutrient Concentration in Fruit Samples

The micronutrient concentration of fruit samples revealed that the highest content was recorded by the treatment T_4 and the lowest value was recorded by the absolute control (Table 19). In the case of Fe, Mn, Zn and Mo the treatment N omission recorded a lower value compared to other omission treatments. In the case of Cu and B the treatment (-) P recorded a lower value than other omission treatments.

4.3.1.10. Omission Trial on Plant Uptake of Major and Secondary Nutrients

The uptake values of major and secondary nutrients by the bitter gourd plant are given in Table 20. The highest N uptake was found in the treatment T_4 followed by P omission. The lowest uptake was shown by the treatment T_5. In the case of P uptake by the plant the highest uptake was exhibited by the treatment 100 per cent NPK followed by the K omission. The N omission resulted in lower P uptake compared to other omission treatments. The lowest P uptake by plant was obtained in the absolute control.

The highest K uptake was found in T_4 followed by (-) P treatment. The K omission treatment had a lower value of K uptake than the other omission treatments. The lowest value was obtained in absolute control. In the case of Ca uptake the highest value was expressed in 100 per cent NPK treated plot. K omission showed a lower value of Ca uptake compared to other omission treatments. Absolute control recorded the lowest value of Ca uptake by the plant. In the case of Mg and S uptake, the highest value was observed in T_4 followed by P omission treatment. The lowest value was expressed in the absolute control plot.

4.3.1.11. Omission Trial on Plant Uptake of Micronutrients

The micronutrient uptake by the bitter gourd plants is given in Table 21. The uptake of micronutrients except Mo was highest in the 100 per cent NPK plot followed by P omission treatment. The N and K omission plots showed a lower value of micronutrient uptake, but the lowest value was obtained in the absolute

Table 20. Omission trial on plant uptake of major and secondary nutrients content in bitter gourd, kg ha^{-1}

Treatment	N	P	K	Ca	Mg	S
T_1	12.84	0.98	15.45	13.36	5.11	0.02
T_2	17.92	1.09	18.30	17.54	6.05	0.03
T_3	15.35	1.16	12.28	13.55	5.38	0.02
T_4	23.92	1.86	24.68	21.64	8.53	0.04
T_5	8.15	0.55	7.83	9.17	3.45	0.01

Table 21. Omission trial on plant uptake of micronutrients in bitter gourd, g ha^{-1}

Treatment	Fe	Mn	Zn	Cu	B	Mo
T_1	530.22	133.81	32.57	3.51	12.73	0.14
T_2	661.36	169.05	39.62	4.19	13.98	0.20
T_3	554.57	141.61	33.86	3.64	11.85	0.21
T_4	849.63	207.21	56.10	5:36	19.80	0.33
T_5	390.42	99.48	19.42	2.49	7.84	0.10

Table 22a. Omission trial on fruit uptake of major and secondary nutrients in bitter gourd, kg ha^{-1}

Treatment	N	P	K	Ca	Mg	S
T_1	4.46	2.61	15.97	2.47	1.42	1.0
T_2	7.42	3.90	24.52	3.63	2.28	1.4
T_3	5.24	2.84	13.89	2.29	1.66	1.1
T_4	10.16	4.92	28.27	5.19	3.11	1.8
T_5	2.49	1.22	7.62	1.03	0.52	0.5

Table 22b. Per cent contribution of fruit uptake of major and secondary nutrients to total

Treatment	N	P	K	Ca	Mg	S
T_1	25.79	72.70	50.83	15.60	21.75	98.04
T_2	29.27	78.16	57.26	17.15	27.37	97.90
T_3	25.47	71.00	53.08	14.46	23.58	98.21
T_4	29.81	72.57	53.39	19.34	26.72	97.83
T_5	23.42	68.93	49.32	10.10	13.10	98.04

control. In the case of Mo the highest value was noticed in the treatment T_4 followed by K omission treatment. Here also the lowest value was recorded in the absolute control plot.

4.3.1.12. Omission Trial on Uptake of Major and Secondary Nutrients by Fruit

The fruit uptake of major and secondary nutrients is presented in Table 22a. The uptake of all major and secondary nutrients showed that 100 per cent NPK treatment recorded the highest value followed by the P omission treatment. In the case of N uptake, values in N omission treatment were lower than the other omission treatments but P uptake was found to be the highest in P omission treatment. Potassium omission treatment recorded a lower value of K uptake by fruits than the other omission treatments. In the case of Ca the K omission recorded a lower value than the other omission treatments while N omission recorded a lower value of Mg and S uptake than other omission treatments. The per cent contribution of fruit uptake of N and Ca to total was the highest in (+) NPK. For all others, this was the highest in treatment (-) P (Table 22b).

4.3.1.13. Omission Trial on Fruit Uptake of Micronutrients

The uptake of all micronutrients by the fruits showed that the (+) NPK treatment recorded the highest value and the absolute control recorded the lowest value. The treatment (-) P recorded a higher value of micronutrient uptake in comparison to other omission treatments (Table 23a). The percent contribution of fruit uptake of micronutrients was the highest in T_2 followed by (+) NPK (Table 23b).

4.3.1.14. Omission Trial on Biological Properties of Soil

The microbial count and dehydrogenase activity are presented in Table 24. The absolute control recorded the lowest value of bacterial, fungal and actinomycetes population after omission trial. The 100 per cent NPK treated plots showed comparatively high microbial population. The other omission trials recorded slightly lower values than the 100 per cent NPK. The dehydrogenase

Table 23a. Omission trial on fruit uptake of micronutrients in bitter gourd, g ha^{-1}

Treatment	Fe	Mn	Zn	Cu	B	Mo
T_1	257.53	28.52	4.18	1.75	6.08	0.02
T_2	408.37	47.67	7.06	2.59	8.24	0.09
T_3	274.74	32.64	4.33	1.89	5.51	0.08
T_4	492.55	57.64	8.61	3.31	11.26	0.17
T_5	124.17	15.16	1.71	0.90	2.56	0.01

Table 23b. Per cent contribution of fruit uptake of micronutrients to total

Treatment	Fe	Mn	Zn	Cu	B	Mo
T_1	32.69	17.57	11.37	33.27	32.32	12.50
T_2	38.18	22.00	15.12	38.20	37.08	31.03
T_3	33.13	18.73	11.34	34.18	31.74	27.59
T_4	36.70	21.76	13.31	38.18	36.25	34.00
T_5	24.13	13.22	8.09	26.55	24.62	9.09

Table 24. Omission trial on microbial count and dehydrogenase activity

Treatments	Bacterial count $10^6 CFUg^{-1}$soil	Fungal count $10^4 CFUg^{-1}$soil	Actinomycetes count $10^8 CFUg^{-1}$soil	Dehydrogenase activity ($\mu gTPFg^{-1}$ soil)
T_1	7	6	4	18.00
T_2	8	6	5	20.4
T_3	8	7	5	22.00
T_4	9	7	6	27.50
T_5	6	5	4	16.00

Table 25. Effect of omission trial on physical and chemical properties of soil

Treatment	pH	EC (dS m^{-1})	WHC (%)	BD (Mg m^{-3})	OC (g kg^{-1})
T_1	5.37	0.04	2.66	1.29	6.7
T_2	5.27	0.03	2.70	1.34	8.1
T_3	5.43	0.04	2.74	1.28	6.8
T_4	5.23	0.06	2.64	1.32	9.3
T_5	5.53	0.03	2.78	1.26	6.3

activity was the highest for the treatment T_4 followed K omission. The lowest value was recorded by the absolute control.

4.3.1.15. Omission Trial on Physical and Chemical Properties of Soil

The physical and chemical properties of the soil samples after omission trial are presented in Table 25. The 100 per cent NPK treated plots showed lowest pH (5.23) compared to other treatments. The absolute control recorded the highest pH value (5.53) followed by the K omission. The electrical conductivity was highest for the treatment T_4 followed by T_1 (N omission) and T_3 (K omission). The lowest value of EC was recorded by absolute control and P omission.

The water holding capacity was found to be highest for the treatment absolute control followed by K omission trial. The lowest WHC was recorded by the treatment T_4 (100 per cent NPK). The bulk density varied from 1.26 to 1.34 Mg m^{-3} between the treatments. The highest value of BD was recorded by the P omission treatment followed by the 100 per cent NPK treatment. The lowest value was recorded by absolute control. The organic carbon content varied from 0.63 to 0.93 per cent between the treatments. The highest value was recorded by the treatment T_4 followed by (-) P. Here also the lowest value was recorded by the treatment T_5.

4.3.1.16. Omission Trial on Available Major and Secondary Nutrients

The available major and secondary nutrients concentration are presented in Table 26. The available N varied from 148.73 to 213.60 kg ha^{-1}. The highest available N status was recorded by 100 per cent NPK treatment followed by P omission trial. The N omission trial and absolute control recorded lower values of available N. The available P content ranged from 27.50 to 76.33 kg ha^{-1} in the different treatments. The highest value of available P was recorded by the treatment T_4 followed by K omission. The absolute control and P omission treatments showed lower values of available P. In the case available K the highest value was recorded by the treatment T_4 followed by N omission. The lowest value

Table 26. Effect of omission trial on available major and secondary nutrients in soil

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	S (kg ha^{-1})
T_1	163.82	51.00	154.47	1.80	1.73	22.29
T_2	198.30	38.33	116.23	2.13	1.77	19.36
T_3	167.60	55.00	63.77	2.07	1.67	20.13
T_4	213.60	76.33	185.03	2.20	1.83	23.07
T_5	148.73	27.50	41.14	1.40	1.30	16.07

Table 27. Effect of omission trial on available micronutrient status of soil, mg kg^{-1}

Treatment	Fe	Mn	Zn	Cu
T_1	87.50	2.70	0.36	0.46
T_2	90.30	2.90	0.38	0.47
T_3	94.03	2.70	0.38	0.48
T_4	91.80	2.67	0.39	0.52
T_5	84.93	2.37	0.25	0.41

was recorded by the treatment absolute control. The exchangeable Ca and Mg showed the highest value for 100 per cent NPK treatment followed by P omission. The lowest values were recorded by the absolute control plot. The available sulphur varied between 16.07 to 23.07 kg ha^{-1} in treatments.

4.3.1.17. Omission Trial on Available Micronutrients

The available Fe content varied from 84.93 to 94.03 mg kg^{-1} in the treatments. The lowest value of available Fe was recorded by absolute control followed by the N omission treatment. The highest value was recorded by K omission followed by 100 per cent NPK treatment. The available Mn content ranged between 2.37 and 2.90 mg kg^{-1} in the different treatments. The highest value of available Mn was recorded by P omission treatment followed by N omission and K omission treatments. The 100 per cent NPK treatment recorded a lower value of available Mn than the other omission treatments. The available Zn varied from 0.25 to 0.39 mg kg^{-1}. The highest value of available Zn (0.39 mg kg^{-1}) was recorded by the treatment T_4 followed by P and K omission treatments. The lowest value was obtained for the treatment absolute control. The copper content of the soil varied from 0.41 to 0.52 mg kg^{-1} between treatments. Here the highest value was shown by the 100 per cent NPK treatment and the lowest by absolute control (Table 27).

The available status of boron, molybdenum and exchangeable aluminium are presented in the Table 28. The available hot water soluble boron concentration ranged from 0.11 to 0.14 mg kg^{-1}. The highest value was expressed by the treatments T_3 and T_4 and the lowest value was obtained in absolute control. The exchangeable aluminium content varied from 13.67 to 15.53 mg kg^{-1} in different treatments. The highest value was recorded by the treatment 100 per cent NPK followed by N omission. The lowest value was shown by the treatment absolute control.

Table 28. Effect of omission trial on micronutrient and Al status, mg kg^{-1}

Treatment	Available B	Available Mo	Exchangeable Al
T_1	0.12	0.03	15.27
T_2	0.13	0.03	14.33
T_3	0.14	0.03	14.23
T_4	0.14	0.04	15.53
T_5	0.11	0.03	13.67

Table 29. Irrigation water analysis after omission trial

Parameter assessed	Sample
pH	6.90
EC (dS m^{-1})	0.295
N (mg L^{-1})	4.50
P (mg L^{-1})	0.10
K (mg L^{-1})	4.30
Ca (mg L^{-1})	4.00
Mg (mg L^{-1})	5.00
Fe (mg L^{-1})	0.05
Mn (mg L^{-1})	0.11
Zn (mg L^{-1})	0.05
Cu (mg L^{-1})	traces
Mo(mg L^{-1})	traces

4.3.1.18. Irrigation Water Analysis Data after Omission Trial

The data on irrigation water analysis after the omission trial is presented in Table 29. The pH of the water sample was almost neutral and had safe limit of soluble salts. The mineral nutrient concentration in the water samples were also low and in the safe limits. Heavy metals were present in trace amounts only.

4.3.2. SSNM Experiment

Based on the bitter gourd yield and uptake data collected from different sources of literature, 3 graphs were plotted by taking yield on Y axis and uptake of N, P and K on the X axis to obtain the values of minimum and maximum dilution for the above three nutrients. The values obtained for N were 125 and 279, for P it was 400 and 1111.1 and for K the values were 79 and 242. The indigenous nutrient supply was obtained from the omission trial as INS 41.5, IPS 9.8, IKS 64.5 and recovery efficiency were 0.34 for nitrogen, 0.23 for phosphorus and 0.30 for potassium. These parameters were utilized for formulating the QUEFT recommendation. Graphical representation is presented in Fig 4.

On the basis of the information obtained from field survey, literature and also from the data from omission trial experiment, the site specific nutrient recommendations were formulated for two yield targets in bitter gourd *viz.,* medium yield (16 t ha^{-1}) and high yield (27 t ha^{-1}). The SSNM recommendations with secondary and micronutrients were compared to the KAU package and practices as well as the farmers' practices. Here both foliar and soil application of micronutrients with SSNM recommendations included as treatments. The details of the experiment are presented in the following pages.

4.3.2.1. SSNM on Plant Growth Parameters

The plant growth parameters during the SSNM experiment are presented in Table 30. Among the growth parameters, length of vine was found to be significantly different between treatments. The highest value was obtained for the treatment T_5 (467.67 cm), but it was on a par with the treatment T_7. The value

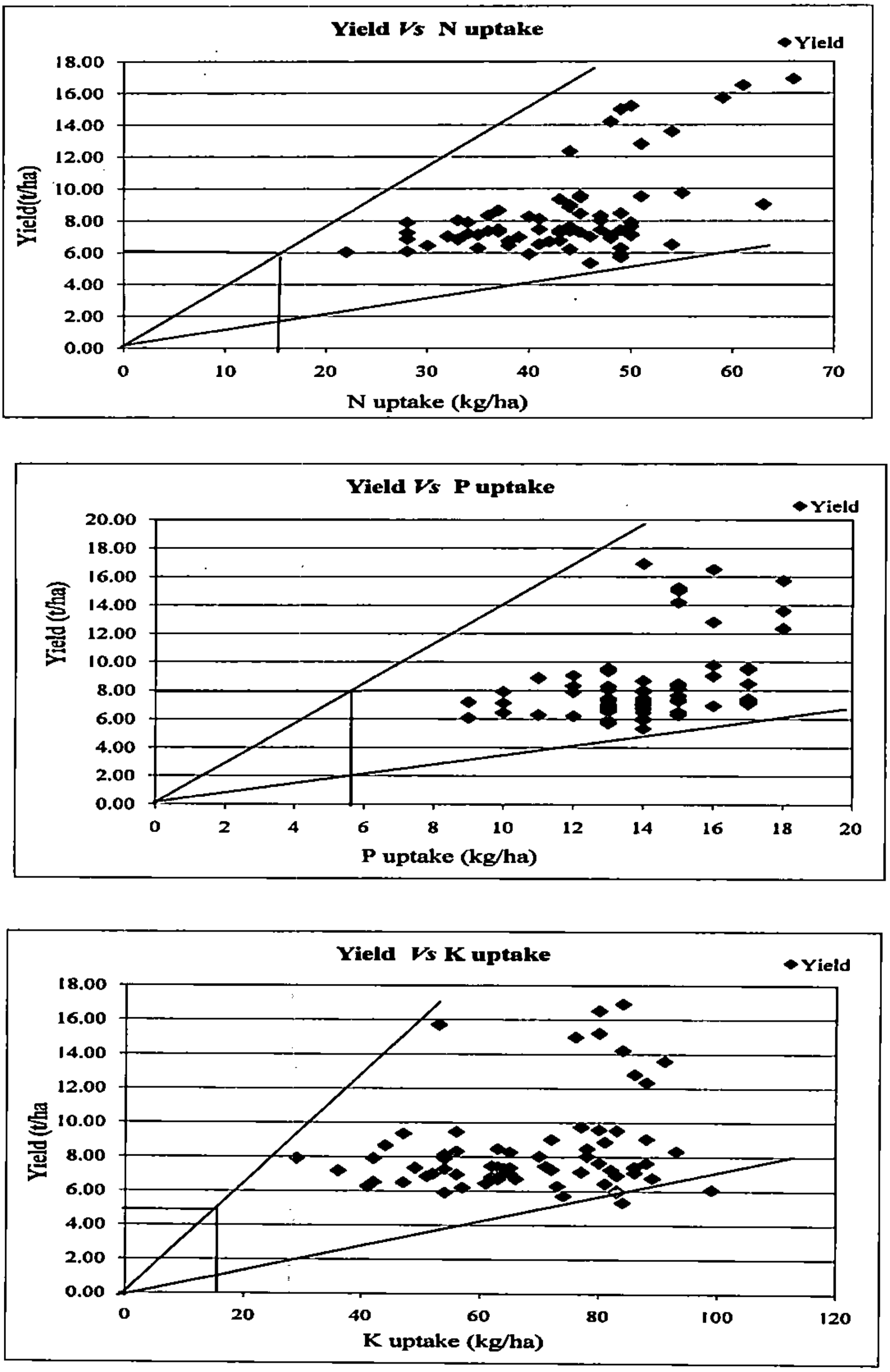

Fig. 4. Yield *Vs* nutrient uptake

Table 30. Effect of SSNM treatments on plant growth parameters

Treatments	Length of vine (cm)	Node at which first male flower appears	Node at which first female flower appears	Number of days to fruit harvest
T_1	423.33	13.33	19.33	64.33
T_2	464.00	13.67	18.67	63.33
T_3	452.00	13.67	19.67	63.00
T_4	421.67	12.67	18.33	63.00
T_5	467.67	15.00	20.33	65.00
T_6	415.67	13.00	18.33	66.33
T_7	466.33	15.00	19.33	63.33
T_8	311.00	15.67	22.33	63.67
T9	357.67	16.67	22.00	65.00
T_{10}	197.00	19.67	25.33	64.00
C.D.	19.83	0.96	1.03	N/A
SE(m)	6.62	0.32	0.34	0.89
SE(d)	9.37	0.46	0.48	1.25
C.V.	2.88	3.76	2.91	2.39

obtained in treatment T_1 (RDF) was significantly lower compared to the SSNM treatments for medium and high yield targets. Those of farmers' practices (T_8 and T_9) were significantly lower than the RDF as well as the SSNM treatments. The lowest value was recorded by the treatment absolute control (T_{10}). It was found that the treatments with the same dose of fertilisers but different method of application were on a par with each other in the case of length of vine. The node at which first male flower appeared (Table 30) was found significantly different with soil application of micronutrients recorded the lowest number of node where the first male flower appeared. This is followed by T_6 having the same between treatments. The treatments T_1, T_2 and T_3 recorded slightly higher numbers than T_6 but all were on par with each other. The highest number was recorded by the treatment absolute control (T_{10}) followed by farmers' practices (T_8 and T_9). But the SSNM recommendation with high yield targets (T_5 and T_7) recorded values on par with farmers' practices.

The node at which first female flower appeared was also showed significant difference between treatments. The lowest number of node at which female flower appeared was recorded by the treatments T_4 and T_6 followed by T_2. The values recorded by the treatments T_1, T_2 and T_3 did not show any significant difference between each other. The highest value was recorded by the treatment T_{10} followed by farmers' practice-1 (T_8). The number of days to fruit harvest did not show significant difference between treatments. The lowest number of days to fruit harvest was recorded by the treatments T_3 and T_4 followed by T_2. The highest number of days taken for harvest was recorded by the treatment T_6 followed by T_9 and T_5.

4.3.2.2. SSNM on Fruit Characters

The data on fruit characters are recorded in Table 31. The number of fruits per plant was found significantly different between treatments. The highest number of fruits per plant was recorded by the treatment T_7 followed by T_6. All the SSNM treatments recorded a high number of fruits per plant compared to the

Table 31. Effect of SSNM treatments on fruit characters

Treatments	Number of fruits/plant	Fruit length (cm)	Fruit girth (cm)
T_1	24.33	22.73	18.50
T_2	27.67	24.97	20.17
T_3	31.33	23.00	19.10
T_4	37.33	24.73	20.50
T_5	40.00	26.50	21.00
T_6	47.67	23.13	20.33
T_7	52.00	23.73	20.73
T_8	17.67	18.83	12.20
T9	24.00	19.83	13.07
T_{10}	15.00	16.17	10.50
C.D.	4.02	2.16	2.53
SE(m)	1.34	0.72	0.85
SE(d)	1.90	1.02	1.20
C.V.	7.34	5.58	8.31

recommended practices as well as farmers' practices. It was found that the treatments where micronutrients were foliar applied, recorded more number of fruits than the soil application of micronutrients. The farmers' practices recorded a lower number of fruits per plant compared to SSNM and recommended practices. The fruit length showed significant difference between treatments (Table 31. The fruit length was maximum for the treatment T_5 followed by T_2. Significant difference between soil and foliar application of micronutrients was observed in both the SSNM treatments for high yield and medium yield. Higher values were obtained for soil application of micronutrients. The farmers' practices showed significantly lower values compared to SSNM treatments. The recommended practices (RDF) recorded higher values compared to FPs. The lowest value was observed in absolute control.

The fruit girth in the SSNM experiment is presented in Table 31. The values were significantly different between treatments. The highest value was recorded by the treatment T_5 followed by T_7 but was on a par with each other. The soil and foliar application of micronutrients did not show significant difference. But the recommended practice (T_1) showed significantly higher value compared to FPs. The lowest value was recorded by the treatment absolute control.

4.3.2.3. SSNM on Yield and Yield Attributes

The average fruit weight was significantly different due to treatments (Table 32). The highest value of average fruit weight was recorded by the treatment T_5, followed by T_7. The SSNM treatments for medium yield target did not show significant difference in average fruit weight. The farmers' practices showed a significantly lower value of average fruit weight compared to the SSNM treatments and the recommended practices (RDF). The lowest value of average fruit weight was recorded by absolute control.

Yield per plant was significantly different between the treatments (Table 32). The highest yield per plant was recorded by the treatment T_5 followed by T_7. The yield per plant for the two SSNM treatments for medium yield target were on

Table 32. Effect of SSNM treatments on yield and yield attributes of bitter gourd

Treatments	Average fruit weight (g)	Yield per plant (kg)	Fruit yield (t ha^{-1})
T_1	166.58	4.06	10.16
T_2	178.86	5.43	13.58
T_3	176.90	4.44	11.10
T_4	183.48	8.55	21.37
T_5	206.05	9.89	24.73
T_6	181.80	7.82	19.56
T_7	189.57	9.10	22.74
T_8	131.95	1.95	4.87
T_9	150.36	2.83	6.57
T_{10}	28.27	0.39	0.98
C.D.	13.96	0.74	1.90
SE(m)	4.66	0.25	0.63
SE(d)	6.59	0.35	0.90
C.V.	5.07	7.81	8.09

par, but it is interesting to note that soil application of micronutrients gave higher yield compared to the foliar application. The SSNM treatments for high yield targets recorded double yield compared to the recommended practice (T_1). The FPs recorded a less yield per plant compared to SSNM and recommended practices. However, the lowest value (0.39 kg) was recorded by the absolute control. The yield per hectare showed a similar trend since they were calculated from yield per plant. The highest value recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium targets also recorded significantly higher yield compared to the recommended practices and the farmers' practices.

4.3.2.4. SSNM on Dry Matter Production

The data on plant and fruit dry matter production is presented in Table 33. The plant and fruit dry matter production were found significantly different between treatments. In the case of plant dry matter production the highest value was recorded by the treatment T_5 followed by T_7. The farmers' practices recorded a lower value of plant dry matter production compared to the recommended practices. The SSNM treatments with soil application of micronutrients were significantly different from corresponding treatments with foliar application of micronutrients. But the RDF treatments T_2 and T_3 were not significantly different from each other even though they received the same dose of nutrients but different application methods. The lowest value was recorded by the absolute control treatment.

In the case of fruit dry matter production the highest value was recorded by the treatment T_5 followed by T_7. Here also the soil application of micronutrients had resulted in accumulation of more dry matter than the foliar application. The SSNM treatments with high yield targets were significantly different from each other but those with medium yield targets were on par in the case of fruit dry matter production. The farmers' practices recorded a lower value of fruit dry matter production compared to the recommended practices as well as the SSNM treatments.

Table 33. Effect of SSNM treatments on dry matter production

Treatments	Plant DMP (g plant^{-1})	Plant DMP (kg ha^{-1})	Fruit DMP (g plant^{-1})	Fruit DMP (kg ha^{-1})
T_1	403.96	1009.90	253.96	634.90
T_2	644.17	1610.42	339.58	848.96
T_3	598.96	1497.40	277.50	693.75
T_4	592.25	1480.63	447.50	1118.75
T_5	741.46	1853.65	578.13	1445.31
T_6	588.83	1472.08	443.36	1108.40
T_7	678.54	1696.35	528.54	1321.35
T_8	231.67	579.17	121.67	304.17
T_9	286.67	716.67	164.17	410.42
T_{10}	134.38	335.94	24.38	60.94
C.D.	37.02	92.55	24.73	61.82
SE(m)	12.37	30.91	8.26	20.65
SE(d)	17.49	43.72	11.68	29.20
C.V.	4.37	4.37	4.50	4.50

4.3.2.5. SSNM on Quality Attributes of Bitter Gourd

The data on quality attributes of bitter gourd fruits are presented in Table 34. The keeping quality of the fruits was found significantly different between treatments. Highest keeping quality was showed by the treatment T_4 followed by T_6 but they were on par. The SSNM treatments showed high keeping quality than the recommended practices. The lowest value of keeping quality of fruits were shown by the treatment T_9 (FP-2) followed by T_8 (FP-1). The organoleptic tests conducted revealed that the scores obtained were significantly different between treatments. The highest score was obtained for the treatment T_4 followed by T_6 but were on par with each other. The treatments SSNM for high yield target with foliar application of micronutrients recorded a significantly low value of organoleptic scores compared to control. Similarly the recommended practice (T_1) also recorded a lower score which also had significant difference with control.

