EFFECT OF SECONDARY NUTRIENTS ON YIELD AND QUALITY OF TURMERIC (*Curcuma longa* L.)

By

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRONOMY)

Faculty of Agriculture
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COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR – 680656

KERALA, INDIA

2014

DECLARATION

I hereby declare that the thesis entitled **"Effect of secondary nutrients on yield and quality of turmeric (*Curcuma longa* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me any degree, diploma, fellowship or other similar title of any other University or Society.

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ACKNOWLEDGEMENT

And so comes the time to look back on the path traversed during the endeavor and to remember the faces and spirits behind the action with a sense of gratitude. Nothing of significance can be accomplished without the acts of assistance, words of encouragement and gestures of help from the other members of the society.

It is with immense pleasure I avail this opportunity to express my deep sense of whole hearted gratitude and indebtedness to my major advisor Dr. Meera V. Menon, Associate Professor, Department of Agronomy, for her expert advice, inspiring guidance, valuable suggestions, constructive criticisms, motherly approach, constant encouragement, affectionate advice and above all, the extreme patience, understanding and wholehearted co-operation rendered throughout the course of my study. I really consider it my greatest fortune in having her guidance for my research work and my obligation to her lasts forever.

I consider it as my privilege to express my heartfelt gratitude to Dr. C. T. Abraham, Professor and Head, Department of Agronomy for his constant support, valuable suggestions, cooperation throughout the research programme and critical scrutiny of the manuscript.

I sincerely thank Dr. P. S. John, Professor, Department of Agronomy for his expert advice, constant inspiration, precious suggestions, generous support and constructive criticism during my entire study which helped in successful completion of this work.

I am delighted to place on record my profound sense of gratitude to Dr. K. M. Durgadevi, Associate Professor, AICRP on Weed Control and member of my Advisory Committee for her support, critical comments and valuable advice.

My heartfelt thanks to my beloved teachers Dr. P. A. Joseph, Dr. C. George Thomas, Dr. K.E. Savithri, Dr. R. Gopinathan , Dr. Lalitha Bai, Dr. A. Latha, Dr. K. E. Usha, Dr. P. Prameela, Dr. S. Anitha, and Dr. P.V. Sindhu for their encouragement, valuable help and advice rendered during the course of my study.

I express my gratitude to Dr. S. Krishnan, Associate Professor and Head, Dept. of Agricultural Statistics, College of Horticulture, for his valuable assistance, immense help and guidance during the statistical analysis of the data.

I am deeply obliged to Dr. P. K. Sushama, Professor and Head, Dr. Jayasree Shankar, Mr. Vishveswaran S. and Smt. Bhindhu P. S. from the Department of Soil Science and Agricultural Chemistry for their sincere help during chemical analysis and constant support during the course of study.

My sincere thanks to Ms. Prasanthi and Mr. Bijoy, Research Assistants, Department of Agronomy. A word of thanks to Mrs. Sreela, Mrs. Valsala and Mrs. Rajitha for their help and concern. I am extremely thankful to the labourers attached to the Department of Agronomy for their co operation and support during the conduct of the field experiment.

I express my sincere thanks to my classmates Anila, Sajeera, Harsha and Vemaraju for their affection and kind help offered during my thesis work. I am happy to place on record my sincere thanks to my seniors especially Kavitha chechi and juniors for their immense help and support during the course of this study. I have great pleasure to express whole hearted thanks to my Hassanmates Jeevan, Gowrish, Darshan, Priya, Ashwini KN and BC for their affection and support.

I wholeheartedly thank my loving friends Shobha, Renuka, Chaitanya, Asha, Surabhi, Prathik, Subrahmanya, Vinitha, Anusha, Archana, Sushma, Alaka and Divya for their encouragement and moral support which helped me get over all odds and tedious circumstances.

I am in dearth of words to express my soulful gratitude to my loving Appa and Amma for their blessings, selfless support, boundless patience, prayers, inspiration, sacrifices, unflagging interest and eternal love which sustains peace in my life. I am forever indebted to my loving sister, cousins, Ajja, Ajji's and my entire family without whose blessings and support I would not have completed this work.

I express my deep sense of gratitude to Kerala Agricultural University for financial and technical support for persuasion of my study and research work.

It would be impossible to list out all those who have helped me in one way or another in the successful completion of this work. I once again express my heartfelt thanks to all those who helped me in completing this venture on time.

Sanghamithre V. K.

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Introduction

1. INTRODUCTION

Primary nutrients viz. nitrogen, phosphorus and potassium are generally considered to be mainly responsible, either individually or together, to maintain growth, yield and quality of plants. The secondary nutrients sulphur, magnesium and calcium which are required in lesser quantities than the primary nutrients, do not always get the recognition they deserve. However, they are reported to play key roles in the growth, yield and quality of crops. They have been called the "synthesizers" because of their functions in living organisms.

Continuous mining of nutrients from soils, coupled with inadequate and imbalanced fertilizer use, causes emergence of macro and micronutrient deficiencies in soils. Tewatia (2008) reported that at least six nutrients (N, P, K, S, Zn and B) have widespread deficiency in Indian soils. In Kerala, of the samples collected from alluvial soils and brown hydromorphic soils, 56% and 83% respectively were sulphur deficient (Nair, 1995). Seventy per cent of soil samples collected from different parts of the four districts of Palakkad, Kollam, Thiruvanathapuram and Thrissur were low in sulphur (John *et al.*, 2005; Sheela *et al.*, 2006). A recent report by Sureshkumar *et al.* (2013) says that the availability of Ca and Mg is very low in Kerala soils due to leaching under heavy rainfall and about 45 and 80 per cent of soils of Kerala are deficient in available Ca and Mg respectively. Magnesium deficiency has been reported in the laterite soils of Kerala (Bose *et al.*, 2008). There is thus, a growing awareness of the need to include these nutrients in the fertilizer schedule of crops.

Crops respond differentially to nutrient elements, when applied alone or in combination with others, and hence proper nutrient management for plant species is important for increasing yield and quality. This is particularly relevant for rhizomatous crops, where quality component of yield is as important as quantitative yield.

Turmeric (*Curcuma longa* L.), commonly known as "Indian Saffron", is one of the most important ancient spices of India and is a traditional item of export. There are about 80 species reported in the genus *Curcuma*. India is the leading producer, consumer and exporter of turmeric in the world. Turmeric has been in use from ancient times as a spice, food preservative, colouring agent, cosmetic, and drug and as a component in religious ceremonies and in traditional system of medicines. Turmeric, a long duration and high yielding commercial crop consumes greater amount of nutrients from the soil as well from applied fertilizers for a prolonged period (Jagadeeswaran *et al.,* 2005). Turmeric rhizome contains essential oil which includes ar-turmerone and ar-curcumene as major constituents. Some other compounds are α- and β-pinene, sabinene, myrcene, a-terpinene, limonene, p-cymene, perillyl alcohol, turmerone, eugenol, iso-eugenol, eugenol methyl ether and iso-eugenol methyl ether. Curcumin and related compounds have also been reported as major constituents of the rhizomes. A number of sesquiterpenes have also been reported from *C. longa* (Husain *et al.*, 1992).

Curcumin (diferuloylmethane) is the major principle responsible for the yellow colour. It is shown to have excellent pharmaceutical attributes with its antioxidant, antiarthritic, antimutagenic, antitumorous, antithrombotic, antivenomous, antimicrobial properties and action against Alzheimer's disease (Akram *et al.*, 2010). Research on turmeric is mainly focused on improving rhizome yield and quality attributes.

Of late, cultivation of turmeric has greatly expanded in Kerala and even large areas of paddy fields have been converted for the cultivation of this crop. The climatic and soil conditions prevailing in Kerala being optimally suited, there is immense scope for its cultivation. The crop is grown on a tried and tested package of organic manures and primary nutrients as per the recommendations of the Kerala Agricultural University (KAU, 2011).

There is an approved *ad hoc* recommendation for secondary nutrients to be adopted in Kerala based on soil pH (KAU, 2011). However there is no specific recommendation for turmeric. There are reports of high rhizome yield in turmeric with increasing concentrations of foliar sprays of magnesium sulphate in the acidic soils of Meghalaya (Chandra *et al.*, 1997). Bose *et al.* (2008) reported that inclusion of S and Mg in the fertilization schedule dramatically improved the fresh yields of turmeric in the depleted red lateritic soils of West Bengal. Optimum doses for these nutrients in the nutritional management of turmeric are yet to be standardized for the laterite soils of Kerala.

An attempt was made to develop a nutrient application schedule for turmeric by incorporating secondary nutrients Ca, Mg and S along with recommended N, P and K doses to increase yield and quality of turmeric.

The specific objectives were:

1. To study the effect of secondary nutrients viz. calcium, magnesium and sulphur on yield and quality of turmeric
2. To develop a recommendation for these nutrients to optimize productivity of turmeric

Review of Literature

2. REVIEW OF LITERATURE

Nutrient management of crops is normally focused only on the primary nutrients, nitrogen, phosphorus, potassium, even though the beneficial effects of secondary and micronutrients application have been reported. Sulphur, calcium and magnesium are known to improve quantitative and qualitative yields in many crops. However, recommendations for application of these nutrients are few. This project is an attempt to study the effect of the secondary nutrients on the yield and quality of an important spice crop, turmeric.

Turmeric (*Curcuma longa* L.) is one of the vital spice crops and is a valued indigenous herbal medicine. It is utilized for flavouring and colouring of a variety of dishes on a domestic scale as well as in food industries. Turmeric is a rhizomatous perennial plant. Its nutrient requirement is quite high due to shallow rooting and potential to produce large amount of dry matter per unit area. Turmeric yields essential oil which includes ar-turmerone and ar-curcumene as major constituents (Husain *et al.*, 1992).

Very little work has been documented on the effect of secondary nutrients, viz. sulphur, calcium and magnesium on the yield, productivity and quality aspects of turmeric. In this chapter an attempt is being made to trace the available research information on these lines of work.

Review of literature is classified into four aspects, *viz.*, (i) effect of organic manures on biometric characters, yield and quality (ii) effect of inorganic nutrients on biometric characters, yield and quality (iii) interaction effects of nutrients and (iv) effect of integrated nutrient management in turmeric, and other oleoresin and essential oil yielding crops as well as rhizome and root crops.

1. Effect of organic manures

Gradual deficiency in soil organic matter and reduced yield of crops are alarming factors and burning issues for farmers and agriculturists. The importance of soil organic matter and sustainable soil productivity for getting higher yield of crops cannot be underestimated. In recent years, poultry and livestock farming have boosted the supply of manures like poultry litter, cow dung etc. Organic manures have been reported to improve the vegetative growth as well as yield and quality of rhizomatous and root crops.

a. Effect of organic manures on biometric characters

Hossain and Ishimine (2007) observed that vegetative growth parameters (number of leaves per plant, plant height, number of tillers per plant, leaf biomass) and yield of turmeric were increasing with FYM application over control.

Kamal and Yousuf (2012) evaluated the effect of different organic manures on turmeric with reference to vegetative growth, biomass production, rhizome yield and yield attributes of turmeric (*Curcuma longa* L.). Turmeric showed better response to the application of organic manures. Neem cake application produced the taller plant, highest number of tillers per plant, leaf number, leaf area, leaf area index, fresh weight of haulm, fresh weight of root, fresh weight of rhizome per plant, dry weight of haulm, dry weight of root, dry weight of rhizome per plant and total dry matter production than other types of manures.

Amin *et al.* (2013) reported that application of 1.2 kg poultry litter + NPK (106g urea + 76g TSP + 68g MOP) /plot gave significantly higher number of tillers per clump in turmeric.

b. Effect of organic manures on yield and quality

Geetha *et al.* (2000) observed the effect of FYM @ 25 t/ha and potassium fertilizer @ 200 kg/ha in the form of MOP and their interaction on onion. Effect of both increased the potassium content, bulb yield and dry matter production of onion at harvest of the crop. Significantly higher bulb yield (200 q/ha) was observed with the application of K @180 kg/ha

Vidyadharan and Swadija (2000) observed that in arrowroot (*Maranta arundinaceae*), rhizome yield increased with increasing levels of FYM, the highest yield (13.95 t/ha) being recorded at 20 t/ha. In *Curculigo orchioides,* application of FYM @ 40 t/ha resulted in significant improvement in number, length and thickness of tuber and dry recovery (Kothari and Singh, 2003). A combined dose of 100 kg K_2O and 5 tonnes farmyard manure per ha was optimum for higher productivity and quality of ginger, maximum K use efficiency (30.9 %) with adequate K build up (Majumdar *et al.*, 2005).

Joy *et al.* (2002) found that in galangal (*Alpinia galanga* L.), the treatment receiving FYM (20 t/ha) recorded the highest number of clumps per plot (19.17), highest plant height (90.18cm), number of suckers per clump (57.10), number of leaves per sucker (10.23), fresh rhizome yield (45.14 t/ha) and oil yield (94.80 l/ha).

Hossian and Ishimine (2007) observed that application of cow manure was more effective for increasing the yield and productivity of turmeric both in dark red and grey soil, and was on par with goat manure. Kamal and Yousuf (2012) concluded that application of cow dung, poultry manure, mustard cake and neemcake have significant influence on growth and yield parameters and quality of turmeric. However, plants applied with neem cake performed better in terms of yield and yield attributes than other manures. Therefore, a fertilization strategy that involved organic manure was crucial for nutrient exhaustive crops like turmeric for commercial cultivation. Manhas and Gill (2010) also reported that application of FYM increased the growth, dry matter accumulation, yield and quality of turmeric. Yield attributes such as number of mother rhizomes per plant (1.75), number of primary rhizomes per plant (5.19), secondary rhizomes per plant (18.03) and tertiary rhizomes per plant (7.69) were increased by neem cake application. The same treatment was the best in terms of size of mother rhizome (7.69 cm), primary rhizome (21.86 cm) and secondary rhizome (7.05 cm). All these parameters cumulative contributed to produce the highest estimated fresh rhizome yield and cured rhizome yield (29.48 t/ha, 5.59 t/ha respectively) in turmeric (Kamal and Yousuf, 2012). Weight of mother rhizome per plant, weight of primary and secondary fingers per plant and also highest turmeric yield was produced when 1.2 kg poultry litter + NPK (106 g urea + 76 g TSP + 68 g MP) per plot was applied as reported by Amin *et al.* (2013) in turmeric.

Singh *et al.* (2006) revealed that in *Curcuma aromatica*, application of 22.5 t of FYM/ha provided higher oil yield (234.4 kg/ha). Shamrao *et al.* (2013) reported that application of neem cake at 6.0 t/ha along with microbial inoculants *Azospirillium*, AMF, *Trichoderma* and *Pseudomonas* gave highest B: C ratio and high rhizome yield (fresh) of *Curcuma aromatica* and, thereby it could be considered as the best cost effective manurial recommendation for kasthuri turmeric cultivation.

2. Effect of inorganic fertilizers

Due to its long duration and high productivity, turmeric requires heavy input of fertilizers (Balashanmugam and Chezhiyan, 1986; Balashanmugam and Subramanian, 1991). Considerable reduction in nutrient input can be achieved through optimum use of inorganic nutrients at appropriate stage of growth. Rao and Rao (1988) observed that turmeric being a rhizomatous crop and a heavy feeder of N, P_2O_5 and K_2O responded well to heavy manuring. Along with this, secondary nutrients also play an important role in producing higher yields. (Velmurugan *et al.*, 2008).

a. Effect of inorganic fertilizer application on biometric characters

Yamgar *et al.* (2001) reported that in turmeric that application of 200, 100 and 100 kg NPK/ha recorded highest plant height, number of leaves, length of leaf, and yield of green rhizome. Split application of N at different growth stages was significantly superior to single application of N, which gave highest rhizome yield and maximum net returns. Akamine *et al.* (2007) found that in turmeric, N applied alone or in combination with P and K resulted in a significantly higher plant height, and number of leaves and tillers. Similar results were observed by Haque *et al.* (2007), who reported that plant height, number of leaves and finger number of turmeric increased with increase in N levels up to 150 kg/ha. The finger weight, finger size and turmeric yield were also increased. Banwasi and Singh (2010) observed that highest rhizome yield, plant height, number of tillers/clump, leaf length and leaf width were recorded with application of P at the rate of 150 kg/ha in turmeric. Similar results were also reported by Sheshgiri and Uthaiah (1994) in turmeric. Maximum number of leaves, leaf length, weight of leaves, root length, root diameter, root weight and yield were recorded when N was applied at the rate of 200 kg/ha in turmeric (Jilani *et al.*, 2010).

Sugatto and Mafzuchah (1995) observed that yield attributes like plant height, number of leaves and finger number responded significantly to K levels in ginger. Greatest plant height, and highest number of leaves and finger number in ginger were seen when K was applied at the highest level (160 kg/ha). Dayankatti and Sulikeri (2000) observed that in ginger, application of high level of N (125 kg/ha) produced the most plant height, number of tillers, number of leaves, leaf area index and spread of rhizome. Lujiu *et al.* (2004) found that plant height, stem circumference, number of branches and tuber weight/plant increased with increased rates of 375 kg N/ha and 450 kg K/ha in ginger. Plant growth was vigorous and robust when K was applied in ginger. Similar result was observed in turmeric by Haque *et al.* (2007), where the application of K (100 kg/ha) enhanced plant height, number of leaves and finger number/plant.

Maheswarappa *et al.* (2000a) found that N content and dry matter in *kacholam* were significantly higher in plants treated with FYM (20 t/ha) and inorganic fertilizers (50:50:50 kg N, P, K/ha), compared with composted coirpith and inorganic fertilizers applied singly.

In onion, highest plant height (48.62cm), number of leaves (9.14), weight of 10 bulbs (1.02 kg), diameter of bulb (6.13 cm) and yield (30.19 t/ha) were recorded when sulphur @ 30 kg/ha and 40 kg/ha was applied (Jana and Kabir, 1990).

Kakar *et al.* (2002) reported that increasing nitrogen level to 100 kg resulted in longer leaves (64.83), greater number of leaves per plant (17.90), highest single bulb weight (42.60 g) and bulb weight per plant (7.08 kg) and total bulb yield (6746.03 kg/ha) of garlic. Ali *et al.* (2003) observed that greatest number of leaves, plant height, root length, root diameter, fresh and dry weight of shoot, fresh and dry weight of root and root yield, when 150 kg N per hectare was applied in carrot. Hussain *et al.* (2005) reported that increasing levels of nitrogen application significantly increased plant height, number of tillers per clump and number of leaves per tiller up to 100 kg N/ha in galangal.

b. Effect of inorganic fertilizer application on yield and quality

i. Nitrogen

Nitrogen is a primary plant nutrient that plays a major role in achieving the maximum economic yields. It is an essential macronutrient needed by all plants to thrive. It is an important component of many structural, genetic and metabolic compounds in plant cells. It is also one of the basic components of chlorophyll, the compound by which plants use sunlight energy to produce sugars during the process of photosynthesis. Of all the essential nutrients, nitrogen is required by plants in the largest quantity and is most frequently the limiting factor in crop productivity. Nitrogen is an essential element of all amino acids, the building blocks of proteins. It is also a component of nucleic acids, which form the DNA of all living things and holds the genetic code. Nitrogen is a component of chlorophyll, which is the site of carbohydrate formation (photosynthesis). Chlorophyll is also the substance that gives plants their green color. Photosynthesis occurs at high rates when there is sufficient nitrogen. A plant receiving sufficient nitrogen will typically exhibit vigorous plant growth. Leaves will also develop a dark green color.

N is a major constituent of protoplasm, enzymes and chlorophyll. It plays a role as a catalytic agent in various physiological process, accelerates cell division and speeds up the assimilation of photosynthates, which in turn boost plant growth (Pandey, 1992).

