RESPONSE OF PUMPKIN (*Cucurbita moschata* POIR.) TO FOLIAR APPLICATION OF MICRONUTRIENTS

By

VINESH KUMAR K. V.

THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2007

DECLARATION

I, hereby declare that this thesis entitled **"Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara

Vineh Kumar K.V.

CERTIFICATE

Certified that this thesis entitled **"Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients"** is a bonafide record of research work done independently by **Mr. Vineh Kumar K.V.** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara

Dr. S. Nirmala Devi
(Major Advisor, Advisory Committee)
Associate Professor
Department of Olericulture
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Vinesh Kumar K.V.** a candidate for the degree of **Master of Science in Horticulture** with major in **Olericulture**, agree that this thesis entitled **"Response of pumpkin (*Cucurbita moshata* Poir.) to foliar application of micronutrients"** may be submitted by **Mr. Vinesh Kumar K.V.** in partial fulfilment of the requirement for the degree.

Dr. S. Nirmala Devi
Associate Professor
Department of Olericulture
College of Horticulture
Vellanikkara
Chairperson, Advisory Committee

21/12/07
Dr.T.E. George
Professor and Head
Department of Olericulture
College of Horticulture
Vellanikkara.
(Member, Advisory Committee)

Dr. Baby Lissy Markose
Professor
Department of Olericulture
College of Horticulture
Vellanikkara.
(Member, Advisory Committee)

21.12.07
Dr. P. Sureshkumar
Associate Professor &
Radiological Safety Officer, RTL,
College of Horticulture
Vellanikkara
(Member, Advisory Committee)

N.C.N. 21/12/07

EXTERNAL EXAMINER
(N. C. NARASE GOWDA)

ACKNOWLEDGEMENT

I humbly bow my head before the Lord Almighty whose grace had endowed me the inner strength and confidence, blessed me with a helping hand to complete this venture successfully.

It is great respect and devotion. I place on record my deep sense of gratitude and indebtedness to my major advisor ***Dr. S.Nirmala Devi,*** *Assistant Professor(SS), Department of Olericulture and Chairperson of my advisory committee, for her sustained and valuable guidance, constructive suggestions, unfailing patience, motherly affection, constant support and encouragement during the conduct of this research work and preparation of the thesis. I gratefully remember her knowledge and wisdom which nurtured this research project in right direction without which this would have been a futile excercise. I really consider it my fortune in having her guidance for the thesis work.*

It is my pleasant privilege to oblige ***Dr. T. E. George,*** *Associate Professor and Head, Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee, for his ardent interest, valuable suggestions, critical scrutiny of the manuscript and ever willing help which has helped a lot for the refinement of this work.*

No words can truly represent my profound gratitude and indebtedness to ***Dr. Baby Lissy Markose,*** *Associate Professor Department of Olericulture, College of Horticulture, Vellanikkara and member of my advisory committee for her expert counsel, invaluable guidance, untiring interest, patient hearing, constructive suggestions, esteemed advice and immense help rendered through out the course of this investigation.*

I place a deep sense of obligation to ***Dr. P.Sureshkumar,*** *Assistant Professor (SS) and Radiological Safety Officer, RTL, College of Horticulture and member of my Advisory Committee for the help and co-operation received from him during the entire programme. He in spite of a busy schedule has offered constructive suggestions for the betterment of this manuscript.*

I consider it as my privilege to express my deep-felt gratitude to Dr.T.R. Gopalakrishnan, CEO, VFPCK (Former Associate Professor and Head, Department of Olericulture) for his sustained interest and constructive criticisms throughout the course of my work.

I express my deep sense of gratitude to **Dr. P.G. Sadan Kumar, Dr.K.P. Prasanna, Dr. P. Indira, Dr. K.V. Suresh Babu, Dr. Salikutty Joseph and Dr. K. Krishna Kumari** of department of Olericulture for their friendly help and whole hearted support.

I convey my heart felt thanks to **Sri S. Krishnan**, Assistant Professor, Department of Agricultural Statistics and Mr. C.G.Joshy for their keen interest, valuable suggestions, and immense help rendered in the statistical analysis of data.

I am extremely grateful to Mr. K. Sajnanath, Ph.D.Scholar, Department of Soil Science who rendered immense help, timely advice and full hearted support during the course of work during soil and plant analysis.

I am greatly thankful to Dr. V. Indira, Assoc. Professor and Head, Department of Home Science, College of Horticulture for her timely assistance for chemical analysis during the course of study.

I wish to express my sincere gratitude to my dearest friends Naveen, and Sreekanth, for their wholehearted help and supports.

Words cannot really express the true friendship that I relished from **Johnkutty, Jaisal, Anoop, Dr.P. Sanal Kumar, Dr. Anup Balakrishnan, Biju Daniel, Mini Sankar, Sindhu P.V, Sujitha K** and Sindy (RA, RTL) who rendered immense help timely advice and full hearted support during the course of work.