The beta carotene content was found significantly different between treatments (Table 34). The highest value was shown by the treatment T_7 followed by T_5 but were on par. The SSNM treatments for medium yield targets recorded a lower value compared to SSNM with high yield targets and the recommended practices. Farmers' practices also recorded significantly lower values compared to the other treatments and control. Vitamin C values were found to be significantly different between treatments. The highest value was recorded by the treatment T_5 followed by T_7 but they were on par with each other. The values for SSNM treatments (medium yield target) were also not significantly different from each other. But that of recommended practices (T_1) was found to be significantly lower compared to other treatments except farmers' practices and control.

The iron and crude protein content of plant and fruits are presented in Table 35. Iron contents of fresh fruits were significantly different between treatments. The highest value was recorded by the treatments T_6 and T_7 followed by T_3 where the foliar application of micronutrients was done but were on par with each other. The soil application of micronutrients recorded significantly low

Table 34. Effect of SSNM treatments on quality attributes of bitter gourd

Treatments	Keeping quality (Shelf Life in days)	Organoleptic Tests scores	Beta Carotene ($\mu g\ 100^{-1}$)	Vitamin C (mg $100g^{-1}$)
T_1	3.83	2.33	94.67	92.67
T_2	4.00	3.43	96.67	94.67
T_3	4.33	3.33	93.67	93.33
T_4	5.17	3.63	91.67	91.33
T_5	4.50	2.93	97.67	97.67
T_6	4.83	3.57	90.33	90.33
T_7	4.67	2.60	100.33	96.00
T_8	3.67	2.17	84.67	83.67
T_9	3.33	2.03	85.67	82.67
T_{10}	3.83	2.87	57.67	60.33
C.D.	0.78	0.16	3.29	1.77
SE(m)	0.26	0.05	1.10	0.59
SE(d)	0.37	0.08	1.56	0.84
C.V.	10.63	3.24	2.13	1.16

values of iron content in fresh fruits compared to the foliar application. The farmers' practices also recorded a lower value which was significantly different from the other treatments and control. The lowest value was recorded by the absolute control.

Significant difference between treatments was observed in the crude protein content (Table 35) of both plant and fruits. The highest value was recorded by the treatment T_5 followed by T_7, but the values of the two SSNM treatments for high yield were on a par. The treatments T_4 and T_6 recorded significantly lower values compared to other treatments except farmers' practices and control. The crude protein content of fruit samples also showed the same trend

4.3.2.6. SSNM on Major and Secondary Nutrients Concentration in Bitter Gourd Plant

The data on major and secondary nutrients in the bitter gourd plant is presented in Table 36. The N content varied from 1.45 to 3.13 per cent. The values were significantly different between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The N content in SSNM treatments with medium yield target was significantly lower than those of high yield targets. But the recommended practice (T_1) showed significantly higher plant N content compared to SSNM treatments with medium yield targets (T_4 and T_6). The FPs recorded significantly lower nitrogen content than other practices except control. The P content in plant also showed significant difference between treatments (Table 36). The highest value was recorded by the treatment T_7 followed by T_5. The P values of SSNM treatments for medium yield targets and the RDF were on a par. The lowest value was recorded by the treatment absolute control. The farmers' practices (T_8 and T_9) recorded the same value for phosphorus content of plant.

The data on potassium content of plant is presented in Table 36. The values were significantly different due to treatments. The highest value was recorded by the treatment T_5 followed by T_7. The treatments with soil application

Table 35. Effect of SSNM treatments on iron and crude protein content of bitter gourd

Treatments	Iron (mg $100g^{-1}$)	Crude protein content of plant (%)	Crude protein content of fruit (%)
T_1	3.60	17.71	9.79
T_2	3.93	18.02	10.11
T_3	4.87	18.23	10.05
T_4	3.83	15.75	9.65
T_5	4.23	19.59	10.44
T_6	4.93	15.94	9.53
T_7	4.93	19.07	10.32
T_8	3.43	15.31	8.65
T_9	3.33	15.31	8.49
T_{10}	2.37	9.06	5.31
C.D.	0.27	0.68	0.26
SE(m)	0.09	0.23	0.09
SE(d)	0.13	0.32	0.12
C.V.	3.97	2.41	1.60

of micronutrients showed comparatively high K content than the corresponding treatments with foliar application. The farmers' practices showed significantly lower values compared to the RDF and the SSNM treatments. The data on Ca content of plant was significantly different due to treatments (Table 36). The treatments with Ca supply showed comparatively higher values than those without Ca supply. The SSNM treatments with high and medium yield targets recorded significantly higher values than the recommended practice (T_1). The highest value of Ca content in plant tissue was recorded by the treatment T_5 followed by T_7. The FPs recorded significantly lower values of Ca than other practices except control.

The Mg content of plant tissue of bitter gourd was found to be significantly different due to treatments (Table 36). The values varied between 0.49 to 1.39 per cent. The highest value was recorded by the treatment T_5 followed by T_7. The treatments with Mg supply showed significantly higher values compared to those without Mg supply. The FPs showed significantly lower values than the RDF (T_1). The lowest value was recorded by the treatment absolute control. The sulphur content of plant is presented in Table 36. The sulphur content of plant varied from 0.13 to 0.27 per cent. The highest value was recorded by T_7 followed by T_5. The two SSNM treatments with medium yield target recorded the same value for plant sulphur content. The treatments with sulphur supply showed significantly higher content of sulphur in the plant tissue than those without sulphur supply. The absolute control showed the lowest amount of plant sulphur content among all the treatments.

4.3.2.7. SSNM on Micro Nutrients Concentration in Bitter Gourd Plant

The effect of SSNM on plant micronutrient concentration is presented in Table 37. The plant content of iron showed significant difference between treatments. The values varied from 770 to 1236 mg kg^{-1} between treatments. The highest value was recorded by the treatment T_7 followed by T_6 but were on par. The treatments with foliar application of micronutrients showed significantly higher values compared to the soil application of nutrients. The SSNM treatments

Table 36. Effect of SSNM treatments on major and secondary nutrients concentration in bitter gourd plant, per cent

Treatments	N	P	K	Ca	Mg	S
T_1	2.83	0.24	2.53	2.22	1.05	0.14
T_2	2.88	0.25	2.60	2.26	1.23	0.23
T_3	2.92	0.25	2.57	2.24	1.21	0.20
T_4	2.52	0.25	2.67	2.33	1.18	0.25
T_5	3.13	0.27	2.73	2.58	1.39	0.26
T_6	2.55	0.26	2.63	2.27	1.17	0.25
T_7	3.05	0.29	2.70	2.53	1.28	0.27
T_8	2.45	0.22	2.37	1.99	0.53	0.14
T_9	2.45	0.22	2.33	2.22	0.58	0.16
T_{10}	1.45	0.20	1.63	1.84	0.49	0.13
C.D.	0.11	0.02	0.15	0.07	0.03	0.01
SE(m)	0.04	0.01	0.05	0.02	0.01	0.00
SE(d)	0.05	0.01	0.07	0.03	0.01	0.00
C.V.	2.40	4.05	3.52	1.77	1.46	2.10

with soil application of micronutrients for medium and high yield showed significant difference in iron content of plant. The RDF (T_1) also showed significant difference with FPs (T_8 and T_9). Absolute control recorded the lowest value of iron content of plant.

Data on Mn content of plant tissue is recorded in Table 37. The manganese content of plant tissues showed significant difference between treatments. The treatment T_7 recorded highest value of plant Mn followed by T_6. The values varied between 221 and 361 mg kg^{-1}. The lowest value was recorded by the treatment T_{10} followed by T_1. The soil application of micronutrients recorded comparatively lower values of manganese content in plant than the foliar application. The RDF (T_1) did not show significant difference in Mn content of plant with absolute control. The plant zinc content values are presented in Table 37. The Zn content varied from 52 to 88 mg kg^{-1} between treatments. The highest Zn content was recorded by the treatment T_7 followed by T_6 but were on par. The treatments with foliar application showed significantly higher values of zinc in plant than those with soil application of zinc. The RDF did not show significant difference in zinc content of plant with T_9 (FP-2). The lowest value of plant zinc content was recorded by absolute control. The copper content of plant showed significant difference due to treatments (Table 37). The highest value was recorded by T_7 followed by T_6. The SSNM treatments with soil application of micronutrients for medium and high yield targets did not show significant difference between treatments. The absolute control (6.03 mg kg^{-1}) did not show significant difference in Cu content of plant with treatments T_4 and T_5.

The boron content of bitter gourd plant tissue is presented in Table 37. The values showed significant difference between treatments. The highest value of plant boron was recorded by the treatment T_7 followed by T_6 but were on par. The foliar application treatments (T_3, T_6 and T_7) showed significantly higher values than the soil application treatments (T_2, T_4 and T_5). The treatment T_8 (FP-1) did not show significant difference with absolute control. The RDF showed significantly lower value of boron content than the other treatments except T_8, T_9

Table 37. Effect of SSNM treatments on micronutrients concentration in bitter gourd plant, mg kg^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo
T_1	929.33	226.67	61.00	5.73	21.00	0.33
T_2	1052.67	246.67	75.00	5.57	24.67	0.86
T_3	1217.33	344.00	83.00	6.17	30.67	0.88
T_4	1160.00	302.00	78.00	6.07	23.33	1.23
T_5	1188.00	334.00	79.00	6.10	28.33	1.87
T_6	1234.00	355.33	86.00	6.27	31.33	1.07
T_7	1236.67	361.33	88.00	6.53	31.67	1.70
T_8	990.00	323.33	56.00	5.97	11.67	0.35
T_9	949.33	245.67	61.00	5.17	19.33	0.20
T_{10}	770.00	221.67	52.00	6.03	10.67	0.18
C.D.	14.14	4.62	3.64	0.10	1.15	0.12
SE(m)	4.72	1.54	1.22	0.03	0.38	0.04
SE(d)	6.68	2.18	1.72	0.05	0.54	0.06
C.V.	0.76	0.90	2.93	0.92	2.85	7.71

and T_{10}. The plant molybdenum content is presented in Table 37. The values ranged between 0.18 and 1.87 mg kg^{-1}. The treatment T_1 recorded a low value compared to T_8 (FP-1) but were on par. The lowest value of plant molybdenum was recorded by absolute control treatment.

4.3.2.8. SSNM on Major and Secondary Nutrients Concentration in Bitter Gourd Fruit

The data on major and secondary nutrient concentration of nutrients in bitter gourd fruits are presented in Table 38. The N content of fruits was found to be significantly different due to treatments. The SSNM treatments with medium yield targets recorded significantly lower values compared to T_2 and T_3 treatments. The farmers' practices also recorded significantly lower values than the other treatments except control. The lowest value of fruit N content was recorded by absolute control. Compared to plant tissues the fruit sample recorded a high value of phosphorus content (Table 38). The highest value of fruit phosphorus was recorded by the treatment T_7 followed by T_5 and T_6 but were on par. The treatment T_4 showed lower phosphorus content in fruit than other SSNM treatments. The SSNM treatments recorded significantly higher values than the other treatments. The lowest value was recorded by absolute control treatment.

Fruit K concentration also was comparatively higher than the plant K content (Table 38). The values ranged between 3.50 to 4.50 per cent. The values were significantly different due to treatments. The SSNM treatment with medium yield targets showed same value of K content in fruit sample. The treatment T_2 showed lower values compared to the SSNM treatments with high yield targets. The farmers' practices also reported low Mg content in fruits than the RDF (T1). The sulphur content of fruit sample is presented in Table 38. The values showed significant difference between treatments. The highest value was showed by the treatments T_5 and T_7 followed by T_4. The treatment T_1 (RDF) recorded the same value of sulphur content as that of treatment T_8 (FP-1). The SSNM treatments

Table 38. Effect of SSNM treatments on major and secondary nutrients concentration in bitter gourd fruit, per cent

Treatments	N	P	K	Ca	Mg	S
T_1	1.57	0.74	4.20	0.76	0.37	0.29
T_2	1.62	0.76	4.27	0.85	0.43	0.32
T_3	1.61	0.76	4.23	0.83	0.41	0.31
T_4	1.54	0.78	4.43	0.89	0.46	0.37
T_5	1.67	0.79	4.47	0.95	0.54	0.38
T_6	1.53	0.79	4.43	0.86	0.46	0.35
T_7	1.65	0.80	4.50	0.93	0.52	0.38
T_8	1.38	0.69	4.03	0.72	0.29	0.29
T_9	1.36	0.65	3.97	0.65	0.27	0.28
T_{10}	0.85	0.57	3.50	0.50	0.21	0.24
C.D.	0.04	0.02	0.15	0.05	0.04	0.01
SE(m)	0.01	0.01	0.05	0.02	0.01	0.00
SE(d)	0.02	0.01	0.07	0.02	0.02	0.01
C.V.	1.62	1.34	2.01	3.70	5.71	2.38

showed significantly higher sulphur content than the rest of the treatments. The lowest value was recorded by the treatment absolute control.

4.3.2.9. SSNM on Micro Nutrients Concentration in Bitter Gourd Fruit

The effect of SSNM experiment on micronutrient concentration of bitter gourd fruit samples is presented in Table 39. The iron content of fruit sample was comparatively higher than the plant samples. The values showed significant difference between treatments. The values varied from 842 to 1445 mg kg^{-1} between treatments. The highest value was recorded by the treatment T_5 followed by T_4 but were on par. The soil application of micronutrients showed high values of iron content in fruit samples than the foliar application. The treatments T_1 and T_3 were significantly lower compared to treatment T_2. The lowest value was recorded by the treatment absolute control (T_{10}). The data on manganese content of fruit sample is presented in Table 39. The values showed significant difference between treatments. The highest values were recorded by treatments T_7 and T_5. The treatments with foliar application of micronutrients showed significantly higher values than those with soil application of micronutrients. The values varied from 24.5 to 66.40 mg kg^{-1} between treatments. The fruit samples recorded a lower content of manganese than the plant sample. The lowest value was recorded by the treatment absolute control.

Zinc content of fruit sample is presented in Table 39. The values ranged from 30.67 to 54.67 mg kg^{-1} between treatments. The fruit zinc content showed significant difference between treatments. The highest value was recorded by the treatment T_5 followed by T_4 but were on par. All the SSNM treatments recorded a high content of zinc in fruit samples than the rests of the treatments. The Zn content in treatment RDF (T_1) did not show significant difference with T_9 (FP-1). The lowest value of fruit zinc was recorded by the treatment absolute control. Copper content of fruit sample showed significant difference between treatments (Table 39). The highest value was recorded by the treatment T_7 followed by T_6.

Table.39. Effect of SSNM treatments on micronutrients concentration in bitter gourd fruit, mg kg^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo
T_1	1125.00	32.00	36.67	4.57	16.00	0.18
T_2	1295.00	47.60	48.00	4.73	21.67	0.71
T_3	1135.00	61.20	46.00	5.17	20.33	0.73
T_4	1435.00	58.20	53.33	5.07	26.33	1.08
T_5	1445.00	64.60	54.67	5.10	26.67	1.72
T_6	1192.50	58.60	48.67	5.27	24.67	0.92
T_7	1207.50	66.40	51.33	5.53	25.67	1.55
T_8	990.00	55.00	33.33	4.97	6.67	0.20
T_9	922.50	31.70	36.67	4.17	14.33	0.05
T_{10}	842.50	24.50	30.67	3.53	5.67	0.03
C.D.	47.92	1.04	2.43	0.10	1.02	0.12
SE(m)	16.00	0.35	0.81	0.03	0.34	0.04
SE(d)	22.63	0.49	1.15	0.05	0.48	0.06
C.V.	2.39	1.20	3.20	1.14	3.12	9.32

The lowest value was recorded by the treatment absolute control followed by T_9 (FP-2). The foliar application of micronutrients showed significantly higher copper content in fruits than the soil application. The RDF (T_1) showed significantly higher value compared to farmers' practices (T_8 and T_9). The lowest value was recorded by the treatment absolute control. The data on boron content of bitter gourd fruit is presented in Table 39. The values showed significant difference between treatments. The highest value was recorded by the treatment T_5 (26.67 mg kg^{-1}) followed by T_4 (26.33 mg kg^{-1}) but were on par. All the SSNM treatments showed significantly higher values compared to RDF (T_1), T_2 and T_3. The lowest value recorded was by the absolute control treatment. The molybdenum content of fruit tissue showed significant difference between treatments (Table 39). The values ranged from 0.03 to 1.72 mg kg^{-1} between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments showed significantly higher values of molybdenum content of fruits than the rest of the treatments. The lowest value was recorded by the treatment T_{10}.

4.3.2.10. SSNM on Plant Uptake of Major and Secondary Nutrients in Bitter Gourd

The effect of SSNM treatments on plant uptake of major and secondary nutrients bitter gourd is presented in Table 40. The N uptake by plant varied significantly due to treatments. The values ranged from 4.87 to 58.09 kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium yield targets recorded significantly lower values of N uptake than the SSNM treatment for high yield targets. The treatments T_2 and T_3 recorded significantly higher values of plant N uptake when compared to the SSNM treatments for medium yield target. Farmers' practices showed significantly lower values for plant N uptake than other treatments except absolute control. The plant phosphorus uptake is presented in Table 40. The values showed significant difference between treatments. The values varied between 0.67 and

Table 40. Effect of SSNM treatments on uptake of major and secondary nutrients by bitter gourd plant, kg ha^{-1}

Treatments	N	P	K	Ca	Mg	S
T_1	28.61	2.39	25.59	22.39	10.64	1.42
T_2	46.40	3.97	41.88	36.38	19.85	3.68
T_3	43.68	3.74	38.42	33.55	18.12	2.99
T_4	37.31	3.75	39.48	34.41	17.52	3.75
T_5	58.09	4.94	50.66	47.75	25.70	4.88
T_6	37.54	3.83	38.77	33.37	17.27	3.63
T_7	51.69	4.87	45.80	42.99	21.78	4.53
T_8	14.19	1.25	13.71	11.50	3.09	0.84
T_9	17.56	1.58	16.73	15.87	4.16	1.13
T_{10}	4.87	0.67	5.49	6.16	1.65	0.43
C.D.	2.55	0.33	3.03	2.70	1.22	0.28
SE(m)	0.85	0.11	1.01	0.90	0.41	0.10
SE(d)	1.20	0.16	1.43	1.27	0.57	0.13
C.V.	4.34	6.19	5.53	5.49	5.03	6.01

4.94 kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7 but were on par. The SSNM treatments for medium yield target recorded significantly lower values of plant P uptake than the SSNM treatments for high yield target. The farmers' practices showed significantly lower values than the rest of the treatments except absolute control. The plant K uptake is presented in Table 40. The values showed significant variation due to treatments. The K uptake by different treatments varied between 5.49 and 50.66 kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium yield target recorded lower values compared to the treatment T_2. The farmers' practices recorded a significantly lower value of K uptake by plant than other treatments. The lowest value was recorded by the treatment T_{10}.

The Ca uptake values are presented in Table 40. The values were significantly different due to treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium yield target recorded significantly lower values compared to the SSNM treatments for high yield target. The treatment T_1 (RDF) showed significantly lower Ca uptake by plants compared to SSNM treatments. The farmers' practices also recorded lower K uptake values compared to the recommended practice. The lowest value was recorded by absolute control. The data on Mg uptake by plant is presented in Table 40. The values were significantly different due to treatments. Here also the highest value was recorded by the treatment T_5 followed by T_7. The treatments T_2 and T_3 recorded comparatively high values of Mg uptake than the SSNM treatments for medium yield target. The farmers' practices showed very low Mg uptake values than the other treatments. Plant uptake of sulphur showed significantly different values between treatments (Table 40). The values varied from 0.43 to 4.8 kg ha^{-1} between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for high yield target showed higher values of S uptake by plant than the SSNM treatments for medium yield target. The soil application of fertiliser recorded high values of S uptake than

Table 41. Effect of SSNM treatments on uptake of micronutrients by bitter gourd plant, g ha^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo
T_1	938.54	228.91	61.60	5.79	21.20	0.33
T_2	1695.42	397.26	120.65	8.96	39.71	1.38
T_3	1822.69	514.97	124.23	9.23	45.95	1.32
T_4	1717.53	447.15	115.49	8.98	34.55	1.83
T_5	2202.08	619.20	146.38	11.31	52.51	3.46
T_6	1816.51	523.08	126.59	9.23	46.13	1.57
T_7	2097.49	612.93	149.38	11.09	53.73	2.89
T_8	573.34	187.27	32.46	3.45	6.76	0.20
T_9	680.41	176.06	43.71	3.70	13.85	0.14
T_{10}	258.65	74.47	17.47	2.03	3.59	0.06
C.D.	105.37	29.88	8.39	0.58	3.08	0.26
SE(m)	35.19	9.98	2.80	0.19	1.03	0.09
SE(d)	49.77	14.11	3.96	0.27	1.46	0.12
C.V.	4.42	4.57	5.17	4.56	5.60	11.27

the foliar application of nutrients. The lowest value was recorded by the treatment T_{10}.

4.3.2.11. SSNM on Plant Uptake of Micronutrients in Bitter Gourd Plant

The plant uptake of micronutrients in bitter gourd is presented in Table 41. The iron uptake by bitter gourd plant showed significant difference between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium yield target recorded a lower value of Fe uptake by plants compared to the treatment T_3. The Fe uptake values ranged between 258.65 and 2202.08 g ha^{-1}. The farmers' practices recorded significantly lower values of Fe uptake by bitter gourd plant compared to the recommended practice (T_1). Manganese uptake by bitter gourd plant showed significant difference between treatments (Table 41). The values varied from 74.47 to 619.20 g ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7 but were on par. But the SSNM treatment for medium yield target with soil application recorded a significantly lower value compared to the corresponding treatment with foliar application. The RDF also recorded significantly lower Mn uptake compared to other practices except farmers' practices and control.

The values of zinc uptake by bitter gourd plant were significantly different due to treatments (Table 41). The highest value was recorded by the treatment T_7 followed by T_5 but were on par. The treatments with foliar application of micronutrients recorded high values of zinc uptake than the soil application treatments. The farmers' practices recorded significantly lower values than the RDF and SSNM treatments. The lowest value was recorded by the treatment T_{10} (Absolute control) followed by T_8 (FP-1). The plant Cu uptake is presented in Table 41. The values varied significantly between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatment for medium yield target with foliar application of micronutrients showed higher values of Cu uptake by plants than the soil application but were on par. The RDF

Table 42. Effect of SSNM treatments on uptake of major and secondary nutrients by bitter gourd fruit, kg ha^{-1}

Treatments	N	P	K	Ca	Mg	S
T_1	9.95	4.72	26.67	4.83	2.33	1.84
T_2	13.72	6.45	36.26	7.19	3.65	2.75
T_3	11.16	5.29	29.34	5.76	2.84	2.11
T_4	17.27	8.73	49.60	9.99	5.11	4.08
T_5	24.14	11.42	64.56	13.68	7.81	5.49
T_6	16.90	8.72	49.14	9.49	5.14	3.92
T_7	21.83	10.53	59.46	12.33	6.91	4.99
T_8	4.21	2.10	12.26	2.18	0.87	0.87
T_9	5.56	2.68	16.31	2.69	1.08	1.15
T_{10}	0.52	0.35	2.13	0.30	0.13	0.15
C.D.	0.87	0.49	2.92	0.61	0.37	0.20
SE(m)	0.29	0.16	0.97	0.20	0.13	0.07
SE(d)	0.41	0.23	1.38	0.29	0.18	0.10
C.V.	4.01	4.63	4.88	5.11	6.04	4.26

recorded significantly lower values of Cu uptake by plants compared to other treatments except farmers' practices and absolute control.

The boron uptake by bitter gourd plant was significantly different due to treatments (Table 41). The treatment T_7 registered highest value of boron uptake followed by T_5. The treatments with foliar application of micronutrients recorded higher values of B uptake than those with soil application of micronutrients. The farmers' practices recorded significantly lower values of B uptake by plants than the other treatments except control. The molybdenum uptake by bitter gourd plant is presented in Table 41. The values were found significantly different due to treatments. The highest value was recorded by the treatment T_5 followed by T_7. The farmers' practices showed very low values of Mo uptake by bitter gourd plants but were on par with the RDF (T_1).

4.3.2.12. SSNM on Fruit Uptake of Major and Secondary Nutrients in Bitter Gourd

The effect of SSNM experiment on fruit uptake of major and secondary nutrient are presented in Table 42. The N uptake by fruit showed significant difference due to treatments. The treatment T_5 recorded the highest value of fruit N uptake followed by T_7. The treatments with soil application of micronutrients showed significantly higher values than those with foliar application. The RDF (T_1) recorded significantly lower value compared to other treatments except farmers' practices and control. The fruit N uptake values varied between 0.52 to 24.14 kg ha^{-1}. The fruit phosphorus uptake showed significant difference between treatments. The values varied between 0.35 and 11.42 kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for medium yield target recorded significantly lower values of plant P uptake than the SSNM treatments for high yield target. The RDF treatments showed significantly lower values than other treatments except farmers' practices and control. The fruit K uptake is presented in Table 42. The values showed significant variation due to treatments. The K uptake by different treatments varied between 2.13 and 64.56

Table 43. Effect of SSNM treatments on uptake of micronutrients by bitter gourd fruit, g ha^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo
T_1	714.26	20.32	23.28	2.90	10.16	0.12
T_2	1099.17	40.41	40.73	4.02	18.40	0.60
T_3	787.61	42.47	31.88	3.59	14.12	0.51
T_4	1605.50	65.11	59.67	5.67	29.47	1.21
T_5	2088.59	93.36	79.01	7.37	38.53	2.48
T_6	1321.79	64.95	53.94	5.84	27.34	1.02
T_7	1595.60	87.75	67.83	7.31	33.92	2.05
T_8	301.07	16.73	10.16	1.51	2.04	0.06
T_9	379.51	13.01	15.07	1.71	5.89	0.02
T_{10}	51.35	1.49	1.87	0.22	0.35	0.00
C.D.	89.67	3.23	3.11	0.31	1.38	0.13
SE(m)	29.95	1.08	1.04	0.10	0.46	0.04
SE(d)	42.35	1.53	1.47	0.15	0.65	0.06
C.V.	5.22	4.20	4.69	4.49	4.42	9.46

kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The farmers' practices recorded a significantly lower value of K uptake by plant than other treatments. The treatments with foliar application of micronutrients showed comparatively higher K uptake values than the corresponding treatments with soil application of micronutrients. The lowest value was recorded by the treatment T_{10}.

The fruit Ca uptake values are presented in Table 42. The values were significantly different due to treatments. The SSNM treatments for medium yield targets recorded significantly lower values compared to the SSNM treatments for high yield targets. The treatment T_1 (RDF) showed significantly lower Ca uptake by plants compared to SSNM treatments and the farmers' practices. The lowest value was recorded by absolute control. The data on Mg uptake by fruit is presented in Table 42. The values were significantly different due to treatments. Here also the highest value was recorded by the treatment T_5 followed by T_7. The Mg uptake by fruits varied from 0.13 to 7.81 kg ha^{-1}. The Mg applied treatments showed significantly higher values of Mg uptake than the unapplied treatments. The farmers' practices showed significantly lower Mg uptake values than the other treatments. Fruit uptake of sulphur differed significantly between treatments (Table 42). The values varied from 0.15 to 5.49 kg ha^{-1} between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The SSNM treatments for high yield target showed higher values of S uptake by plant than the SSNM treatments for medium yield target. The soil application of fertiliser recorded high values of S uptake than the foliar application of nutrients. The lowest value was recorded by the treatment T_{10}.