Agnihotri (1949) found 80-100 kg N/ha as crucial for good yield of turmeric. It has been advocated that the response of turmeric would vary at different locations for different doses of nutrients (Nair, 1964; Nair, 1982). Pandey (1992) reported that increasing rates of N enhanced the yield and other yield parameters significantly in turmeric. Nitrogen is responsible for 26-41% increase in crop yield in turmeric (Maier *et al.*, 1996).

Study on effect of nitrogen on turmeric revealed that the response was higher at 100 to 140 kg/ha (Ahmed-Shah and Muthuswamy, 1981; Balashanmugam and Chezhiyan, 1986). Many workers (Rajput *et al.* 1982; Rao and Reddy, 1990; Pandey and Mishra., 2009) stated that application of 100 kg N/ha along with 45 × 45 cm spacing gave maximum weight and number of fingers/plant in turmeric. Shashidhar and Sulikeri (1996) reported that highest level of nitrogen application (200 kg N/ha) gave highest number and size of rhizomes in turmeric.

Geetha and Nair (1990) studied the differential response of coleus to graded doses of nitrogen (0, 30, 60, 90 and 120 kg/ha). They reported that nitrogen at 60 kg/ha produced greatest plant height, number of branches, number of leaves, leaf area index and dry matter yield. Further increase in the dose of nitrogen had no significant effect on growth and yield of the crop. Mastiholi (2008) reported in medicinal coleus the yield contributing characters like number of tubers/plant (17.7), length (20.8 cm) and diameter of tubers (13.8 mm) were highest at harvest with application of 50 kg N/ha were significantly superior over 100 and 150 kg N/ha.

Mohanty *et al.* (1993) reported more plant height, number of tillers, number of leaves, leaf area index and rhizome spread when nitrogen was applied at the dose of 125 kg N/ha in ginger. Significant increase in rhizome yield was attributed to increased level of nitrogen (100 kg N/ha) in ginger (Thakur and Sharma, 1997). Similarly, application of 100 kg N/ha resulted in highest oil content and rhizome yield as observed by Hussain *et al.* (2005).

Shashidhar and Sulikeri (1996) reported that in turmeric nitrogen levels had significant influence on curcumin content, and the curcumin content increased with increase in nitrogen level up to 100 kg N/ha (3.34 %) and thereafter, adverse effect of higher N levels on curcumin content was noticed.

Ganorkar *et al.* (2006) reported that highest values for nutrient uptake and tuber yield in safed musli were observed with FYM application of 20 t/ha and nitrogen of 75 kg/ha, when apllied alone or in combination.

Jilani *et al.* (2010) studied the effect of nitrogen on yield and quality of radish and reported that among different doses of N (50, 100, 150, 200 and 250 kg/ha) applied, 200 kg N/ha gave highest yield. Cabonce (1993) reported that radish plants supplied with 80 kg N/ha produced longer, bigger and heavier roots over all other treatments.

Diriba-Shiferaw *et al.* (2013) studied the bulb quality of garlic with different doses of nitrogen (0, 92, 138 kg/ha). They reported that N at 92 kg/ha produced best quality of the crop for enhanced household income. Kakar *et al.* (2002) reported that increasing nitrogen level up to 100 kg resulted in longer leaves (64.83), great number of leaves per plant (17.90), highest single bulb weight (42.60), bulb yield per plant (7.08) and total yield (6746.03 kg/ha) of garlic.

ii. Phosphorus

Phosphorus plays a vital role in virtually every plant process that involves energy transfer. High-energy phosphate, held in the chemical structures of adenosine di phosphate (ADP) and adenosine tri phosphate (ATP), is the source of energy which drives the multitude of chemical reactions within the plant. When ADP and ATP transfer the high energy phosphate to other molecules (termed phosphorylation), the stage is set for many essential processes to occur. Phosphorus is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy storage and transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. ADP and ATP act as energy currency within plants (Tisdale *et al.*, 1993).

When P is limiting, the most striking effects are a reduction in leaf expansion and leaf surface area, as well as the number of leaves. Shoot growth is more affected than root growth, which leads to a decrease in the shoot-root dry weight ratio. Nonetheless, root growth is also reduced by P deficiency, leading to less root mass to reach water and nutrients (Tisdale *et al.*, 1993).

Veeraraghavathatham *et al.* (1988) studied response of coleus to P levels and reported higher tuber yield at 60 kg P_2O_5/ha over control. Similarly another study revealed higher growth, yield attributes and tuber yield by applying 60 kg P_2O_5/ha along with VAM (Ravi, 2004).

Bopaiah and Shetty (1991) revealed that the application of FYM increased the activity of phosphate enzymes which enhanced P availability in ginger. Application of 80 kg P_2O_5/ha resulted in greater plant height, maximum number of leaves and higher yield in ginger (Singh and Neopaney, 1993).

Banwasi and Singh (2010) studied the effect of five levels of phosphorus (0, 50, 100, 150 and 200 kg P_2O_5/ha) on growth and yield of turmeric and revealed that application of phosphorus @ 150 and 100 kg/ha resulted in better vegetative growth as well as higher yield of turmeric. However, application of phosphorus @ 150 kg/ha was the best with respect to cost: benefit ratio (1:2.22).

iii. Potassium

Potassium is vital to many plant processes. A review of its role involves understanding the basic biochemical and physiological systems of plants. While K does not become a part of the chemical structure of plants, it plays many important regulatory roles in development.

Potassium plays significant roles in enhancing crop quality. High levels of available K improve the physical quality, disease resistance, and shelf life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops. Fiber quality of cotton is improved. Quality can also be affected in the field before harvesting, such as when K reduces lodging of grains or enhances winter hardiness of many crops. The effects of K deficiency can cause reduced yield potential and quality long before visible symptoms appear.

Potassium is actively taken up from the soil solution by plant roots. The concentration of K+ in vegetative tissue usually ranges from 1-4% on dry matter basis. Thus plant requirements for available K are quite high. Potassium apparently does not form an integral part of any plant component and its function is catalytic in nature. It is essential for the physiological functions of carbohydrate metabolism and synthesis of proteins, control and regulation of activities of various essential mineral elements, neutralization of physiologically important organic acids, activation of various enzymes, promotion of the growth of meristemic tissue and adjustment of stomatal movement and water relations (Tisdale *et al.*, 1993). It is also involved in imparting resistance to drought, frost, pests, diseases and physiological disorders (Balram *et al.*, 1977; Singh and Tripathi, 1979).

Nair and Sadanandan (1987) studied the effect of graded levels of K application and observed that K nutrition profoundly influences the number of storage roots and mean tuber weight per plant. An increase in the number of tubers per plant and tuber size was observed with an increase in K_2O application rates up to 200 kg/ha.

Potassium uptake increased with graded levels of potash and highest K uptake was recorded under 90 kg K_2O/ha, which was significantly superior to other treatments (Balashanmugam and Subramanium, 1991). Majumdar *et al.* (2005)

reported that a combined dose of 100 kg K_2O and 5 tonnes farmyard manure per ha was optimum for higher productivity and quality of ginger, maximum K use efficiency (30.9 %) with adequate K build up.

Babu and Muthuswami (1986) reported that in turmeric, 60 kg K_2O/ha recorded the highest content of curcumin followed by 90 kg K_2O/ha and 120 kg K_2O/ha. However, the higher doses of K_2O (150 kg/ha and 180 kg/ha) were observed to reduce the curcumin content. Mother rhizomes recorded the highest average curcumin content followed by primary and secondary ones. They further revealed that the highest essential oil content (3.19 %) was acquired in the treatment combinations of 120 kg N/ha, 60 kg P_2O_5/ha and 60 kg K_2O/ha. Akamine *et al.* (2007) observed that K is the principal element involved in curcumin formation in turmeric, and application of K alone resulted in the highest curcumin content in rhizomes. The influence of potassium on growth, yield, nutrient uptake and quality parameters of turmeric showed that increasing the application rate of potassium in the form of KCl enhanced growth, nutrient uptake and utilization, increasing yield and quality of turmeric. Application of 260 kg K_2O/ha gave good results. This more than doubled cured rhizome yield and increased curcumin content by over 50 per cent. These results suggest that the turmeric crop requires large amounts of potassium for both yield and quality (Karthikeyan *et al.*, 2010).

Salimath (1990) reported that dry matter production, bulb size and bulb yield increased with the increase in level of K from 0 to 150 kg/ha in onion. Kumar *et al.* (2001) observed that in onion, an increase in potassium application up to 40 kg K_2O/ha. Significantly increased the dry weight of top and bulbs, bulb diameter, 100 bulb weight and bulb yield.

Nair and Aiyer (1986) found improvement in starch and quality parameters of starch increased with increasing rate of K application in cassava. Higher doses of K reduced the cyanogenic glucoside content in cassava (Ramanujan and Indira, 1987). Hossain *et al.* (2004) reported that in carrot, plants receiving 250 kg K/ha produced maximum root fresh weight (180 g) and minimum (160.95 g) was obtained in control. Increased level of K produced longer and thicker roots giving higher individual fresh weight of roots.

iv. Calcium

Calcium plays a major role in the quality of many crops. It is a constituent of calcium pectate. It has a role in cell structure and also plays a role in regulating various cell and plant functions as a secondary messenger. This function as a secondary messenger assists in various plant functions from nutrient uptake to changes in cell status to help the plant react to the impact of environmental and disease stresses. Calcium stimulated the absorption of P and K (Jacobson *et al.*, 1961), and accelerated more effectively the translocation of photosynthetic products compared to K and Mg.

Simmons and Kelling (1987) reported that in potato, when calcium was applied in various doses, tuber size, tuber grade and yield were observed to be highest with the use of 100 kg Ca/ha as $Ca(NO_3)_2$ in combination with $CaSO_4$ rather than $CaSO_4$ alone.

v. Magnesium

Magnesium is a structural component of chlorophyll, and gives green colour to leaves. This helps in uptake and transformation of phosphorus. Magnesium is necessary for the synthesis of proteins, fatty acid and oils. It is an activator of enzymes in carbohydrate metabolism and also helps in transformation of sugar and starch in plants, thereby it regulates the uptake of other nutrients and also serves as a structural component of rhibosomes. Magnesium deficiency results in chlorosis in plants (Tisdale *et al.*, 1993).

Rhizome yield of turmeric was found to increase with increasing concentrations of foliar sprays of magnesium sulphate in the acidic soils of Meghalaya (Chandra *et al.*, 1997). Application of high rates of Mg (22 kg/ ha) along with sulphur (44 kg/ha) and recommended dose of NPK, improved the yield and quality of turmeric (Bose *et al.*, 2008).

Gangadharan (2003) concluded that application of $MgSO_4$ at the stage of rhizome formation, favors the development of quantitative components in the rhizome of *kacholam*.

Kleiber *et al.* (2011) reported that Mg nutrition was found to have a positive effect on yield and quality, producing significantly higher total yield (485 kg/m^2) and increased yield by 45% in comparison with the control combination in onion.

vi. Sulphur

Sulphur is considered to be the fourth major nutrient after N, P and K. It is essential for the growth and development of all crops. Without exception most of the plants requirement of S is absorbed through the roots in the sulphate (SO_4) form. Like any essential nutrient, sulphur also has certain specific functions to perform in the plant. Thus, S deficiencies can only be corrected by the application of S fertilizer.

Sulphur is essential for the formation of chlorophyll, the green substance in leaves that permits photosynthesis. Sulphur influences protein production, primarily because S is a constituent of three s-containing amino acids (cysteine, cystine and methionine), which are the building blocks of protein. About 90% of plant S is present in these amino acids, which are essential for synthesis of oils and therefore adequate sulphur is so crucial for oilseeds. Sulphur helps in activation of enzymes, which aid in biochemical reactions within the plant. Specifically with reference to crop quality, S improves protein and oil percentage in seeds, cereal quality for milling and baking, marketability of dry coconut kernel (copra), quality of tobacco, nutritive value of forages, etc.

Sulphur deficiency symptoms are more often observed in crops at early stages of crop growth, because sulphur can be easily leached from the surface soil. Sulphur deficient plants had poor utilization of N, P and K and a significant reduction of catalase activity at all stages (Nasreen *et al.*, 2003).

Singh (1970) and Pillai (1972) observed that sulphur application is known to reduce the plant content of iron by reducing leaf sap pH and increasing chlorophyll content.

Tantawy *et al.* (2009) reported that sulphur has a direct effect on soil properties as it may reduce soil pH which improves the availability of micronutrients such as Fe, Zn, Mn and Cu as well as crop yield and its related characteristics.

In onion, Jana and Kabir (1990) recorded greatest plant height (48.62 cm), number of leaves (9.14), weight of 10 bulbs (1.02 kg), diameter of bulb (6.13 cm) and yield (30.19 t/ha) in the treatment which received sulphur @ 30 kg/ha followed 40 kg/ha. Thippeswamy (1993) tried different levels of sulphur (0, 20, 40 and 80 kg/ha) in onion and reported an increase in TSS with increase in sulphur levels. TSS was highest (12.36%) in the treatment receiving 80 kg S/ha and lowest (11.81%) in control. Maximum pungency (0.30 μg/g) was noticed when 80 kg S/ha was applied and minimum pungency (0.21 mg/g) was noticed in control. Increase in plant height, fresh and dry herbage yields and essential oil was attributed to nitrogen supplied as ammonium sulfate in onion (Nasreen *et al.*, 2003). Singh (2008) concluded that application of 40 kg S/ha was found. to be advantageous for achieving higher productivity of bulb yields in onion. Ullah *et al.* (2008) studied the impact of sulphur levels on yield and other attributes in onion and concluded that highest bulb yields (19.75 and 19.88 t/ha) were obtained from sulphur levels between 60 and 75 kg/ha and sulphur at the dose of 45 kg/ha gave minimum rotten bulbs. Application of 200 kg S/ha + Thiobacillus produced highest yield and highest bulb pyruvic acid content in onion thereby being the best treatment (Khodadadi, 2012). Mishu *et al.* (2013) studied the effect of sulphur on growth, yield and yield attributes in *Allium cepa* L. and concluded that the effect of different doses of sulphur played important roles on growth, yield and yield attributes. Number of split bulb, bulb diameter, neck diameter, and neck bulb ratio were not affected by different doses of sulphur application. Number of leaves/plant increased up to a certain growth stage and then declined. Dry weight of root, dry weight of bulb, dry weight of stem, and TDM showed an increasing trend up to the last stage of growth. Application of 40 kg S/ha showed the highest yield (10.65 t/ha) among the other doses of sulphur.

Singh and Dwivedi (1993) reported that sulphur when applied through gypsum gave highest tuber yields (414.8 and 418.75 q/ha) in potato.

Higher value for plant height, number of leaves/plant, bulb diameter, bulb weight and highest bulb yield (246.50 q/ha) were recorded with application of 30 kg S/ha in the form of gypsum followed by 20 kg S/ha in garlic (Dabhi *et al.*, 2004). Zaman *et al.* (2011) studied the effect of sulphur fertilization on growth and yield of garlic in two consecutive years and found that bulb yield increased with successive increase in the level of sulphur up to 45 kg/ha and thereafter decreased. The highest bulb yield (7.05 t/ha in 2005-06 and 7.22 t/ha in 2006-07) was achieved at 45 kg S/ha and the control treatment receiving no fertilizer had the lowest yield (3.21 t/ha in 2005-06 in and 3.26 t/ha in 2006-07). The yield benefit for 45 kg sulphur per ha was 34.2% in 2005-06 and 40.0% in 2006- 07 over no sulphur. Sulphur at 45 kg/ha produced 54.5% and 54.9% higher yield over control treatment in both the years. The optimum and economic doses of sulphur for the yield of garlic were 44.0 and 43.6 kg/ha, respectively.

3. Effect of nutrient interactions on yield and quality

When two or more growth factors interact, their individual influence is modified by the presence of one or more factors. When factors in combination result in a growth response that is greater than the sum of their individual effects, interaction is positive and when the combined effect is less, the interaction is negative. In the former case the factors are synergistic, whereas in the latter they are antagonistic. Additivity indicates the absence of interaction. The highest yields are obtained where nutrient and other growth factors are in a favorable state of balance. As one moves away from this state of balance, nutrient antagonisms are reflected in reduced yields (Summer and Farina, 1986). Interaction has been defined as mutual or reciprocal influence of one element upon another in relation to plant growth and its differential response to one element in combination with varying levels of the second element (Olsen, 1972).

i. N and P

Kilgori (2007) in his studies on productivity of two garlic varieties with different levels of nitrogen and phosphorus fertilizers revealed that combined application of 120 kg N/ha and 22 kg P/ha for both the cultivars gave good yield of garlic.

Islam *et al.* (2010) showed that the combined effect of nitrogen and potassium produced significant variation in the number of leaves per plant, pseudostem diameter, root dry matter, individual bulb weight, bulb yield and days to harvest. Plants grown with nitrogen and potassium at their highest levels (120 kg N/ha × 112.5 kg K/ha) with straw mulch showed the highest bulb yield (14.67 t/ha) in onion.

ii. N and K

Haque *et al.* (2007) revealed that treatment combination of N and K, 180 and 100 kg/ha respectively recorded highest plant height (110.2 cm and 107.3 cm), maximum leaf number per plant (13.8 and 14.3 per plant) and number of fingers (55.10 and 46.8 per plant). Similarly, finger size, finger weight and yield were also significantly influenced by applying N and K recording the highest finger size (8.7 cm x 8.3 cm and 8.6 cm x 8.7 cm), maximum finger weight (450 g and 457 g/plant), highest turmeric yield (26.7 t/ha and 28.2 t/ha) and the mean yield of 27.45 t/ha.

Similar results were observed in ginger by Haque *et al.* (2007) revealed that both N and K, singly or in combination, exhibited significant influence on yield and other yield components of ginger. Combined effect of N and K was more reactive than N and K in single application. All the yield contributing characters increased significantly linearly up to the level of N180 and K100 kg/ha. Improved plant height (63.7 cm and 64.3 cm), leaf number (19.2 and 19.7 per plant) and finger number (16.3 and 16.6 per plant) were recorded at the highest level of N and K. Other yield contributing parameters like weight of ginger per plant, ginger yield, highest finger weight (270 g and 273 g/plant) and rhizome yield (26.3 t/ha and 27.6 t/ha) were also significantly enhanced by the same treatment combination of nitrogen and potassium.

Suja *et al.* (2006) observed that in arrowroot, combined effect of N and K levels significantly affected fresh rhizome yield. Application of N at 50 kg/ha and K at 75 kg/ha resulted in higher rhizome yield, total dry matter production and harvest index. Nagar (1985) observed that tuber yield was found to increase with increase in the rates of N (200 kg/ha) and K (200 kg/ha) under irrigated conditions in cassava.

iii. N and S

Nitrogen and sulphur are involved in protein synthesis and play an important role in the protection of plants against nutrient stress and pests, and in the synthesis of vitamins and chlorophyll in the cell (Luit *et al.*, 1999). The interaction of nutrients is of great importance because decline in S supply from the atmosphere has already caused substantial losses of N from agro-ecosystems to the environment. Sulphur deficiency can reduce NUE and N deficiency can also reduce S-use efficiency (Fismes *et al.*, 2000). Plants grown without N fertilizer showed no apparent S stress, whereas plants receiving N fertilizer, particularly at higher rate without S, showed symptoms suggesting severe physiological disorder in N nutrition (Kopriva and Rennenberg, 2004).