A special note of thanks is due to my dearest friends, especially Shareesh, Liffey Fayaz, Praveen, Kishore, Rathish, Remya, Hazmin, Nisha, Riya, Hima., and Shinoj for their timely and thoughtful help during the course of study.

I wish to express my sincere gratitude to my seniors Margarett, Smitha Sara and Smitha for all the help and support.

A special note of thanks is due to my juniors Jaseena and Kimi for their support during the course of study.

I am extremely grateful to Mr. Joy, Farm Asst., Department of Olericulture for his valuable help in taking photographs.

I am highly indebted to the labourers of Olericulture and Home science Departments who took a genuine interest in my case and offered me all the required assistance.

The award of KAU Junior Fellowship is thankfully acknowledged.

Above all, I am forever behold to my Parents, sisters, brother in law and all relatives to their love affection, personal sacrifices, incessant inspiration and constant prayers which helped me to complete this venture successfully.

A word of apology to those I have not mentioned in person and a note of thanks to one and all who helped in the successful completion of this endeavour.

Vinesh Kumar K.V.

Dedicated to those who inspired me

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Introduction

I. INTRODUCTION

Vegetables are rich source of carbohydrates, proteins, minerals and vitamins, which constitute an important component in human nutrition. The vegetables occupying an important place in crop diversification play a key role in food nutritional and economic security of our country. About 175 different types of vegetables are grown in India, including 82 leafy vegetables and 41 root crops. Vegetable production in India is unevenly distributed across the country, with 57 per cent of the total vegetable area being cultivated in Uttar Pradesh, Tamil Nadu, Orissa and Bihar. At the national level, the share of vegetables in gross cropped area is more than 7 per cent in 11 states and Union Territories. The vegetable production in India is around 1 billion tonnes (Kalloo, 2006). The per capita consumption is only 148g, which is just half of the recommended per capita consumption rate. The productivity of vegetables in Kerala is only 22.2 tonnes per hectare (Survey of Indian agriculture, 2005). Major share of the state is met by import from neighboring states, Tamil Nadu and Karnataka

Cucurbits form an important group of vegetables cultivated extensively in Kerala. Of the four cultivated species of genus Cucurbita, pumpkin (*Cucurbita moschata* Poir.) is the most widespread in tropics. It belongs to the family cucurbitaceae and believed to be originated in the region of Central and South America. The pumpkin fruits with its high carotene content and seeds with high protein and oil content have good nutritive value. The fruits also serve as an industrial raw material for carotene production. Pumpkin also has a longer shelf life as compared to most of the vegetables. The fruits also have an importance in processing industry due to the scope for diversified product preparation.

All around the globe several elements are reported to be below critical levels in the soil. After moisture stress, nutrient deficiency is one of the major limiting factors in crop productivity. The micronutrient deficiencies in soil and crops have increased in recent years due to the factors like intensive cropping, loss of top soil by erosion, leaching, decreased use of farmyard manure, increased use of chemical fertilizers and liming of acid soils. Increase in quality and yield of vegetables by the application of micronutrients have been reported in many parts of the world. Many soil and plant factors have profound influence on plant ability to absorb and utilize micronutrients from the soil. The use of plant protecting foliar nutrients can partly replace pesticides and minimize the residues of such materials in food and the environment. In recent years tremendous emphasis has been given for food and nutritional security as micronutrients malnutrition is seriously damaging the health of over 40 per cent of the worlds' population (De and Rai, 2005).

An advance in yield and quality could be achieved with IPNM module using inorganic fertilizer, organic inputs, biofertilizers, micronutrients and advanced agro-techniques starting from high-tech seedling raising. For instance, foliar spraying of Zn, Mo, B at 50ppm at active growth, flowering and peak harvesting increases yield from 12 to 39 per cent (Rai, 2006).

The micronutrients though required in small quantities are as important as macronutrients. Micronutrients play a catalystic role in nutrient absorption and balancing other nutrients. These are essential for protein synthesis, seed and cell wall formation, germination of pollen grains and growth of pollen tube, sugar translocation, enzymatic regulations, biomass production, photosynthesis etc.

The beneficial response of crops to this foliar nutrition is attributed to better growth, yield, improvement in quality and nutrition, reduction in disease incidence and increased crop production. Hence the present investigation was conducted in the Department of Olericulture, College of Horticulture, Vellanikkara during 2006-2007 to study the "Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients" with the following objectives.

- To study the effect of micronutrients on the growth, yield and quality of pumpkin.

- To study the available content of organic C, P, K, S, Fe, Cu, Mn and Zn in soil.

- To study the contents of N, P, K, S, Fe, Cu, Mn and Zn in plant.