4.3.2.13. SSNM on Fruit Uptake of Micronutrients in Bitter Gourd Plant

The fruit uptake of micronutrients in bitter gourd is presented in Table 43. The iron uptake by bitter gourd fruit showed significant difference between treatments. The highest value was recorded by the treatment T_5 (2088.59 g ha^{-1}) followed by T_7 (1595.60 g ha^{-1}). The Fe uptake values ranged between 51.35 and 2088.59 g ha^{-1}. The SSNM treatments with soil application of micronutrients

Table 44. Effect of SSNM treatments on total uptake of major and secondary nutrients, kg ha^{-1}

Treatments	N	P	K	Ca	Mg	S
T_1	38.56	7.11	52.25	27.21	12.97	3.26
T_2	60.12	10.43	78.14	43.58	23.50	6.43
T_3	54.84	9.04	67.76	39.30	20.96	5.10
T_4	54.58	12.48	89.08	44.41	22.63	7.83
T_5	82.22	16.36	115.21	61.43	33.51	10.37
T_6	54.44	12.54	87.91	42.86	22.41	7.55
T_7	73.51	15.39	105.27	55.32	28.69	9.52
T_8	18.40	3.35	25.97	13.68	3.97	1.70
T_9	23.12	4.26	33.04	18.56	5.24	2.27
T_{10}	5.39	1.02	7.61	6.46	1.78	0.58
C.D.	2.93	0.69	5.19	2.90	1.40	0.37
SE(m)	0.98	0.23	1.73	0.97	0.47	0.13
SE(d)	1.39	0.33	2.45	1.37	0.66	0.18
C.V.	3.65	4.32	4.53	4.75	4.61	3.97

recorded significantly higher values of Fe uptake by fruits. The farmers' practices recorded significantly lower values of Fe uptake by bitter gourd fruit compared to the recommended practice (T_1). Manganese uptake by bitter gourd fruit showed significant difference between treatments (Table 43). The values varied from 1.49 to 93.36 g ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. But the SSNM treatment for medium yield target with soil application recorded a significantly lower value compared to the corresponding treatment with foliar application. The RDF also recorded significantly lower Mn uptake compared to other practices except farmers' practices and control.

The values of zinc uptake by bitter gourd fruit were significantly different due to treatments (Table 43). The treatments with soil application of micronutrients recorded higher values of zinc uptake than the foliar application treatments. The farmers' practices recorded significantly lower values than the RDF and SSNM treatments. The lowest value was recorded by the treatment T_{10} (Absolute control) followed by T_8 (FP-1). The fruit Cu uptake is presented in Table 43. The values varied significantly between treatments. The highest value was recorded by the treatment T_5 (7.37 g ha^{-1}) followed by T_7 (7.31 g ha^{-1}) but were on par. The SSNM treatment for medium yield target with foliar application of micronutrients showed higher values of Cu uptake by fruit than the soil application but were on par. The RDF recorded significantly lower values of Cu uptake by plants compared to other treatments except farmers' practices and absolute control. The values for boron uptake by bitter gourd fruit were significantly different due to treatments (Table 43). The treatment T_5 (38.53 g ha^{-1}) registered highest value of boron uptake followed by T_7 (33.92 g ha^{-1}). The treatments with foliar application of micronutrients recorded higher values of boron uptake than those with soil application of micronutrients. The farmers' practices recorded significantly lower values of B uptake by plants than the other treatments except control. The molybdenum uptake by bitter gourd fruit is presented in Table 43. The values were found to be significantly different due to treatments. The highest value was recorded by the treatment T_5 (2.48 g ha^{-1})

Table 45. Effect of SSNM on total uptake of micronutrients by bitter gourd, g ha^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo
T_1	1652.79	374.25	84.88	8.69	31.36	0.45
T_2	2794.59	735.13	161.37	12.98	58.11	1.98
T_3	2610.30	871.85	156.12	12.82	60.06	1.83
T_4	3323.03	947.36	175.15	14.65	64.01	3.04
T_5	4290.67	1514.63	225.39	18.68	91.04	5.94
T_6	3138.30	1102.84	180.54	15.06	73.47	2.60
T_7	3693.09	1422.72	217.21	18.40	87.64	4.94
T_8	874.41	244.52	42.62	4.97	8.80	0.26
T_9	1059.92	248.50	58.78	5.41	19.75	0.17
T_{10}	309.99	79.01	19.35	2.24	3.93	0.06
C.D.	158.20	75.98	8.60	0.75	3.39	0.38
SE(m)	52.84	25.38	2.87	0.25	1.13	0.13
SE(d)	74.72	35.89	4.06	0.35	1.60	0.18
C.V.	3.85	5.83	3.76	3.79	3.94	10.44

followed by T_7 (2.05 g ha^{-1}). The treatments with soil application of micronutrients showed significantly higher values than the foliar application treatments. The farmers' practices showed very low values of Mo uptake by bitter gourd fruits but were on par with the RDF (T_1).

4.3.2.14. SSNM on Total Uptake of Major and Secondary Nutrients in Bitter Gourd Plant

The effect of SSNM experiment on total uptake of major and secondary nutrients are presented in Table 44. The total N uptake was found significantly different due to treatments. The uptake values ranged from 5.39 to 82.22 kg ha^{-1} between treatments. The highest total N uptake was recorded by the treatment T_5 (82.22 kg ha^{-1}) followed by T_7 (73.51 kg ha^{-1}). The SSNM treatments for medium yield targets recorded almost same values of total N uptake. The treatment T_2 recorded significantly higher value of total N uptake compared to SSNM for medium yield targets. The FPs recorded significantly lower values of total N uptake. The total phosphorus uptake by bitter gourd plant is presented in Table 44. The values were significantly different due to treatments. The values ranged from 1.02 to 16.36 kg ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The treatment SSNM for medium yield target recorded almost the same values for phosphorus uptake. The farmers' treatment showed lower total phosphorus uptake by bitter gourd plant. The total K uptake by bitter gourd plant was found significantly different due to treatments (Table 44). The total K uptake values ranged from 6.46 to 115.21 kg ha^{-1} between treatments. The highest value was recorded by the treatment T_5 followed by T_7. The treatments T_4 and T_6 recorded almost similar values and were on par. The RDF (T_1) recorded significantly lower value compared to other treatments except the farmers' practices and absolute control.

The total Ca uptake by bitter gourd plant is presented in Table 44. The values showed significant difference due to treatments. The highest value was recorded by the treatment T_5 (61.43 kg ha^{-1}) followed by T_7 (55.32 kg ha^{-1}). The

SSNM treatment for medium yield targets recorded close values which were on par each other. The treatment which received Ca showed higher total Ca uptake than the others. The farmers' practices recorded low values of total Ca uptake. The total Mg uptake by bitter gourd plant is presented in Table 44. The values showed significant difference due to treatments. The highest value was recorded by the treatment T_5 (33.51 kg ha^{-1}) followed by T_7 (28.69 kg ha^{-1}). The SSNM treatments for medium yield target recorded almost similar values which were on par each other. The treatment which received Mg showed higher total Mg uptake than the others. The farmers' practices recorded low values of total Mg uptake. The total S uptake by bitter gourd plant showed significant difference due to treatments (Table 44). The highest value was recorded by the treatment T_5 (10.37 kg ha^{-1}) followed by T_7 (9.52 kg ha^{-1}). The SSNM treatments for medium yield target recorded almost similar values which were on par with each other. The treatment which received sulphur showed higher total sulphur uptake than the others. The treatments with soil application of micronutrients recorded higher total sulphur uptake than the treatments with foliar application. The farmers' practices recorded low values of total S uptake.

4.3.2.15. SSNM on Total Uptake of Micronutrients in Bitter Gourd Plant

The total uptake of micronutrients in bitter gourd is presented in Table 45. The total iron uptake by bitter gourd showed significant difference between treatments. The highest value was recorded by the treatment T_5 (4290.67 g ha^{-1}) followed by T_7 (3693.09 g ha^{-1}). The total Fe uptake values ranged between 309.99 and 4290.67 g ha^{-1}. The SSNM treatments with soil application of micronutrients recorded significantly higher values of total Fe uptake than the treatments with foliar application of micronutrients. The farmers' practices recorded significantly lower values of total Fe uptake by bitter gourd compared to the recommended practice (T_1). The total manganese uptake showed significant difference between treatments (Table 45). The values varied from 75.96 to 712.55 g ha^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. But the SSNM treatment for medium yield target with soil application recorded a significantly lower value compared to the corresponding treatment with foliar application. The RDF also recorded significantly lower Mn uptake compared to other practices except farmers' practices and control.

The values of total zinc uptake by bitter gourd were significantly different due to treatments (Table 45). The highest value was recorded by the treatment T_5 followed by T_7. The treatments with soil application of micronutrients recorded significantly lower values of total zinc uptake than the foliar application treatments. The farmers' practices recorded significantly lower values than the RDF and SSNM treatments. The lowest value was recorded by the treatment T_{10} (Absolute control) followed by T_8 (FP-1). The total Cu uptake is presented in Table 45. The values showed significant variation between treatments. The highest value was recorded by the treatment T_5 (18.68 g ha^{-1}) followed by T_7 (18.40 g ha^{-1}) but were on par. The SSNM treatment for medium yield target with foliar application of micronutrients showed higher values of total Cu uptake than the soil application but were on par. The RDF recorded significantly lower values of total Cu uptake compared to other treatments except farmers' practices and absolute control.

The total boron uptake by bitter gourd was significantly different due to treatments (Table 45). The treatment T_5 (91.04 g ha^{-1}) registered the highest value of boron uptake followed by T_7 (87.64 g ha^{-1}). The treatments with soil application of micronutrients recorded high values of total boron uptake than those with foliar application of micronutrients. The farmers' practices recorded significantly lower values of total B uptake by plants than the other treatments except control. The total molybdenum uptake by bitter gourd is presented in Table 45. The values showed significant difference due to treatments. The highest value was recorded by the treatment T_5 (5.94 g ha^{-1}) followed by T_7 (4.94 g ha^{-1}). The treatments with soil application of micronutrients showed significantly higher values than the corresponding treatments with foliar application. The farmers' practices showed very low values of Mo uptake but were on par with the RDF (T_1).

4.3.2.16. Effect of SSNM on Pests and Disease Scores

The pests and disease scores observed during the SSNM experiment is presented in Table 46. The pest score was found to be significantly different due to treatments. The highest pest score was obtained for the treatments T_8, T_9 and T_{10} with a score value of 2.67. The treatments T_1, T_2 and T_7 recorded same value of 2.33 for pest score. The lowest value was recorded by the treatments T_4, T_5 and T_6 with score value 1.67. The disease scores during the SSNM experiment is recorded in the Table 46. It was found that the values were not significantly different due to treatments. The highest score was obtained for the treatments T_3, T_8, T_9 and T_{10} with a score value of 1.67. The lowest score was obtained for the treatments T_5 and T_1 with value 1.00.

4.3.2.17. SSNM on Harvest Index

The harvest index recorded in the SSNM experiment is presented in Table 47. The harvest index values varied significantly due to treatments. The highest value of HI was recorded by the treatment T_5 and T_7 (0.78) followed by T_4 (0.76). The treatment T_2 and T_3 showed a significantly lower harvest index than the RDF (T_1). The farmers' practices also showed higher value of HI than the treatments T_2 and T_3. The lowest value of HI was recorded by absolute control (0.18).

4.3.2.18. Initial Soil and Water Properties

The initial analysis of soil sample during the SSNM experiment is presented in Table 48. The data showed that the soil of the site was slightly acidic in nature. The electrical conductivity value was 0.039 dS m^{-1}. The water holding capacity of the soil was good. The bulk density of the soil was 1.27 Mg $m^{-3}$and the organic carbon status of the soil was medium (8.79 g kg^{-1}). The available major and secondary nutrient status showed varying trends (Table 48). The available N showed low status 193.4 kg ha^{-1}. The available phosphorus content of the soil showed a high value (78.43 kg ha^{-1}). But the available K recorded medium status

Table 46. Effect of SSNM treatments on pests and disease scores

Treatments	Pest score	Disease score
T_1	2.33	1.00
T_2	2.33	1.33
T_3	2.00	1.67
T_4	1.67	1.33
T_5	1.67	1.00
T_6	1.67	1.33
T_7	2.33	1.00
T_8	2.67	1.67
T_9	2.67	1.67
T_{10}	2.67	1.67
C.D.	0.75	N/A
SE(m)	0.25	0.29
SE(d)	0.36	0.40
C.V.	19.76	36.18

Table 47. Effect of SSNM treatments on HI in bitter gourd

Treatments	HI
T_1	0.63
T_2	0.53
T_3	0.47
T_4	0.76
T_5	0.78
T_6	0.75
T_7	0.78
T_8	0.52
T_9	0.57
T_{10}	0.18
C.D.	0.07
SE(m)	0.02
SE(d)	0.03
C.V.	6.38

(165.9 kg ha^{-1}) The exchangeable Ca and Mg content of soil showed medium status. The sulphur content of the soil was 20.48 kg ha^{-1}. In the case of micronutrient status of the soil, the initial analysis revealed that the DTPA extractable Fe content was high (Table 48). The Mn content of soil showed medium status where as the Zn and B statuses were low. The available copper varied between 0.40 to 0.67 mg kg^{-1} in soil. The exchangeable Al showed comparatively high value of 15.09 mg kg^{-1}.

The initial analysis results of biological analysis of soil are presented in Table 48. The initial microbial analysis revealed that the predominance of bacteria than fungus and actinomycetes. The dehydrogenase activity showed a low value (25.15 μgTPF g^{-1} soil $24h^{-1}$). The results of irrigation water analysis are presented in Table 49. The initial irrigation water analysis revealed that the water had a pH of 6.6. The electrical conductivity was found in the safe limit. The mineral nutrient analysis revealed that the water contained all the minerals in safe limits.

4.3.2.19. Soil Properties after Harvest

The soil properties after harvest of the crop are presented in Table 50. The pH of the soil after harvest of the crop showed significant variation due to treatments. The values varied from 5.23 to 5.57. A slight increase in pH values was found in treatments T_2, T_3, T_5 and T_6. The highest value of pH was recorded by the treatment T_3 followed by T_5 and T_6. The lowest value was obtained in the treatment T_{10}. The electrical conductivity values also recorded significant difference due to treatments. The values varied from 0.04 to 0.08 dS m^{-1}. The highest EC value was registered by the treatments T_4, T_5 and T_6. The lowest value was recorded by the treatment T_{10}.

The water holding capacity of the soil after harvest showed significant difference due to treatments (Table 50). The treatment T_5 recorded highest value (29.23 per cent) of WHC followed by T_6 (28.67 per cent). The lowest value was recorded by the treatment T_1 (26.47 per cent) followed by T_8 (27.00 per cent). The bulk density of the soil also varied significantly between treatments. The

Table 48. Initial physical, chemical and biological properties of soil during SSNM experiment

Sl. No	Parameter	Range of values
1	Texture	Clay loam
2	Bulk Density (Mg m^{-3})	1.27
3	Water Holding Capacity (%)	29.85
4	CEC (cmols kg^{-1})	8
5	pH	5.36
6	EC (dS m^{-1})	0.039
7	OC (g kg^{-1})	8.79
8	Available N (kg ha^{-1})	193.40
9	Available P (kg ha^{-1})	78.43
10	Available K (kg ha^{-1})	165.90
11	Exchangeable Ca (cmol kg^{-1})	1.06
12	Exchangeable Mg (cmol kg^{-1})	0.60
13	Available Sulphur (kg ha^{-1})	20.48
14	Available Fe (mg kg^{-1})	87.15
15	Available Mn (mg kg^{-1})	2.48
16	Available Zn (mg kg^{-1})	0.19
17	Available Cu (mg kg^{-1})	0.54
18	Hot Water Soluble Boron (mg kg^{-1})	0.21
19	Available Mo (mg kg^{-1})	0.08
20	Exchangeable Aluminium (mg kg^{-1})	15.09
21	Bacterial count (10^6 CFU g^{-1}soil)	9
22	Fungal count (10^6 CFU g^{-1}soil)	7
23	Actinomycetes count (10^6 CFU g^{-1}soil)	4
24	Dehydrogenase activity (μgTPF g^{-1}soil $24h^{-1}$)	25.15

Table 49. Initial irrigation water analysis during SSNM experiment

Parameter assessed	Sample
pH	6.60
EC (dS m^{-1})	0.275
N (mg L^{-1})	5.00
P (mg L^{-1})	0.11
K (mg L^{-1})	5.30
Ca (mg L^{-1})	4.50
Mg (mg L^{-1})	4.80
Fe (mg L^{-1})	0.05
Mn (mg L^{-1})	0.12
Zn (mg L^{-1})	0.05
Cu (mg L^{-1})	Traces
Mo(mg L^{-1})	Traces

treatments T_6 and T_7 showed the highest value (1.29 Mg m^{-3}) followed by T_4 (1.27 Mg m^{-3}). The lowest value was recorded by the treatment T_1 (1.21 Mg m^{-3}). The values varied from 1.21 to 1.29 Mg m^{-3}. The organic carbon content after harvest showed significant variation due to treatments (Table 50). The highest value was recorded by the treatment T_7 (12.2 g kg^{-1}) followed by T_6 (11.7 g kg^{-1}). The absolute control recorded the lowest value of organic carbon (4.8 g kg^{-1}).

The data on available major and secondary nutrients after the harvest of the crop was recorded and is presented in Table 51. The available N content showed significant variation due to treatments. The values varied from 155 to 245 kg h^{-1}. The highest value was recorded by the treatment T_7 (245 kg h^{-1}) followed by T_5 (242.67 kg h^{-1}). The farmers' practices showed lower values of available N compared to other treatments. The SSNM treatment recorded an increase in available N status after harvest. The available P content after harvest is presented in Table 51. The values showed significant variation due to treatments. The SSNM treated plots showed a comparatively higher content of available P compared to other treatments. The highest value of available P was recorded by the treatment T_7 (110.33 kg ha^{-1}) followed by T_5 (108.67 kg ha^{-1}). The farmers' practices and control showed a decrease in available P status. The available K status of soil showed significant difference due to treatments (Table 51). The values ranged from 56 to 249.33 kg ha^{-1}. The highest value of available K was recorded by the treatment T_5 (249.33 kg ha^{-1}) followed by T_7 (246.67 kg ha^{-1}). The SSNM treated plots showed an increase in available K in comparison to other treatments.

The data on exchangeable Ca and Mg are presented in Table 51. The values of Ca showed significant difference due to treatments. The values varied

Table 50. Effect of SSNM treatments on physical and chemical properties of soil after harvest

Treatments	pH	EC ($dS\ m^{-1}$)	WHC (%)	BD ($Mg\ m^{-3}$)	OC ($g\ kg^{-1}$)
T_1	5.37	0.06	26.47	1.21	7.53
T_2	5.47	0.07	27.63	1.25	8.83
T_3	5.57	0.07	27.87	1.25	8.83
T_4	5.37	0.08	27.57	1.27	9.30
T_5	5.47	0.08	29.23	1.26	9.40
T_6	5.47	0.08	28.67	1.29	11.67
T_7	5.33	0.07	27.97	1.29	12.23
T_8	5.37	0.06	27.00	1.26	6.93
T_9	5.40	0.06	27.07	1.26	7.00
T_{10}	5.23	0.04	25.50	1.21	4.83
C.D.	0.11	0.01	0.47	0.016	0.51
SE(m)	0.05	0.003	0.16	0.005	0.17
SE(d)	0.05	0.004	0.22	0.007	0.24
C.V.	1.21	7.65	0.99	0.717	3.44

Table 51. Effect of SSNM treatments on available major and secondary nutrients after harvest

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	S (kg ha^{-1})
T_1	226.67	82.67	189.00	2.07	1.57	28.27
T_2	238.33	84.67	196.83	2.20	1.73	35.80
T_3	232.00	78.00	193.33	2.23	1.77	36.23
T_4	211.67	100.67	241.67	2.67	2.23	51.20
T_5	242.67	108.67	249.33	2.93	2.50	55.77
T_6	218.50	103.67	236.33	2.67	1.87	45.97
T_7	245.00	110.33	246.67	2.90	2.47	54.47
T_8	190.33	56.00	164.33	1.70	1.33	22.10
T_9	182.00	55.00	158.00	1.67	1.33	22.50
T_{10}	155.00	46.33	56.00	1.20	1.07	15.10
C.D.	8.39	4.74	6.67	0.16	0.19	2.53
SE(m)	2.80	1.58	2.23	0.05	0.06	0.85
SE(d)	3.96	2.24	3.15	0.08	0.09	1.20
C.V.	2.27	3.32	2.00	4.12	5.98	3.98

between 1.20 to 2.93 cmol kg^{-1}. The highest value was recorded by the treatment T_5 followed by T_7. The Ca treated plots showed significantly higher exchangeable Ca content than the others. Similarly exchangeable Mg content showed variation from 1.07 to 2.50 cmol kg^{-1}. Here the SSNM treatments recorded higher values of Mg content of soil than other treatments. The lowest value was recorded by the absolute control followed by farmers' practices. The sulphur content of the soil after harvest of the crop is presented in Table 51. The values showed significant difference due to treatments. The highest value was recorded by the treatment T_5 (55.77 kg ha^{-1}) followed by T_7 (54.47 kg ha^{-1}). The values varied from 15.10 to 55.77 kg ha^{-1}.

The micronutrient and exchangeable Al status of soil is presented in Table 52. The Fe content of soil showed significant difference between treatments. The values ranged from 86.10 to 97.65 mg kg^{-1} in different treatments. The Fe content was found to increase in the SSNM treatments than others. The highest value was recorded by the treatment T_7 followed by T_5. The treatment T_8 (FP-1) also recorded an increase in Fe content of soil after harvest. The lowest value was recorded by the absolute control plot. The data on Mn content of soil is presented in Table 52. The data revealed that the values significantly varied between treatments. The highest value was recorded by the treatment T_7 followed by T_5. The farmers' practices recorded similar values of Mn content to the recommended practices. The zinc content of soil varied significantly due to treatments (Table 52). The soil application of zinc increased the available zinc status of soil. The zinc treated plots showed significantly higher content of available Zn than the unapplied fields. The highest value of zinc was recorded by the treatment T_5 followed by T_4. The available copper content of soil after harvest showed significant difference due to treatments (Table 52). The values varied between 0.44 to 0.67 mg kg^{-1}. The treatments T_5 and T_7 showed highest values of available copper. The farmers' practices showed a lower value of soil copper than the other treatments except control.

Table 52. Effect of SSNM treatments on available micronutrients and Al after harvest, mg kg^{-1}

Treatments	Fe	Mn	Zn	Cu	B	Mo	Al
T_1	90.53	2.53	0.17	0.58	0.18	0.09	12.23
T_2	94.73	2.50	1.02	0.65	1.06	0.13	12.77
T_3	94.97	2.80	0.91	0.65	0.58	0.13	14.93
T_4	97.07	2.97	1.17	0.66	1.08	0.14	15.37
T_5	97.53	3.12	1.20	0.67	1.17	0.14	16.10
T_6	96.83	2.87	1.03	0.66	0.60	0.14	16.27
T_7	97.65	3.13	1.10	0.67	0.68	0.14	17.33
T_8	96.13	2.53	0.75	0.56	0.23	0.09	15.07
T_9	94.50	2.60	0.81	0.58	0.19	0.09	14.67
T_{10}	86.10	2.17	0.14	0.44	0.09	0.01	14.17
C.D.	2.76	0.17	0.06	0.02	0.05	0.01	0.73
SE(m)	0.92	0.06	0.02	0.01	0.02	0.00	0.24
SE(d)	1.30	0.08	0.03	0.01	0.03	0.00	0.34
C.V.	1.69	3.69	4.14	2.10	5.22	2.90	2.83

The boron content of soil after harvest is presented in Table 52. The values showed significant difference due to treatments. The treatments with soil application of boron showed higher content of soil boron than the treatments with foliar application. The boron applied field showed significantly high boron content than the unapplied fields. The highest value was recorded by the treatment T_5 followed by T_4. The molybdenum content after harvest of crop showed significant difference due to treatments (Table 52). The SSNM treatments showed same values of soil Mo content (0.14 mg kg^{-1}). The lowest content of Mo was recorded by the treatment T_9 and T_{10}. The exchangeable Al content of soil also showed significant difference due to treatments. The highest value was recorded by the treatment T_7 (17.33 mg kg^{-1}) followed by T_6 (16.27 mg kg^{-1}). The treatments T_1 and T_2 recorded a significantly lower value of exchangeable Al than the other treatments.

The N balance sheet after the experiment is presented in Table 53. The treatment T_7 recorded the highest amount of balance N content followed by T_5. The absolute control recorded the lowest amount of available N after the crop. The treatments T_4 and T_6 recorded a lower N balance than the farmers' practice-2. The available phosphorus balance sheet is presented in Table 54. The values showed that the treatment T_9 recorded the highest amount of available P after the crop followed by T_5 and T_7. Here also the farmers' practice (FP-2) recorded high nutrient balance compared to all other treatment. The absolute control recorded the lowest nutrient balance in case of available phosphorus. The potassium balance sheet is presented in Table 55. The values showed that the treatment T_7 recorded highest nutrient balance followed by T_5. Farmers' practices registered comparatively high K balance than other treatments except T_5 and T_7. The lowest value of K balance was recorded by the treatment T_2 followed by T_3.

4.3.2.20. Soil Biological Properties

The soil biological properties after the harvest of the crop are presented in Table 56. The bacterial, fungal and actinomycetes counts showed significant difference due to treatments. The bacterial count was the highest for the treatment T_5 and T_9 and the lowest for absolute control. In the case of fungal count the highest count was observed in the treatment T_9 followed by T_8. The lowest fungal count was recorded by the treatment T_1 and T_2. Actinomycetes count was highest for the treatment T_9 followed by T_5 and T_7. The lowest count was recorded by the treatment absolute control. The dehydrogenase activity after harvest of the crop is presented in Table 56. The values showed significant difference due to treatments. The highest value was recorded by the treatment T_9 followed by T_3. The lowest value was recorded by the treatment T_{10}. The SSNM treatments showed a lower value of dehydrogenase activity compared to farmers' practices - II.

4.4. ECONOMIC ANALYSIS OF SSNM PRACTICES

The B: C ratio of the SSNM field experiment was calculated and is presented in Table 57. The values showed significant difference due to treatments. The highest B: C ratio was recorded by the treatment the treatment T_5 followed by T_7. The SSNM treatments provided high benefit per rupee cost compared to the RDF (T_1). The B: C ratio values revealed that all the treatments were able to provide profit to farmers' due to the high cost of bitter gourd.

4.5. CORRELATION STUDIES

Correlation of yield with uptake parameters was worked out and presented in Table 58. The values revealed that yield was well correlated with the uptake of nutrients as well as the harvest index. High positive correlation was obtained for uptake of major and secondary nutrients and yield.