Nasreen *et al.* (2007) conducted an experiment on the effect of nitrogen (0, 80, 120, and 160 kg/ha from urea) and sulphur (0, 20, 40, and 60 kg/ha from gypsum) fertilization on N and S uptake and yield performance of onion. Addition of nitrogen and sulphur fertilizers exerted significant influence on the number of leaves/plant, plant height, diameter of bulb, single bulb weight and yield of onion. The uptake of N and S by the bulbs also significantly responded to the application of nitrogen and sulphur. The highest yield of onion and uptake of N and S were recorded by the combined application of 120 kg N and 40 kg S/ha with a blanket dose of 90 kg P_2O_5, 90 kg K_2O and 5 kg Zn/ha plus 5 tonnes of cowdung/ha. The antagonistic effect of nitrogen and sulphur on the uptake of N and S by bulb, yield components and yield of onion was observed only when they were applied together at higher rates of nitrogen (160 kg/ha) and sulphur (40 kg/ha).

Farooqui *et al.* (2009) studied the productivity of garlic through assessing the effect of different levels of nitrogen and sulphur. Nitrogen levels (50, 100, 150 and 200 kg/ha) and sulphur treatments (0, 20, 40 and 60 kg/ha) were applied as basal dose and top dressing. Application of 200 kg nitrogen/ha significantly increased the plant height (cm), number of leaves per plant, neck thickness, bulb diameter, number of cloves per bulb, fresh weight of 20 cloves, fresh and dry weight of bulb and bulb yield. Among various levels of sulphur tried, 60 kg/ha resulted in the best growth and yield attributes. Significantly higher yield of garlic was obtained with the treatment combination 200 kg N/ha + 60 kg S/ha.

iv. P and Mg

Phosphatic fertilization with P_2O_5 at 112 kg /ha along with MgO at 22 kg/ha not only registered 14-20 per cent higher yield but also improved the dry matter content of rhizomes of ginger (Aiyadurai, 1966).

v. K and Mg

Karthikeyan *et al.* (2010) studied the influence of potassium and magnesium on growth, yield, and quality parameters of turmeric. Increasing the rate of application of potassium (200 kg K_2O kg/ha) in the form of KCl and magnesium (20 kg $MgSO_4$ kg/ha) enhanced growth, nutrient uptake and utilization, increasing yield and quality of turmeric. This more than doubled, cured rhizome yield and increased curcumin content by over 50 percent. These results suggest that the turmeric crop requires large amounts of potassium and magnesium for both yield and quality. Increased potassium fertilization or availability, relative to magnesium, would inhibit magnesium absorption and accumulation and vice versa. The degree of this antagonistic effect varied with potassium and magnesium fertilization rates, as well as the ratio of the two nutrients to one another (Lasa *et al.*, 2000).

vi. S and K

Application of S and K showed significant increase in yield of radish (Chandrasekharan, 1983). Nandi *et al.* (2002) recorded highest bulb yield of onion and post harvest shelf life qualities like sprouting %, rotting % and weight loss % were lowest with the application of K and S at the rate of 180 kg/ha and 60 kg/ha respectively.

vii. S and Mg

Bose *et al.* (2008) found that application of different levels of S and Mg did not have any significant effect on the vegetative growth of the plants, though maximum number of mother rhizomes and primary fingers, as well as greatest length of primary fingers was noted at 44 kg/ha of S and 22 kg Mg/ha. There was significant increase in the weight of the mother rhizome at the above dose, which then declined with further increases in S and Mg levels. Significant variation in weight of primary fingers was observed due to S and Mg applications, also peaking with 44 kg S/ha and 22 kg Mg/ha. Results showed that inclusion of S and Mg in the fertilization schedule dramatically improved the fresh yield. Maximum fresh yield of 26 t/ha was obtained with 44 kg S/ha and 22 kg Mg/ha, along with soil test based N, P, and K application rates.

viii. S and P

Kumar and Singh (1994) observed that under sulphur deficient conditions, phosphorus in plants was not properly utilized and hence an increase in total phosphorus occurred.

Chandel *et al.* (2012) in his experiment revealed that the bulb yield and dry matter of garlic increased significantly with increasing doses of S and P. Significant positive interaction of P and S on bulb yield was noted with the combined application of 80 kg P_2O_5/ha and 40 kg S/ha. The uptake of P increased with increasing doses of P from 4.42 to 6.12 kg/ha with the addition of 120 kg P_2O_5/ha. The uptake of sulphur increased from 5.51 to 8.96 kg/ha with the addition of 60 kg S/ha. The interaction between P and S resulted in an additional and beneficial effect on P and S uptake by the garlic crop.

4. Effect of Integrated nutrient management (INM) on rhizomatous and root crops

While fertilizer misuse can contribute to environmental contamination, it is often an indispensable source of the nutrients required for growth and production of crop plants. The increasing use of chemical fertilizers is corrected with secondary nutrient deficiencies, deterioration of physical condition of the soil etc. INM is an integral part of sustainable agriculture. It helps in keeping the soil healthy. It is a practice where all sources of nutrients organic, inorganic, and biofertilizers can be combined and applied to soils so as to enhance the crop growth in order to attain high yield. Large quantities of organic manures are applied to the field usually in conventional turmeric farming system. Organic manures such as FYM, oil cakes, and vermicompost are known to play a crucial role in maintaining soil health and beneficial microbial population leading to improved soil characteristics and enhanced fertility levels. The general recommendation in many states is 25-30 t/ha of FYM or compost along with inorganic fertilizers (Soorianathasundaram *et al.*, 2007). In addition to organic manure, plant residues also help to improve the fertilizer use efficiency in turmeric. Addition of organic matter to the soil by way of incorporating green manures and mulching with leaves of daincha (*Sesbania aculeata*) and sunnhemp (*Crotalaria juncea*) are found to be useful.

Muralidharan and Balakrishnan (1972) stated that in rainfed cultivation at Kerala (Wayanad), application of 100 kg N/ha along with a basal dose of 15 t/ha of FYM and 50 t/ha of green leaves mulch applied at planting and again at 60 DAP was found to maximize turmeric yield. Liu *et al.* (1974) found striking improvement in curcumin content due to potassium application at the rate of 60 kg K_2O/ha in turmeric. The quality of turmeric rhizomes were enhanced the fertilizers up to 187.5 kg N/ha, 62.5 kg P/ha and 125 kg K/ha. Above this, adverse effect was seen on the quality (Rao and Swamy, 1984).

Sadanandan and Hamza (1998) reported that, application of neem cake, groundnut cake and cotton cake gave highest curcumin content in turmeric when compared to NPK fertilizers. However rhizome yield was found to be maximum with NPK fertilizers as compared to different oil cakes. Study revealed that curcumin content of turmeric variety, Bangalore Local was higher (4.03 %) than CO-1 (2.97 %) when NPK were applied at the rate of 150:125:250 kg/ha (Venkatesha *et al.*, 1998). Krishnamurthi *et al.* (1999) in his study on turmeric concluded that in red sandy loam soil with low available nitrogen (192 kg/ha), medium phosphorus (12.6 kg/ha) and high potassium (296 kg/ha), highest fresh rhizome yield of turmeric was observed in NPK + poultry manure, when compared to NPK + sheep manure or FYM or cattle manure or compost. Digested coir pith compost was also found to increase the yield of turmeric rhizomes (Krishanamurthi *et al.* 2002). Manjunathgoud *et al.* (2002) found that the curcumin content of turmeric increased from 3.42 to 3.65 % with increased fertilizer levels (0 to 150:125:250 kg NPK/ha respectively).

Maheswarappa *et al.* (1999) observed that in arrowroot (*Maranta arundinaceae)* intercropped with coconut, the treatment combination of FYM along with inorganic fertilizers recorded the highest dry matter of 65.12 g per plant and 125.69 g per plant at 120 and 240 days after planting, respectively and at harvest

(167.93 g per plant). The contents of chlorophyll a and b were significantly higher in FYM + inorganic fertilizer (2.1 and 2.113 mg/g fresh leaf respectively).

In *kacholam*, the essential oil and oleoresin contents were significantly higher in treatments with FYM (20 t/ha) and NPK (50:50:50 kg/ha), followed by FYM and vermicompost treatments (Maheswarappa *et al*., 2000b). Kavitha and Menon (2013) reported that in *kacholam*, top dressing of sulphur and magnesium resulted in higher rhizome yields (8.56 and 8.24 t/ha). Sulphur application also resulted in higher oleoresin and essential oil contents. Higher sulphur and calcium contents in rhizomes were related to application of these elements. Path co-efficient analysis revealed that the secondary nutrients play a decisive role in the development of oleoresin and essential oil in *kacholam*.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Effect of secondary nutrients on yield and quality of turmeric (*Curcuma longa* L.)" was carried out in the Department of Agronomy, College of Horticulture, Vellanikkara during the year 2013-2014. The materials used and the methodology adopted for the study is described in this chapter.

3.1 General details

Location

The experiment was carried out at the farm of the Department of Agronomy, College of Horticulture, KAU, Vellanikkara.

Experimental site

The area is located at $10^0 31'$ N latitude and $76^0 13'$ E longitude and at an altitude of 40.3 m above mean sea level.

Weather and climate

The area has humid tropical climate with more than 80 per cent of the rainfall distributed through south-west and north-east monsoon showers. The mean monthly averages of important meterological parameters observed during the experimental period are presented in Appendix-1.

3.2 Cropping history of the experimental site

The experimental site has not been under cultivation for last three years.

3.3 Details of experiment

The layout of the field experiment is given in Fig.1. The experiment was laid out in Randomised Block Design (RBD) with three replications.

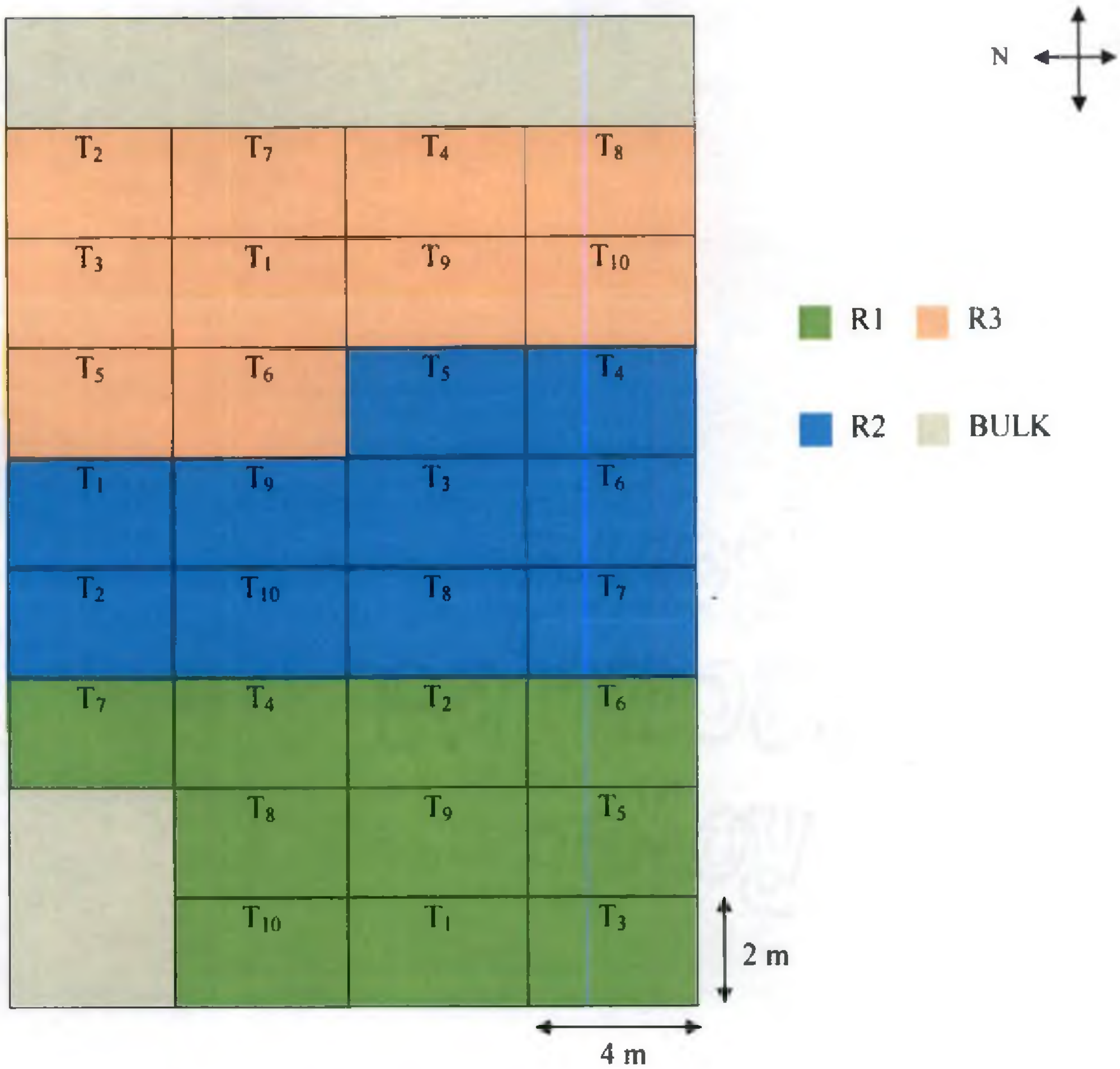

Fig. 1. Layout of the experiment

Soil characters

The soil of the experimental site is sandy clay loam in texture, belonging to the order Ultisol. The soil is acidic in reaction with pH of 5.3. The physico-chemical characteristics of the soil of the experimental field are presented in Table 1.

Table 1. Physico-chemical properties of soil before the experiment

Particulars	Value
A. Particle size analysis	
Sand (%)	68.00
Silt (%)	19.50
Clay (%)	12.50
B. Chemical composition	
Organic carbon (%)	1.30
Available nitrogen (kg/ha)	593.74
Available phosphorus (kg/ha)	9.50
Available potassium (kg/ha)	386.77
Available sulphur (mg/kg)	11.20
Available calcium (mg/kg)	170.80
Available magnesium (mg/kg)	9.33
pH	5.3

Treatments:

The ten treatments which formed the experiment were as follows:

T_1 - POP viz. 40 t FYM + 30:30:60 kg NPK/ha [30 kg P + 30 kg K as basal dose, 20 kg N 30 days after planting (DAP), 10 kg N + 30 kg K 60 DAP]

T_2 - POP + S, 25kg/ha at 30 DAP

T_3 - POP + S, 25kg/ha at 60 DAP

T_4 - POP + Ca, 25kg/ha at 30 DAP

T_5 - POP + Ca, 25kg/ha at 60 DAP

T_6 - POP + Mg, 25kg/ha at 30 DAP

T_7 - POP + Mg, 25kg/ha at 60 DAP

T_8 - POP + S, 25kg/ha + Ca, 25kg/ha + Mg, 25kg/ha at 30 DAP

T_9 - POP + S, 25kg/ha + Ca, 25kg/ha + Mg, 25kg/ha at 60 DAP

T_{10} - Absolute control

Details of the quantity of different fertilizers applied at different stages are given in Table 4.

All the three replications were laid in compact blocks. Planting was done on 05-06-2013. The variety used was Sobha and the spacing adopted, 25×25 cm. Gross plot area was 8 m^2 (4 beds of 2 × 1 m^2). The experiment consisted of ten treatments with different combination of fertilizers. Treatments were applied basally, one month and two months after planting.

3.4. Fertilizers

Urea, ammonium sulphate, rajphos, muriate of potash, magnesium oxide and calcium oxide were used as the sources for different nutrients. The nutrient content of the fertilizer is given in Table 2.

Table 2. Sources of nutrients

Nutrients	Fertilizer	Nutrient content (%)
Nitrogen	Urea	46
	Ammonium sulphate	20.6
Phosphorus	Rajphos	18
Potassium	Muriate of potash	60
Sulphur	Ammonium sulphate	24
Calcium	Calcium oxide	70
Magnesium	Magnesium oxide	45

3.5 Field operations

The cultural operations were carried out as per the Package of Practices Recommendations (KAU, 2011)

Land preparation

The land was first ploughed and leveled. Raised beds of 2.0 m length, 1.0 m width and 25 cm height were prepared using a bund former.

Planting material and planting

Planting was done during the month of June, 2013 with the receipt of four to five pre-monsoon showers. Small pits were taken in beds in rows at spacing of 25×25 cm. Rhizome bits were planted with a viable healthy bud facing upwards, at a depth of 4 to 5 cm along with farmyard manure as per treatment requirements and then covered with soil. Mulching was done immediately after planting as well as 50 days after planting with locally available leafy material. Weeding was done thrice, at 60, 120 and 150 days after planting. Earthing up was done at 60 days after planting. Fertilizers were applied in channels taken in between rows as per treatments. The crop was totally rainfed.

Table 3. Dates of different operations

Sl. No.	Particulars	Date
1	Planting	05/06/13
2	Mulching	06/06/13
		25/07/13
3	Earthing up	05/07/13
4	Weeding	05/07/13
		23/09/13
		21/10/13
5	Harvesting	17/01/14

Harvesting

The crop was harvested during third week of January, 2014 when leaves dried completely in the field. Rhizome yield was recorded from each bed after removing the outer most border row. Yields from net plot areas were expressed in terms of tonnes per hectare.

3.6 Field observations

Sampling technique

The boarder rows were avoided and five plants were selected from each plot and labelled for recording various morphological characters. Monthly observations for biometric character were recorded from the same five plants and the mean values worked out. Two other plants were marked separately to measure the leaf area index.

Biometric observations

3.6.1 Plant height

Plant height was measured from ground level to tip of top most (youngest) leaf. It was recorded at monthly intervals from the five sample plants. The average was worked out for each plant.

3.6.2 Number of leaves per clump

Total number of leaves produced per plant from the sample plant was recorded at monthly intervals and the mean was worked out.

3.6.3 Number of tillers per clump

Number of tillers produced by each sample plant was recorded and the mean was worked.

Table 4. Details on the application of the treatments

Treatment	FYM (t/ha)	Fertilizers applied basally (kg/ha)	Fertilizers applied 1 MAP* (kg/ha)	Fertilizers applied 2 MAP (kg/ha)
T_1**	40	N:P:K - 0:30:30	N:P:K - 20:0:0	N:P:K - 10:0:30
T_2	40	N:P:K - 0:30:30	N:P:K - 20:0:0 + 25 kg S as $(NH_4)_2SO_4$	N:P:K - 10:0:30
T_3	40	N:P:K - 0:30:30	N:P:K - 20:0:0	N:P:K - 10:0:30+ 25kg S as $(NH_4)_2SO_4$
T_4	40	N:P:K - 0:30:30	N:P:K - 20:0:0 + 25 kg Ca as CaO	N:P:K - 10:0:30
T_5	40	N:P:K - 0:30:30	N:P:K - 20:0:0	N:P:K - 10:0:30 + 25 kg Ca as CaO
T_6	40	N:P:K - 0:30:30	N:P:K - 20:0:0 + 25 kg Mg as MgO	N:P:K - 10:0:30
T_7	40	N:P:K - 0:30:30	N:P:K - 20:0:0	N:P:K - 10:0:30 + 25 kg Mg as MgO
T_8	40	N:P:K - 0:30:30	N:P:K - 20:0:0 + S + Ca + Mg (25 kg each)	N:P:K - 10:0:30
T_9	40	N:P:K - 0:30:30	N:P:K - 20:0:0	N:P:K - 10:0:30 + S + Ca + Mg (25 kg each)
T_{10}	-	Absolute control	-	-

* MAP - months after planting **Package of practices recommendations

3.6.4 Leaf area index (LAI)

Leaf area index is the ratio of leaf area to ground area. The length of the leaf was measured from the leaf base to the tip of leaf and width was recorded at the widest point of the leaf lamina. The leaf area was calculated by multiplying the leaf length, width and number of leaves with conversion factor 0.72 to arrive at the actual leaf area. The conversion factor was worked out by dividing the actual leaf area recorded by computed leaf area (length x breadth) as outlined by Rao and Swamy (1984). Leaf area index was measured at monthly intervals starting from the 2^{nd} month and the mean was worked out.