Review of literature

II. REVIEW OF LITERATURE

Pumpkin is an important cucurbitaceous vegetable grown in Kerala. To increase the production and productivity of the crop, adoption of recommended package of practice is a need of the day. It also influences the produce quality and keeping quality of the vegetables. Macro and micronutrients play a vital role in the physiology of plants. Foliar fertilizer application is a feasible alternative for increasing yield and quality, particularly in soils with specific nutrient deficiencies. The use of plant protecting foliar nutrients can partly replace pesticides and minimize the residues of such materials in food and the environment. Application of zinc, boron, copper and iron has been studied for the yield improvement of several vegetable crops. Information on the influence of micronutrients on the growth, yield and quality characters of cucurbitaceous vegetables, particularly in pumpkin is meager. Therefore, the present investigation was aimed at studying the response of pumpkin to foliar application of micronutrients, under field conditions. The available literatures on the topic are reviewed below.

2.1 Effect of foliar nutrition by primary nutrients in crops.

In a field experiment on greengram (Co 4), using diammonium phosphate and urea as either basal application or as foliar treatments or combined, the highest N and P uptake at harvest was obtained when N and P applied as DAP + urea as foliar sprays. Garin yield was also highest with this application (Rajendran, 1991).

Srinivasan and Ramasamy (1992) found that in *Vigna unguiculata* all fertilizer treatments to soil along with foliar spray with urea or DAP at 20 or 20 and 30 days after sowing, increased seed yield compared with control plants. Spraying 2 per cent DAP produced a similar yield to soil application of N and P and higher yields than other fertilizer sprays.

It has been found that the use of certain foliar feeds at 30 per cent of the plant requirement, could afford control of certain pests and diseases. The use of plant protecting foliar nutrients (PPFN) could partly replace pesticides and minimized the residues of such materials in food and the environment (Nowosielski and Bartkowski, 1993).

In field trials on potatoes cv. Darga and Marta, the tuber microelements content was increased by foliar application of urea 6 per cent and multinutrient fertilizer Agrosol –K (Boliglowa, 1996).

In late sown chickpea, foliar application of 2 per cent urea solution at flowering increased the grain yield by 22.9 per cent over control. A significant increase in number of pods / plant was recorded with foliar sprays of 2 per cent urea and KCl while 1000 seed weight was increased by 2.5 per cent with urea solution (Nandan *et al.*, 1998).

Utilization of Ekolist (PPFW) in foliar nutrition of field vegetables at 1.5 or 3 per cent sprays four times during intensive growth periods was found to increase the yields in cucumber, onion and cabbage (Osinska and Koota, 1998). It also reduced the incidence of downy mildew on cucumber.

Lateef *et al.* (1998) reported that foliar sprays of urea combined with Fe or Zn enhanced mung bean growth, increased seed yield and improved the quality of seeds.

Three foliar sprays of 8 per cent urea solution applied during early vegetative growth when the canopy covered the interrow spaces increased tuber yield by 12.79 per cent and starch content by 2.4 per cent in potato as compared to traditional urea fertilizer application (Witek, 1999). The proportion of large tubers was also increased by foliar fertilizer application.

Govindan and Thirumurugan (2000) conducted a study to find the effect of the foliar application of K fertilizer on the yield and yield components of green gram cv. VBN 1. In this study among different treatments 1 per cent KCl + 1 per cent KNO_3 recorded the highest values for plant height at harvest, leaf area index at 60 days after sowing, dry matter production at harvest, number of pods per plant, pod length, number of grains per pod, 1000 grain weight, grain yield and benefit cost ratio.

In a greenhouse experiment on yield and quality of tomato, results indicated that foliar nutrient application was only beneficial when nutrient supply in the growing medium was limited. The maximum fruit yield was obtained from plots given pre plant MIS – 4 (compound fertilizer) at 50 per cent of the recommended rate combined with foliar sprays of Ekolist S. This enhanced the marketable yield of fruits by 9.8 per cent and early yield by 11.3 per cent as compared to pre planting and top dressing soil application (Kolota and Osinska, 2000). Foliar nutrient application did not change dry matter and vitamin C contents but increased total and reducing sugar accumulation in tomato fruits.

Ramesh and Thirumurugan (2001) found that seed pelleting with 250 gm ammonium molybdate + 500 gm ferrous sulfate/ kg of seeds and foliar spraying of 2 per cent DAP + 1 per cent potassium chloride + 25 ppm benzyladenine as individual treatments were effective in enhancing plant height, leaf area index, dry matter production and growth rate.

In a foliar nutrition study using a multicomponent fertilizer Ekolist U containing different essential nutrients and having some fungicidal activity, there was an increase in marketable yield by 20.3 per cent in cabbage, 10.8 per cent in onion and 7.3 per cent in cucumber. The foliar fertilization significantly decreased the level of cucumber leaf infestation by downy mildew (Kolota and Osinska, 2001).