4.6. VALIDATION TRIAL

Among the 10 treatments the best treatments in terms of yield was validated in farmer's field. The treatments for SSNM for high yield targets including both

Table 53. Nitrogen balance sheet after SSNM experiment

Treatments	Initial N status (kg ha^{-1})	N added by fertiliser (kg ha^{-1})	N removed by the crop (kg/ha)	N status after crop (kg ha^{-1})	Nitrogen balance	Gain/loss
T_1	190	75	38.56	206.67	226.44	-19.77
T_2	200	75	60.12	218.50	214.88	3.62
T_3	205	75	54.84	211.67	225.16	-13.49
T_4	205	52	54.58	232.00	202.42	29.58
T_5	200	123	82.22	235.67	240.78	-5.11
T_6	195	52	54.44	238.33	192.56	45.77
T_7	199	123	73.51	245.00	248.49	-3.49
T_8	185	35	18.40	190.33	201.60	-11.27
T_9	180	82	23.12	182.00	238.88	-56.88
T_{10}	175	0	5.39	155.00	169.61	-14.61

Table 54. Phosphorus balance sheet after SSNM experiment

Treatments	Initial P status (kg ha^{-1})	P added by fertiliser (kg ha^{-1})	P removed by the crop (kg ha^{-1})	P status after crop (kg ha^{-1})	Nutrient balance	Gain/loss
T_1	76.0	25	6.87	82.67	94.13	-11.46
T_2	65.5	25	7.79	84.67	82.71	1.96
T_3	70.0	25	9.25	78.00	85.75	-7.75
T_4	78.0	30	13.36	100.67	94.64	6.03
T_5	81.0	59	14.5	103.67	125.5	-21.83
T_6	75.6	30	15.69	108.67	89.91	18.76
T_7	84.0	59	17.54	110.33	125.46	-15.13
T_8	73.0	37	3.35	56.00	106.65	-50.65
T_9	93.2	97	4.26	55.00	185.94	-130.94
T_{10}	88.0	0	1.02	46.33	86.98	-40.65

Table 55. Potassium balance sheet after SSNM experiment

Treatments	Initial K status (kg ha^{-1})	K added by fertiliser (kg ha^{-1})	K removed by the crop (kg ha^{-1})	K status after crop (kg ha^{-1})	Nutrient balance	Gain/loss
T_1	150	25	52.25	189.0	122.75	35.0
T_2	155	25	78.14	196.8	101.86	46.8
T_3	154	25	67.76	193.3	111.24	13.3
T_4	150	52	89.08	236.3	112.92	26.3
T_5	180	160	115.21	246.7	224.79	46.7
T_6	210	52	87.91	249.3	174.09	99.3
T_7	200	160	105.27	241.7	254.73	81.7
T_8	150	90	25.97	164.3	214.03	14.3
T_9	160	95	33.04	158.0	221.96	158.0
T_{10}	150	0	7.61	56.0	142.39	56.0

Table 56. Effect of SSNM treatments on soil biological properties after harvest

Treatments	Bacterial count 10^6 CFU g^{-1}soil	Fungal count 10^4 CFU g^{-1}soil	Actinomycetes count 10^8 CFU g^{-1}soil	Dehydrogenase activity (μgTPF g^{-1} soil $24h^{-1}$)
T_1	9.67	5.67	5.00	29.83
T_2	9.00	5.67	5.67	30.22
T_3	10.00	6.33	5.00	30.78
T_4	9.00	6.00	5.00	29.11
T_5	11.00	6.00	6.00	28.11
T_6	10.00	7.00	5.33	26.44
T_7	10.67	6.33	6.00	28.00
T_8	10.33	7.33	6.33	28.33
T_9	11.00	7.67	6.67	31.56
T_{10}	8.00	6.00	3.67	23.33
C.D.	0.57	0.82	0.71	0.72
SE(m)	0.19	0.27	0.24	0.24
SE(d)	0.27	0.39	0.34	0.34
C.V.	3.32	7.37	7.55	1.45

soil (T_5) and foliar (T_7) applications were validated in farmer's field in Kalliyur village. It was found that the expected yields were obtained in the validation trial. The SSNM trial for high yield target with soil application of micronutrients recorded fruit yield of 24 t ha^{-1} where as the foliar application recorded fruit yield of 22 t ha^{-1}. Hence these treatments could be recommended to the area for increasing bitter gourd productivity. It was found that the adoption of this recommendation increased the profit of farmers.

Table 57. Benefit: Cost ratio of SSNM experiment

Treatments	B:C Ratio
T_1	2.96
T_2	2.59
T_3	3.13
T_4	4.64
T_5	5.29
T_6	4.22
T_7	4.87
T_8	1.80
T_9	2.35
T_{10}	0.59
C.D.	0.46
SE(m)	0.15
SE(d)	0.22
C.V.	7.99

Table 58. Correlation analysis of SSNM experiment data

Parameters	Yield	N uptake	P uptake	K uptake	Ca uptake	Mg uptake	S uptake	Fe uptake	Mn uptake	Zn uptake	Cu uptake	B uptake	Mo uptake	HI
Yield	1.000													
N uptake	0.927	1.000												
P uptake	0.986	0.974	1.000											
K uptake	0.980	0.982	0.998	1.000										
Ca uptake	0.955	0.995	0.989	0.993	1.000									
Mg uptake	0.938	0.992	0.979	0.984	0.995	1.000								
S uptake	0.984	0.963	0.995	0.992	0.984	0.974	1.000							
Fe uptake	0.974	0.980	0.993	0.996	0.994	0.988	0.992	1.000						
Mn uptake	0.953	0.952	0.976	0.969	0.968	0.961	0.979	0.974	1.000					
Zn uptake	0.956	0.980	0.987	0.990	0.991	0.988	0.985	0.993	0.977	1.000				
Cu uptake	0.967	0.982	0.994	0.994	0.992	0.986	0.987	0.993	0.980	0.996	1.000			
B uptake	0.955	0.975	0.986	0.986	0.987	0.984	0.982	0.987	0.984	0.996	0.994	1.000		
Mo uptake	0.927	0.910	0.938	0.926	0.930	0.922	0.956	0.934	0.966	0.921	0.926	0.926	1.000	
HI	0.878	0.758	0.835	0.831	0.778	0.727	0.807	0.796	0.762	0.764	0.799	0.762	0.713	1.000

** All values are significantly different at 1 per cent level

DISCUSSION

5. DISCUSSION

Among the different nutrient management methods, Site Specific Nutrient Management concept is getting more importance as it 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 SSNM approach was developed to increase mineral fertiliser use efficiency and achieve balanced plant nutrition (Dobermann and White, 1999; Witt *et al.*, 1999; Dobermann and Fairhurst, 2000). Field and season-specific fertiliser rates were calculated after taking into account indigenous soil nutrient supplies, plant nutrient demand (based on yield targets), and interactions among nitrogen (N), phosphorus (P), and potassium (K). This concept is valid for modern, high yielding varieties with a harvest index of about 0.5. A plant based SSNM approach initially developed for rice by International Rice Research Institute (IRRI) is now available for maize and wheat. But reports on application of SSNM principles in vegetables are still fewer. In this situation, the present study entitled "Site Specific Nutrient Management for Bitter gourd (*Momordica charantia* L.)" was taken up at College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing the productivity of bitter gourd in Kalliyur village. The significant findings of the study are discussed in this chapter.

5.1. SURVEY OF SITE CHARACTERISTICS

Kalliyur village is one of the major vegetable growing tracts of Thiruvananthapuram district. Majority of people in the village are tenant farmers cultivating in leased lands. A major part of their income goes to pay the lease rent. Vegetables are the preferred crop for cultivation (Fig. 5). A variety of vegetables is cultivated in garden lands and reclaimed wet lands throughout the village. The source of irrigation is the Vellayani Lake, which is a fresh water lake. Farmers are economically poor and they depend on co-operative banks and private money lenders for financial support.

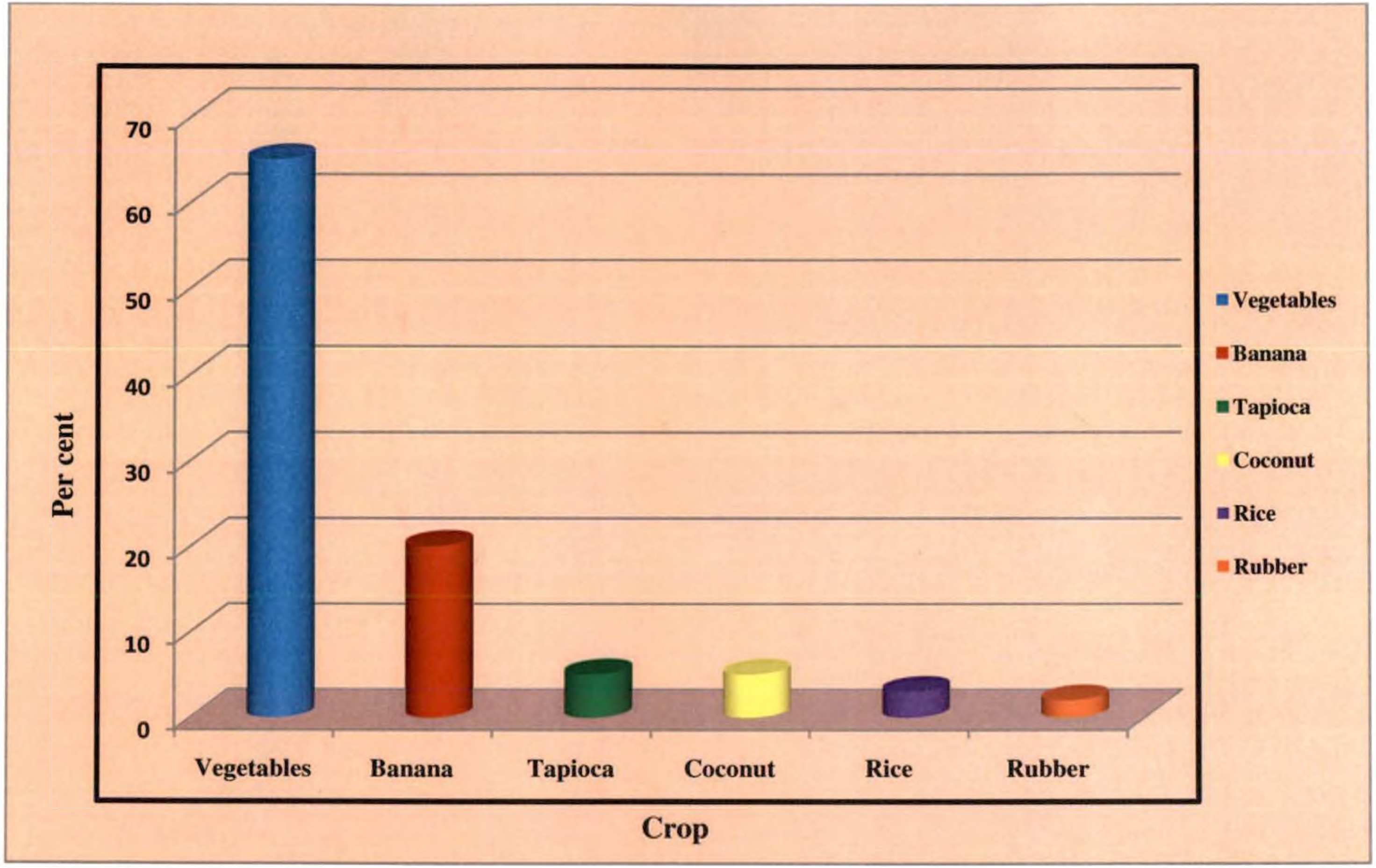

Fig. 5. Per cent distribution of crops in Kalliyur village

The survey revealed that farmers' preference to crops, varieties, cultivation practices, type of manures irrigation management etc varied between individuals. But bitter gourd is a choice vegetable in the locality since the fruits fetch high price in the local markets generating high income for farmers. The main constraints pointed out by farmers for bitter gourd cultivation were absence of modern storage methods, timely availability of fertilizers and labour and increasing labour charges. Weather constraints included untimely rainfall and occasional flash floods.

5.2. SPATIAL VARIABILITY OF SOIL PROPERTIES

The variation in the physiography of the village was well reflected in the soil properties. Wide variation was noticed in physical, chemical and biological properties of the soil (Fig. 6). The texture of soil varied from sandy loam to clay. The values on soil pH indicated that soils of the village were acidic in reaction (Table 4). The EC values of the samples also varied widely but it was in the admissible range and there was not remarkable amount of salt to hamper crop production. The frequency distribution of organic carbon in various sites at Kalliyur is depicted in Fig. 7. It can be noted that the variation observed in values of organic carbon (from 4.0 to 38.3 g kg^{-1}) is suggestive of the unscientific practice of organic manure addition followed by farmers in the locality.

The proximity to lake and consequent silt deposition contributes to high content of organic carbon in certain patches. In addition, the farmers in the village are in the habit of adding different kinds of organic manures, which also might have favoured high build up of organic carbon in such places. Huge variation was noticed in the available nutrient status of major and secondary nutrients at different locations. The standard deviation values of available N, P and K indicated that high variation occurred in these parameters from site to site (Table 5). The P status of the soil showed medium to high values. This may be due to the over addition of factamfos, a preferred source for N and P in the area and also due to the high P fixation property of the soil. Similar cases were reported from

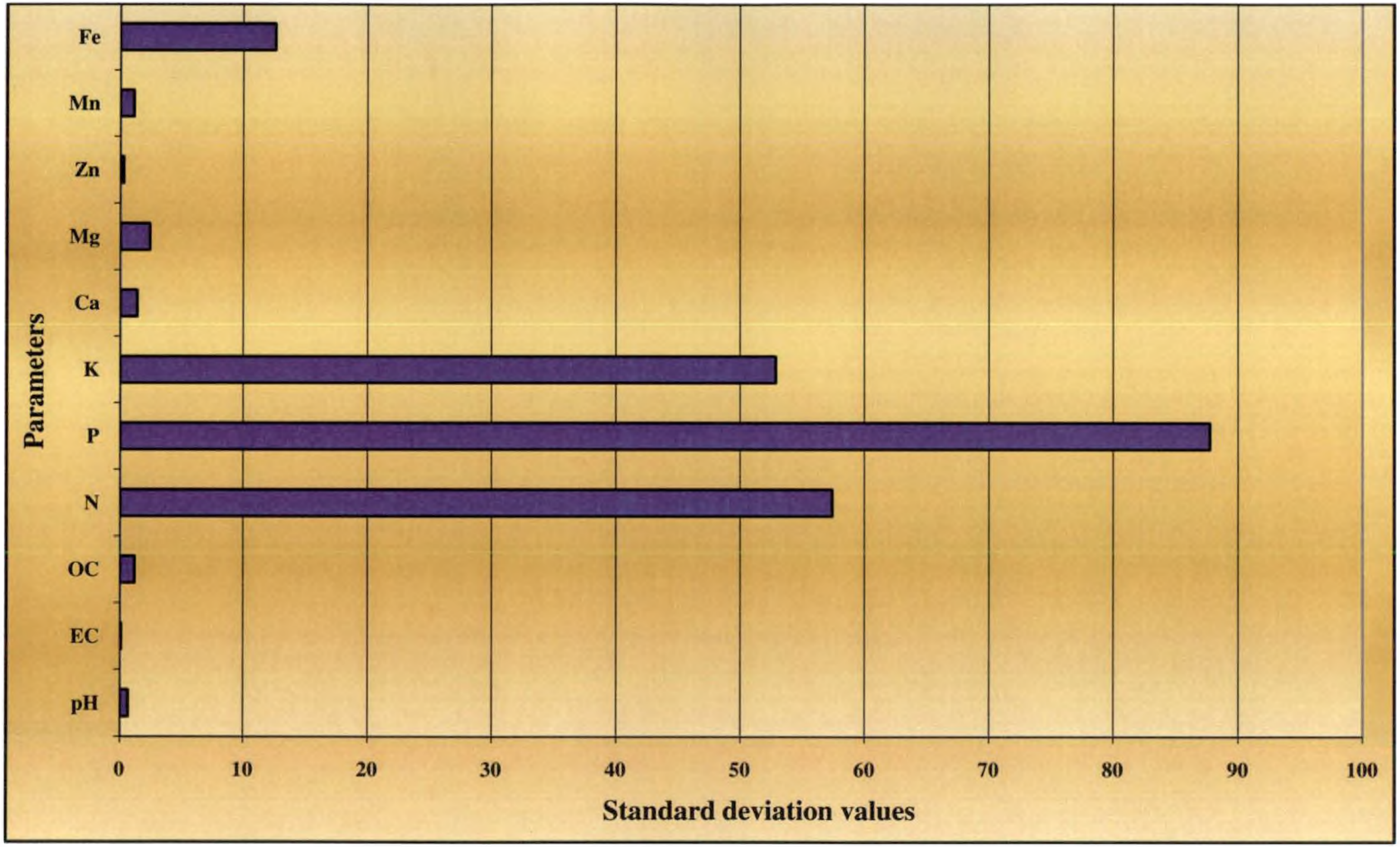

Fig. 6. Standard deviation observed in different soil properties of Kalliyur village

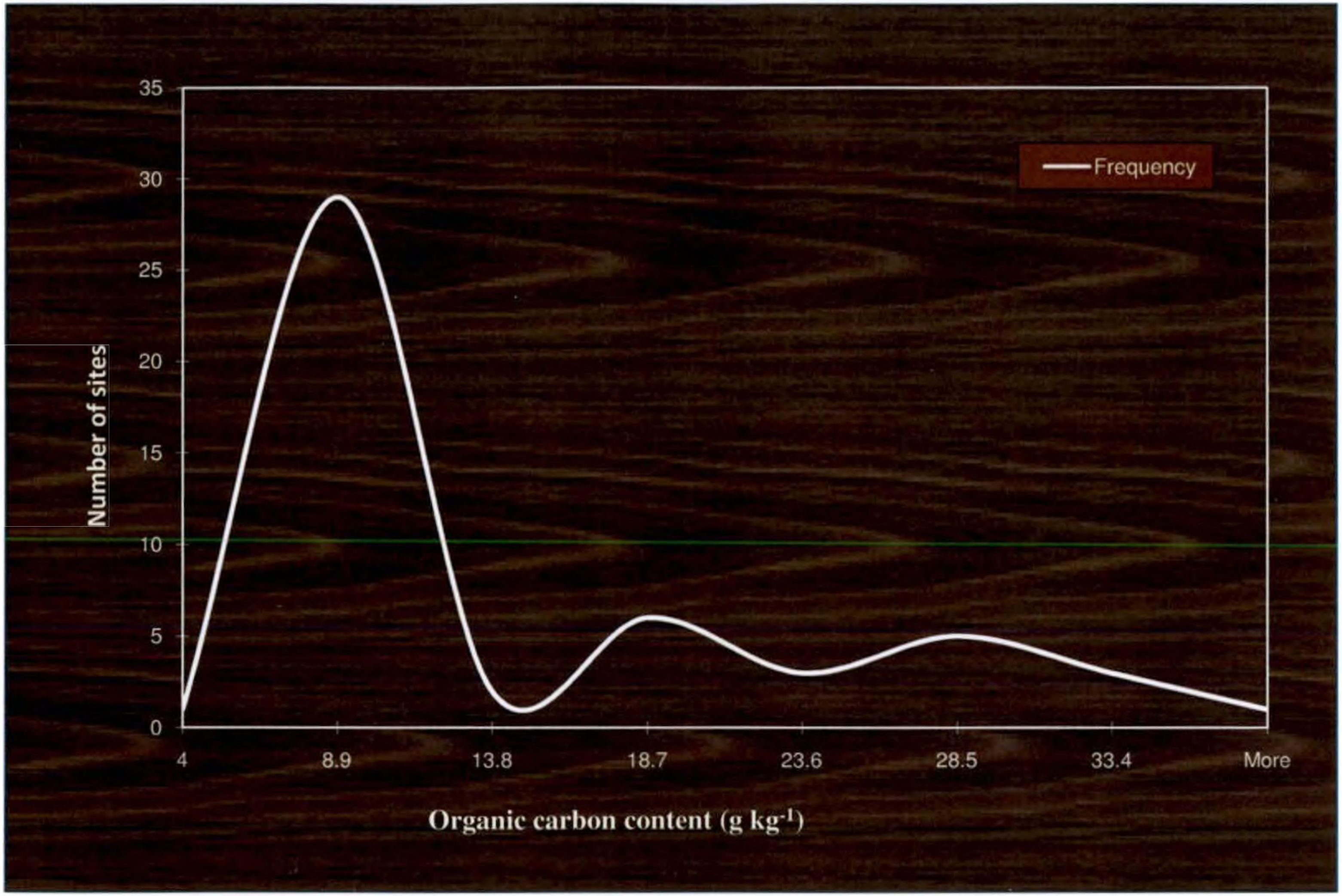

Fig. 7. Frequency distribution of organic carbon in various sites at Kalliyur village

various parts of the country (Vasuki, 2010). Available K in various locations ranged from low to medium.

The intensity of variation in distribution as depicted by kurtosis of soil properties in Kalliyur village (Fig. 8) shows that all the soil properties had an asymmetric distribution except available P. Kurtosis characterizes the relative peakedness of a distribution compared to the normal distribution. Positive kurtosis indicates a relatively peaked distribution. Negative kurtosis indicates a relatively flat distribution (Microsoft, 1996). So the kurtosis statistic of 0.48 in the case of pH would be an acceptable value for a mesokurtic distribution because it is close to zero. But values of Fe, Zn and Ca show that they had a leptokurtic distribution.

Exchangeable Ca and Mg and available Fe and Zn values are highly skewed (Fig. 9) whereas all the other parameters are moderately skewed. Skewness characterizes the degree of asymmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymmetric tail extending towards more positive values. The values obtained in the present study show that parameters like pH, Ca, Mg, Zn and Fe are positive indicating a high number of samples fell in the range above that of mean value. Negative skewness indicates a distribution with an asymmetric tail extending towards more negative values" (Microsoft, 1996). Available K, Mn, N and EC were negatively skewed. Soil properties in Kalliyur village can vary spatially due to a variety of factors such as physiography of land, depth of water table, cropping practices and land use practices. Similar reports on variation in soil properties have been made by Weijun *et al.* (2010). Despite the skewness of the distributions, the mean and median values for most parameters were similar, with the medians having smaller values than the means. This indicates that there is no dominant influence of extreme values in the distributions.

Much variation was not observed in the microbial counts between sites as in the case of dehydrogenase activity (Table 6). Dehydrogenase activity is an indirect measure of microbial activity and can therefore be used as an indicator of

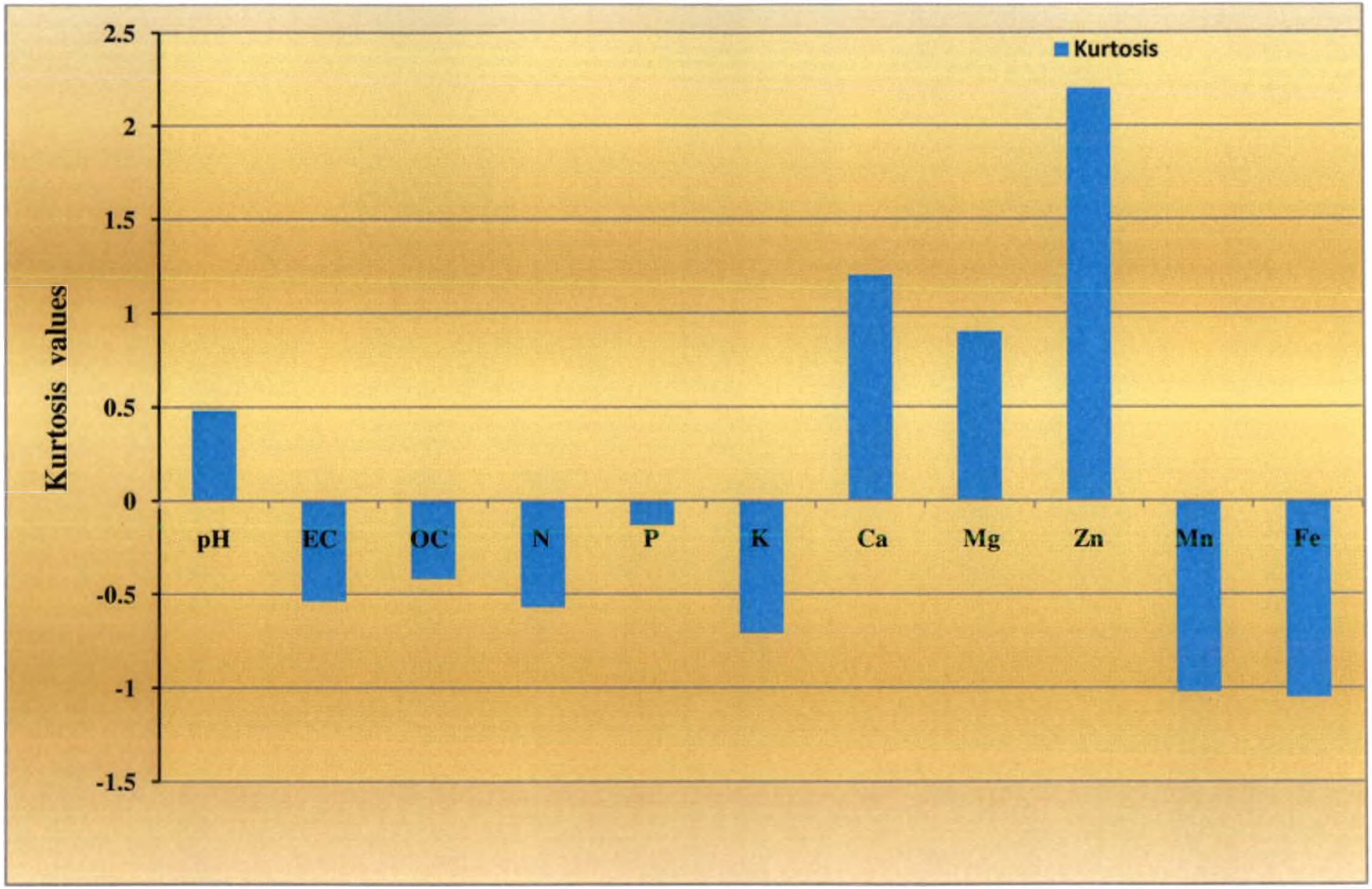

Fig. 8. Kurtosis observed in different soil properties of Kalliyur village

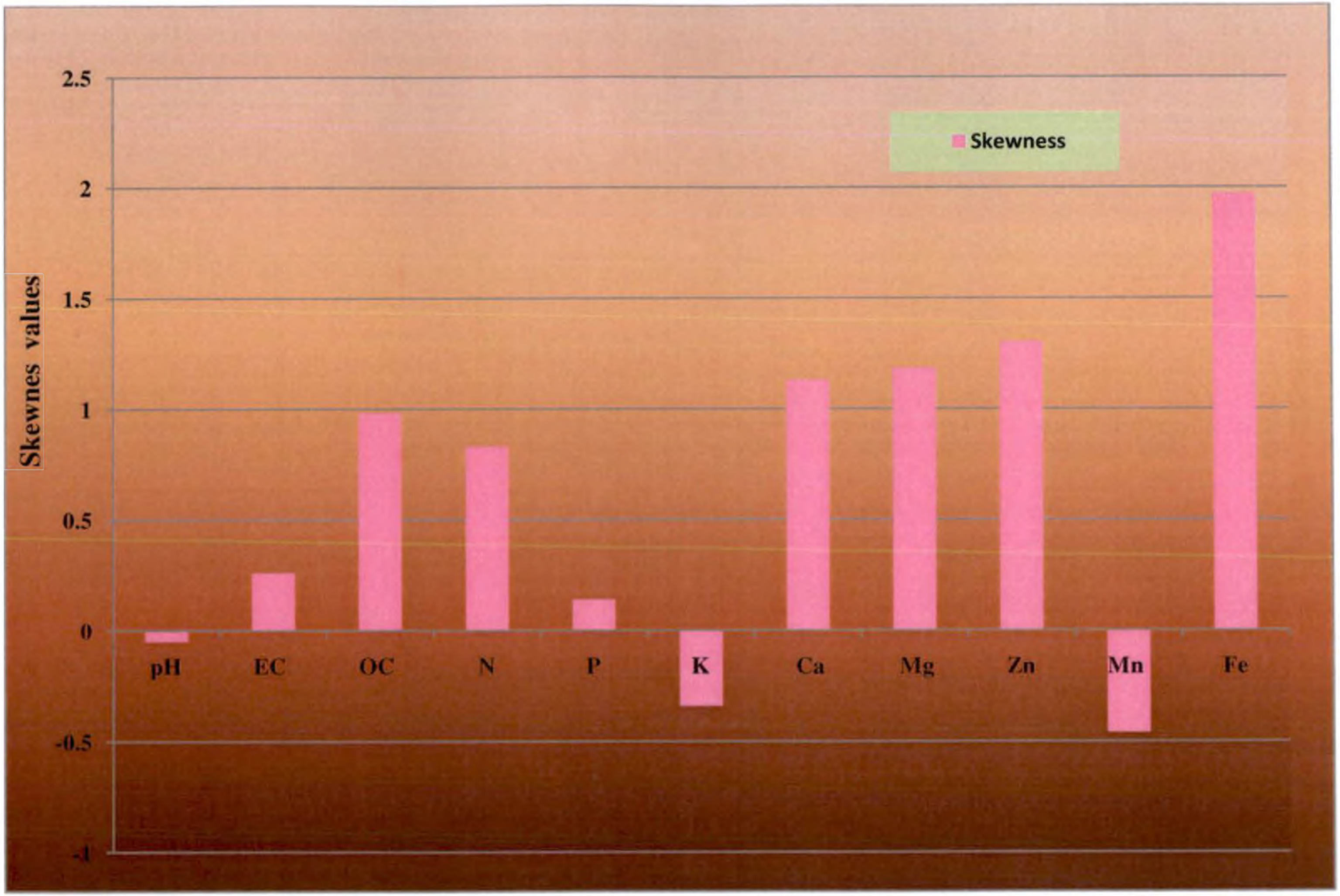

Fig. 9. Skewness observed in different soil properties of Kalliyur village

biological redox systems. Sites with low dehydrogenase activity will have low biomass accumulation because of low microbial activity. Concentration of soil dehydrogenase also depends on conditions and intensity of biological conversion of organic compounds. Data on irrigation water analysis (Table 7) showed that the water used for irrigation was slightly acidic but safe for use as it did not contain significant amount of soluble salts and other toxic elements.