Leaf area index (LAI) = Leaf area/Land area

3.6.5 Fresh weight of rhizomes

Rhizomes were harvested from the net plot area separately for each treatment and the yields were expressed on per hectare basis.

3.6.6 Dry weight of rhizomes and driage percentage

Rhizomes were chopped into small pieces and then dried to constant weight at 70^0 C in hot air oven. Dry rhizome yield per plot was calculated and expressed on per hectare basis. Driage was calculated from fresh and dry weight and expressed in percentage.

Driage % = 100 – [(Fresh weight - Dry weight)/Fresh weight×100]

3.7 Dry matter production

Five plants per plot were taken for estimating dry matter production. They were cleaned, air dried and then oven dried at 70° C and dry weight was recorded in g at 3 MAP, 6 MAP and at harvest and then expressed as kg/ha.

3.8 Chemical analysis

3.8.1 Soil analysis

Initial and final (after harvest) status of nutrients in soil was estimated. Soil samples were collected and soil analysis was done to arrive at the status of major and secondary nutrients viz. organic carbon, available N, P, K, S, Ca and Mg using the standard procedures as detailed in Table 5.

3.8.2 Plant analysis

Major and secondary nutrients in turmeric shoots were estimated at 3 MAP, 5 MAP and also from rhizomes at harvest. Destructive sampling was done to estimate nutrient contents. For this five plants were uprooted randomly from outside the net plot area. After uprooting, the plant parts were cleaned, dried in a hot air oven at 70^0 C, powdered well and then analysed for major and secondary nutrients. The methods used for the analysis of different nutrients are given in Table 6.

3.8.3 Chlorophyll content in leaf

Total chlorophyll content in the leaves was estimated at 3 MAP and 6 MAP. The first fully opened leaves from top were selected as index leaves and were removed from the plants sampled for chemical analysis. For analysis, 0.2 gm of finely cut fresh sample was taken in a beaker and 10 ml DMSO (dimethyl sulphoxide) solution was added. This was kept in dark place overnight and next day made up to 25 ml in a volumetric flask after filtering. The chlorophyll content was read at two wavelength, *i.e.,* 663 and 645 nm. Using the equation given below, chlorophyll a, chlorophyll b and total chlorophyll contents were estimated. Chlorophyll content of index leaves was estimated colorimetrically using spectrophotometer (Yoshida *et al.*, 1972)

Table 5. Methods used for chemical analysis of soil

Sl. No.	Parameter	Method used	Reference
1	Soil texture	Robinson International pipette method	Piper (1942)
2	Soil pH	Soil - H_2O suspension in the ratio 1:2.5 read in pH meter	Jackson (1958)
3	Organic carbon (%)	Chromic acid wet digestion method	Walkley and Black (1934)
4	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
5	Available P_2O_5	Bray and Kurtz method	Bray and Kurtz (1945)
6	Available K_2O	Neutral normal ammonium acetate extract using flame photometer	Jackson (1958)
7	Available S	$CaCl_2$ extract-turbidimetry method	Chesin and Yien (1951)
8	Exchangeable Ca, Mg	Neutral normal ammonium acetate extract using Atomic Absorption Spectrophotometer	Jackson (1958)

Table 6. Methods used for chemical analysis of plant samples

Sl. No.	Nutrient	Digestion procedure	Method of estimation	Reference
1	N	H_2SO_4 digestion	Distillation and titration	Jackson (1958)
2	P	2:1 HNO_3:$HClO_4$ Diacid digestion	Vanado-molybdate yellow colour method using spectrophotometer	Jackson (1958)
3	K	2:1 HNO_3:$HClO_4$ diacid digestion	Direct reading using flame photometer	Jackson (1958)
4	S	2:1 HNO_3:$HClO_4$ diacid digestion	Turbidimetric method using spectrophotometer	Williams and Steinberg (1959)
5	Ca and Mg	2:1 HNO_3:$HClO_4$ diacid digestion	Direct reading using atomic absorption spectrophotometer	Page (1982)

Chlorophyll a = 12.7 × OD at 663 nm – 2.69 × OD at 645 nm × V/1000 × W

Chlorophyll b = 22.9 × OD at 645 nm – 4.63 × OD at 663 nm × V/1000 × W

Total chlorophyll = 8.02 × OD at 663 nm + 20.2 × OD at 645 nm × V/1000 × W

OD-optical density V-volume made up W-weight of the sample

3.8.4. Plant uptake of nutrients

Uptake of nutrients was estimated at 3 MAP, 6 MAP and of rhizome at harvest. Total uptake of nutrients was calculated as the product of the content of the nutrients in the plant and rhizome dry weight and expressed in kilograms per hectare.

3.9 Quality attributes in turmeric

Quality components in turmeric estimated in the study were curcumin content and oleoresin.

3.9.1 Curcumin and oleoresin content in rhizomes

Boiled, dried and powdered rhizome samples were packed in polythene covers and sent to the Indian Institute of Spices Research, Calicut, where they analyzed for curcumin and oleoresin contents. The values were tabulated.

3.10 Statistical analysis

The data on biometric, yield and quality attributes were subjected to analysis of variance using the statistical package MSTAT-C (Freed, 1986). Duncan's Multiple Range Test (DMRT) was used to compare means (Duncan, 1955; Gomez and Gomez, 1984).

Plate 1. General view of experimental field

Plate 2. Layout of experiment

Plate 3. Mulching in experimental plot

Plate 4. Plants at 3 months after planting

Plate 5. Plants at 6 months after planting

Plate 6. Harvested rhizomes of turmeric

Plate 7. Single clump

Results

4. RESULTS

The results of the study on "Effect of secondary nutrients on yield and quality of turmeric (*Curcuma longa* L.)" conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during the year, 2013-2014 are presented below.

4.1 Vegetative growth of turmeric

4.1.1 Plant height

Data regarding plant height at one, two, three, four, five and six months after planting are given in Table 7. In general, throughout the period of observation, there was increase in plant height from 1st month to 6th month. However growth rate was slow from 5th month to 6th month. Initially at one MAP (month after planting) all treatments were on par, however absolute control (T_{10}), which recorded significantly lower plant height (21.20). Of the treatments, T_2 (POP + S at 30 DAP) and T_3 (POP + S at 60 DAP) recorded taller plants. Treatments were also not significantly different at 2 and 3 MAP except for absolute control. This trend continued until 6 MAP. Treatment (T_5) where Ca was top dressed at 60 DAP along with T_1 (POP) showed higher plant heights every month except for the 1st and 3rd month. During entire period of observation, T_{10} (absolute control) recorded significantly lower plant heights.

4.1.2 Number of leaves per clump

The data pertaining to the number of leaves per clump are presented in Table 8. Number of leaves increased from 1 MAP to 5 MAP and thereafter a decreasing trend was noticed. In general, number of leaves per clump did not differ significantly between treatments. Highest leaf number of 12.40 was recorded at 4 and 5 MAP, after which it deceased. Treatment (T_9) where T_1 (POP) along with S, Ca and Mg were top dressed at 60 days recorded higher number of leaves every month from 4 MAP.

4.1.3 Number of tillers per clump

Data pertaining to the number of tillers/clump are presented in Table 9. Tiller counts were recorded from 3 MAP since initially tillers where not seen. Increasing trend of tillers where noticed from 3 MAP to 6 MAP. Number of tillers per clump did not differ significantly between treatments.

4.1.4 Leaf area index (LAI)

Leaf area index was recorded from 2 MAP to 6 MAP (Table 10). Initially increasing trend was observed and it continued up to 5 MAP and thereafter LAI decreased. At 2 MAP treatments T_1 and T_2 recorded highest LAI of 1.87 and 1.85, whereas T10 showed least LAI of 0.93. At 3 MAP, highest LAI (4.80) was observed in T_5 (POP + Ca at 60 DAP) and it was on par with treatments T_4 (POP + Ca at 30 DAP) and T_6 (POP + Mg at 30 DAP). At 4 MAP, 5 MAP and 6 MAP, T_5 recorded highest LAI, where Ca was top dressed at 60 days. Absolute control (T_{10}) showed least LAI during the entire period of observation.

4.1.5 Dry matter accumulation

Dry matter production was calculated for 3 MAP and 6 MAP and the data are presented in Table 11. At 3 MAP, dry matter production was high in T_5 (POP + Ca 60 DAP) with 2069kg/ha and the least was in absolute control (T_{10}) with 829.7 kg/ha. At 6 MAP, T_5 (POP + Ca 60 DAP) gave highest dry matter of 9237 kg/ha and was on

Table 7. Effect of treatments on plant height (cm) at monthly intervals

Treatment No.	Treatments	Stage of growth					
		I MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	23.03[ab*]	49.09[b]	77.03[ab]	95.07[abc]	104.5[ab]	111.6[a]
T_2	POP + S, 25 kg/ha 30 DAP	25.63[a]	50.29[b]	78.27[ab]	92.97[abc]	106.7[ab]	116.9[a]
T_3	POP + S, 25 kg/ha 60 DAP	25.19[a]	47.19[b]	82.01[ab]	88.73[bc]	107.7[ab]	113.7[a]
T_4	POP + Ca, 25 kg/ha 30 DAP	25.11[ab]	58.24[ab]	93.59[a]	103.3[ab]	112.0[ab]	118.3[a]
T_5	POP + Ca, 25 kg/ha 60 DAP	24.11[ab]	66.55[a]	89.82[ab]	104.4[a]	112.7[a]	113.5[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	24.39[ab]	51.11[b]	73.76[b]	85.51[c]	94.38[ab]	102.0[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	23.08[ab]	51.19[b]	73.61[b]	90.20[abc]	96.83[ab]	106.8[a]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	22.86[ab]	58.20[ab]	74.53[b]	82.73[c]	93.15[b]	102.9[a]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	22.53[ab]	55.16[ab]	79.72[ab]	93.43[abc]	103.9[ab]	110.8[a]
T_{10}	Absolute control	21.20[b]	33.13[c]	52.83[c]	65.59[d]	72.35[c]	74.43[b]

*In a column, means superscribed by common letters do not differ significantly as 5% level in Duncan's Multiple Range Test (DMRT)

Table 8. Effect of treatments on number of leaves per clump at monthly interval

Treatment No.	Treatments	Stage of growth					
		1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	2.66[ab*]	5.46[a]	8.00[a]	10.80[abc]	11.67[a]	6.73[ab]
T_2	POP + S, 25 kg/ha 30 DAP	2.66[ab]	6.26[a]	8.80[a]	10.73[abc]	11.20[ab]	5.13[b]
T_3	POP + S, 25 kg/ha 60 DAP	2.73[ab]	5.73[a]	8.80[a]	11.33[ab]	11.47[a]	5.53[ab]
T_4	POP + Ca, 25 kg/ha 30 DAP	3.00[ab]	5.40[a]	8.00[a]	11.67[ab]	12.00[a]	6.20[ab]
T_5	POP + Ca, 25 kg/ha 60 DAP	2.53[b]	5.80[a]	8.73[a]	11.53[ab]	11.87[a]	8.13[ab]
T_6	POP + Mg, 25 kg/ha 30 DAP	2.80[ab]	5.33[a]	8.06[a]	10.53[bc]	11.17[ab]	5.60[ab]
T_7	POP + Mg, 25 kg/ha 60 DAP	2.46[b]	6.26[a]	7.13[a]	11.60[ab]	11.00[ab]	6.13[ab]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	2.66[ab]	5.66[a]	8.86[a]	12.27[ab]	12.33[a]	6.00[ab]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	2.93[a]	5.20[a]	8.73[a]	12.40[a]	12.40[a]	9.73[a]
T_{10}	Absolute control	2.66[ab]	5.00[a]	7.46[a]	9.13[c]	9.86[b]	5.20[b]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 9. Effect of treatments on number of tillers/clump at different stages

Treatment No.	Treatments	Stage of growth			
		3MAP	4MAP	5MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	1.46[a*]	1.73[a]	1.93[a]	2.06[a]
T_2	POP + S, 25 kg/ha 30 DAP	1.26[a]	1.66[a]	1.73[a]	1.80[a]
T_3	POP + S, 25 kg/ha 60 DAP	1.46[a]	1.66[a]	1.80a	1.80a
T_4	POP + Ca, 25 kg/ha 30 DAP	1.40[a]	1.73[a]	1.80[a]	1.80[a]
T_5	POP + Ca, 25 kg/ha 60 DAP	1.40[a]	1.46[a]	2.00[a]	2.0[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	1.26[a]	1.33[a]	1.47[a]	1.53[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	1.40[a]	1.66[a]	1.66[a]	1.66[a]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	1.60[a]	1.66[a]	1.73[a]	1.73[a]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	1.40[a]	1.73[a]	1.73[a]	1.93[a]
T_{10}	Absolute control	1.33[a]	1.53[a]	1.66[a]	1.66[a]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 10. Effect of treatments on leaf area index at different stages

Treatment No.	Treatments	Stage of growth				
		2MAP	3MAP	4MAP	5MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	1.87[a*]	3.98[bc]	5.58[d]	5.65[d]	3.03[de]
T_2	POP + S, 25 kg/ha 30 DAP	1.85[a]	3.88[bc]	5.45[d]	5.55[d]	2.27[f]
T_3	POP + S, 25 kg/ha 60 DAP	1.45[cd]	3.95[bc]	7.76[b]	7.77[b]	3.60[bc]
T_4	POP + Ca, 25 kg/ha 30 DAP	1.80[ab]	4.34[ab]	7.70[b]	7.77[b]	2.41[f]
T_5	POP + Ca, 25 kg/ha 60 DAP	1.59[abcd]	4.80[a]	8.14[a]	8.17[a]	5.53[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	1.75[abc]	4.30[ab]	7.73[b]	7.76[b]	3.88[b]
T_7	POP + Mg, 25 kg/ha 60 DAP	1.59[abcd]	3.47[c]	7.46[bc]	7.53[bc]	3.12[de]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	1.51[bcd]	3.81[bc]	7.18[c]	7.32[c]	2.90[e]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	1.40[d]	3.89[bc]	7.62[b]	7.76[b]	3.38[cd]
T_{10}	Absolute control	0.93[e]	1.69[d]	2.23[e]	2.59[e]	1.58[g]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

par with T_6 (POP + Mg 30 DAP) viz. 8897 kg per ha and T_9 (POP + S + Ca + Mg 60 DAP) viz. 8751 kg per ha. Lower dry matter accumulation of 6387 kg per ha was noticed in absolute control (T_{10}).

4.2 Rhizome yield and quality components

4.2.1 Rhizome yield

Data on fresh and dry yields of turmeric at harvest are presented in Table 12. Harvest was done at seven months after planting. Treatments varied significantly both in case of fresh weight and dry weight. Treatment T_5, where Ca was top dressed at 60 DAP recorded significantly higher fresh yield of 30.58 t/ha and dry yield of 4.96 t/ha respectively. And in both the case it was on par with T_6 (POP + Mg 30 DAP), T_2 (POP + S 30 DAP) and T_4 (POP + Ca 30 DAP). Absolute control (T_{10}) recorded the lower yield of 10.42 t/ha (fresh yield) and 1.64 t/ha (dry yield). There was no significant difference between treatments with respect to driage per cent.

4.2.2 B: C ratio

Comparing B: C ratios between treatments (Table 13), highest was observed in treatment receiving Ca at 60 DAP (T_5) followed by Mg at 30 DAP (T_6) viz. 1.7 and 1.6 respectively and least B: C ratio of 0.7 was noticed in absolute control (T_{10}).

4.2.3 Curcumin and oleoresin contents in turmeric

Data regarding curcumin and oleoresin content are given in Table 14. Curcumin content of turmeric ranged from 4.09 to 5.07 per cent. There was no significant difference between the treatments. Treatment T_3 (POP + S 60 DAP) and T_{10} (absolute control), were significantly inferior. Highest curcumin content was noticed in T_2 (POP + S 30 DAP) with 5.07 per cent. In case of oleoresin, it ranged

Table 11. Effect of treatments on dry matter production (kg/ha)

Treatment No.	Treatments	Dry matter production	
		3 MAP	6 MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	1575^{abc*}	8492^{bcd}
T_2	POP + S, 25 kg/ha 30 DAP	1716^{abc}	8022^{d}
T_3	POP + S, 25 kg/ha 60 DAP	1699^{abc}	8110^{cd}
T_4	POP + Ca, 25 kg/ha 30 DAP	1817^{ab}	8312^{bcd}
T_5	POP + Ca, 25 kg/ha 60 DAP	2069^{a}	9237^{a}
T_6	POP + Mg, 25 kg/ha 30 DAP	1827^{ab}	8897^{ab}
T_7	POP + Mg, 25 kg/ha 60 DAP	1153^{cd}	7958^{d}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	1639^{abc}	8273^{bcd}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	1418^{bc}	8751^{abc}
T_{10}	Absolute control	829^{d}	6387^{e}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 12. Effect of treatments on yield of rhizome

Treatment No.	Treatments	Fresh yield (t/ha)	Dry yield (t/ha)	Driage (%)
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	22.86[cd*]	3.71[cd]	16.35[a]
T_2	POP + S, 25 kg/ha 30 DAP	26.29[abc]	4.24[abc]	16.72[a]
T_3	POP + S, 25 kg/ha 60 DAP	23.63[cd]	3.89[cd]	16.47[a]
T_4	POP + Ca, 25 kg/ha 30 DAP	25.92[abcd]	4.36[abc]	16.35[a]
T_5	POP + Ca, 25 kg/ha 60 DAP	30.58[a]	4.96[a]	16.25[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	29.55[ab]	4.78[ab]	16.17[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	24.78[bcd]	4.03[bcd]	16.16[a]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	23.26[cd]	3.71[cd]	15.95[a]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	21.36[d]	3.36[d]	15.76[a]
T_{10}	Absolute control	10.42[e]	1.64[e]	15.73[a]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 13. Effect of treatments on Benefit: Cost ratios

Treatment No.	Treatments	Cost (Rs/ha)	Benefit (Rs/ha)	B:C ratio
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	2,01,580	2,59,700	1.2
T_2	POP + S, 25 kg/ha 30 DAP	2,02,642	2,96,800	1.4
T_3	POP + S, 25 kg/ha 60 DAP	2,02,642	2,76,300	1.3
T_4	POP + Ca, 25 kg/ha 30 DAP	2,02,518	3,05,200	1.5
T_5	POP + Ca, 25 kg/ha 60 DAP	2,02,518	3,47,200	1.7
T_6	POP + Mg, 25 kg/ha 30 DAP	2,03,142	3,34,600	1.6
T_7	POP + Mg, 25 kg/ha 60 DAP	2,03,142	2,82,100	1.3
T_8	POP + S, 25 kg/ha + Ca, 25 kg /ha + Mg, 25 kg/ha 30 DAP	2,05,142	2,59,700	1.2
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	2,05,142	2,35,200	1.1
T_{10}	Absolute control	1,58,400	1,14,800	0.7

Table 14. Effect of treatments on curcumin and oleoresin content (%) in turmeric rhizomes

Treatment No.	Treatments	Curcumin	Oleoresin
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	4.38^{ab*}	11.44^{a}
T_2	POP + S, 25 kg/ha 30 DAP	5.07^{a}	11.53^{a}
T_3	POP + S, 25 kg/ha 60 DAP	4.11^{b}	10.68^{a}
T_4	POP + Ca, 25 kg/ha 30 DAP	4.68^{ab}	11.05^{a}
T_5	POP + Ca, 25 kg/ha 60 DAP	4.33^{ab}	9.93^{a}
T_6	POP + Mg, 25 kg/ha 30 DAP	4.69^{ab}	10.85^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	4.34^{ab}	10.21^{a}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	4.62^{ab}	11.18^{a}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	4.48^{ab}	10.78^{a}
T_{10}	Absolute control	4.09^{b}	10.50^{a}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

from 9.93 to 11.53 per cent. There was no significant difference between any treatments.