5.3. NUTRIENT OMISSION TRIAL

5.3.1. Nutrient Omission on Plant Growth Parameters

The nutrient omission trial conducted on farmers' field in Kalliyur indicated that the soil of the area was largely exhausted in terms of soil fertility. This was visible from the response of bitter gourd to added fertilisers in omission trial. A glance through the data on growth parameters shows that maximum reduction in plant growth and growth attributes occurred in plots which did not receive N, P or K (Fig. 10a & 10b). Reduction in length of vine observed in N omission plot was 1.2 to 1.5 times that observed in (-) K and (-) P plots. Appearance of first female flower was also highly delayed in N omission plot. All these observations indicate the essentiality of N for normal plant growth. Nitrogen is an important constituent of all cell constituents and plays a critical role in its biochemical machinery. Reduction in P omitted plot was not remarkable because the high indigenous status of P in the soil was sufficient to supply P in quantities which will not affect plant growth. But K omission resulted in marked difference in length of vine and the node at which first male and female flower appeared. As seen in Table 9 the inherent capacity of soil to supply K is low. Omission of fertiliser K deprived the plants of sufficient amount of K for normal functioning of plant cells. Though it is not a structural component of any cell constituents, K is inevitable for enzyme action which mediates almost all cell activities. These results show that not only the vegetative but the reproductive capacity of the plants get affected by improper/ imbalanced NPK nutrition. Maya *et al.* (1997) also observed that growth parameters like plant height, number of branches per

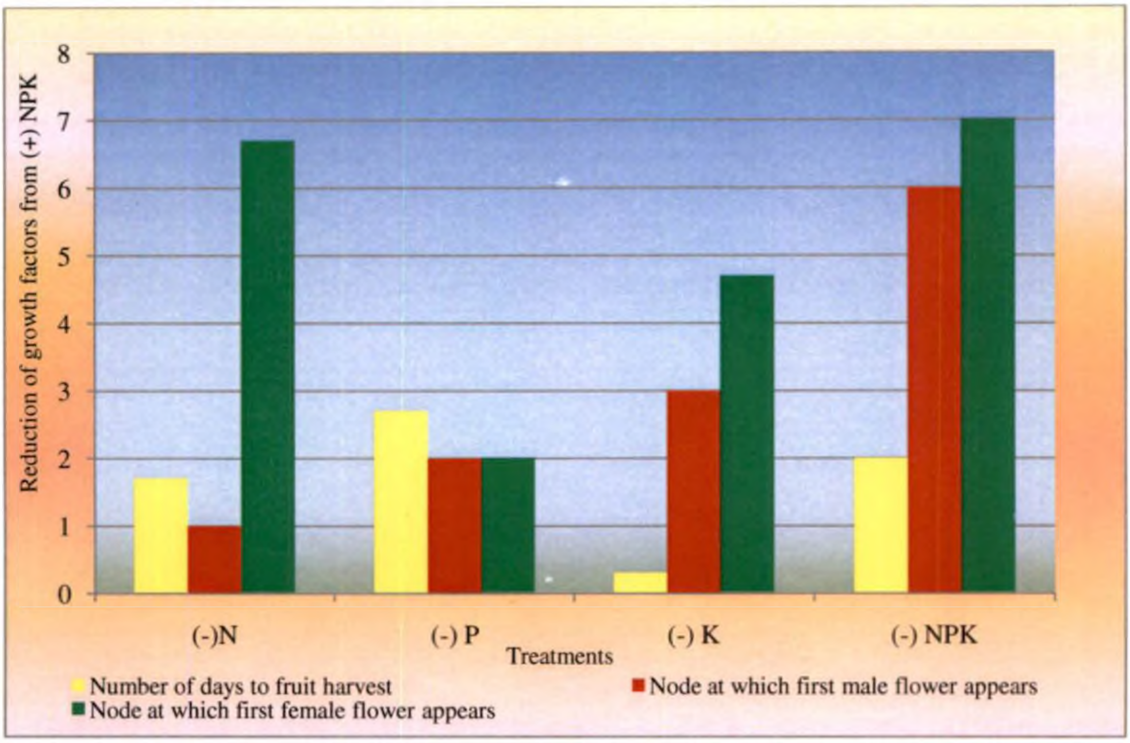

Fig. 10a. Reduction of growth parameters from (+) NPK treatment

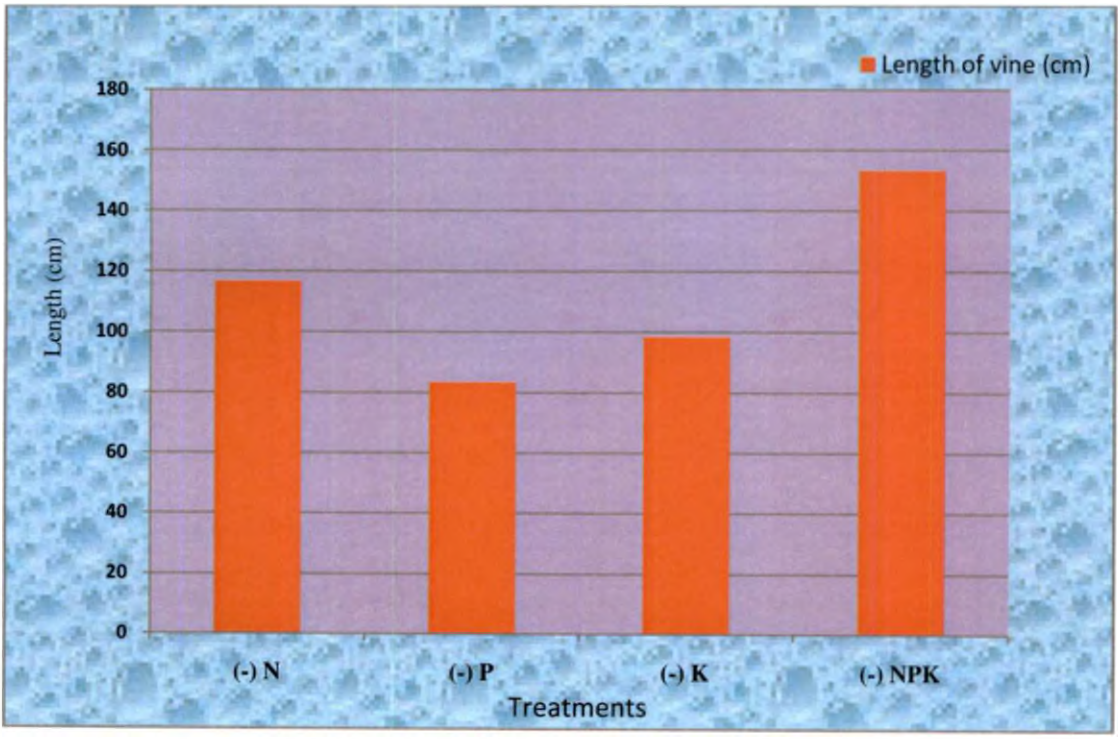

Fig. 10b. Reduction of growth parameters from (+) NPK treatment

plant, dry matter production etc in sweet pepper (cv. California wonder) was obtained at the highest dose of N and P ha^{-1}. Similarly, Balaraj (1999) noticed that the fertiliser level of 150: 75: 75 kg of N, P_2O_5 and K_2O ha^{-1} recorded significantly higher plant height in chilli over lower fertiliser level (100: 50: 50 kg N, P_2O_5 and K_2O ha^{-1}). The results thus stress the need for judicious management of essential nutrients so as to help sustain the supply of them at levels that do not limit crop growth, ensure optimal use efficiency and increase plant resistance to pests and disease. N, P and K are the primary major nutrients which are vital for cell division, cell growth and all cellular activities, leading to the normal development of plants. If one of these nutrients is in short supply the chain of cellular activity is broken affecting normal functioning of the cell. This is evident from the data on per plant dry matter production, the highest value being recorded by the treatment (+) NPK. The lowest value was recorded by the treatment absolute control showing the low indigenous supply of all nutrients in the site. The plant dry matter production on per hectare basis also showed the same trend as in the case of per plant DMP proving the deficiency of nutrients in the omission and control treatments. The uptake and utilization of element K greatly depend on the supply of other nutrients especially N (Tisdale *et al.*, 1995). The better growth components observed in (+) NPK treatment can be attributed to increased availability of nutrients for longer period and continuous supply of nutrients. These results are in conformity with those recorded by Subbaiah *et al.* (1982), Chavan *et al.* (1997) and Shashidhara (2000).

5.3.2. Nutrient Omission on Yield and Yield Attributes

As growth in the vegetative phase of bitter gourd plants was affected which was evident by data on growth parameters one can definitely anticipate its reflections on the yield of plants. Data on yield and yield attributes revealed that the (+) NPK treatment recorded the highest values. Nutrient omission affected the various yield attributes as shown in the data in Table 12. Here also the high P status of the soil of the experimental site masked the effects of P omission in (-) P treatment. The average fruit weight was lowest for (–) NPK treatment followed by

Plate 1. (-) NPK plot

Plate 2. N omission plot

Plate 3. P omission plot

Plate 4. K omission plot

Plate 5. (+) NPK plot

Plate 6. Omission trial on fruit yield

(–) N plots revealing the importance of N in the yield of bitter gourd. If only there is adequate N supply, plants are able to grow, develop and produce maximum yields with the potential for a high-quality product with desired colour, flavour, texture, and nutritional composition (Rajsree and Pillai, 2012). Since NPK are major and primary nutrients the omission of any one of these reduces the growth and yield if there is not sufficient indigenous supply of the above nutrients. The data on fruit dry matter production also showed that 100 per cent NPK treatment recorded the highest amount followed by P omission. The K and N omission treatments recorded a tremendous decrease in fruit dry matter production advocating the high demand for these elements for better yield in bitter gourd. The lowest value of fruit dry matter production was recorded by absolute control. Malarvizhi *et al.* (2009) reported that use of the optimum nutrient treatment resulted in a dry matter yield which varied from 1.94 to 2.51 g pot^{-1}, with an average of 2.17 g pot^{-1} across the different soil series in maize.

It is widely known that N promotes rapid growth and affects all parameters that contribute to yield. Crop N status is closely related to rate of photosynthesis and crop production. According to Huett (1989), for most vegetable species the N level producing the highest yield produced the best quality edible plant part. Sufficient N supply to the crop increases the demand for other nutrients such as P, K and other micro and secondary nutrients which are required for 100 per cent expression of yield potential. Singh *et al.* (2008) reported that yield reduction in sugar cane varied from 8.4 to 11.6, 12.3 to 24, 8.8 to 11.8 and 9.6 to 14.5 t ha^{-1} due to P, K, S and Mg omissions respectively. Mandal *et al.* (2009) also reported yield reduction due to P, K and S omission in cowpea.

5.3.3. Nutrient Omission on Uptake of Nutrients

It is clear from Fig. 11 that the nutrient concentration was the highest in (+) NPK plants and lowest in the absolute control. There is a positive correlation between availability of nutrients in soil and nutrient concentration in the plant. For plants to absorb nutrients they must be present in soils in available forms. The soil

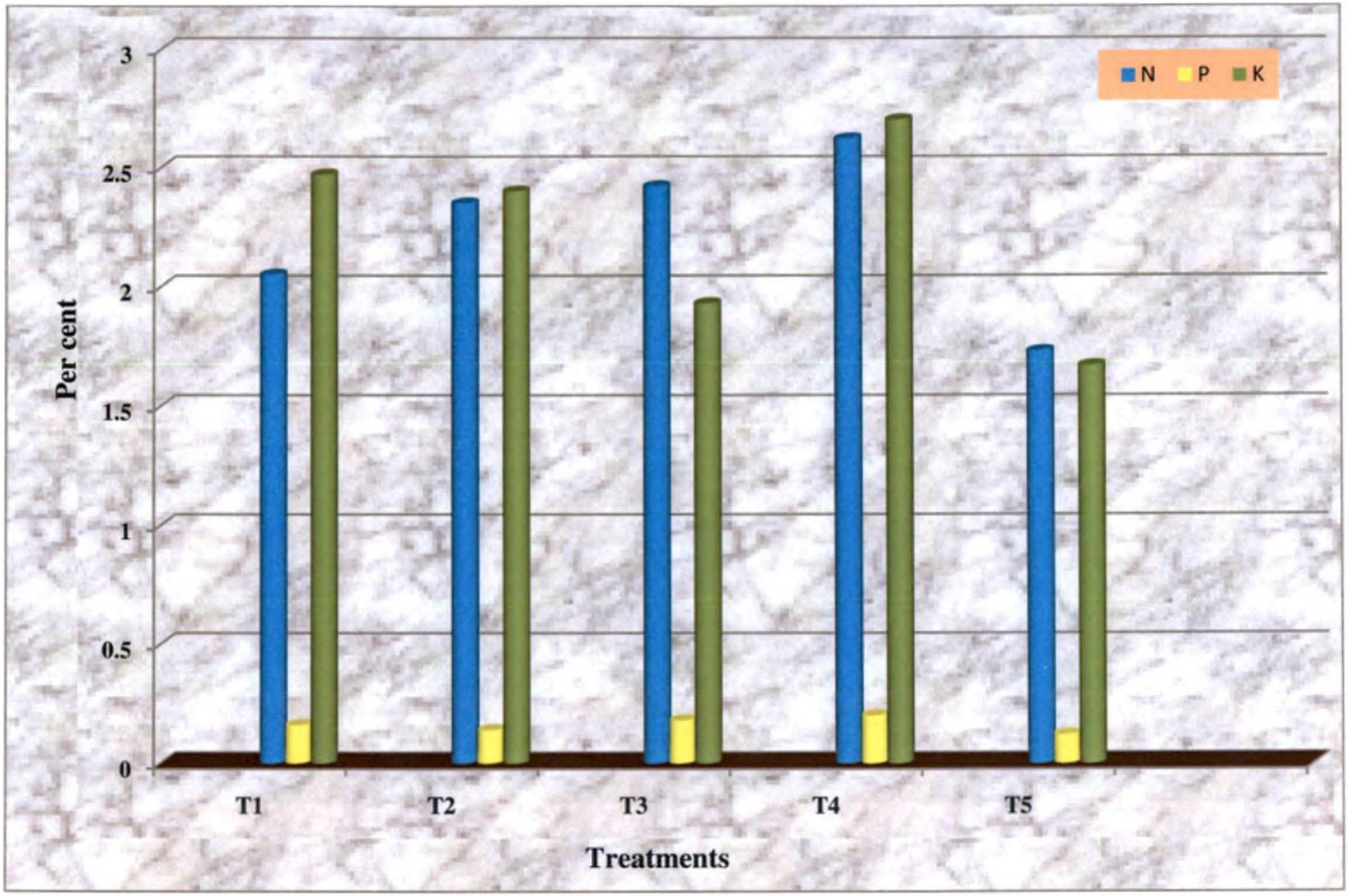

Fig. 11. Effect of omission trial on NPK content in bitter gourd plant

availability of nutrients (Table 26, 27 & 28) was the lowest in (-) NPK plots which reduced the plant uptake. The recovery efficiency of the major nutrients (Fig. 12) in Kalliyur soil was very low. This throws light on the limitations of the present soil and nutrient management practices of the area. Suresh (2000) reported increased uptake of K in chilli with increasing levels of K. Majumdar *et al.* (2000) also reported increased levels of K significantly influenced the K content in tomato and chilli. In the case of all micronutrients the absolute control recorded values lower than the plant critical values indicating the lower absorption of these nutrients. Priya (2011) also reported similar results in chilli after omission trial in Kalliyur village.

5.3.4. Nutrient Omission on Soil Properties

The (+) NPK treated plots showed lowest pH (5.23) compared to other treatments (Table 25). The absolute control recorded the highest pH value (5.53) followed by the K omission trial. The addition of nitrogenous fertiliser might be the reason for low pH after the crop. The electrical conductivity was the highest for the treatment T_4 followed by T_1 (N omission) and T_3 (K omission). The presence of more soluble salts after the fertiliser addition might have increased the EC value over that of the control. The lowest value of EC was recorded by absolute control and P omission trial. The organic carbon content varied from 0.63 to 0.93 per cent between the treatments. The highest value was recorded by the treatment T_4 followed by P omission treatment. As per Fig. 13 the dry matter production in these plots was also high and this might be the reason for high organic carbon in these plots. Here also the lowest value was recorded by the treatment T_5. Similar trend was observed for available N status also. The application of N fertiliser was the reason for high available N in these plots. The N omission trial and the absolute control recorded lower values of available N. To have high available N in soil there must be some external source or addition of plant dry matter. The available P content ranged from 27.50 to 76.33 kg ha^{-1} between treatments. Since the soil in the experimental site was laterite the added P might have been fixed and would be available slowly to the crop in the subsequent

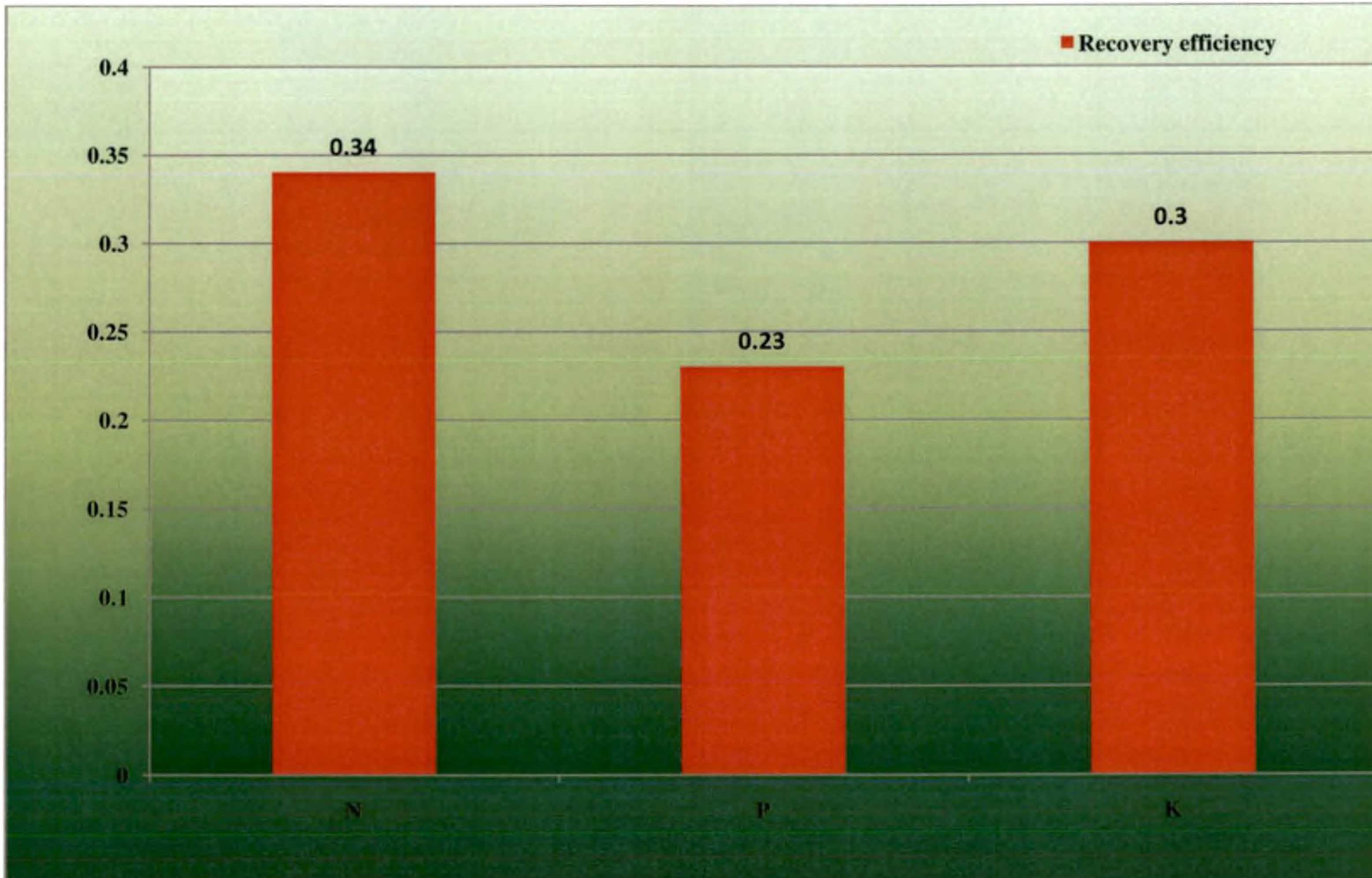

Fig. 12. Recovery efficiency of available NPK in Kalliyur village

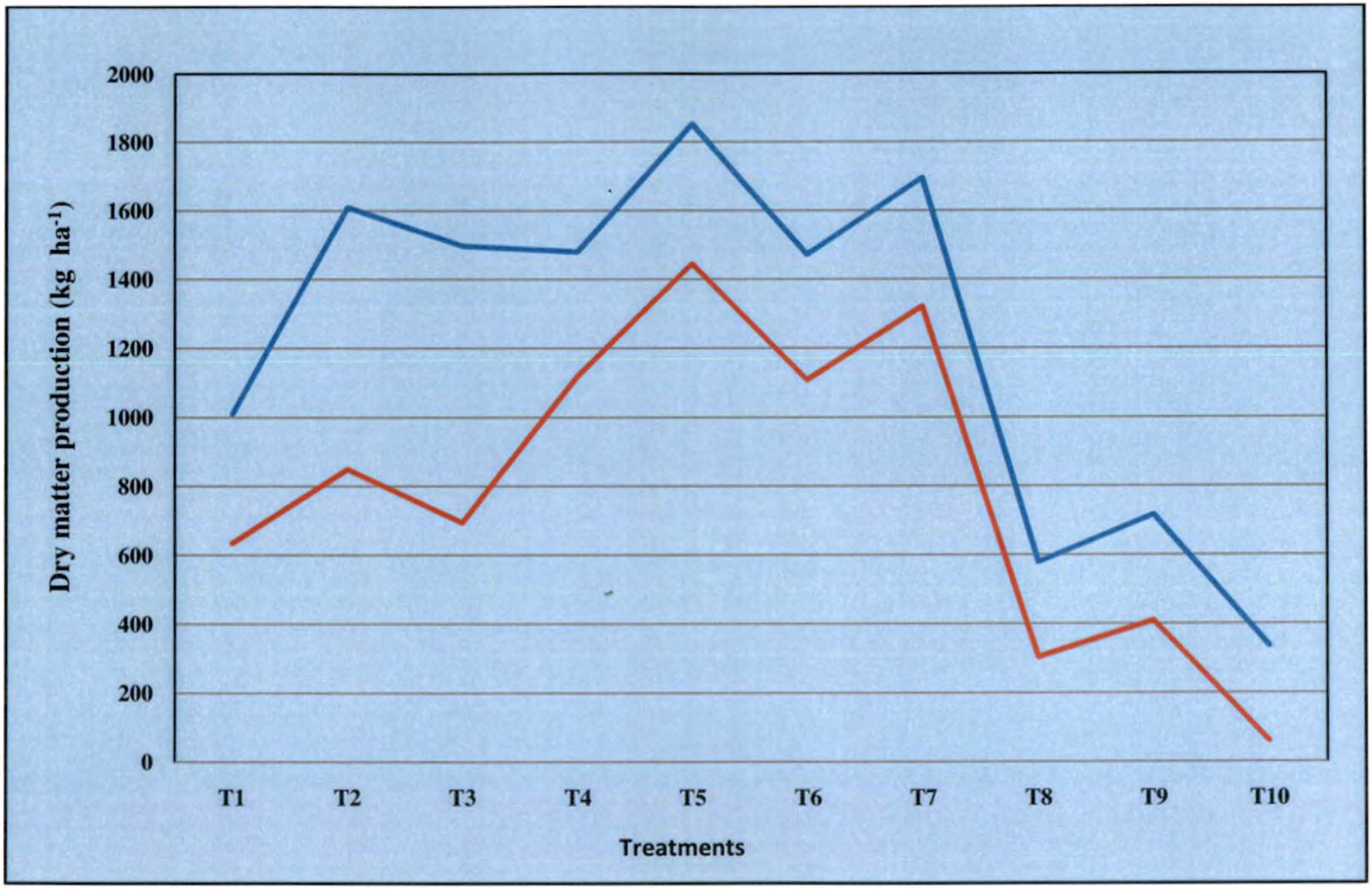

Fig. 13. Effect of omission trial on dry matter production

season. The highest value of available P was recorded by the treatment T_4 followed by K omission. The absolute control and P omission treatments showed lower values of available P. Since the initial P status of the soil was high, the P content in the P omission plot was slightly more than the control plot. In the case of available K the highest value was recorded by the treatment T_4 followed by N omission. These plots had received potash fertiliser at the recommended dose.

The absolute control recorded the lowest value of bacterial, fungal and actinomycetes population after omission trial. The 100 per cent NPK treated plots showed comparatively higher microbial population because of the high biomass production as a result of application of fertilisers at recommended doses. It was reported that the count and activity of soil microorganisms as important indicators of soil biological productivity can be indicative of the economic justifiability of the use of different types, combinations and rates of fertilisers (Cerny *et al.*, 2003; Stark *et al.*, 2007). The dehydrogenase activity was also the highest for the treatment T_4 followed the K omission. The presence of microbes increased the dehydrogenase activity and hence the plots receiving sufficient nutrients recorded high enzyme activity. Chu *et al.* (2007) also had reported that dehydrogenase activity in (-) N and (-) P treatments was significantly ($P<0.05$) lower than that in the NPK treatment, while the activity in the (-) P treatment was significantly lower ($P<0.05$) than that in the (-) N treatment.

5.4. SSNM EXPERIMENT

5.4.1. Site Specific Recommendation on Growth Parameters of Bitter Gourd

Statistically significant difference between treatments was observed in the various growth parameters studied. Remarkable difference could be observed between SSNM treatments and farmers' practices. The length of vine in SSNM treatments and the RDF was about twice that of absolute control. The node, at which first male and female flowers appeared in SSNM treatments where soil application of micronutrients was resorted to, showed that flowering started early in these treatments compared to farmers' practices and absolute control. Earliness

Plate 7. POP recommendation

Plate 8. POP + SN + MN (soil application)

Plate 9. POP + SN + MN (foliar application)

Plate 10. SSNM (MYT) - soil application

might be due to the enhanced production of growth substances like gibberellic acid, indole acetic acid etc which had a positive influence on physiological activity of plants that could assist the plants to induce female flowers, thereby modifying the sex ratio in bitter gourd (Sanap *et al.*, 2010). The shape of leaves and spreading nature of the bitter gourd plant might reduce the effective absorption of nutrients during foliar spraying.

Ullah *et al.* (2012) reported that foliar application of B significantly affected the vegetative growth parameters of 'Kinnow' mandarin. Though the flowering was delayed in SSNM (foliar) treatments, this was not statistically significant to soil application. Wide difference in length of vine was noticed between RDF treatments with and without secondary and micronutrients. The data thus clearly indicates the pronounced effect of application of secondary and micronutrients on the growth parameters of bitter gourd. The inherent status of secondary and certain micronutrients in the experimental site was low as presented in Table 48. Hence application of secondary and micronutrients had a beneficial effect on plant growth. Sanap *et al.* (2010) reported maximum length of lateral branches with the application of 250: 100: 100 kg ha^{-1} NPK in bitter gourd. Balanced concentration of macronutrients increased the number of branches per plant in gerbera (Khosa *et al.*, 2011).

5.4.2. Site Specific Recommendation on Yield and Yield Attributes of Bitter Gourd

Data on yield attributes (Table 32) showed that performance of SSNM treatments was superior to all other treatments. The SSNM treatments recorded a high number of fruits per plant compared to the recommended practices as well as farmers' practices. Fruit length and girth were also highest in SSNM (HYT). These treatments received all the plant essential nutrients including Zn and B. The effect of K and Ca in improving yield attributes in plants has been widely reported (Locascio *et al.*, 1992; Bhatt *et al.*, 2012). In addition micronutrients Zn and B are also reported to have a favourable effect on fruit growth and quality (Batru *et al.*, 1984; Shorrocks and Nicolson, 1980). Boron is essential for the formation of reproductive organs. It also plays a significant role in carbohydrate synthesis, uptake of Ca and absorption of nitrate N. According to Sanap *et al.* (2010) application of inorganic sources of nutrients affected the plant growth favourably with the production of more carbohydrates which accelerated better fruit girth and weight of bitter gourd. Appreciable improvement in fruit weight by borax application has been reported by Dutta *et al.* (2000) in litchi and Dutta (2004) in mango cv. Himsagar. They have attributed the increase in fruit weight with the sprays of borax due to the involvement in hormonal metabolism, increase in cell division and expansion of cell. Boron is also known to stimulate rapid mobilization of water and sugar in the fruit.

Average fruit weight, yield per plant and fruit yield ha^{-1} were also significantly greater in SSNM treatments. The SSNM treatments for high yield target recorded double the yield over the RDF. Khurana *et al.* (2007) reported that SSNM significantly increased grain yield in wheat and rice crops compared to FP. Micronutrient application had a significantly positive effect on 'Mosambi' yield under the experimental conditions as reported by Srivastava *et al.* (2009). Tariq *et al.* (2007) also observed that application of micronutrients lead to more number of fruits and yield increase in sweet orange significantly. Ghosh and Basra (2000) also reported highest number of fruits in sweet orange due to combined application of micronutrients along with NPK. It has been reported that Zn affects enzyme systems that regulate various metabolic activities like protein synthesis, formation of chlorophyll, transformation of carbohydrates and regulation of the sugar consumption in the plant. Moreover they play important role in flowering, maturation date, plant height, if present in sufficient quantities in the leaf ultimately resulting in high yield (Horn and Wimmer, 2003).

Yield reduction from the highest yield obtained (Fig. 14) was maximum in control plots and FP. This point to the need of educating farmers about the scientific methods of fertiliser application giving thrust to balanced and judicious application. It becomes clear from the picture that crops responded to site-specific

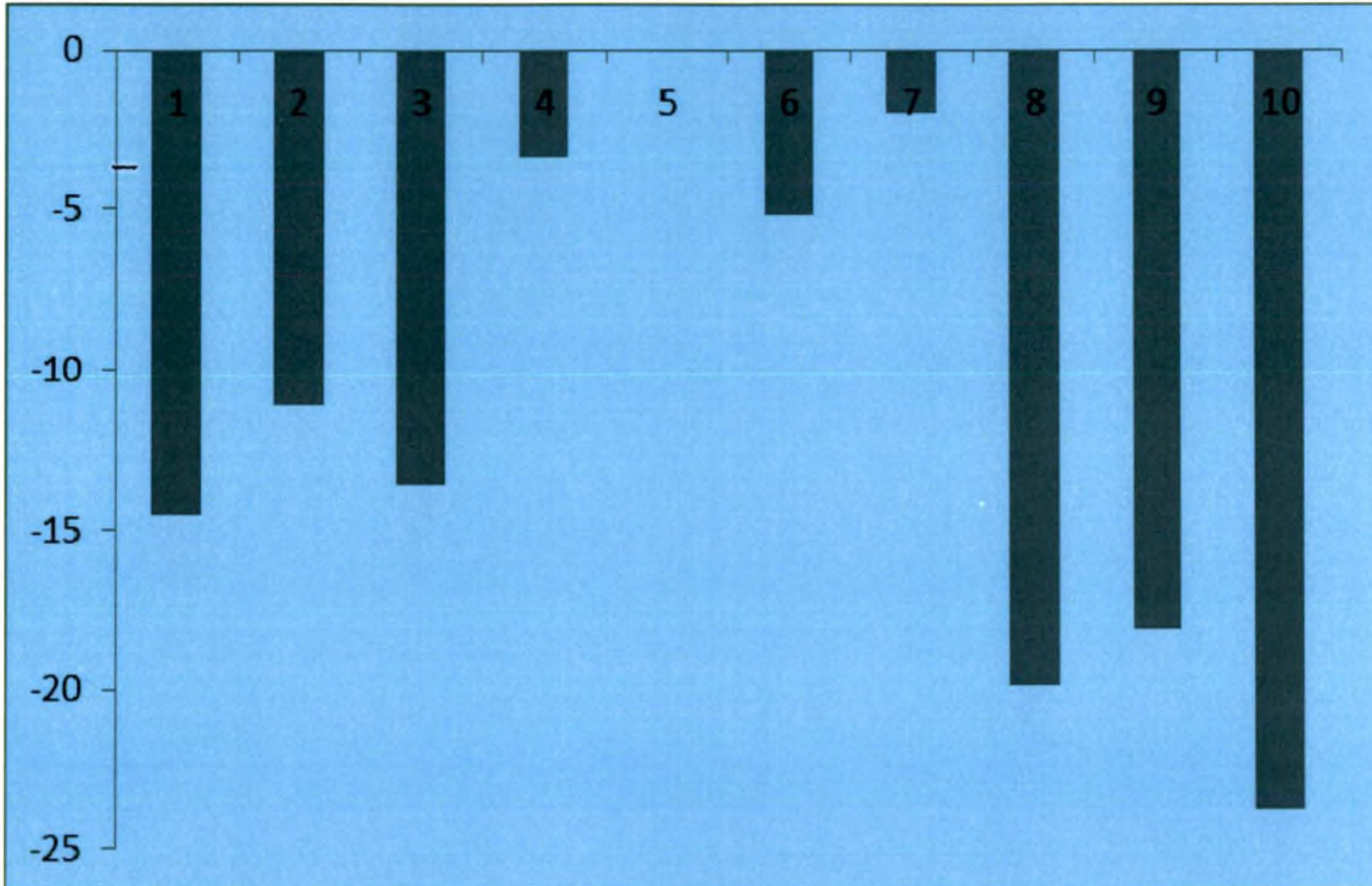

Fig. 14. Deviation from maximum yield in different treatments in SSNM experiment

Plate 11. SSNM (HYT) - soil application

Plate12. SSNM (MYT) - foliar application

Plate 13. SSNM (HYT) - foliar application

Plate 14. Farmer's practice – I

prescription of nutrients, whatever may be the method of micronutrient application. This is because of inherent shortage of plant essential nutrients in soil.

5.4.3. Site Specific Recommendation on Dry Matter Production in Bitter Gourd

Accumulation and partitioning of dry matter among the plant parts are very important in regulating crop yield. The dry matter production and its accumulation in the reproductive parts invariably depend upon the magnitude and persistence of photosynthetic capacity of the plant. Photosynthetic capacity of the plant is reflected on the dry matter accumulation in leaves and leaf area index. The plant and fruit dry matter production in the present experiment were significantly different between treatments. As can be seen from Fig. 15, delta values (Y_{max} – Y) followed almost a linear pattern stressing the importance of essential nutrients.

In the case of plant dry matter production the highest value was recorded by the SSNM treatment for high yield targets. The fact that an early start leads to better yields has been pointed out in capsicum by Bernstein and Froncios (1973) and Horton *et al.* (1982). The SSNM target for medium yield recorded low plant dry matter than the recommended practices with secondary and micronutrient addition. This might be due to the high level of N in these treatments. The farmers' practices also recorded a low value of plant dry matter production compared to the recommended practice due to the inadequate supply of nutrients. The higher dry matter production was recorded in targeted yield level treatment of 30 q ha^{-1} at all growth stages of the crop (Deshmukh, 2008) in chilli. The SSNM treatments with soil application of micronutrients were significantly different from corresponding treatment with foliar application of micronutrients. But the treatments T_2 and T_3 were not significantly different from each other even though they were having the same dose but different application methods. It was reported that soil application of micronutrients is superior to foliar application in acidic soils (Dwivedi and Dwivedi, 1991).

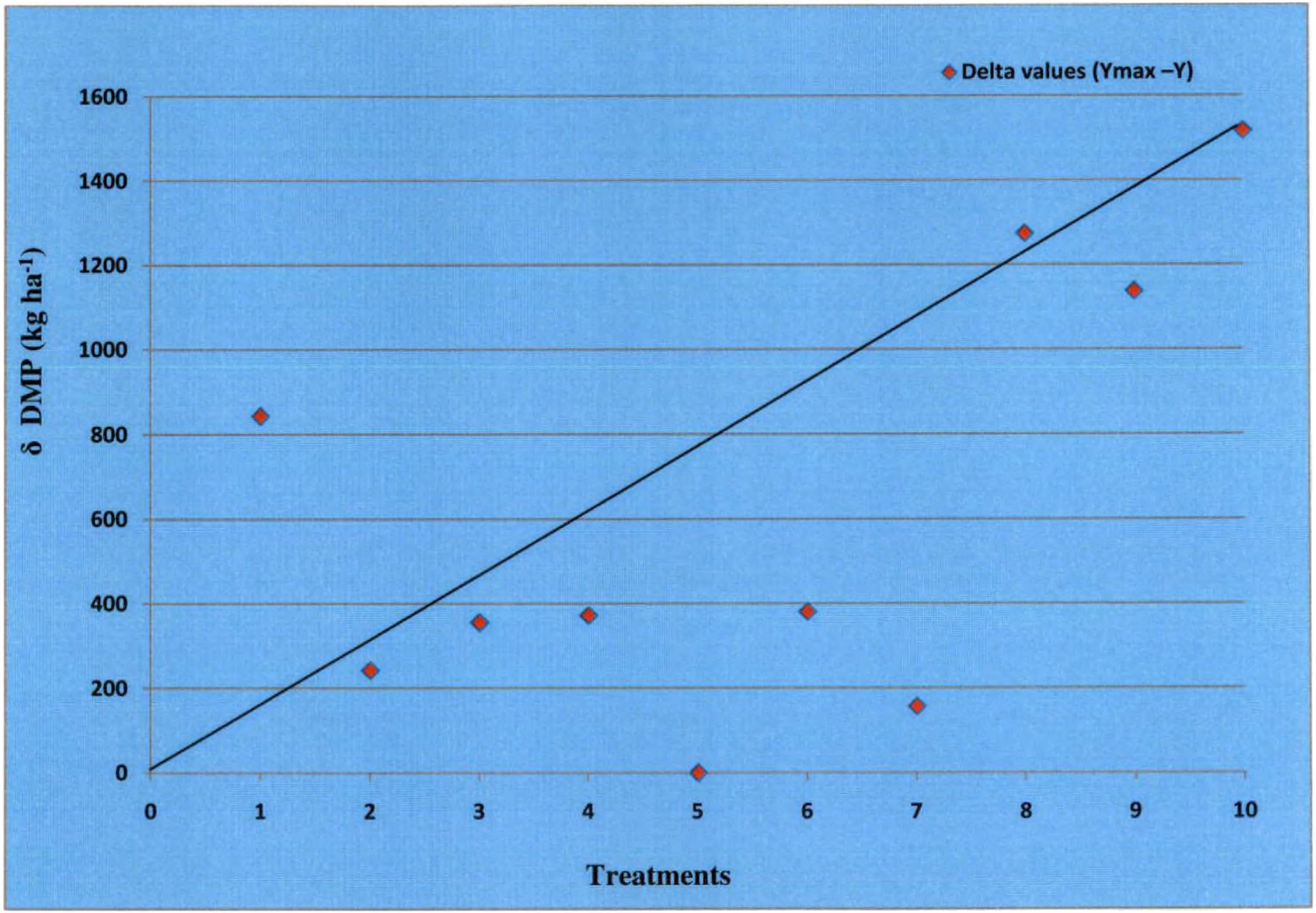

Fig 15. δ Values (Y_{max} – Y) for dry matter production

Plate 15. Farmer's practice – II

Plate 16. Absolute control in SSNM

Plate 17. SSNM validation trial

In the case of fruit dry matter production the highest value was recorded by the SSNM treatment for high yield targets. Here also the soil application of micronutrients had resulted more dry matter than the foliar application. The nutrients showed high use efficiency through soil application than the foliar application. Improved dry matter production and its accumulation in reproductive parts of the plant can be achieved only with the development of a sound photosynthetic structure in the early period of crop growth with the application of the right amounts of essential nutrients. The SSNM treatments with high yield targets were significantly different from each other but those with medium yield targets were on par in the case of fruit dry matter production. The percentage allocation of dry matter to fruits (Fig. 16) indicates that dry matter was maximum partitioned to fruits in SSNM treatments. This higher allocation was possible perhaps due to better sink capacity as indicated by the higher number of fruits and fruit yield. The farmers' practices recorded a lower value of fruit dry matter production compared to the recommended practices as well as the SSNM treatments. These results are in line with Dhillon *et al.* (2006), Chand *et al.* (2006) and Kadam and Sonar (2006) who reported that the targeted yield could be achieved with 10 ± deviation from the target in different crops. But it is surprising to note that though the RDF (T_1) did not receive micronutrient fertilization, the percentage allocation to fruit dry matter was highest in this treatment among RDF treatments with and without micronutrient application. However this is not reflected in the total production since in this treatment the fruit yield was significantly lower to RDF (with micronutrient).

5.4.4. Site Specific Recommendation on Fruit Quality Parameters

The influence of plant nutrition on quality of vegetables has become a topic of interest since more and more cases of deficiency disorders are being reported worldwide. Even though fruit quality usually increases as soil nutrient levels increase from deficient to optimum levels, nutrient levels that produce maximum yield may not always correspond to levels that result in highest fruit quality. In the present experiment, fruits from SSNM treatments recorded high

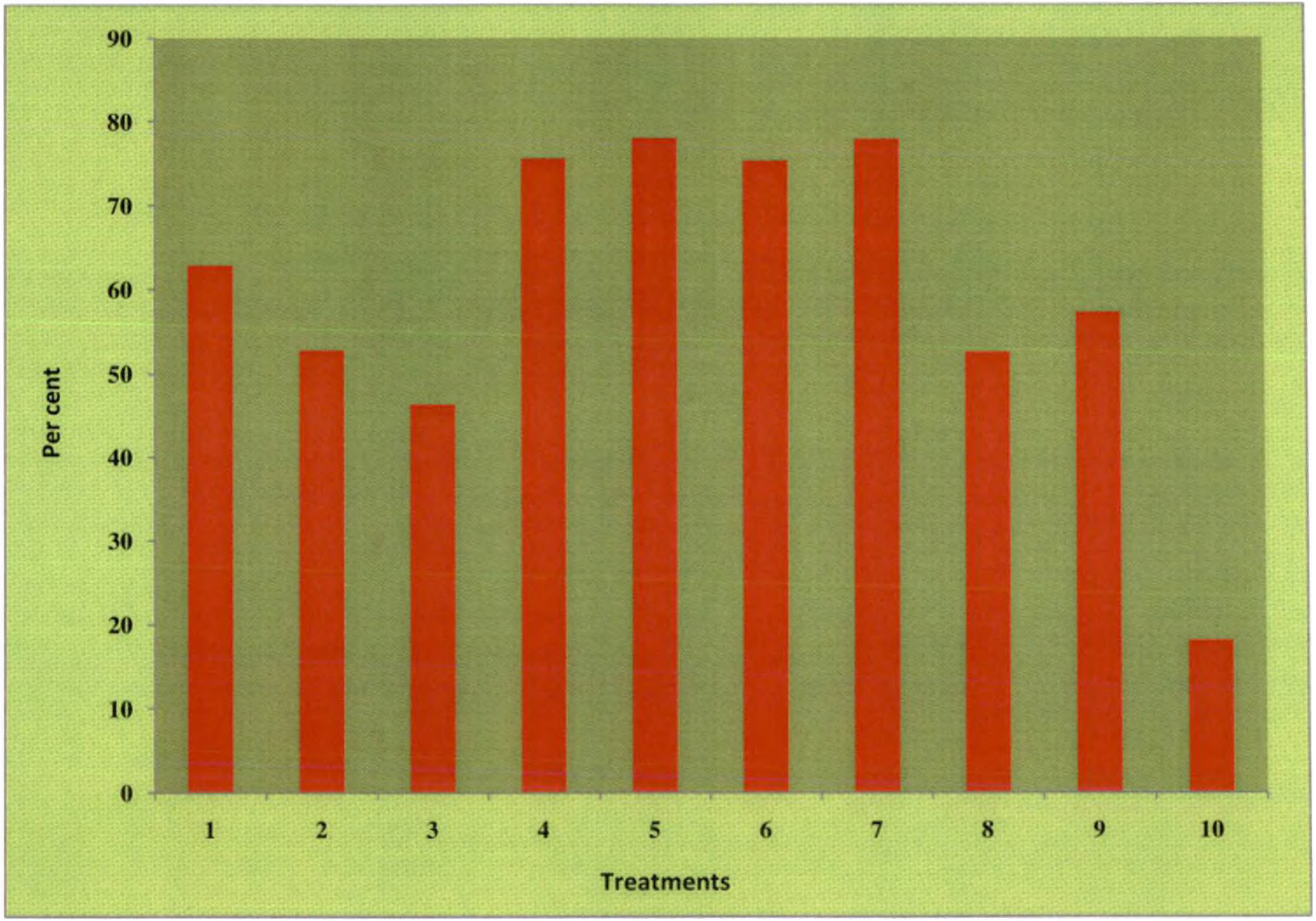

Fig. 16. Effect of SSNM on per cent dry matter allocation to bitter gourd fruits

keeping quality than the recommended practices. The K, Ca and B are known to have significant roles in improving fruit quality parameters. In SSNM treatments, plants have received these nutrients in the right quantity, thereby improving the quality of fruits. Singh *et al.* (2008) also reported that inclusion of micronutrients produced a significantly favourable response on juice and TSS of sugarcane. But in another experiment, inclusion of secondary nutrients increased juice yields significantly, but did not have a significant effect on TSS (Srivastava *et al.*, 2009). An improvement in juice quality with the application of P and K also has been reported by Kumar *et al.* (2002). Importance of micronutrients like boron on the keeping quality of fruits and tubers was indicated by Tisdale *et al.* (1995). Vitamin C values were found significantly different between treatments. The highest value was recorded by the SSNM treatments for high yield targets. This might be due to the high amount of fertiliser nutrients in these treatments. Significant increase in vitamin C content of chilli fruits (cv. K.2) with increased levels of K application was observed by Shibila Mary and Balakrishnan (1990). The increased content of ascorbic acid was attributed to better nutrient availability and uptake. Another reason was the close relationship between carbohydrate metabolism and formation of ascorbic acid due to application of higher doses of fertiliser which provided adequate nutrients (Majumdar *et al.*, 2000; Ananthi, 2004). But the value in recommended practice (T_1) was found to be significantly lower compared to other treatments except farmers' practices and control. Deshmukh (2008) reported that the ascorbic acid content increased with the application of higher targeted yield level treatments. There are also reports that an inverse relationship exists between ascorbic acid and N (Mapson, 1955; Chenoy, 1984).

The iron and crude protein content of plant and fruits were significantly different between treatments. The highest value was recorded by the treatments where the foliar application of micronutrients was done. The soil application of micronutrients recorded significantly low values of iron content in fresh fruits compared to the foliar application. The farmers' practices also recorded a lower value which was significantly different from the other treatments and control. The lowest value was recorded by the absolute control. The crude protein content (Table 35) of both plant and fruits was significantly different between treatments. The highest value was recorded by the SSNM treatment for high yield. This might be due to the supply of high levels of N to these treatments. The effect of plant N in regulating the crude protein content in bitter gourd is evident from Fig. 17.

The biochemical pathway of nutrient N in plants indicate the N in the form of ammonium (NH_4^+) or nitrate (NO_3^-), which after a series of reductions will be assimilated into numerous amino acids that are subsequently incorporated into protein synthesis (Tisdale *et al.*, 1995). Therefore higher levels of N nutrition would have favourably influenced the crude protein content of fruits on account of increased N assimilation. The N application, promoting the crude protein content was previously reported by Fritz and Habben (1972) in spinach, Maurya (1987) in cucumber, Haris (1989) in snake gourd and Olaniyi (2008) in spinach. But the treatments T_4 and T_6 recorded significantly low values compared to other treatments because of the low levels of N nutrition in these treatments. Rajasree and Pillai (2012) reported that higher levels of N nutrition would have favourably influenced the crude protein content of bitter gourd fruits on account of increased N assimilation. The negative influence of N nutrition on fruit quality has been reported by Baser (1986) in potato and Aschcroft and Jones (1993) in tomato. Besides reduced yields, low N levels generally result in less protein content and inferior quality in harvested vegetables (Rajasree and Pillai, 2012). But favorable influence of N nutrition on Fe content as observed in the present experiment has been reported earlier by Cheng (1982). There is also a direct favorable effect of N on root growth of plants in general which in turn would have promoted the uptake and accumulation of Fe. Effect of N nutrition in increasing the iron content was recently reported by Safaa and AbdElFattah (2007).