4.3. Elemental composition in shoot and rhizome

4.3.1 Major nutrient contents of shoot

Content of major nutrients in shoot at 3 MAP and 6 MAP are presented in table 15. In general, N content of leaves decreased from 3 MAP to 6 MAP. At 3 MAP, content of N in leaves ranged from 1.10 to 1.98%, but at 6 MAP, the content ranged from 0.87 to 1.57%. Nitrogen content was found to be higher in the treatment receiving POP recommendation (T_1) viz. 1.98 and 1.57% at 3 MAP and 6 MAP respectively. At 3 MAP, the only treatment on par with T_1 (POP) was T_5 where 25 kg Ca/ha was applied. However, at 6 MAP, most treatments were equal in N content except for T_4 (POP + Ca 30 DAP), where Ca was applied 30 DAP. At both stages the lowest values were in absolute control (T_{10}).

P content of shoot also showed a decrease from 3 MAP to 6 MAP. At 3 MAP, highest P content in T_7 (0.32%) where Mg was applied at 60 days. Content of P in leaves ranged from 0.15 to 0.32 per cent. At 6 MAP, T_5 where Ca was applied 60 DAP showed higher P content of 0.13 per cent. At 6 MAP, P content varied significantly among treatments, and Ca and Mg application was seen to enhance leaf P content. The least content was in absolute control (T_{10}) at both the stages.

Compared to 3 MAP, K content was higher at 6 MAP. K content ranged from 0.57 to 1.85 per cent. At 3 MAP, K content was more in T_3 (POP + S 60 DAP) and T_4 (POP + Ca 30 DAP) viz. 1.85 and 1.78 per cent. At 6 MAP, K content ranged from 1.12 to 2.26 per cent. In both, 3 MAP and 6 MAP, K content was seen to be higher in T_4 (POP + Ca 30 DAP) viz. 1.78 and 2.26 per cent respectively. T_{10} (absolute control) showed lower K content at both stages of observation.

4.3.2 Secondary nutrient contents of shoot

Data on secondary nutrient contents of shoot at 3 MAP and 6 MAP are given in Table 16. Application of secondary nutrient was seen to increases S content in leaves at 3 months stage. At 6 MAP, the effect was sustained only when S was applied 30 DAP. Higher values for all the nutrients were recorded at 6 MAP. Treatments, T_2 (POP + S 30 DAP), T_3 (POP + S 60 DAP), T_8 (POP + S + Ca + Mg 30 DAP) and T_9 (POP + S + Ca + Mg 60 DAP) at 3 MAP showed higher content of S. S content ranged from 0.11 to 0.22 per cent. At 6 MAP, T2 (0.45 %) showed higher S content where sulphur was top dressed along with T_1 (POP) at 30 days. At both stages, the lowest contents were in T_{10} (absolute control). Application of Mg was seen to have depressing effect on S content of leaves at 6 months stage.

Ca content was highest in T_5, both at 3 MAP and at 6 MAP, wherein Ca was top dressed at 60 DAP. Treatments T_4 (POP + Ca 30 DAP), T_8 (POP + S + Ca + Mg 30 DAP) and T_9 (POP + S + Ca + Mg 60 DAP) were on par with this treatment. Generally, At 6 MAP, the content of Ca increased compared to 3 MAP. At 6 MAP, except when S and Mg were top dressed at 60 DAP, all treatments were equally effective on increasing Ca content. As for other nutrients, the content of Ca was least in absolute control (T_{10}).

At 3 MAP and 6 MAP, highest Mg content was recorded in T_6 (POP + Mg 30 DAP) viz. 0.29 and 0.37 per cent respectively. At 6 MAP, T_8 (POP + S + Ca + Mg 30 DAP) also recorded highest Mg content (0.37 %) and was on par with T_1 (POP) and T_7 (POP + Mg 60 DAP). Contents of Mg increased from 3 MAP to 6 MAP. At 3 MAP, Mg content ranged from 0.08 to 0.29 per cent. But at 6 MAP, Mg content ranged from 0.19 to 0.37 per cent. The content was lowest in absolute control (T_{10}).

4.4 Effect of treatments on nutrient contents of turmeric rhizome

4.4.1 Major nutrient contents of rhizome

N content in rhizome at harvest are presented in Table 17. The package of practices recommendations (T_1) had the highest N content of 1.86 per cent. Application of S, Mg and combined application of S, Ca and Mg at 30 DAP, as well as Ca application at 30 DAP resulted in N content in rhizome are on par with this treatment. Lowest values of N content were registered in absolute control T_{10} (1.04 %).

P content in rhizome varied from 0.15 to 0.37 %. There was no significant different among the treatments except absolute control. However highest P content was recorded in treatment T_9 (0.37 %) wherein POP with combination of S, Ca, Mg at 60 days was top dressed. T_{10} (absolute control) showed the least P content.

K contents of rhizome at harvest were seen highest when Ca was applied 60 DAP and it was on par with T_1 (3.20 %) where POP recommendation was followed. K content in rhizome varied from 2.22 to 3.47 per cent. The least K content was again recorded in absolute control. A significant observation was that contents of all three primary nutrients were high when package of practices recommendations were followed.

4.4.2 Secondary nutrient contents of rhizome

Table 18 is a record of the content of S, Ca and Mg in rhizomes at harvest. Sulphur in rhizome varied from 0.11 to 0.37 per cent. Highest content of sulphur was recorded where sulphur was top dressed at 30 days, followed by T_3 (0.29 %) where sulphur was top dressed with POP at 60 days. Lowest S content was in T10 (absolute control) viz. 0.11 per cent.

Table 15. Effect of treatments on major nutrient contents of shoot (%)

Treatment No.	Treatments	N		P		K	
		3MAP	6MAP	3MAP	6MAP	3MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	1.98^{a*}	1.57^{a}	0.23^{bc}	0.062^{g}	1.07^{bc}	1.17^{cd}
T_2	POP + S, 25 kg/ha 30 DAP	1.34^{cd}	1.16^{abc}	0.24^{bc}	0.057^{h}	1.22^{b}	1.39^{cd}
T_3	POP + S, 25 kg/ha 60 DAP	1.45^{cd}	1.16^{abc}	0.25^{bc}	0.067^{f}	1.85^{a}	2.17^{ab}
T_4	POP + Ca, 25 kg/ha 30 DAP	1.28^{cd}	1.10^{bc}	0.19^{cd}	0.092^{d}	1.78^{a}	2.26^{a}
T_5	POP + Ca, 25 kg/ha 60 DAP	1.86^{ab}	1.45^{ab}	0.23^{bc}	0.130^{a}	0.98^{cd}	1.37^{cd}
T_6	POP + Mg, 25 kg/ha 30 DAP	1.51^{bc}	1.33^{ab}	0.25^{b}	0.107^{b}	0.86^{d}	1.91^{b}
T_7	POP + Mg, 25 kg/ha 60 DAP	1.34^{cd}	1.28^{abc}	0.32^{a}	0.097^{c}	0.84^{d}	1.39^{cd}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	1.34^{cd}	1.28^{abc}	0.21^{bcd}	0.086^{e}	0.86^{d}	1.18^{cd}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	1.28^{cd}	1.23^{abc}	0.26^{ab}	0.092^{d}	1.14^{bc}	1.47^{c}
T_{10}	Absolute control	1.10^{d}	0.87^{c}	0.15^{d}	0.037^{i}	0.57^{e}	1.12^{d}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 16. Effect of treatments on secondary nutrient contents of shoot (%)

Treatment No.	Treatments	S		Ca		Mg	
		3MAP	6MAP	3MAP	6MAP	3MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	0.17^{ab*}	0.28^{cde}	0.22^{de}	0.67^{abc}	0.11^{f}	0.32^{abc}
T_2	POP + S, 25 kg/ha 30 DAP	0.21^{a}	0.45^{a}	0.27^{cde}	0.68^{abc}	0.09^{g}	0.27^{cde}
T_3	POP + S, 25 kg/ha 60 DAP	0.22^{a}	0.34^{bc}	0.26^{cde}	0.58^{bcd}	0.09^{g}	0.24^{ef}
T_4	POP + Ca, 25 kg/ha 30 DAP	0.17^{ab}	0.27^{de}	0.39^{ab}	0.74^{ab}	0.11^{f}	0.30^{bcde}
T_5	POP + Ca, 25 kg/ha 60 DAP	0.19^{a}	0.30^{cde}	0.44^{a}	0.76^{a}	0.12^{e}	0.25^{de}
T_6	POP + Mg, 25 kg/ha 30 DAP	0.11^{bc}	0.27^{ef}	0.29^{bcde}	0.61^{abcd}	0.29^{a}	0.37^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	0.19^{a}	0.26^{ef}	0.21^{de}	0.54^{cd}	0.28^{b}	0.33^{ab}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	0.21^{a}	0.33^{bcd}	0.32^{abcd}	0.74^{ab}	0.13^{d}	0.37^{a}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	0.22^{a}	0.38^{b}	0.35^{abc}	0.62^{abcd}	0.16^{c}	0.31^{bcd}
T_{10}	Absolute control	0.11^{c}	0.21^{f}	0.18^{e}	0.47^{d}	0.08^{h}	0.19^{f}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 17. Effect of treatments on major nutrient contents of rhizome (%)

Treatment No.	Treatment	Harvest		
		N	P	K
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	1.86[a*]	0.33[a]	3.20[ab]
T_2	POP + S, 25 kg/ha 30 DAP	1.69[abc]	0.36[a]	2.72[cd]
T_3	POP + S, 25 kg/ha 60 DAP	1.23[cde]	0.31[ab]	2.60[d]
T_4	POP + Ca, 25 kg/ha 30 DAP	1.22[de]	0.27[b]	2.54[de]
T_5	POP + Ca, 25 kg/ha 60 DAP	1.51[abcd]	0.33[a]	3.47[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	1.80[ab]	0.32[ab]	3.09[bc]
T_7	POP + Mg, 25 kg/ha 60 DAP	1.39[bcde]	0.35[a]	2.86[bcd]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	1.45[abcde]	0.32[ab]	2.70[d]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	1.22[de]	0.37[a]	2.72[cd]
T_{10}	Absolute control	1.04[e]	0.15[c]	2.22[e]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Ca content of rhizome varied from 0.25 to 0.46 per cent. The highest Ca content (0.46 %) was recorded by the application of Ca at 30 DAP, followed by T_5 (POP + Ca 60 DAP) and T_8 (POP + S + Ca + Mg 30 DAP). Absolute control (T_{10}) recorded least Ca content (0.25%).

Magnesium content in rhizome were found to be higher when Mg was top dressed. T_6 (POP + Mg 30 DAP) and T_7 (POP + Mg 60 DAP) recorded 0.23 % Mg in rhizome. POP and combined application of S, Ca and Mg at 60 DAP recorded values which were on par with T_6 and T_7. The least Mg content (0.15 %) recorded in absolute control (T_{10}).

4.5 Uptake of nutrients

4.5.1 Uptake of different nutrients at 3 MAP by shoot

Uptake of different nutrients was estimated at 3 MAP in shoot and the data are presented in Table 19. Highest nitrogen uptake of 38.57 kg per ha was noticed in T_5 (POP + Ca 60 DAP) and it was on par with POP (T_1) viz. 31.91 kg/ha and when Mg was applied at 30 DAP (27.87 kg/ha). There were no significant differences between treatment with regard to phosphorus uptake except in T_{10} (absolute control) which recorded lowest value. However highest uptake of 4.82 kg/ha was noticed in T_5 (POP + Ca 60 DAP). Highest uptake of K (32.30 kg/ha) was noticed in T_4 (POP + Ca 30 DAP) followed by T_3 (POP + S 60 DAP) with 31.42 kg/ha.

S uptake in shoot did not differ significantly except in T_6 and T_7, indicating that Mg application reduced the S uptake. Highest S uptake of 3.92 kg/ha was recorded when Ca at 25 kg/ha top dressed at 60 DAP. Highest calcium uptake was recorded in T_5 (9.06 kg/ha) and it was on par with T_4 (7.13 kg/ha) where calcium was top dressed at 30 DAP and 60 DAP. Mg at 25 kg/ha top dressed at 30 DAP (T_6) recorded highest uptake of Mg, followed by T_7 (3.22 kg/ha) where Mg was top dressed at 60 DAP. Uptake of all the nutrients are found to be least in T_{10} (absolute control).

4.5.2 Uptake of different nutrients at 6 MAP by shoot

Uptake of different nutrients viz. N. P, K, S, Ca and Mg were estimated and presented in Table 20. Uptake of nutrients was, in general, lower than at 3 MAP as the senescence of the leaves had started. Higher N uptake was recorded in T_5 (POP + Ca 60 DAP) with 35.86 kg/ha and it was on par with T_1 (POP) and T6 (POP + Mg 30 DAP) viz. 28.23 and 28.76 kg/ha. Phosphorus uptake was also found to be highest in T_5 (3.19 kg/ha) where calcium was top dressed at 60 DAP. While K uptake was highest in treatment T_4 (47.45 kg/ha) where calcium was top dressed at 30 DAP and it was on par with the treatments T_6 (POP + Mg 30 DAP) and T_3 (POP + S 60 DAP) with 41.17 and 40.22 kg/ha respectively. K uptake in T_1 was seen to be lesser than that of N which is not usual in a crop like turmeric. This can be explained by the the high Fe content in the soil which led to competition between K and Fe. High uptake of S (8.91 kg/ha) was noticed in T_2 where sulphur was top dressed at 30 DAP and it was on par with T_5 where calcium was top dressed at 60 DAP which recorded 7.61 kg/ha. Calcium uptake was high in T_5 (POP + Ca 60 DAP) with a value of 19.14 kg/ha and it was on par with T_4 (POP + Ca 30 DAP), T_8 (POP + S + Ca + Mg 30 DAP), T_2 (POP + S 30 DAP) and T_6 (POP + Mg 30 DAP). In case of Mg, T_6 (POP + Mg 30 DAP) recorded the highest uptake value of 8.02 kg/ha and it was on par with treatments T7 (POP + Mg 60 DAP), T_5 (POP + Ca 60 DAP) and T_4 (POP + Ca 30 DAP). While absolute control showed the least uptake of all the nutrients.

4.5.3 Uptake of different nutrients by rhizome at harvest

Data presented in Table 21 are a record of the uptake of primary and secondary nutrients in rhizomes at harvest as influenced by nutrient management. Uptake of

Table 18. Effect of treatments on secondary nutrient contents of rhizome (%)

Treatment No.	Treatments	Harvest		
		S	Ca	Mg
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	0.18^{cdef*}	0.30^{de}	0.21^{ab}
T_2	POP + S, 25 kg/ha 30 DAP	0.37^{a}	0.32^{d}	0.15^{de}
T_3	POP + S, 25 kg/ha 60 DAP	0.29^{b}	0.32^{d}	0.17^{c}
T_4	POP + Ca, 25 kg/ha 30 DAP	0.19^{cde}	0.46^{a}	0.15^{cd}
T_5	POP + Ca, 25 kg/ha 60 DAP	0.13^{fg}	0.43^{ab}	0.20^{bc}
T_6	POP + Mg, 25 kg/ha 30 DAP	0.15^{efg}	0.31^{de}	0.23^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	0.17^{def}	0.36^{cd}	0.23^{a}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	0.24^{bc}	0.40^{bc}	0.19^{b}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	0.23^{cd}	0.35^{cd}	0.21^{ab}
T_{10}	Absolute control	0.11^{g}	0.25^{e}	0.14^{d}

* In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 19. Effect of treatments on uptake of different nutrients (kg/ha) at 3 MAP by shoot

Treatment No.	Treatments	N	P	K	S	Ca	Mg
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	31.91[ab*]	3.69[a]	17.08[bc]	2.66[abc]	3.54[cde]	1.78d[e]
T_2	POP + S, 25 kg/ha 30 DAP	24.15[bcd]	4.31[a]	21.42[b]	3.56[ab]	4.90[bcde]	1.60[ef]
T_3	POP + S, 25 kg/ha 60 DAP	24.88b[cd]	4.27[a]	31.42[a]	3.71[a]	4.42[bcde]	1.63[ef]
T_4	POP + Ca, 25 kg/ha 30 DAP	23.18b[cd]	3.47[a]	32.30[a]	3.13[abc]	7.13[ab]	2.00[cde]
T_5	POP + Ca, 25 kg/ha 60 DAP	38.57[a]	4.82[a]	20.35[b]	3.92[a]	9.06[a]	2.48[c]
T_6	POP + Mg, 25 kg/ha 30 DAP	27.87[abc]	4.68[a]	15.88[bc]	2.14[cd]	5.25[bcd]	5.28[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	15.63[cd]	3.68[a]	9.17[cd]	2.26[bcd]	2.51[de]	3.22[b]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	21.73[bcd]	3.44[a]	14.45[bc]	3.62[ab]	5.73[bc]	2.42[cd]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	18.26[cd]	3.73[a]	16.23[bc]	3.12[abc]	4.90[bcde]	2.12[cde]
T_{10}	Absolute control	9.15[d]	1.33[b]	4.71[d]	0.90[d]	1.57[e]	0.74[f]

* In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 20. Effect of treatments on uptake of different nutrients (kg/ha) at 6 MAP by shoot

Treatment No.	Treatment	N	P	K	S	Ca	Mg
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	28.23^{ab*}	1.11^{cd}	21.41^{cd}	5.13^{c}	12.21^{bc}	5.85^{bc}
T_2	POP + S, 25 kg/ha 30 DAP	22.47^{b}	1.14^{cd}	27.76^{c}	8.91^{a}	13.46^{abc}	5.25^{c}
T_3	POP + S, 25 kg/ha 60 DAP	21.44^{b}	1.25^{c}	40.22^{ab}	6.35^{bc}	10.86^{bcd}	4.60^{c}
T_4	POP + Ca, 25 kg/ha 30 DAP	23.13^{b}	1.93^{bc}	47.45^{a}	5.67^{bc}	15.87^{ab}	6.27^{abc}
T_5	POP + Ca, 25 kg/ha 60 DAP	35.86^{a}	3.19^{a}	32.79^{bc}	7.61^{ab}	19.14^{a}	6.30^{abc}
T_6	POP + Mg, 25 kg/ha 30 DAP	28.76^{ab}	2.29^{b}	42.17^{ab}	5.79^{bc}	13.17^{abc}	8.02^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	20.13^{b}	1.49^{bc}	21.69^{cd}	4.10^{cd}	8.58^{cd}	7.17^{ab}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	23.16^{b}	1.74^{bc}	22.45^{cd}	6.29^{bc}	14.11^{abc}	5.15^{c}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	20.12^{b}	1.43^{bc}	23.48^{c}	6.00^{bc}	10.01^{bcd}	4.98^{c}
T_{10}	Absolute control	8.57^{c}	0.37^{d}	11.22^{d}	2.12^{d}	4.76^{d}	1.90^{d}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 21. Effect of treatments on uptake of different nutrients (kg/ha) by rhizome at harvest

Treatment No.	Treatments	N	P	K	S	Ca	Mg
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	68.88[abc*]	12.39[b]	118.76[bc]	6.84[cd]	11.36[c]	7.94[cd]
T_2	POP + S, 25 kg/ha 30 DAP	72.83[ab]	15.53[ab]	114.88[c]	15.86[a]	13.59[c]	6.72[cde]
T_3	POP + S, 25 kg/ha 60 DAP	49.53[cd]	12.23[b]	101.18[c]	11.42[b]	12.57[c]	6.58[de]
T_4	POP + Ca, 25 kg/ha 30 DAP	54.48[bcd]	11.97[b]	113.54[c]	8.62[c]	17.47[ab]	5.90[e]
T_5	POP + Ca, 25 kg/ha 60 DAP	75.38[ab]	16.69[a]	172.20[a]	6.46[d]	20.51[a]	9.90[ab]
T_6	POP + Mg, 25 kg/ha 30 DAP	86.10[a]	15.51[ab]	147.67[ab]	7.61[cd]	14.81[bc]	10.97[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	55.80[bcd]	14.29[ab]	117.77[bc]	7.12[cd]	12.77[c]	8.51[bc]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	54.41[bcd]	11.96[b]	100.44[c]	8.06[cd]	15.10[bc]	6.97[cde]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	41.43[d]	12.41[b]	92.12[c]	6.90[cd]	14.24[bc]	7.13[cde]
T_{10}	Absolute control	17.38[e]	2. 53[c]	36.71[d]	1.87[e]	4.19[d]	2.51[f]

* In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

nutrients varied significantly among treatments. It was seen that combined application of secondary nutrients at 60 DAP reduced the uptake of N, K, S and Mg compared to application of individual nutrients. T_5, where Ca was top dressed at 60 DAP showed higher values for uptake of N, P, K, Ca and Mg. However, application of Ca at 30 DAP was seen to decrease the uptake of N, K, S and Mg. S application at 30 DAP was seen to enhance uptake of N, P and S while Mg application both at 30 and 60 DAP enhanced P uptake.