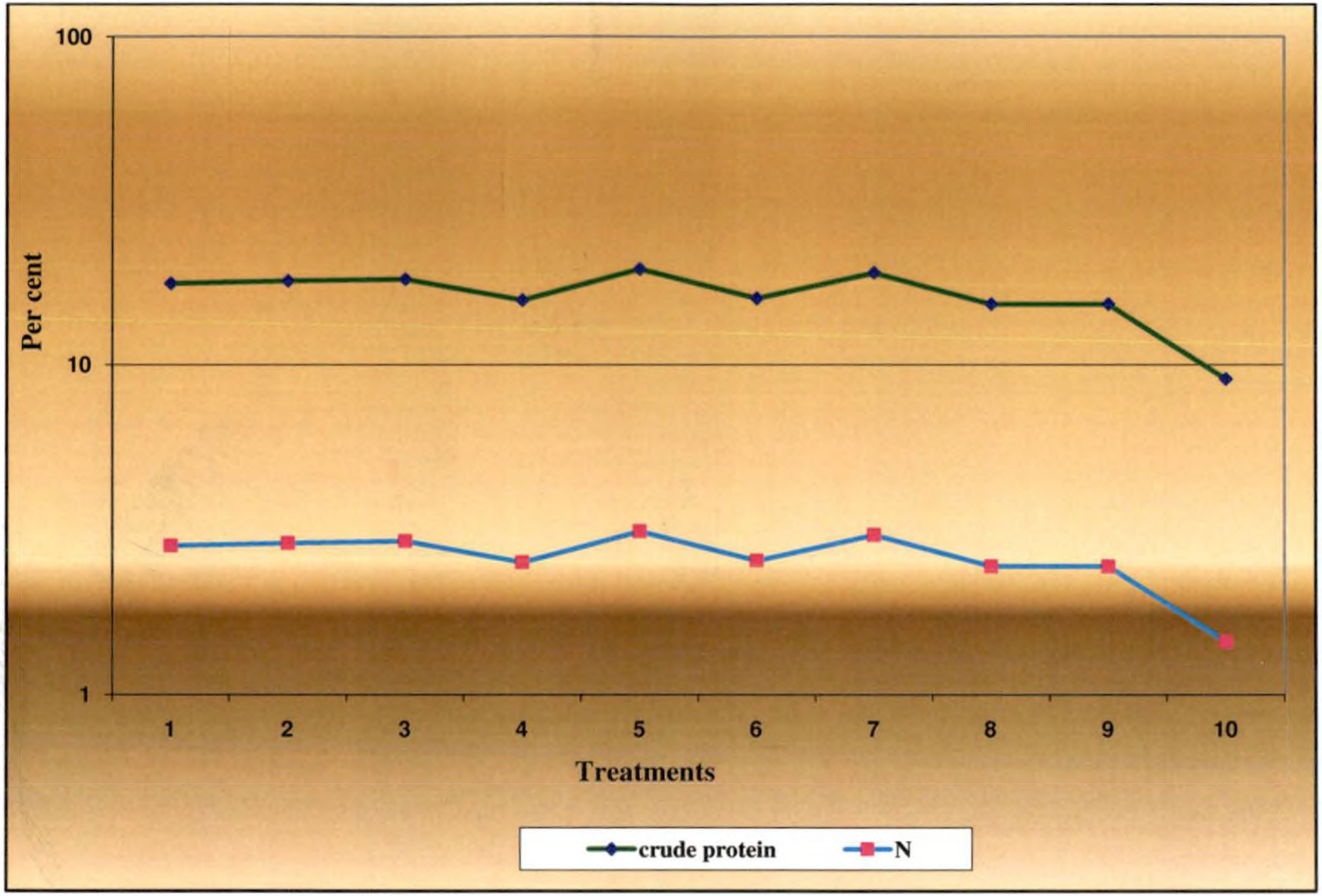

Fig. 17. Effect of SSNM on plant N and crude protein content

5.4.5. Site Specific Recommendation on Pests and Disease Scoring

The pest score was found to be significantly different between treatments. The highest pest scores were obtained for the treatments T_8, T_9 and T_{10} with score value 2.67. The high pest attack observed in these treatments might be due to the application of organic manures in high quantity. The treatments T_1, T_2 and T_7 recorded the same value of 2.33 for pest score. The high rate of N application also might be one of the reasons for high pest attack as it increases the vegetative growth of the plant. Similar reports have been made by Deshmukh (2008) in chilli. The lowest value was recorded by the treatments T_4 and T_6 with score value of 1.67 as this treatment received low rate of N along with micronutrients Zn and B. Effect of Zn and B in reducing fruit fly infestation in bitter gourd has been previously reported by Akram *et al.* (2010). The disease scores in SSNM experiment were not significantly different between treatments. The variety Preethi was found to be resistant to the major disease mosaic and this might be reason for low score of disease appearance in all the treatments.

5.4.6. Site Specific Recommendation on Nutrient Uptake and Use

The data on nutrient content revealed that plants receiving site-specific recommendations had a higher efficiency of nutrient absorption. Maximum absorption of almost all nutrients was recorded in SSNM treatments with high yield target (Fig. 18). This is anticipated since harnessing synergistic nutrient interactions operating at higher levels at crop productivity is vital for achieving high productivity targets. The dry matter yield and fruit yield in these treatments were significantly superior to other treatments, which necessitated a high plant uptake. The FPs recorded significantly low nutrient content than other practices except control because of the low indigenous as well as the external sources of nutrients. It has been reported that foliar application of B brought a significant increase in leaf N, P and K levels of sprayed 'Kinnow' mandarin trees as compared to control trees (Ullah *et al.,* 2012). Application of higher levels of N also could significantly increase the total P in fruit of bitter gourd (Rajasree and

Pillai, 2012). The treatment T_2 recorded significantly high value of total N uptake compared to SSNM for medium yield targets as the N level in this treatment was higher than the SSNM treatment for medium yield target. The SSNM treatments for medium yield targets and the RDF did not show significant difference between treatments as rates of P application were 30 and 25 kg ha^{-1}. The lowest value was recorded by the treatment absolute control. Deshmukh (2008) reported significantly high total uptake of nutrients N, P and K at different targeted yield level treatments in chilli. The FPs recorded significantly low values of total N uptake because of the low application of N sources as well as the low availability of N in the location. The plant uptake of nutrients also was the highest in SSNM (HYT) treatment. The uptake and utilization of element K greatly depends on the supply of other nutrients especially N (Tisdale *et al.*, 1995). When N was applied in higher levels, the plant requirement and uptake of K also might have increased which would have resulted in better accumulation of K in fruits. The N nutrition promoted the total K content was reported by Singh *et al.* (1970) in cauliflower heads and Funda *et al.* (2008) in broccoli. Higher levels of N application significantly increased the iron content in bitter gourd as reported by Rajasree and Pillai (2012). The same results were earlier reported by Saafa and AbdElFattah (2007) and Funda *et al.* (2008).

The highest value of plant boron was recorded by the treatment T_7 followed by T_6 but were on par. The foliar application treatments (T_3, T_6 and T_7) showed significantly high values than the soil application treatments (T_2, T_4 and T_5). Foliar fertilization not only improves plant growth traits, crop yields and nutrient uptake by crops (Maitlo *et al.*, 2006) but also enhances nutrient use efficiency of crops (Fageria *et al.*, 2009). The RDF also showed significantly low value of boron content than the other treatments except T_8, T_9 and T_{10} because of the low boron content of native soil. The Ca, Fe, Mn, and B contents of 'Kinnow' mandarin leaves showed an increase after the foliar application of B except leaf Mn contents reported by Ullah *et al.* (2012). In the case of Zn, the highest value was recorded by the SSNM treatment for high and medium yield targets with soil

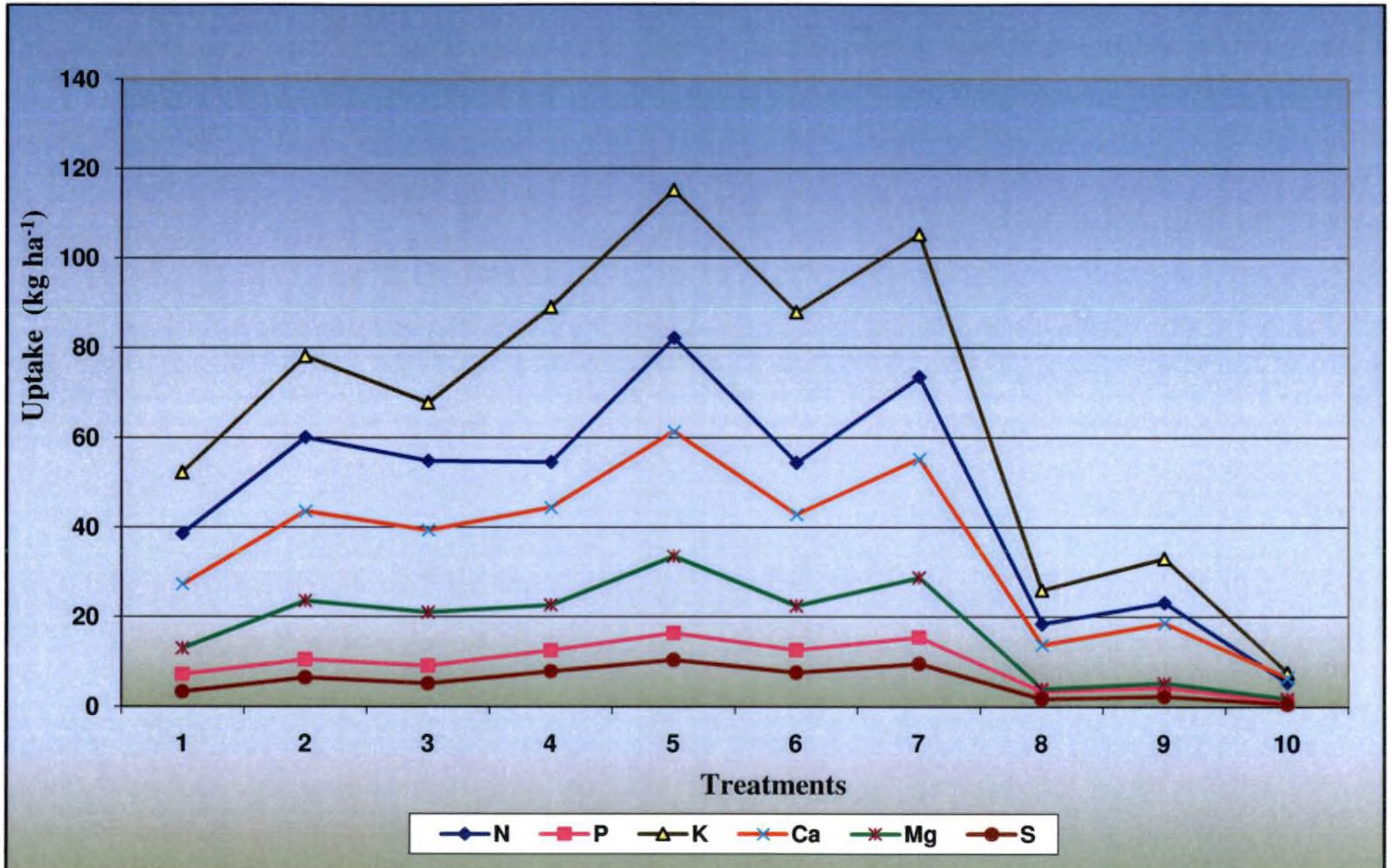

Fig. 18. Effect of SSNM on total uptake of major and secondary nutrients in bitter gourd

application of zinc. It was reported that soil Zn application (50 kg $ZnSO_4 \cdot 7H_2O$ ha^{-1}) effectively increased the grain Zn concentration in Zn-deficient locations, while foliar Zn application significantly increased the Zn concentration of whole grains and each grain fraction in all locations (Cakmak *et al.*, 2010a; 2010b). Rengel *et al.* (1999) reported increase in Zn concentrations in roots, leaves, and stems of plants by applying Zn-fertilisers to soil. All the SSNM treatments recorded a high content of zinc in fruit samples than the rests of the treatments. Nutrient interaction is an important phenomenon influencing their use, efficiency and also the balance in nutrient uptake. The N and P interactions are generally recorded to be positive and their effects are associated with the nutrient balance in the plant. Several studies have shown that the interaction effects of N x S, K x S, Ca x S and S x Zn are synergistic whereas P x S (at high levels only), and S x Mo were antagonistic in influencing the yield, quality (oil, protein, amino acid and fatty acid synthesis) and uptake of nutrients by different crops.

5.4.7. Site Specific Nutrient Recommendation on Soil Properties

The nutrient availability to crops is dependent on the inherent fertility status of the soils, the level of soil management and amendments of soil problems like acidity, nutrient fixation, salt deposition etc. which are considered unfavourable soil situations which put constraints in native nutrient availability and availability from applied fertilisers. The physical, chemical and biological reactions in the soil-plant system affect the fate of the applied nutrients in terms of their use by the crops or loss through various phenomena. In the present study, the pH of the soil after harvest of the crop showed significant variation due to treatments. The values varied from 5.23 to 5.47. The electrical conductivity values also recorded significant difference due to treatments. The values varied from 0.04 to 0.08 dS m^{-1}. The application of different fertiliser salts might increase the total soluble salt concentration in soil this in turn amplified the EC.

The water holding capacity of the soil after harvest showed significant difference due to treatments. The treatment T_5 recorded the highest value (29.23

per cent) of WHC followed by T_6 (28.67 per cent) (Table 56). The high dry matter production in this treatment improved the organic matter content of the soil and this might have increased the WHC of the soil under this treatment. The lowest value was recorded by the treatment T_1 (26.47 per cent) followed by T_8 (27.00 per cent) which might be due to the low organic matter addition from this treatments. The soil organic carbon content after harvest showed significant variation due to treatments. The highest value was recorded by the treatment T_7 (1.22 per cent) followed by T_6 (1.17 per cent). The high vegetative growth and subsequent fall of the dry matter to the soil might have improved the total organic matter status of the soil and hence the organic carbon content also. The absolute control recorded the lowest value of organic carbon (0.48 per cent) probably due to the low production of plant dry matter.

The available N content showed significant variation due to treatments. The values varied from 155 to 245 kg ha^{-1}. The highest value was recorded by the treatment T_7 (245 kg ha^{-1}) followed by T_5 (242.67 kg ha^{-1}). The reason for this might be the high rate of N addition as treatment. The farmers' practices showed lower values of available N compared to other treatments because of the low rate of application of N as well as the use of low quality manures as source of nutrients. Deshmukh (2008) reported significant increase of available N, P and K (kg ha^{-1}) of soil after harvest of the crop under different targeted yield level treatments. The available P content after harvest showed significant variation due to treatments. The SSNM treated plots showed a comparatively high content of available P compared to other treatments. The farmers' practices and control showed a decrease in available P status. The available K status of soil showed significant difference due to treatments (Table 51). The highest value of available K was recorded by the treatment T_5 (249.33 kg ha^{-1}) followed by T_7 (246.67 kg ha^{-1}). The SSNM treated plots showed an increase in available K than other treatments due to the high K rate in these treatments.

The values of Ca showed significant difference due to treatments. The values varied between 1.20 to 2.93 cmol kg^{-1}. The Ca treated plots showed significantly high exchangeable Ca contents than the others. The addition of N, P and K at high rates has significantly influenced Ca availability in soil. Similarly exchangeable Mg content showed variation from 1.07 to 2.50 cmol kg^{-1}. Here the SSNM treatments recorded high values of Mg content of soil than other treatments. The addition of Mg as fertiliser source might have increased the available Mg in soil. The Fe content of soil showed significant difference between treatments. The values ranged from 86.10 to 97.53 mg kg^{-1} between treatments. The SSNM treatments were found to increase the Fe content than others. This might be due to the positive interaction of other applied nutrients on Fe availability. The treatment T_8 (FP-1) recorded increase in Fe content of soil after harvest. The data on Mn content of soil revealed that the values significantly varied between treatments. The farmers' practices recorded similar values of Mn content as the supply might be the same and the indigenous supply also same. The soil application of zinc increased the available zinc status of the soil. The zinc treated plots showed significantly high content of available Zn than the unapplied plots. The highest value of zinc was recorded by the treatment T_5 followed by T_4. The soil applications were found to have high content of zinc than the foliar application. In annual crops soil application of Zn is a preferred method over less efficient foliar sprays (Katyal and Randhawa, 1983). Soil application of Zn is prophylactic but foliar sprays are therapeutic treatment.

The available copper content of the soil after harvest showed significant difference due to treatments (Table 52). The values varied between 0.44 to 0.67 mg kg^{-1}. The farmers' practices showed a low value of soil copper than the other treatments except control. The boron content of soil after harvest showed significant difference due to treatments. The treatments with soil application of boron showed high content of soil boron than the treatments with foliar application. The boron applied field showed significantly high boron content than the unapplied fields. The SSNM treatments showed same values of soil Mo content (0.14 mg kg^{-1}). The lowest content of Mo was recorded by the treatment T_9 and T_{10}. The exchangeable Al content of soil also showed significant difference due to treatments. The highest value was recorded by the SSNM treatments. The reason for this might be the application of high dose of major and secondary nutrient which in turn enhanced the exchangeable Al in the soil.

The N balance sheet after the experiment revealed that the treatment T_6 recorded highest amount of balance N content followed by T_2. The absolute control recorded the lowest amount of available N after the crop due to the low status of available N and crop removal. The treatments T_4 and T_5 recorded a lower N balance than the farmers' practices. This might be due to the high uptake of N by crop and low indigenous available N status of the soil. The available P balance sheet values showed that the treatment T_6 recorded the highest amount of available P after the crop followed by T_7. Here also the farmers' practices recorded high nutrient balance compared to T_1, T_2, T_3, T_4 and T_5. The reason might be the low crop removal of P and high indigenous status of available P. The absolute control recorded the lowest nutrient balance in case of available P. The K balance sheet values also showed the treatment T_6 recorded highest nutrient balance followed by T_7. Farmers' practices registered comparatively high K balance than other treatments except T_6 and T_7. This might be due to the low crop uptake of applied K. Deshmukh (2008) studied the nutrient balance sheet for major nutrients (N, P and K) and observed that the available nutrient status increased with increasing targeted yield levels. Also the contribution of nutrients from N fixation and mobilization decreased with increasing targeted yield levels.

The bacterial, fungal and actinomycetes counts showed significant difference due to treatments. The bacterial count was highest for the treatment T_5 and T_9 and the lowest count was recorded by absolute control. In the case of fungal count the highest count was observed in the treatment T_9 followed by T_8. This might be due to the addition of high amount of organic manures as sources of plant nutrients. The lowest fungal count was recorded by the treatment T_1 and T_2. Actinomycetes count was highest for the treatment T_9 followed by T_5 and T_7. The soil pH also might have influenced the microbial growth in soil. The WHC of soil in the FPs were high and this might be one of the reasons for high microbial population in these soils. The values showed significant difference due to treatments (Table 56). Fertilization greatly increased soil dehydrogenase activity after long-term application. The highest value was recorded by the treatment T_9 followed by T_3. Increased dehydrogenase activity by mineral N fertiliser was also reported in several studies (Serra-Wittling *et al.*, 1995). The SSNM treatments showed a lower value of dehydrogenase activity compared to farmers' practices - 2.

5.5. ECONOMIC ANALYSIS

As per Table 57, maximum net profit was obtained from the treatment SSNM (HYT). It is evident from the Table 32 that the yield in SSNM (HYT) and (MYT) were 3.7 times that of FP. The maximum return in terms of monetary benefit is also from these treatments. The cost of cultivation was more for SSNM treatments compared to others, but the high net profit obtained has nullified this (Appendix – IX). In SSNM experiment with chilli Deshmukh (2008) reported that higher net returns were recorded in the targeted yield level treatment of 30 q ha^{-1} (₹ 1, 25, 788 ha^{-1}). Priya (2011) also reported the same in chilli. These results thus proved the economic benefits of SSNM to farmers even with the high cost of fertilisers.

5.6. CORRELATION STUDIES

The bitter gourd yield had a significant positive correlation with uptake of nutrients, dry matter production and HI. This result is in conformity with the findings of Deshmukh (2008) in chilli. Similar results have also been reported by Suresh (2000), Vadhana (2003) and Kattimani (2004).

5.7. VALIDATION TRIAL

The validation trial with the most profitable treatments proved that the yield increase was consistent and the yield did not vary beyond ±5 percent. Hence the SSNM treatment for high yield with soil application of micronutrients could be recommended for getting high yield in bitter gourd.

5.8. SSNM ON ENVIRONMENTAL QUALITY

It is clear from Table 48-52 that crop removal of major nutrients was highest for the SSNM treatments. From this we can infer that net loss of the costly nutrients is minimized in SSNM treatments. Thus the nutrients added were fully utilized for growth and developmental activities of the plants, which were well reflected in the high productivity obtained in these treatments. High production in terms of fruit or plant dry matter is a beneficial aspect as far as environmental quality is concerned because higher dry matter production leads to higher percentage of carbon sequestration thereby reducing carbon dioxide build up in the atmosphere. Efficient nutrient management practices thus will impact the energy use and carbon footprint of the crops.

Thus we can conclude that adoption of SSNM can save fertilisers, stabilize and raise fruit yield and nutrient use efficiency and reduce fertiliser cost, contribute to increased profit to farmers. A site-specific nutrient prescription of 123: 59: 160: 30: 40: 25: 10 N P K Ca Mg Zn B kg ha^{-1} was found to produce 24 t of fruits ha^{-1} and a dose of 123: 59: 160: 30: 40 kg N P K Ca Mg + 1 per cent Zn foliar + 0.5 per cent B foliar ha^{-1} was found to yield 22 t fruits ha^{-1}. The farmers in the area could get a monetary benefits of ₹ 6,01,604/- and ₹ 5,42,104/- respectively by adopting these recommendations (Appendix - IX).

SUMMARY

6. SUMMARY

A study entitled 'Site specific nutrient management for bitter gourd (*Momordica charantia* L.) was conducted in College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing the bitter gourd production in Kalliyur village of Kerala. The experiment set up included three steps namely Omission trial, SSNM field study and validation of results. All the experiments were conducted in farmer's fields of Kalliyur village.

Kalliyur village is located in Thiruvananthapuram district and has an area of 17.23 km^2. Kalliyur is one of the major vegetable growing tracts of Thiruvananthapuram district. Majority of people in the village are tenant farmers cultivating in leased lands. Kalliyur is situated on the fringes of Vellayani Lake and this is the main water source for agriculture. Bitter gourd is a popular vegetable in the locality but there are different kinds of yield constraints for its cultivation. Even though the labour charge is huge, the high price fetched by bitter gourd irrespective of the season encouraged the people to continue the cultivation of bitter gourd.

1. The field survey conducted in the village revealed many kinds of yield constraints related to cultivation of bitter gourd. Most of the farmers were not having own land. Hence they have to depend on leased land for agriculture. Cultivation is done in reclaimed wet lands and the garden lands. Most of the farmers are using different kinds of organic manures. Application of poultry manure for crops is common in the village. The use of chemical fertilisers was low and most of the farmers were preferring fertiliser mixtures which were easily available.

2. Spatial variability studies conducted along with the field survey revealed that remarkable variations existed in the soil properties across the village. The values on soil pH indicated that soils of the village were acidic in reaction. The EC values of the samples also varied widely but it was in the admissible range and

there were not a notable amount of salt to cause threat to the crop production. The content of organic carbon varied from 0.40 per cent to a high value of 3.83 per cent. Available N status varied from low to medium. The P status of the soil showed medium to high values. Available K in various locations ranged from low to medium. Available Fe was not deficient but available Zn was deficient in majority of the sites.

3. The microbial analysis revealed that the bacterial, fungal and actinomycetes counts and dehydrogenase activity moderately varied in different sites of the village.

4. Data on irrigation water analysis showed that the water used in the village for irrigation was slightly acidic but safe for irrigation as it did not contain significant amount of soluble salts and other elements.

5. Nutrient omission trial conducted at selected location showed that the indigenous supply of major nutrients in the locality is limited except phosphorus. The highest yield was obtained for (+) NPK treatment and lowest for (-) NPK. Yield reduction in P omission plot was less compared to N and K omission owing to the higher supply of indigenous P in soil.

6. Number of fruits was the highest in NPK treatment followed by the P omission plots but a marked reduction of number of fruits was recorded in K omission plots. This indicated the importance of K in bitter gourd fruit production.

7. Small sized fruits were produced in absolute control but reduction in fruit size was also observed in K omission plots. The low supply of indigenous K to plants is the reason for this.

8. Dry matter production was highest for 100 per cent NPK followed by P omission. The plant dry matter production on per hectare basis also showed the same trend as in the case of per plant DMP proving the deficiency of nutrients in the omission and control treatments.

9. The nutrient concentration in plant and fruit samples revealed that nutrient omission had profound influence in nutrient use and uptake by bitter gourd plant. Absolute control recorded the lowest content and uptake of nutrients in bitter gourd plant and fruits.

10. The micronutrient analysis of the soil after harvest recorded low status demanding application of micronutrients especially Zn and B.

11. The microbial and enzyme analysis of soil revealed that the 100 per cent NPK treatment recorded the highest number of microbes as well as the enzyme activity. The absolute control and N omission plots recorded more or less the same microbial number and enzyme activity.

12. Initial analysis of the soil sample during SSNM experiment revealed that the soil was acidic in reaction with low soluble salts and medium status of organic carbon.

13. The initial available nutrient status showed that N and K were low and P was high. Availability of Ca and Mg was medium and micronutrients like Zn and B was deficient. A high status of available Fe and Al was found in the soil, but that of Mn and Cu was in the sufficient range.

14. The initial Irrigation water analysis revealed that the pH of the water is slightly acidic with low values of EC and had safe levels of minerals and heavy metals, posing no threat for irrigation.

15. SSNM experiment revealed that the treatment T_5 (Site specific nutrient recommendations for high yield target (Soil application of micronutrients)) recorded the highest value of length of vine followed by T_7 (Site specific nutrient recommendations for high yield target (Foliar application of micronutrients)). However there was significant difference between the treatments.

16. Significant difference between SSNM treatments were recorded for node at which first male and female flower appeared where as the number of days to harvest was not significantly different between the ten treatments.

17. SSNM for high target yield with soil application of micronutrients (T_5) recorded the highest yield and yield attributing characters. This was followed by the SSNM high yield target with foliar application of nutrients. The yields recorded were more than two times than the recommended dose. The deviation from the highest yield was maximum in control plots and FP indicating the need of educating farmers about the scientific methods of fertiliser application giving thrust to balanced and judicious application.

18. The dry matter production also showed that the high and medium yield targets with soil application of micronutrients resulted in the highest values compared to the corresponding treatments with foliar application of micronutrients and RDF with soil and foliar application of secondary and micronutrients.

19. The treatment T_4 recorded highest number of days in terms of keeping quality as well as organoleptic scores followed by T_6. The treatments T_7 recorded the highest beta carotene content where as the vitamin C content was highest for the treatment T_5.

20. The nutrient concentration in plant samples as well as fruit samples significantly varied between treatments. SSNM treatments for high yield targets resulted in high concentration of major and secondary nutrient concentrations. Plant content of Fe, Mn, Zn, Cu and B were the highest in T_7 followed by T_6 (both treatments received foliar application of micronutrients) and Mo values were highest for the treatment T_5 followed by T_4. Fruit content of Fe, Zn, B and Mo were the highest in treatment T_5 (Site specific nutrient recommendations for high yield target (soil application of micronutrients) followed by T_4. In the case of Mn and Cu the highest value was recorded by T_7 followed by T_5.

21. Nutrient uptake by plant was also significantly different between the treatments. The treatment T_5 recorded the highest uptake of major, secondary and micro nutrients except Zn and B. Absolute control recorded the lowest values. Similar trend was observed in fruit nutrient uptake except for Zn and B.

22. The harvest index was the highest for T_5 and T_7 followed by T_4. The lowest value of HI was recorded by absolute control.

23. The soil physical and chemical properties after final harvest were significantly different between treatments. Lowest value of pH was recorded in absolute control followed by T_7. The highest pH value recorded by T_3 followed by T_2, T_5 and T_6. Highest EC value was recorded by T_4, T_5 and T_6 followed by T_1, T_2 and T_7. Highest value of organic carbon was recorded by the treatment T_7 followed by T_6.

24. Among the major and secondary available nutrients N, P and S were the highest in T_7 where as K, Ca, Mg were highest in T_5. All micronutrient contents except Zn and B after harvest were highest in T_7 plot. The Zn and B content of soil were highest in SSNM treatment for high yield with soil application of micronutrients (T_7).

25. In the case of nutrient balance sheet the highest value of N balance sheet was obtained in T_6 followed by T_2 while the highest value of P balance sheet was obtained in T_6 followed by T_7. The same trend was followed in K balance sheet also.

26. The highest bacterial, fungal and actinomycetes count was recorded in treatment T_9. The dehydrogenase activity was also the highest for T_9 treatment followed by T_3.

27. The correlation study revealed that the parameter yield was highly correlated with nutrient uptake as well as dry matter production and HI.

28. Economic analysis revealed that the SSNM practice is beneficial to farmers as it is able to provide more income than the usual farmer's practice.

29. The validation trial of the best treatments (T_5 and T_7) showed that the yield increase was consistent and hence can be prescribed to other farmers in Kalliyur village.

CONCLUSION

The study conducted in Kalliyur village on bitter gourd conclusively proved that the present rates of fertiliser recommendation are not at all sufficient for getting maximum yield and profit to farmers. The study revealed that the yield barrier could be broken down with substantial rise in yield levels by adopting site-specific nutrient recommendations. A site-specific nutrient prescription of 123: 59: 160: 30: 40: 25: 10 kg N P K Ca Mg Zn B ha^{-1} was found to produce 24 t of fruits ha^{-1} and a dose of 123: 59: 160: 30: 40 kg N P K Ca Mg + 1 per cent Zn foliar + 0.5 per cent B foliar ha^{-1} were found to yield 22 t fruits ha^{-1}. The farmers in the area could get a monetary benefits of ₹ 6, 01, 604/- and ₹ 5, 42, 104/- respectively by adopting these recommendation. Adoption of SSNM prescriptions is advantageous not only from the point of view of increasing profitability to farmers but also minimizing environmental degradation.

FUTURE LINE OF WORK

- Nutrient recommendation for crops should be revised taking into consideration the requirement of secondary and micro nutrients along with the primary nutrients.
- The N, P, K balance for each crop and cropping system should be worked out to prescribe suitable nutrient management for different crops.

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*Original not seen

APPENDICES

APPENDIX-1

Weather parameters

1. **Weather data during cropping period (2009-2010)**

Std Week	Maximum Temperature (^0C)	Minimum Temperature (^0C)	Rainfall (mm)	Relative Humidity (%)
1	31.1	23.2	6	85.0
2	30.9	22.9	36	85.1
3	31.3	23.2	0	85.0
4	31.5	22.9	0	79.7
5	31.6	23.7	0	82.4
6	31.7	24.3	0	80.6
7	31.9	23.7	0	79.4
8	32.6	23.9	0	77.0
9	33.5	24.2	0	73.9
10	33.7	24.3	0	73.5
11	33.8	24.5	0	89.1
12	33.9	24.4	0	89.3
13	33.6	24.5	0	88.3
14	34.1	25.0	13	89.7
15	34.8	25.6	0	84.6
16	34.5	25.8	33	85.0

2. Weather data during cropping period (2011-2012)

Std Week	Maximum Temperature (^0C)	Minimum Temperature (^0C)	Rainfall (mm)	Relative Humidity (%)
1	31.00	20.3	0.86	86.6
2	31.06	22.1	0	86.9
3	31.80	21.7	0.19	86.2
4	30.80	21.2	0	84.6
5	31.20	22.0	0	83.2
6	31.71	21.2	0	82.1
7	31.86	22.4	0	82.4
8	31.60	21.0	5.03	81.1
9	31.66	23.5	0	82.9
10	32.08	22.2	0	81.7
11	32.60	22.2	0	79.9
12	33.94	23.6	0	78.6
13	33.60	23.8	0	88.3
14	34.10	24.1	1.30	89.7
15	34.80	24.3	0	84.6
16	34.50	25.1	3.30	85.0

APPENDIX-II

Input cost

1 kg Urea.............................Rs.10/-

1kg factamfos........................Rs.11.50/-

1 kg Rock phosphate................Rs.8/-

1 kg Muriate of potash..............Rs.10/-

1 kg Zinc sulphate...................Rs.30/-

1 kg Borax...........................Rs.25/-

1 kg Calcium sulphate...............Rs.30/-

1 kg Magnesium sulphate............Rs.30/-

Labour charge........................Rs.300/day

APPENDIX-III

Proforma for field survey

1. Name of farmer:

2. Address:

3. Survey number:

4. Cropping history:

   a. Kharif crop:

   b. Rabi crop:

   c. Variety used:

   d. Area cultivating:

   e. Irrigated area:

   f. Rainfed area:

   g. Yield obtained:

   h. Previous crop in the field:

5. Cultivation practices:

   a. Ploughing method:

   b. Nursery raising/ Direct sowing:

   c. Thinning & 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 available:

k. Plant protection details:

l. Weeding method:

m. Harvesting:

6. Weather data

a. Details of rain:

b. Approximate temperature of the site:

c. Sunlight availability:

d. Details of drought:

e. Details of flood:

f. Relative humidity of the area:

7. Socio- economic conditions

a. Acceptance of the product in the area:

b. Distance to market (km):

c. Type of market:

d. Mode of transport:

e. Involvement of middle man:

f. Whether the land is leased or owned:

g. Credit facility and amount of credit available:

h. Availability of labour:

i. Employment generation:

j. Whether there is support from society or any institution (govt./Pvt.):

k. Influence of nearby farmers if any:

l. Community's influence:

m. Whether agriculture is profitable:

n. Availability of quality inputs:

8. Environmental problems

a. Whether there is drainage facility:

b. Presence of water logged condition:

c. Details of water pollution:

d. Whether there is the practice of excess use of chemical fertilizer:

e. Whether there is mono-cropping is practiced:

f. Details of crop failure due to rain:

g. Details of crop failure due to drought:

h. Details of crop failure due to pests and diseases:

i. Major pests of bittergourd in the area:

j. Major diseases of bittergourd in the area:

k. Details of any type of pollution in the area:

l. Whether the soil is inherently fertile or not:

m. The important eco-friendly practices accepted in the field:

n. Availability of indigenous nutrient sources:

9. Stresses such as water, pests and diseases

a. Whether there is any water scarcity:

b. The periods receiving low irrigation water:

c. Methods of irrigation & facilities available:

d. The extent of yield reduction due to water scarcity:

e. Major pests in the area:

f. Important control measures adopted:

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

h. Important control measures of diseases:

i. Whether there is enough water harvesting structures:

j. Whether there is the practice of rain harvesting:

k. Whether any physiological disorders in plants identified:

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

APPENDIX-IV

List of farmers and site characteristics

Sl. No.	Address	Longitude	Latitude	Elevation	Bearing
1	Unni Palappur	N 8° 25' 621"	E 076° 58' 789"	32m	SE
2	Velukkutty Ottaplavila Kakkamoola	N 8° 24' 290"	E 076° 58' 590"	32m	W
3	Bhavana Varuvila	N 8° 25' 155"	E 076° 59' 971"	41m	NE
4	sathyan Varuvila	N 8° 25' 125"	E 076° 59' 079"	40m	W
5	Bilson Karikkuzhi	N 8° 25' 107"	E 077° 00' 020"	41m	NW
6	Surendran Karikkuzhi	N 8° 25' 124"	E 077° 00' 087"	39m	W
7	Raju Nedingal Kakkamoola	N 8° 25' 076"	E 077° 00' 349"	37m	S
8	Appu Kalliyoor Wet land	N 8° 25' 606"	E 077° 00' 426"	27m	NW
9	Gangadharan Kalliyoor	N 8° 25' 690"	E 77° 00' 336"	31m	NE
10	Baby Kalliyoor	N 8° 25' 629"	E 77° 00' 411"	25m	N
11	Madhu Kalliyoor wet land	N 8° 25' 629"	E 77° 00' 411"	28m	NE
12	Gangadharan Sasthamkovil Kakkamoola	N 8° 25' 742"	E 77° 00' 329"	24m	NW
13	Kakkamoola (Opposite of temple)	N 8° 25' 743"	E 77°00' 332"	23m	S
14	Appu Kulangara, Kalliyoor	N 8° 25' 846"	E 77° 00' 003"	16m	S
15	Robin Jinseng Kakkamoola	N 8° 25' 458"	E 77° 00' 111"	46m	NE

	Junction				
16	Sasi Kuttikkari	N 8° 26' 482"	E 76° 58' 746"	26m	SW
17	Nagappan Kuttikkari	N 8° 26' 482"	E 76° 58' 746"	26m	SW
18	Sadasivan Kuttikari	N 8° 26' 552"	E 76° 58' 787"	22m	N
19	Babu Kuttikari	N 8° 26' 575"	E 76° 58' 777"	21m	S
20	Prasad Perakam	N 8° 26' 755"	E 76° 58' 660"	19m	S
21	Sukumaran Nadar Perakom Thenguvila	N 8° 26' 745"	E 76° 58' 640"	16m	N
22	Mohanan Pappanchani	N 8° 26' 755"	E 76° 58' 659"	20m	N
23	Chandran Kanjiramvila	N 8° 26' 285"	E 76° 58' 584"	30m	NE
24	Manoharan Kanjiramvila	N 8° 26' 254"	E 76° 58' 583"	6m	W
25	Gopan Kanjiramvila	N 8° 26' 294"	E 76° 58' 624"	6m	E
26	Babu Thenguvila	N 8° 26' 306"	E 76° 58' 647"	9m	NW
27	Raveendran Thenguvila	N 8° 26' 303"	E 76° 58' 649"	6m	SW
28	Bilson Kidanguvila	N 8° 26' 302"	E 76° 58' 649"	4m	N
29	Sasi Kidanguvila	N 8° 26' 311"	E 76° 58' 672"	3m	S
30	Vijayan Kidanguvila	N 8° 26' 314"	E 76° 58' 673"	6m	W
31	Viadyantekari (Priya)	N 8° 26' 314"	E 76° 58' 689"	6m	W
32	Nanukkutty Viadyantekari	N 8° 26' 325"	E 76° 58' 869"	-2m	N
33	Sathyan Pandarakari	N 8° 26' 395"	E 76° 58' 951"	11m	S
34	Sekharan Pandarakari	N 8° 26' 417"	E 76° 58' 958"	12m	NW
35	Raghuvaran Varupandarakar i	N 8° 26' 698"	E 76° 58' 978"	12m	S
36	Surendran	N 8° 26'	E 76° 58'	11m	N

	Varupandarakari	706”	968”		
37	Ratnakaran Thenguvila	N 8° 26’ 302”	E 76° 58’ 657”	11m	NW
38	Vijayan Thenguvila	N 8° 26’ 309”	E 76° 58’ 629”	3m	SW
39	Sasi Kanjiramvila, palappur	N 8° 26’ 285”	E 76° 58’ 634”	7m	E
40	Silan Kanjiramvila	N 8° 26’ 244”	E 76° 58’ 534”	4m	E
41	Rajan Kalliyoor	N 8° 25’ 670”	E 77° 00’ 306”	11m	NE
42	Vincent Nedingal ela	N 8° 25’ 069”	E 77° 00’ 326”	12m	N
43	Manoharan Nedigal ela	N 8° 25’ 079”	E 77° 00’ 356”	21m	NE
44	Sekharan Kattakkaithamood Nadekkari	N 8° 25’ 079”	E 77° 00’ 356”	21m	NE
45	Sivarajan Palappur	N 8° 25’ 720”	E 77° 00’ 790”	38m	S
46	Soman Nedigal ela Palappur	N 8° 25’ 085”	E 77° 00’ 343”	31m	E
47	Rajan Nadekkari	N 8° 25’ 069”	E 77° 00’ 396”	22m	NE
48	Soman Palappur	N 8° 25’ 785”	E 77° 00’ 785”	30m	E
49	Ravindran Thenguvila	N 8° 26’ 322”	E 76° 58’ 667”	11m	NW
50	Karunan Thenguvila	N 8° 26’ 315”	E 76° 58’ 649”	3m	SW

APPENDIX-V

Variables utilized for the generation of SSNM fertilizer recommendation

Potential Indigenous N supply (kg ha^{-1}) INS= Crop N uptake in a plot without N application but ample P and K supply.

Potential Indigenous P supply (kg ha^{-1}) IPS= Crop P uptake in a plot without P application but ample N and K supply.

Potential Indigenous K supply (kg ha^{-1}) 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^{-1}) = RN

Recommended P fertilizer rate (kg ha^{-1}) = RP

Recommended K fertilizer rate (kg ha^{-1}) = RK

Slope of envelop function grain yield Vs. N uptake, maximum accumulation of N in the plant, aN

Slope of envelop function grain yield Vs. N uptake, maximum dilution of N in the plant, dN

Slope of envelop function grain yield Vs. P uptake, maximum accumulation of P in the plant, aP

Slope of envelop function grain yield Vs. P uptake, maximum dilution of P in the plant, dP

Slope of envelop function grain yield Vs. K uptake, maximum accumulation of K in the plant, aK

Slope of envelop function grain yield Vs. K uptake, maximum dilution of K in the plant, dK

Climatic Potential Supply of N (kg ha^{-1}), SN = INS + RFN x FN

Potential Supply of P (kg ha^{-1}), SP = IPS + RFP x FP

Potential Supply of K (kg ha^{-1}), SK = IKS + RFK x FK

Actual N uptake as a function of N and P supply (kg ha^{-1}), UN (P)

Actual N uptake as a function of N and K supply (kg ha^{-1}), UN (K)

Actual P uptake as a function of P and N supply (kg ha^{-1}), UP (N)

Actual P uptake as a function of P and K supply (kg ha^{-1}), UP (K)

Actual K uptake as a function of K and N supply (kg ha^{-1}), UK (N)

Actual K uptake as a function of K and P supply (kg ha^{-1}), UK (P)

Final estimate of actual N uptake (kg ha^{-1}), UN= min (UN (P), UN (K))

Final estimate of actual P uptake (kg ha^{-1}), UP= min (UP (N), UP (K))

Final estimate of actual K uptake (kg ha^{-1}), UK= min (UK (N), UK (P))

Estimated yield for the predicted UN at maximum accumulation of N in the plant (kg ha^{-1}),

YNA= aN*UN

Estimated yield for the predicted UN at maximum dilution of N in the plant (kg ha^{-1}),

YND= dN*UN

Estimated yield for the predicted UP at maximum accumulation of P in the plant (kg ha^{-1}),

YPA= aP*UP

Estimated yield for the predicted UP at maximum dilution of P in the plant (kg ha^{-1}),

YPD= dP*UP

Estimated yield for the predicted UK at maximum accumulation of K in the plant (kg ha^{-1}),

YKA= aK*UK

Estimated yield for the predicted UK at maximum dilution of K in the plant (kg ha^{-1}),

YKD= dK*UK

Estimated yield for actual N uptake as limited by yield that can be achieved with the actual P uptake (kg ha^{-1}) YNP

Estimated yield for actual N uptake as limited by yield that can be achieved with the actual K uptake (kg ha^{-1}) YNK

Estimated yield for actual P uptake as limited by yield that can be achieved with the actual N uptake (kg ha^{-1}) YPN

Estimated yield for actual P uptake as limited by yield that can be achieved with the actual K uptake (kg ha^{-1}) YPK

Estimated yield for actual K uptake as limited by yield that can be achieved with the actual N uptake (kg ha^{-1}) YKN

Estimated yield for actual K uptake as limited by yield that can be achieved with the actual P uptake (kg ha^{-1}) YKP

Final average yield estimate (kg ha^{-1}), GY= (YNP, YNK, YPN, YPK, YKN, YKP)

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

Yield producing uptake efficiency of P, YPUEP= UP/SN

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

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

APPENDIX-VI

Chemical analysis data of the soil samples from different sites of the village

Site	pH	EC (dS m^{-1})	OC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
1	4.16	0.18	18.0	350.50	179.96	106.00	3.00	5.00	1.40	14.03	3.36
2	5.09	0.23	6.5	265.00	140.92	94.00	2.50	9.00	0.82	13.63	3.28
3	4.37	0.11	12.0	320.00	14.76	152.00	2.00	3.00	1.42	13.94	4.52
4	5.07	0.18	6.0	275.00	167.58	96.00	3.50	9.50	0.97	13.79	3.48
5	5.22	0.14	5.6	260.00	129.49	172.00	2.00	9.50	0.62	13.52	2.97
6	5.40	0.17	5.8	254.00	161.87	164.00	2.50	3.00	0.60	12.79	1.97
7	4.08	0.17	22.0	365.00	161.87	128.00	1.50	4.50	1.20	14.09	4.94
8	4.59	0.07	17.5	350.00	66.65	90.00	5.00	1.50	1.36	13.08	4.33
9	5.14	0.10	5.9	270.50	99.02	114.00	3.50	1.00	0.75	12.94	3.06

10	4.42	0.18	17.0	340.00	174.25	174.00	3.00	3.00	1.40	13.96	4.41
11	4.11	0.14	27.2	370.00	134.26	124.00	4.50	2.50	1.41	14.06	4.87
12	4.40	0.11	27.5	374.00	180.91	88.00	6.00	5.00	1.39	13.75	4.50
13	4.80	0.10	17.4	350.00	11.40	170.00	2.00	2.00	1.23	13.64	4.08
14	3.90	0.11	33.0	385.00	270.90	168.00	3.50	3.50	1.30	14.08	5.11
15	5.45	0.26	8.5	285.00	244.71	144.00	2.00	1.50	0.58	12.90	2.08
16	6.30	0.19	4.0	225.50	115.21	124.00	3.50	3.50	0.22	12.50	1.63
17	4.62	0.01	21.0	325.00	11.40	18.00	5.50	4.00	1.22	13.58	4.29
18	4.13	0.36	28.0	345.00	134.11	176.00	3.50	6.00	1.40	14.04	4.73
19	5.30	0.27	7.5	286.00	259.40	94.00	4.50	3.00	0.61	13.02	3.09
20	3.20	0.02	38.3	394.20	14.20	18.00	2.00	1.00	1.35	14.12	5.19

21	4.40	0.28	25.0	365.00	269.47	86.00	1.50	4.00	1.39	13.78	4.48
22	5.10	0.17	9.0	290.00	164.73	83.00	2.00	3.50	0.72	13.66	3.28
23	4.80	0.36	15.0	335.00	142.70	79.00	3.00	6.00	1.42	13.64	4.08
24	5.40	0.19	8.5	285.00	176.15	168.00	4.00	3.00	0.84	12.90	1.96
25	5.40	0.04	5.5	246.00	84.70	148.00	2.50	2.50	0.82	12.80	1.97
26	5.20	0.04	5.8	255.60	87.10	146.80	2.75	2.65	0.89	12.75	1.89
27	5.25	0.03	5.4	245.60	85.10	147.80	2.85	2.45	0.79	12.95	1.79
28	5.30	0.03	5.0	240.60	85.70	147.00	2.45	2.55	0.81	12.85	1.99
29	5.40	0.05	6.8	275.60	80.10	156.80	2.70	2.60	0.80	12.70	1.80
30	5.34	0.04	6.3	264.98	82.30	153.20	2.69	2.58	0.81	12.76	1.83
31	5.35	0.04	6.3	269.98	80.30	152.12	2.65	2.53	0.82	12.76	1.85

32	5.35	0.04	6.3	267.48	81.30	152.66	2.67	2.55	0.31	12.76	1.84
33	5.39	0.05	5.4	256.43	71.50	155.73	2.60	2.55	0.29	12.80	1.89
34	5.37	0.04	5.3	255.50	60.50	150.30	2.46	2.45	0.32	12.68	1.79
35	5.41	0.06	6.8	285.50	75.00	170.33	2.46	2.35	0.48	13.80	1.83
36	5.40	0.05	6.5	275.50	70.00	170.33	2.46	2.35	0.45	13.80	1.83
37	5.29	0.04	5.8	254.35	84.50	149.60	2.69	2.56	0.82	12.81	1.87
38	5.28	0.04	5.7	244.30	74.40	150.60	2.67	2.55	0.85	12.82	1.85
39	4.85	0.36	15.5	345.00	105.70	159.00	3.50	6.10	1.35	12.64	4.18
40	5.35	0.18	8.0	280.00	175.15	168.00	4.10	3.30	0.85	12.90	1.86
41	5.10	0.11	6.0	285.50	109.02	111.00	4.50	1.20	0.65	13.94	2.16
42	5.19	0.23	6.4	266.00	130.92	110.00	2.45	9.50	0.80	13.53	3.20

43	4.18	0.17	31.0	368.50	131.87	128.00	1.50	4.20	1.12	14.09	5.19
44	4.10	0.15	29.5	355.80	121.87	148.00	1.52	4.40	1.22	14.10	4.24
45	4.60	0.06	22.5	362.00	96.16	134.00	4.00	3.50	1.31	13.70	4.29
46	4.15	0.11	25.0	350.50	101.87	138.00	2.00	4.10	1.10	13.09	4.54
47	5.10	0.12	5.6	275.50	109.02	110.00	3.50	1.20	0.85	14.11	2.06
48	4.81	0.11	5.1	265.50	109.02	119.00	2.50	1.12	0.75	14.00	2.46
49	5.50	0.09	6.5	270.50	76.30	150.12	2.60	2.00	0.80	12.80	1.63
50	5.45	0.05	6.5	279.98	86.30	152.12	2.65	2.55	0.83	12.70	1.65

Appendix-VII

Determination of quality parameters and pests and disease scores of bitter gourd fruits

1. Assessment of keeping quality of bitter gourd fruits

Sl. No.	Characteristics of fruits	Score
1	Green colour, fresh and firm without any symptoms of shrinkage	0
2	Green colour with shriveled appearance	1
3	Slight yellowing started from the tip	2
4	50 per cent yellowing	3
5	Whole fruits turning yellow, rind remained firm	4
6	Whole fruits yellow, soft and decayed	5

2. Organoleptic analysis

Sl. No.	Quality Attributes	Subdivisions of attributes	Score of each attributes
1	Appearance	Natural colour well preserved	4
		Slightly discoloured	3
		Moderately discoloured	2
		Highly discoloured	1
2	Doneness	Highly acceptable	4
		Moderately acceptable	3
		Slightly acceptable	2
		Least acceptable	1
3	Flavour	Very pleasant	4
		Pleasant	3
		Moderately pleasant	2
		Unpleasant	1
4	Taste	Very good	4
		Good	3
		Fair	2
		Poor	1
5	Bitterness	No bitterness	4
		Slightly bitterness	3
		Moderately bitterness	2
		High bitterness	1

3. Pest scoring (Fruit fly)

Percent of fruit infestation	Score
0-20	1
21-40	2
41-60	3
61-80	4
81-100	5

4. Disease scoring (Mosaic)

Rating Scale	Symptom	Category
0	No symptom	Highly resistant
1	Very light motling of leaves with green colour	Resistant
2	Motling of leaves with light and dark green colour	Moderately resistant
3	Blisters and raised surface on the leaves	Moderately susceptible
4	Distortion of leaves	Susceptible
5	Stunting of the plants with negligible or no flowering	Highly susceptible

Appendix-VIII

Composition of different medium used for isolation of different groups of microorganisms in soil

1. Bacteria – Soil Extract Agar

Soil extract	– 100 ml
Glucose	– 1 g
K_2HPO_4	– 0.5 g
Agar	– 15 g
Tap water	– 900 mL
pH	– 6.8

2. Fungi – Martin's Rose Bengal Agar

Dextrose	– 10 g
Peptone	– 5 g
KH_2PO_4	– 1 g
Rose Bengal Agar	– 20 μg
Agar	– 20 g
$MgSO_4$	– 0.5 g
Streptomycin	– 30 mg

Distilled water – 1L

3. Actinomycetes- Kenknight's medium

Dextrose	– 1 g
K_2HPO_4	– 0.1 g
$NaNO_3$	– 0.1 g
KCl	– 0.1 g
$MgSO_4$	– 0.1 g
Agar	– 15 g

Distilled water– 1 L

Appendix – IX

Details of total cost and benefit of different treatments in SSNM (ha^{-1})

Treatments	Cost	Benefit
T_1	103093	304750
T_2	128658	333000
T_3	130158	407500
T_4	138058	641000
T_5	140146	741750
T_6	139058	586750
T_7	140146	682250
T_8	81125	146000
T9	83833	197000
T_{10}	50000	29250

SITE SPECIFIC NUTRIENT MANAGEMENT FOR BITTER GOURD

(*Momordica charantia* L.)

by

NEENU, S

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ABSTRACT OF THE THESIS

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ABSTRACT

A study entitled 'Site specific nutrient management for bitter gourd (*Momordica charantia* L.) was conducted in College of Agriculture, Vellayani during 2007-12 with the objective of formulating a site specific nutrient recommendation for enhancing the bitter gourd production in Kalliyur village of Kerala. The experiment set up included three steps namely Omission trial, SSNM field study and validation of results. All the experiments were conducted in farmer's fields of Kalliyur village. Kalliyur village, located in Thiruvananthapuram district with an area of 17.23 km^2 is one of the major vegetable growing tracts and bitter gourd is a popular vegetable in the locality. Spatial variability studies conducted revealed that remarkable variations existed in the soil properties across the village. Data on irrigation water analysis showed that the water used for irrigation was slightly acidic but safe for irrigation as it did not contain significant amount of soluble salts and other elements.

Nutrient omission trial conducted in a farmer's field at selected location showed that the indigenous supply of major nutrients in the locality is limited. The growth and yield parameters were the highest in (+) NPK treatment. Though the highest yield was recorded in (+) NPK plots, yield reduction in P omission plot was less compared to N and K omission owing to the higher supply of indigenous P in soil. The SSNM experiment revealed that site specific nutrient recommendations for high yield target with soil application of micronutrients recorded the highest values for all the growth and yield attributes of bitter gourd. Nutrient uptake and harvest index were also the highest in this treatment. The lowest value of harvest index was recorded by absolute control. In the case of nutrient balance sheet the highest value of N and K balance sheet was obtained in site specific nutrient recommendations for high yield target with soil application of micronutrients while the highest value of P balance sheet was obtained in farmer's practice II. The correlation study revealed that bitter gourd yield was highly correlated with nutrient uptake as well as dry matter production and harvest index. Economic analysis showed that the SSNM practice is beneficial to farmers as it is able to provide more income than the usual

farmer's practice. The validation trial of the best treatments SSNM treatments with high yield target showed that the yield increase was consistent and hence can be prescribed to other farmers in Kalliyur village.

The study thus conclusively proved that the present rates of fertiliser recommendation are not at all sufficient for getting maximum yield and profit to farmers. A site-specific nutrient prescription of 123: 59: 160: 30: 40: 25: 10 kg N P K Ca Mg Zn B ha^{-1} was found to produce 24 t of fruits ha^{-1} and a dose of 123: 59: 160: 30: 40 kg N P K Ca Mg + 1 per cent Zn foliar + 0.5 per cent B foliar ha^{-1} were found to yield 22 t fruits ha^{-1}. The farmers in the area could get a monetary benefit of ₹ 601604/- and 542104/- ha^{-1} respectively by adopting these recommendations. Adoption of SSNM prescriptions is advantageous not only from the point of view of increasing profitability to farmers but also minimizing environmental degradation.