4.6 Chlorophyll content in leaves

Chlorophyll content in leaves was estimated at 3 MAP and 6 MAP and data are given in Table 22. Total chlorophyll content was higher at 3 MAP compared to 6 MAP. Both at 3 MAP and 6 MAP, there was no significant difference in chlorophyll a and chlorophyll b among the treatments. Chlorophyll a and total chlorophyll contents were significantly lower in absolute control.

4.7 pH and nutrient content in the soil

4.7.1 pH

Before the experiment, pH of the soil was 5.3. There was slight increase in pH after the experiment (Table 23). 5.7 was the highest pH recorded in treatment T_9 where POP with combination of S + Ca + Mg was top dressed at 60 days. Treatments, T_1 (POP), T_3 (POP + S 60 DAP) and T_{10} (absolute control) recorded a decrease in pH (5.4).

4.7.2 Organic carbon

There was not much variation in treatments regarding organic carbon content (Table 23). Before the experiment, organic content in the soil was 1.30 per cent. There was slight increase in organic carbon content after the experiment except in T_{10}

Table 22. Effect of treatments on chlorophyll content (mg/g) in leaves

Treatment No.	Treatments	Chlorophyll a		Chlorophyll b		Total	
		3MAP	6MAP	3MAP	6MAP	3MAP	6MAP
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	0.71[a*]	0.48[ab*]	0.16[a]	0.13[a]	1.48[abc]	1.03[ab]
T_2	POP + S, 25 kg/ha 30 DAP	0.78[a]	0.60[a]	0.18[a]	0.20[a]	1.63[ab]	1.33[a]
T_3	POP + S, 25 kg/ha 60 DAP	0.64[ab]	0.55[a]	0.15[a]	0.22[a]	1.34[bc]	1.25[a]
T_4	POP + Ca, 25 kg/ha 30 DAP	0.76[a]	0.58[a]	0.19[a]	0.14[a]	1.62[ab]	1.23[a]
T_5	POP + Ca, 25 kg/ha 60 DAP	0.64[ab]	0.59[a]	0.15[a]	0.16[a]	1.35[abc]	1.25[a]
T_6	POP + Mg, 25 kg/ha 30 DAP	0.63[ab]	0.53[ab]	0.15[a]	0.20[a]	1.33[bc]	1.21[a]
T_7	POP + Mg, 25 kg/ha 60 DAP	0.70[a]	0.59[a]	0.22[a]	0.18[a]	1.52[ab]	1.30[a]
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	0.70[a]	0.53[ab]	0.15[a]	0.14[a]	1.47[abc]	1.15[ab]
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	0.81[a]	0.59[a]	0.20[a]	0.23[a]	1.71[a]	1.35[a]
T_{10}	Absolute control	0.49[b]	0.35[b]	0.23[a]	0.18[a]	1.16[c]	0.84[b]

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

(absolute control) viz. 0.95 per cent. In T_6 (POP + Mg 30 DAP) and T_8 (POP + S + Ca + Mg 30 DAP) organic carbon remained the same. Highest value was recorded in T_1 (POP), T_3 (POP + S 60 DAP) and T_2 (POP + S 30 DAP) viz. 1.46, 1.45 and 1.44 per cent respectively.

4.7.3 Available nitrogen

Available nitrogen in the soil showed significant variation among the various treatment (Table 23). Before the experiment, available nitrogen was 593.74 kg/ha. Crop cultivation resulted in decrease available in N content. After the experiment, the highest value was recorded in the treatment (T_5) receiving Ca at 30 DAP (639.70 kg/ha), and it was on par with T_3 (572.80 kg per ha) where S was top dressed at 60 days and T_8 (556.1 kg per ha) where S + Ca + Mg was top dressed at 30 DAP. The lowest value recorded in absolute control (T_{10}).

4.7.4 Available phosphorus

Available phosphorus at the pre planting stage was 9.50 kg/ha. After the experiment available P contents were seen to increase except in absolute control (Table 23). The highest value was recorded in the treatment T_1 (POP) viz. 18.70 kg/ha, and it was on par with T_5 (POP + Ca 60 DAP) and T_6 (POP + Mg 30 DAP). Absolute control T_{10} (8.91 kg ha^{-1}) recorded the least values.

4.7.5 Available potassium

Analysis of soil for available potassium also showed significant variations among the various treatments with contents decreasing (386.77 kg/ha) after the experiment (Table 23). Highest value of 375.9 kg/ha and 352.8 kg/ha were recorded in T_5 (POP + Ca 60 DAP) and T6 (POP + Mg 30 DAP) respectively and least of 231.8 kg/ha was seen in T_{10} (absolute control).

4.7.6 Available sulphur

Available sulphur in soil before the experiment was 11.20 mg/kg (Table 24). After the experiment, sulphur content showed variation among the treatments and it was decreased compared to the content before the experiment. The highest value of 12.26 mg/kg was recorded when S was top dressed at 30 days and 12.05 mg/kg where combinations of S + Ca + Mg were applied at 30 DAP. It was found to be on par with T_3 (11.34 mg/kg) where S was top dressed at 60 DAP, T_9 (10.40 mg/kg) where combinations of S + Ca + Mg were applied at 60 DAP and also in T_4 (9.71 mg/kg) where Ca was applied at 30 DAP. The least was in T_{10} (absolute control).

4.7.7 Available calcium and magnesium

Before the experiment the contents of Ca and Mg were 170.80 mg/kg and 9.33 mg/kg respectively. After the experiment calcium content was highest in the treatment T_5 (203.41 mg/kg) where Ca was top dressed at 60 DAP and it was found to be on par with T_4 (190.96 mg/kg) where Ca was top dressed at 30 DAP, T_8 (188.48 mg/kg) and T_9 (181.08 mg/kg) where S +Ca + Mg was top dressed at 30 and 60 DAP, T_3 (168.81 mg/kg) where S was top dressed at 60 DAP and T_6 (171.14 mg/kg) where Mg was top dressed at 30 DAP. Least was recorded in treatment T_{10} (135.31 mg/kg) which is absolute control (Table 24).

In case of magnesium, treatments T_6 (POP + Mg 30 DAP), T_4 (POP + Ca 30 DAP) and T_1 (POP) recorded highest values of 12.09 mg/kg, 11.76 mg/kg and 11.73 mg/kg respectively and treatments T5 (POP + Ca 60 DAP) and T7 (POP + Mg 60 DAP) were found to be on par. Absolute control (T_{10}) recorded the lowest value.

Table 23. Effect of treatments on pH and major nutrient content in soil after the experiment

Treatment No.	Treatments	pH	Organic carbon (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	5.4^{b*}	1.46^{a}	539.4^{bc}	18.70^{a}	274.0^{bc}
T_2	POP + S, 25 kg/ha 30 DAP	5.5^{ab}	1.44^{a}	468.3^{cd}	14.77^{cd}	275.^{bc}
T_3	POP + S, 25 kg/ha 60 DAP	5.4^{b}	1.45^{a}	572.8^{ab}	13.59^{d}	266.2^{cd}
T_4	POP + Ca, 25 kg/ha 30 DAP	5.6^{ab}	1.37^{ab}	535.2^{bc}	13.65^{d}	280.0^{bc}
T_5	POP + Ca, 25 kg/ha 60 DAP	5.6^{ab}	1.39^{ab}	639.7^{a}	18.23^{ab}	375.9^{a}
T_6	POP + Mg, 25 kg/ha 30 DAP	5.6^{ab}	1.30^{b}	547.8^{bc}	17.52^{ab}	352.8^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	5.6^{ab}	1.39^{ab}	443.2^{de}	15.09^{cd}	311.7^{b}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	5.6^{ab}	1.30^{b}	556.1^{abc}	15.40^{c}	250.1^{cd}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	5.7^{a}	1.31^{b}	577.0^{bc}	16.97^{b}	287.8^{bc}
T_{10}	Absolute control	5.4^{b}	0.95^{c}	368.0^{e}	8.91^{e}	231.8^{d}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Table 24. Effect of treatments on secondary nutrient content (mg/kg) in soil after the experiment

Treatment No.	Treatments	S	Ca	Mg
T_1	POP (40 t FYM + 30:30:60 NPK kg/ha)	8.79^{bc*}	152.31^{bcd}	11.73^{a}
T_2	POP + S, 25 kg/ha 30 DAP	12.26^{a}	138.81^{cd}	8.69^{b}
T_3	POP + S, 25 kg/ha 60 DAP	11.34^{ab}	168.81^{abcd}	8.75^{b}
T_4	POP + Ca, 25 kg/ha 30 DAP	9.71^{ab}	190.96^{ab}	11.76^{a}
T_5	POP + Ca, 25 kg/ha 60 DAP	9.25^{bc}	203.41^{a}	10.54^{ab}
T_6	POP + Mg, 25 kg/ha 30 DAP	6.71^{c}	171.14^{abcd}	12.09^{a}
T_7	POP + Mg, 25 kg/ha 60 DAP	9.02^{bc}	141.84^{cd}	10.50^{ab}
T_8	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 30 DAP	12.05^{a}	188.48^{ab}	8.9^{1b}
T_9	POP + S, 25 kg/ha + Ca, 25 kg/ha + Mg, 25 kg/ha 60 DAP	10.40^{ab}	181.08^{abc}	8.88^{b}
T_{10}	Absolute control	6.71^{c}	135.31^{d}	6.20^{c}

*In a column, means superscribed by common letters do not differ significantly as 5% level in DMRT

Discussion

5. DISCUSSION

An experiment entitled "Effect of secondary nutrients on yield and quality of turmeric (*Curcuma longa* L.)" was conducted in the farm of the Department of Agronomy, College of Horticulture, Vellanikkara during 2013-2014 to evaluate the effect of secondary nutrients on yield and quality of turmeric. The results obtained from the experiment reported in the previous chapter are discussed based on available literature.

5.1 Vegetative growth of turmeric as affected by nutrient management

Turmeric (*Curcuma longa* L.) is a spice crop with a distinct growth habit and has potential for high yield. It is a perennial herb, with a short stem and tufts of erect leaves. The plant produces large, simple leaves which are oblong lanceolate in shape and tapering to the base and petioles as long as the blade. Turmeric being a long duration and high yielding crop requires large amount of nutrients from the soil for a prolonged period. Application of nutrients is therefore an essential feature of turmeric cultivation.

In general, nutritional management with supplemental doses of S, Ca and Mg to the package of practices recommendations did not have any significant effect on the vegetative characters, viz. the plant height, number of leaves and number of tillers per plant. In all treatments, plant height was seen to progressively increase with age, reaching 74 to 118 cm (Fig. 2) by six months after planting (Table 7). Though slight variations were noticed initially, by the time of final observation, all treatments were on par, except for absolute control, which recorded consistently lower values. A similar observation was made with regard to number of tillers per clump (Table 9 & Fig. 3), where even absolute control was on par with all other treatments, indicating

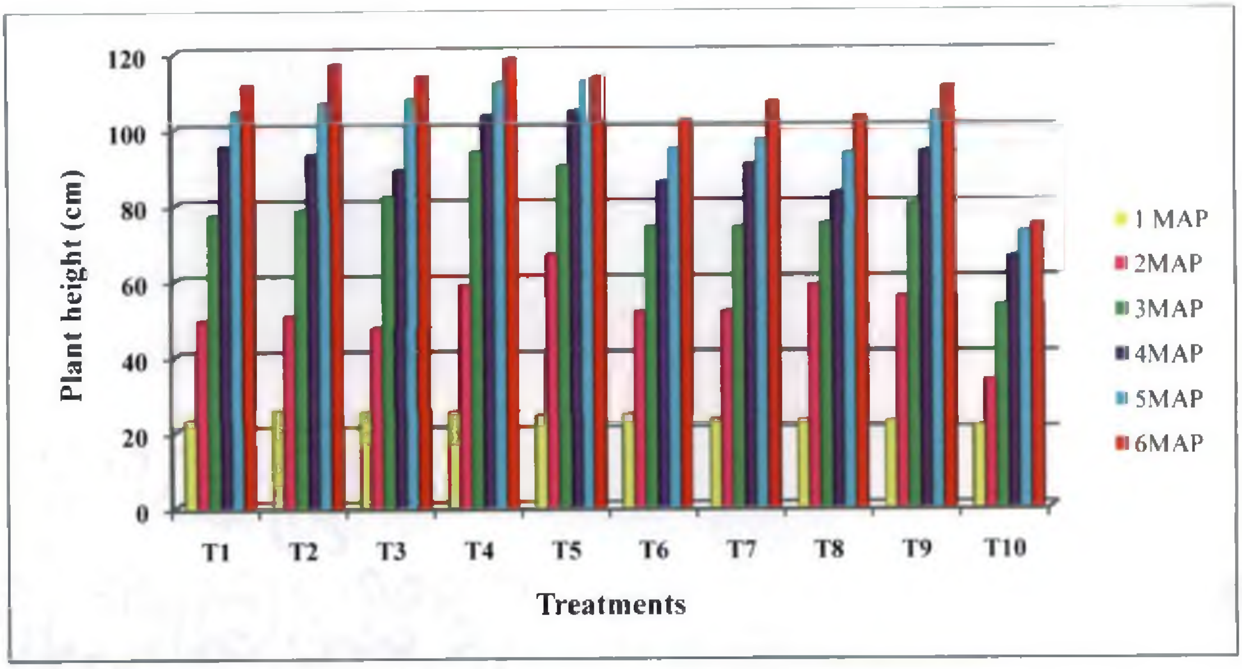

Fig. 2. Effect of treatments on plant height

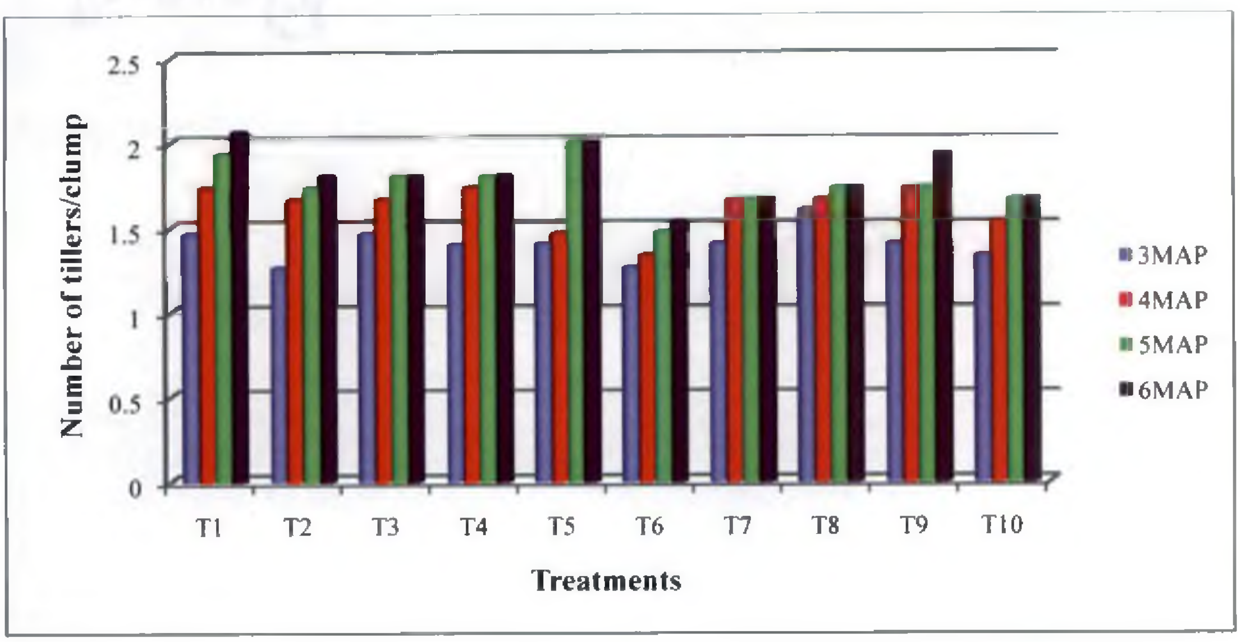

Fig. 3. Effect of treatments on number of tillers/clump

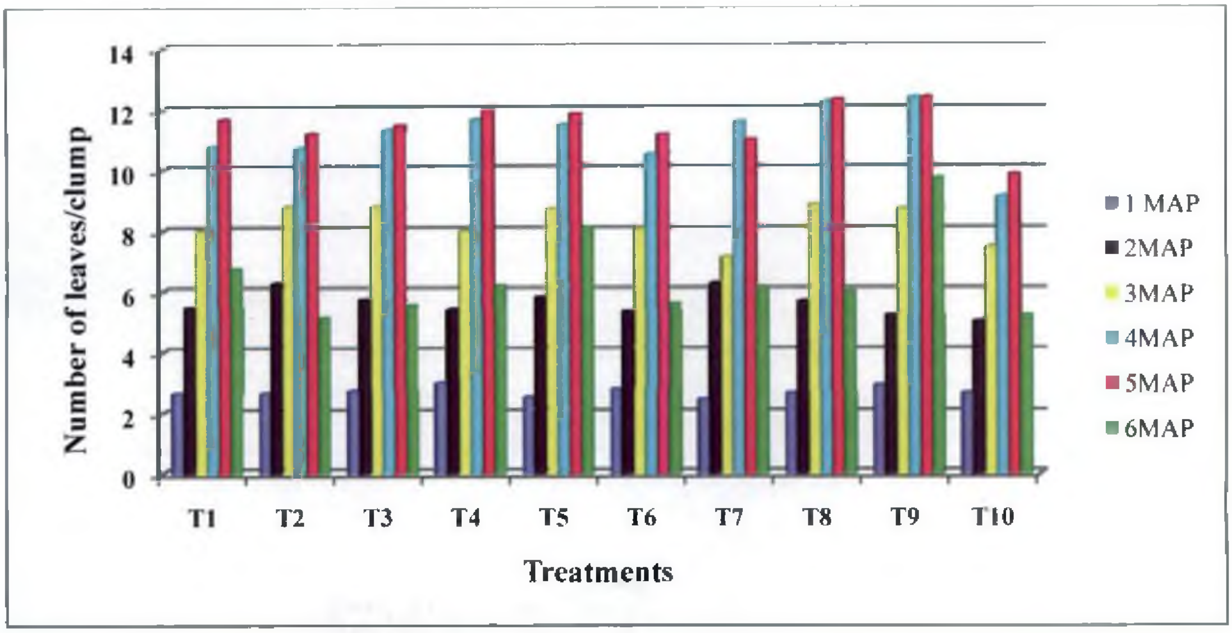

Fig. 4. Effect of treatments on number of leaves/clump

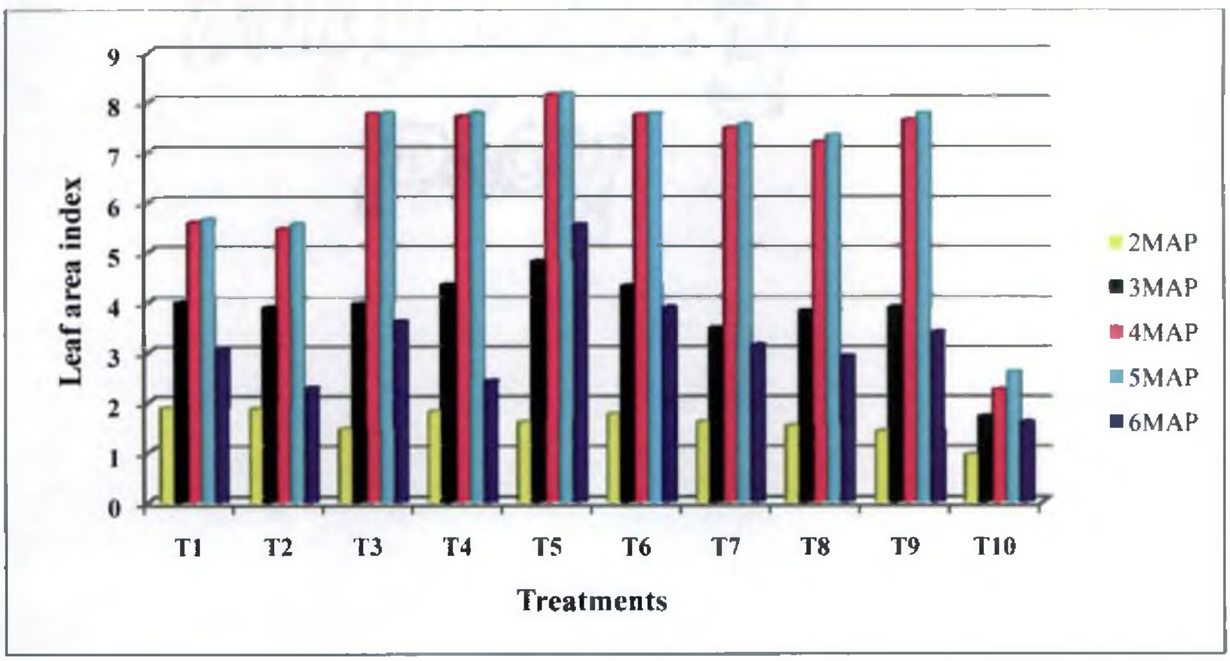

Fig. 5. Effect of treatments on leaf area index (LAI)

that tiller number per clump was pre determined in turmeric and not affected by nutrient management. A similar result on tiller number of *kacholam* has been reported by Kavitha (2012). Turmeric is a crop with inherently poor tillering capacity but it compensates its tillers with larger leaves and enhanced number of leaves.

Application of secondary nutrients did affect the number of leaves produced per clump of turmeric (Table 8). Leaf number was seen to be higher when S, Ca and Mg were applied in combination as top dressing, and a higher number of 9.73 leaves were seen to be produced per clump (Fig. 4). However the effect was on par with almost all other treatments. Similar effect of Ca on enhancing leaf number in garlic was reported by Dabhi *et al.* (2004), while in onion, such an effect was produced by S application (Jana and Kabir, 1990; Mishu *et al.*, 2013).

This variation in leaf number was reflected in the leaf area index, which denotes the proportion of land area covered by the foliage. Table 10 reveals that leaf area of turmeric progressively increased up to five months after planting after which it declined to less than 50 % at six months, coinciding with leaf senescence. Top dressing of calcium at two months of planting resulted in significantly higher LAI (Fig. 5), denoting a capacity for higher photosynthetic ability and consequently, a higher yield.

Higher leaf number and leaf area production resulted in higher dry matter production of shoots both at three months and six months after planting due to top dressed calcium (Table 11). Though Mg application 30 DAP, and combined application of secondary nutrients 60 DAP produced values on par with this treatment, Ca application resulted in much higher dry matter production. The role of Ca as structural component of cell walls for maintaining plant growth and development has been reported by Demarty *et al.* (1984).

5. 2 Yield and quality of turmeric as affected by nutrient management

Rhizome yield, curcumin content and oleoresin are equally important in turmeric. The qualitatively important components are synthesized from primary photosynthates and stored in the rhizomes. Hence the development of both should proceed in a balanced manner.

Turmeric is harvested seven months after planting, by which time complete senescence and drying of the leaves would have occurred. Results showed that significantly higher yields, both fresh and dry, were obtained when Ca was top dressed at two months after planting and when Mg was top dressed at one month after planting (Table 12). This is related to some extent, to the treatments where leaf number and leaf area index were greater. Prakash *et al.* (1997) reported a similar result when gypsum was applied to crops like potato, radish and carrot and gave positive yield response.

The effect of Ca and Mg on increasing rhizome yields was strongly indicated (Table 12 & Fig. 8). Calcium plays a major role in the quality of many crops and it helps in stimulating the absorption of P and K and also helps in accelerating translocation of photosynthetic products (Erdei and Zsoldos, 1977). Simmons and Kelling (1987) reported maximum tuber yields in potato when various forms of Ca were applied. Combined application of N, P, K along with Ca, Mg and S, produced less yield as there may be some antagonistic relationship between them as reported by Loide (2004). The driage showed a different trend, with application of sulphur at one month after planting, recording the highest value of 16.72 %. However, the values were not significantly different (Table 12).

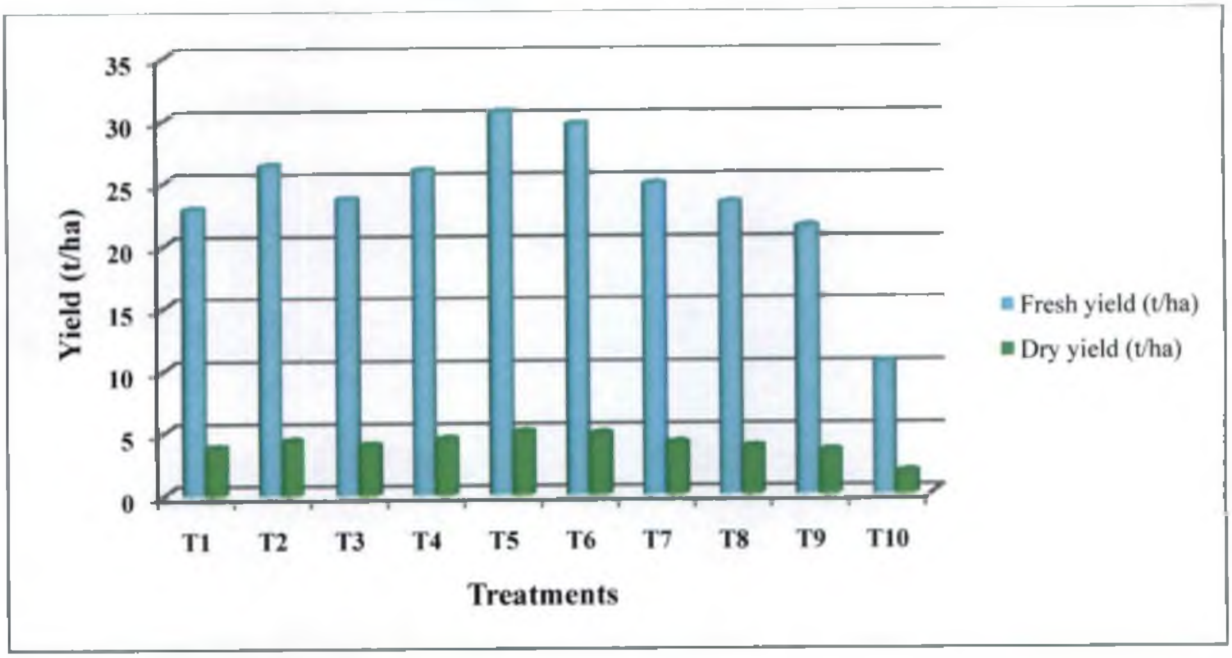

Fig. 6. Effect of treatments on yield of rhizome

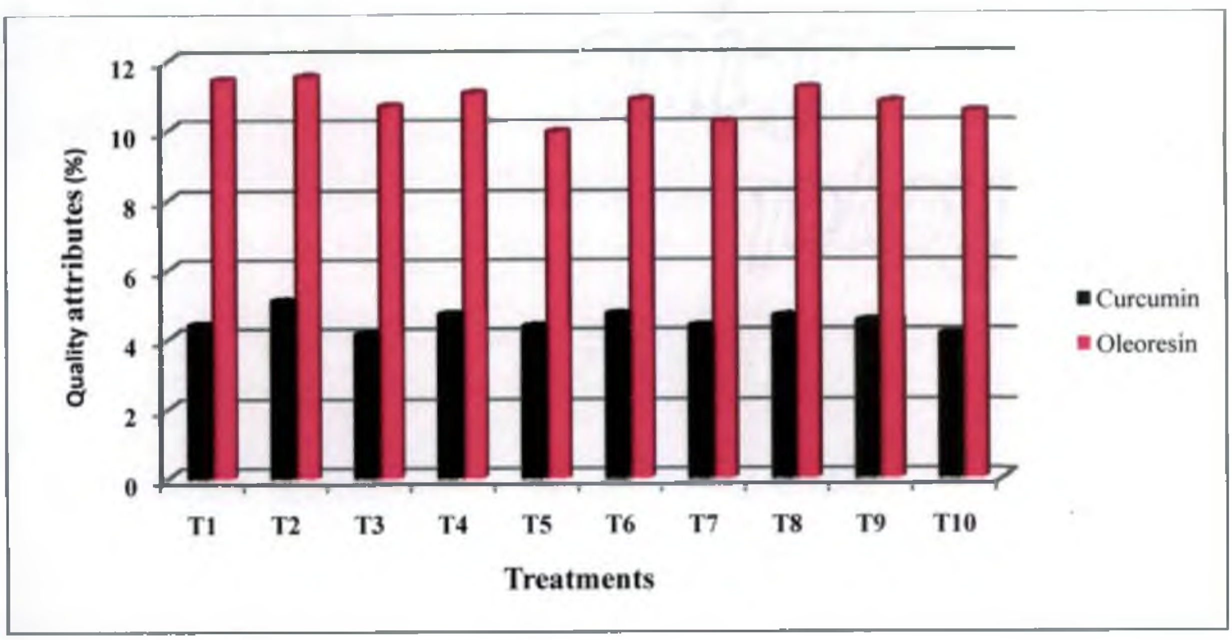

Fig. 7. Effect of treatments on quality attributes in turmeric

A perusal of the qualitative components in the rhizomes (Table 14 & Fig. 7) revealed that curcumin content did not show any significant difference between treatments. However, the highest content of 5.07 % was recorded when sulphur was applied two months after planting and absolute control recorded the least (4.09%). There was no significant difference among treatments with respect to oleoresin content. Role of sulphur in improving quality attributes of *kacholam* was reported by Kavitha (2012).

The results indicate that Ca is definitely involved in higher rhizome yield production in turmeric, and that it is required at later stages of growth, as compared to earlier application. However, considering the development of the qualitative component curcumin, S applied 30 days after planting is seen to have produced an impact, resulting in its highest content. Bose *et al.* (2008) had reported that high rates of Mg and S along with recommended dose of N, P and K improved the yield and quality of turmeric. However, the positive role of Mg on quality was not seen in the present experiment.

An analysis of the data on primary nutrient contents in shoot (Table 15) reveals that top dressing of Ca applied at 60 DAP was associated with higher N and P contents six months after planting. Higher Ca content was also recorded at this stage (Table 16). At harvest, this treatment recorded higher content of N, P and K (Table 17) as well as Ca (Table 18) in rhizome (Figs. 8, 9, 10, 11, 12 & 13). The same effect was reflected in the uptake of these elements (N, P, and Ca) in shoots (Tables 19 & 20), and of N, P, K and Ca in rhizome (Table 21). Magnesium application 30 DAP did not enhance nutrient contents in shoots, except for that of Mg (Table 16). However, higher N, P and Mg content were recorded in rhizome at harvest (Tables 17 & 18). Higher values for N, P and Mg uptake were also recorded in shoot and rhizome (Tables 19, 20 & 21). Havlin *et al.* (2006) reported that soil acidity affected the availability of not only Ca but almost all plant nutrients and therefore compounded deficiency of not only Ca but also other nutrients. Application of Ca in lateritic soil will not only ameliorate the soil but also supplies Ca and increases the uptake of Ca (Fox *et al.*, 1991; Samui and Mandal, 2003). The availability of Ca and Mg is very low in Kerala soils due to leaching under heavy rainfall. Sureshkumar *et al.* (2013) reported that about 45 and 80 per cent of soils of Kerala are deficient in available Ca and Mg, respectively. In addition to being nutrients essential for development of quantitative and qualitative yields, they play important roles in ameliorating the soil and improving the availability of other nutrients. However the effect is location specific.

Similarly, perusing the data on S uptake by turmeric, application of this nutrient at 30 DAP was seen to promote higher uptake of N, P and S by rhizomes at harvest (Table 21)

The involvement of Ca and Mg in the production of higher rhizome yields and of S in higher curcumin contents by way of increased uptake of these elements along with N and P are indicated. Kavitha and Menon (2013) reported higher oleoresin and essential oil contents in *Kacholam* (*Kaempferia galanga*) due to S application, while Bose *et al.* (2008) reported higher yield and quality of turmeric due to application of high rates of Mg and S.

B: C ratio also followed the trend of yields, where Ca at 60 DAP recorded highest B: C ratio followed by Mg at 30 DAP (Table 13). Interestingly, application of secondary nutrients did not produce any change, positive or negative, on oleoresin content of turmeric.

The study indicates that though Ca, Mg and S did have positive effects on yield and quality of turmeric, the enhancement was too low to be significant. Varying the dose and schedule of application of these nutrients can be expected to produce more impressive results.

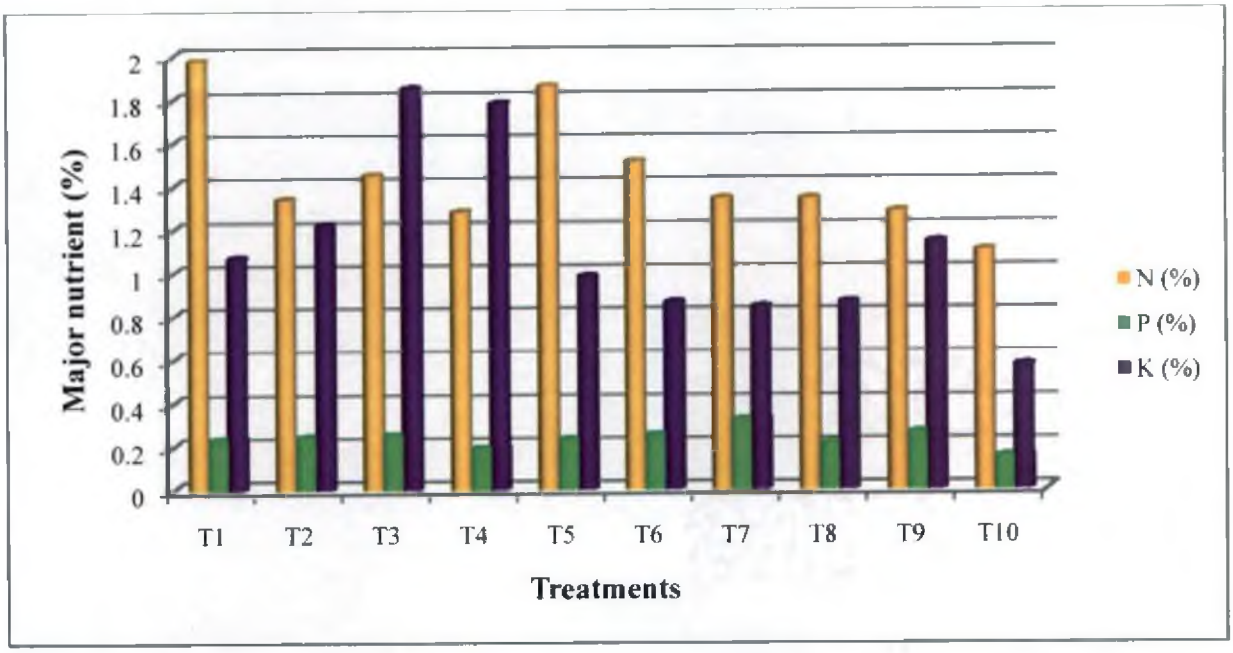

Fig. 8. Effect of treatments on major nutrient contents of shoot at 3 months

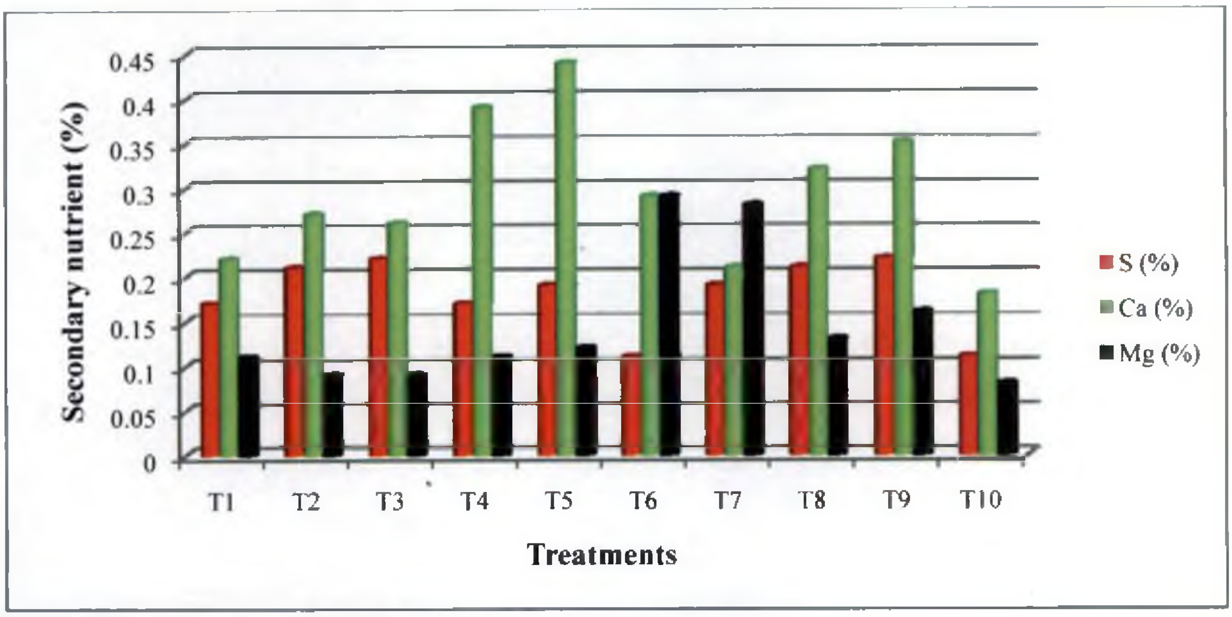

Fig. 9. Effect of treatments on secondary nutrient contents of shoot at 3 months

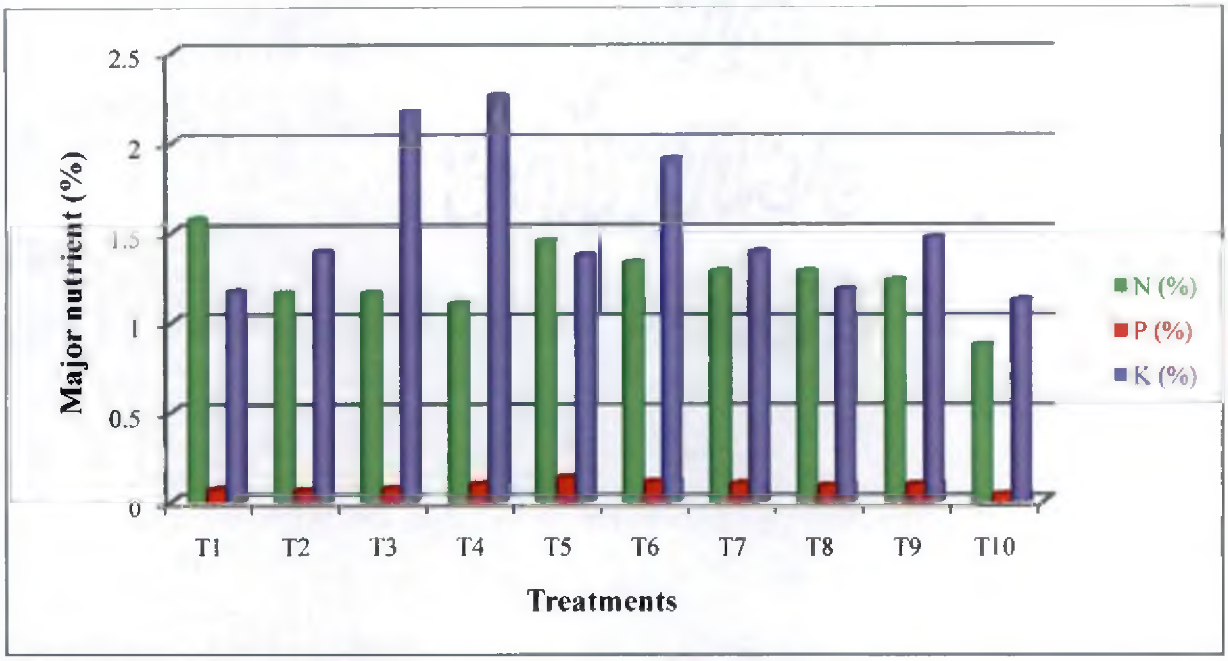

Fig. 10. Effect of treatments on major nutrient contents of shoot at 6 months

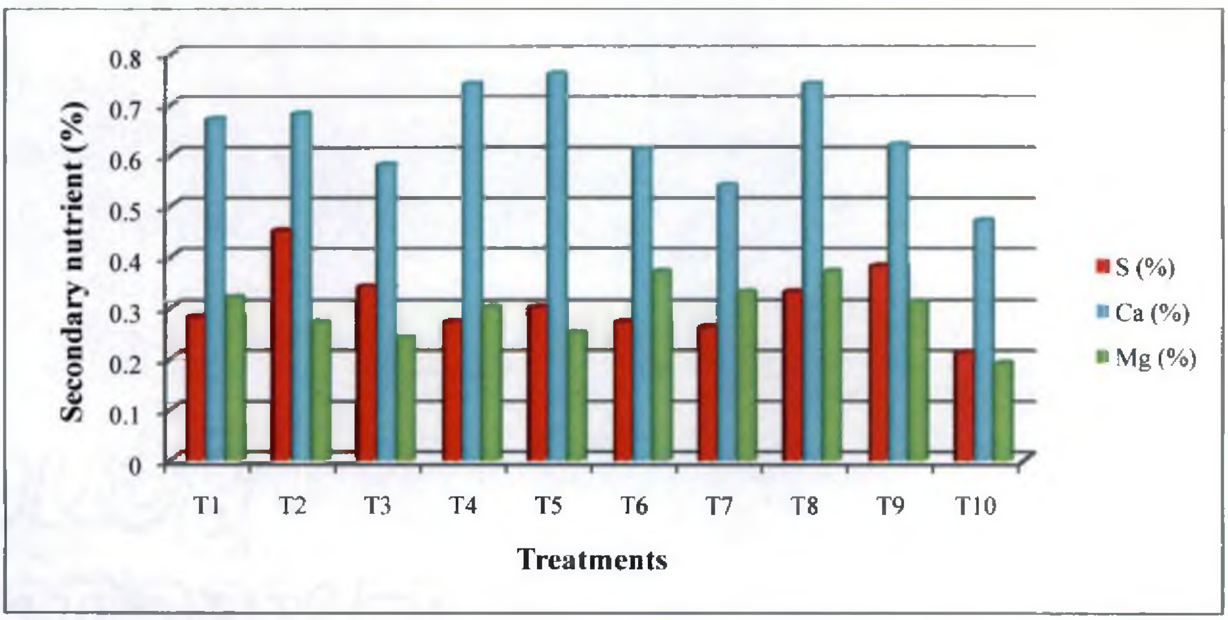

Fig. 11. Effect of treatments on secondary nutrient contents of shoot at 6 months

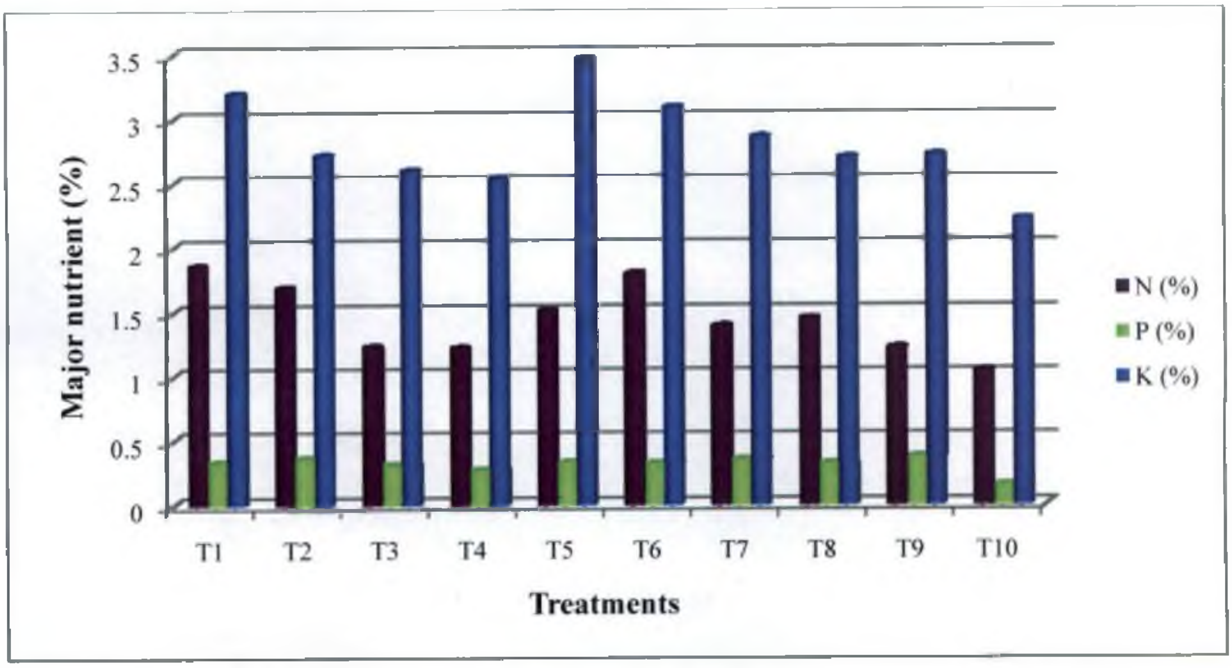

Fig. 12. Effect of treatments on major nutrient contents of rhizome at harvest

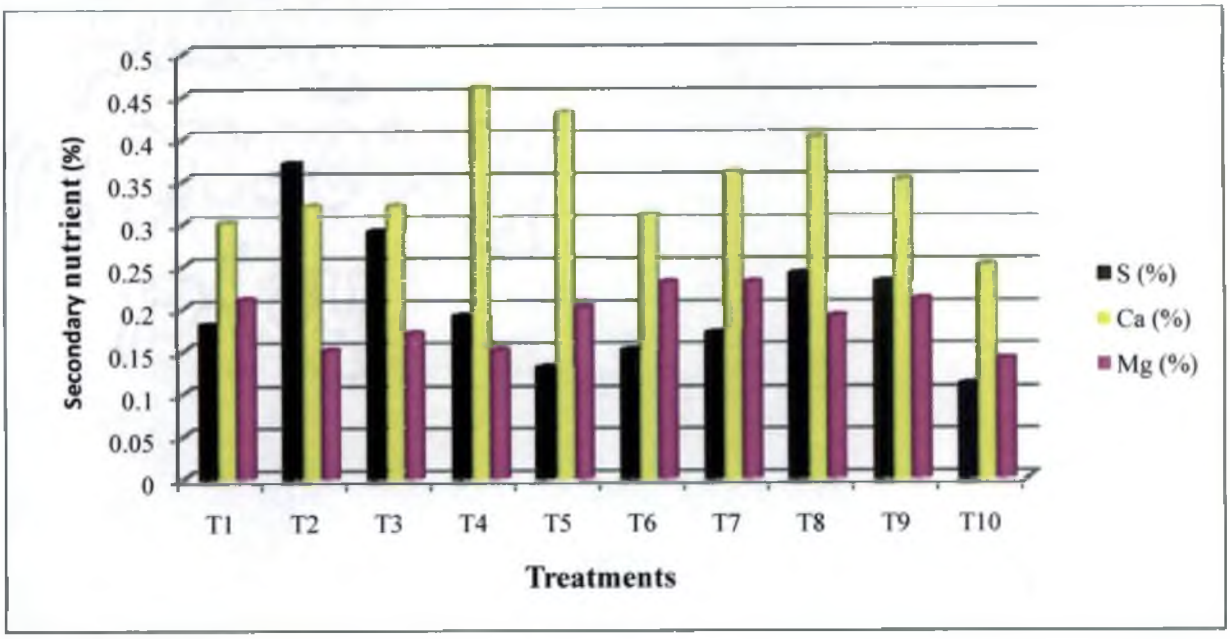

Fig.13. Effect of treatments on secondary nutrient contents of rhizome at harvest

The above discussion brings out some important results and points to certain conclusions which can be summarized as follows:

1. Top dressing of Ca and Mg, the former at a later stage (60 DAP) and the latter earlier (30 DAP) increased rhizome yields of turmeric.
2. Earlier application of S could increase yield and curcumin content of rhizome.
3. Higher yields were associated with higher contents and uptake of N, P, Ca and Mg in shoot and rhizome.
4. Higher curcumin content was related to higher content and uptake of N, P and S in shoot and rhizome.
5. As these effects were not significantly large, further investigation with altered doses and schedules of application of S, Ca and Mg are called for.

Future thrust

Future line of work should focus on the following:

1. Altering and testing the dose and schedule of application of S, Ca and Mg to maximize productivity.
2. Studies on the interaction effects of these secondary nutrients for arriving at the optimum combination.
3. Including micro nutrient application and optimizing their dose and schedule for higher yield and quality.

Summary

6. SUMMARY

A field experiment was conducted during 2013-2014 at the farm of Department of Agronomy, College of Horticulture, Vellanikkara to evaluate the effect of secondary nutrients on yield and quality of turmeric. There were 10 treatments with 3 replications each. Treatments consisted of package of practices (POP) recommendation of 40 tonnes farmyard manure along with 30:60:60 kg N, P, and K/ha and POP recommendations along with 25 kg/ha of S, Ca, Mg alone and in combinations applied one month and two months after planting as first and second top dressing. Rhizome bits were planted at a spacing of 25 × 25 cm in the first week of June, 2013. Harvesting was done seven months after planting.

Plant height, number of leaves per clump and number of tillers per clump were not affected by secondary nutrient management as compared to package of practice recommendations. It was lower only in the treatment where fertilizers were not provided. Only the total avoidance of fertilizer application could bring about a significant decline in vegetative growth.

Leaf area index was seen to be significantly greater in the treatments where Ca was top dressed at two months after planting, and was followed by the treatment where Mg was applied at one month after planting.

When Ca was applied as second top dressing, and where Mg was applied as first top dressing, leaf expansion was favourably influenced. The favourable influence of Ca and Mg was reflected in leaf area index.

Higher yields, both fresh and dry, were obtained when Ca was top dressed two months after planting and when Mg was applied as first top dressing.

Treatment where suphur was top dressed at one month after planting along with recommended package of practices resulted in higher curcumin yield.

Treatment where suphur was top dressed at one month after planting along with recommended package of practices resulted in higher curcumin yield.

The treatment where fertilizer was not applied showed significant reduction in curcumin content.

Higher N content in shoot was recorded in the treatment where package of practices recommendations were adopted both at 3 MAP and 6 MAP. At 6 MAP, all other nutrient management treatments were on par with treatment with regard to P, at 6 MAP, Ca application at 1 MAP and 2 MAP resulted in highest K and P contents respectively. At 6 MAP, higher content of S, Ca and Mg in shoot were recorded in the treatments where these nutrients were applied. Similar results were obtained in the rhizome at harvest. However, higher N and P contents were seen in rhizome when POP recommendations were adopted, whereas highest K content was recorded when Ca was top dressed 2 MAP, In all cases contents were lowest in absolute control.

Uptake of nutrients at three months' stage revealed that the treatment receiving Ca at two months after planting showed highest uptake of all nutrients except K and Mg. N uptake was also high in treatments receiving POP recommendation and Mg one month after planting. Potassium uptake was higher in treatments receiving S at two months after planting and Ca one month after planting. Mg uptake was more where Mg was top dressed at one month after planting.

At six months after planting treatments receiving Ca at two months after planting and Mg one month after planting showed highest uptake of all nutrients except S. N uptake was also high in treatment receiving POP recommendation. Sulphur uptake was high in treatment receiving S at one month after planting.

At harvest, highest values of N, P, K, Ca and Mg uptake by rhizome were obtained in the treatment where Ca was given as second top dressing. S uptake was more when S was applied as first top dressing.

Chlorophyll content in leaves at three months' and six months' stage was found to be on par in all treatments except for the treatment where no fertilizer was applied.

Nutritional management did not affect soil pH significantly. However, in absolute control, pH increased after the experiment

Organic C contents in soil increased after crop cultivation but the values were all on par except in treatments where S, Ca and Mg were applied in combination.

N content in soil decreased after cropping, and the decrease was lowest where Ca was applied 2 MAP. P content increased after cropping and the increase was highest in the treatment receiving package of practice recommendations. In the case of K, the highest soil content after the crop was where Ca was top dressed 2 MAP, and Mg was top dressed 1 MAP. K contents in soil also decreased due to turmeric cultivation.

S content of soil was higher before turmeric was grown. After the crop, S content was highest where 25 kg/ha S was applied 1 MAP. Application of Ca 2 MAP resulted in increase soil Ca content. Mg application 1 MAP increased Mg content to 12.09 mg/kg as compared to 9.33 mg/kg before turmeric cultivation.

Lowest values for soil contents of N, P, K, S, Ca and Mg were recorded in absolute control.

B: C ratio was maximum where Ca was applied at 2 MAP followed by Mg 1 MAP and least in absolute control, this followed the trend of yield.

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Appendix

APPENDIX-1

Monthly weather data during the crop period at COH, Vellanikkara from June 2013 to January 2014 (Latitude $10^0$31'N, Longitude $76^0$13'E and Altitude 40.29MSL)

Month	Temperature (^{0}C)		Relative Humidity (%)		Rainfall (mm)	Rainy days	Mean evaporation (mm)	Sunshine hours (hr/day)	Mean wind speed (Km/hr)
	Maximum	Minimum	Morning	Evening					
June	28.5	22.7	97	83	1031.8	28	2.3	29.4	1.6
July	28.4	22.7	97	84	932.3	30	2.6	23.8	1.9
August	29.9	22.9	96	72	305.9	16	2.7	134.3	2.1
September	30.0	22.2	95	75	344.1	17	2.4	110.3	1.7
October	30.8	22.6	96	70	369.8	16	2.6	163.2	1.7
November	32.6	23.9	87	60	82.0	5	3.1	187.2	3.0
December	31.9	22.3	77	45	0.5	0	4.2	254.7	5.5
January	32.9	23.0	66	36	0.0	0	5.5	277.6	6.9

APPENDIX-2

Details on cost of inputs

Sl. No.	Particulars	Amount (Rs/kg)
1	Seed	70/-
2	FYM	1/-
3	Urea	8/-
4	Rajphos	9/-
5	MOP	18/-
6	Ammonium sulphate	17/-
7	Calcium oxide	10/-
8	Magnesium oxide	30/-

EFFECT OF SECONDARY NUTRIENTS ON YIELD AND QUALITY OF TURMERIC (*Curcuma longa* L.)

By

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(2012-11-153)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Agriculture

(AGRONOMY)

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2014

ABSTRACT

Primary nutrients viz. nitrogen, phosphorus and potassium are generally regarded to be instrumental in maintaining growth, yield and quality of crops. The secondary nutrients, sulphur, calcium and magnesium, though reported to play key roles in the growth and development of crops, seldom get the recognition they deserve. There are no recommendations for these nutrients for most crops. At the same time, there are reports of increasing deficiency of sulphur, calcium and magnesium in the laterite soils of Kerala.

Turmeric (*Curcuma longa* L.) is a vital spice crop of the Zingiberaceae family. The rhizome, which is the economic produce, contains an essential oil, curcumin and related compounds as major constituents. There is immense scope for cultivation of turmeric in Kerala due to favourable climatic and soil condition. Turmeric is a crop requiring heavy fertilization for increasing yield and quality. This research programme was taken up to study the effect of secondary nutrients on the yield and quality of turmeric.

The field experiment was conducted during 2013-2014 in the farm of the Department of Agronomy, College of Horticulture, Vellanikkara. There were 10 treatments with 3 replications each. Treatments consisted of package of practices recommendations (POPR) of 40 tonnes farmyard manure along with 30:30:60 kg N, P and K/ha and its combinations with S, Ca and Mg applied one and two months after planting. Rhizomes were planted at a spacing of 25 × 25 cm and planting was done on 05 June 2013. Harvesting was done after seven months.

Biometric observations were taken at monthly intervals and nutrient contents were analyzed at three and six months after planting and at harvest. Nutrient uptake was also worked out. Curcumin and oleoresin content in rhizomes were also

analyzed. The soil pH and chemical parameters were determined before and after the experiment.

There were significant differences among the treatments with respect to leaf area index, yield, nutrient content and nutrient uptake. In the case of leaf area index, the treatment receiving Ca as second top dressing (viz. two months after planting) recorded the highest LAI compared to other treatments. Fresh and dry yields of turmeric and benefit: cost ratio was also high in the same treatment. This treatment resulted in the highest uptake of all nutrients except S at harvest. Earlier application of sulphur, calcium and magnesium (*viz.* one month after planting) also led to higher yield and benefit: cost ratio, confirming the direct positive effect on yield. Absolute control recorded the lowest values for all parameters including yield and quality components.

Future research should be focused on altering and testing the dose and schedule of application of S, Ca and Mg, and analysis of their interaction effect to maximize productivity, Application of micronutrients and optimizing their dose and schedule for higher yield and quality should also be attempted.

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