Rydz (2001) found that foliar nutrition and fertilizer rates with urea did not have any distinct effect on soluble sugar content in broccoli. There were no distinct difference in ascorbic acid and dry matter contents in all treatments.

Attia and El- Dsousky (2001) found that there was an increase in straw and seed yield increase in faba bean by two sprays with urea compared to control and FYM application. The total N and K content was also increased with spraying N twice or once at the pod filling stage compared with spraying N once at the pre flowering stage.

A field study conducted on sandy soils in Egypt showed that soil application of phosphorus with or without biofertilizer along with foliar fertilization (Stimphol) significantly increased the yield, yield components and quality of faba bean (Yakout and Greish, 2001). Results also indicated that incorporating biofertilizers with soil application of fertilizer improved utilization efficiency thereby resulted in saving of significant amount of P fertilizer use. This effect was more pronounced by including foliar nutrition.

Saglam *et al.* (2002) conducted an experiment to study the effects of different plant growth regulators and foliar fertilizers on yield and quality of crisp lettuce, spinach and pole bean. They found that plant growth regulators and foliar fertilizers had a significant effect on head weight, leaf number, head length and head width of crisp lettuce, yield, leaf length and leaf width of spinach and yield, fruit size and fruit length of pole bean. The applications on pole bean had no influence on fruit diameter and fruit thickness.

Kim *et al.* (2002) found that in *Brassica rapa,* total glucosinolate (GSL) content is strongly affected by N and S application.

Kumar *et al.* (2002) conducted a field experiment to study the effect of plant growth regulators in combination with fertilizer solutions on the growth and yield of Indian mustard cv. Varun. Among seven treatments including a control (water) and combinations of KCl (2%), diammonium phosphate (DAP, 1%) and urea (1%) with commercially available growth regulators, application of DAP + triacontanol resulted in significantly highest seed yield due to high number of seeds per siliqua and test weight. This was followed by application of urea + triacontanol.

Osinska and Koota (2002) found increase in marketable yield, mean head weight, dry matter content and reducing sugars in iceberg lettuce by foliar application of policompound fertilizers.

By application of several organic compounds at lower concentration (0.27 – 1.08 g / litre) to primary leaves of cow pea (*Vigna sinensis* L.) there was an increase in total plant elongation and growth, leaf and root dry matter allocation compared to control and treatments with higher concentration (Neri *et al.*, 2002).

A controlled environment greenhouse study demonstrated that foliar application of K could increase cantaloupe fruit quality, increasing simple carbohydrate content, total sugar, ascorbic acid and beta carotene (Lester, 2004).

Supplementing soil K with foliar applications during muskmelon fruit development and maturation, improved fresh fruit quality by significantly increasing firmness (26 %), sugar content (20 %), ascorbic acid (18 %), β – carotene (17 %) and K (14 %) compared to non treated fruit (Lester *et al.*, 2006). Differences between the two K sources (an organic and an inorganic form) were minimal and use of a surfactant tended to have a positive effect on the response to supplemental foliar K applications.

2.2 Effect of micronutrients on growth of vegetable crops.

Prakash and Bhardwaj (1965) reported that in cabbage, maturity of ball was hastened by about 10 days with improvement in productivity and cover leaf by foliar application of molybdenum. The foliar application of cobalt hastened the maturity of ball

Mohapatra and Kibe (1971) reported that soil application of $ZnSo_4$ at 22.40 kg/ha increased the plant height of tomato.

The chlorophyll content was found to reduce markedly at deficient zinc levels in the leaves of French bean (Edward and Muhammed, 1973).

In cauliflower, application of 20 and 50 kg $ZnSo_4$/ha resulted in good growth, big size and whitish green leaves (Pandey *et al.*, 1974).

Randhawa and Bhail (1976) observed that increased application of nitrogen gave positive response in increasing the number of leaves, height of plants, yield, protein and ascorbic acid content in cauliflower. The application of borax at 15 kg/ha increased the yield.

Suryanarayana and Reddy (1979) reported that in French bean, spraying 2,4-D at 0.1 ppm in combination with micronutrients resulted in the highest number of leaves and inflorescence per plant, maximum pod length and yield of pods per plant.

Singh and Maurya (1979) reported the plant height enhancement due to application of zinc in case of okra.

Arora *et al.* (1983) reported that micronutrients like boron, copper, molybdenum and zinc if applied through foliage could improve the vegetative growth, fruit set and yield of tomato.

Mallick and Muthukrishnan (1980) reported that due to foliar application of zinc, plant height was enhanced in tomato.

In french bean Barcel *et al.* (1986) observed the high correlation coefficient for chlorophyll a, chlorophyll b and carotenoid pigment contents with Fe or Zn contents.

Foliar application of 500ppm of zinc sulphate recorded the maximum plant height (97.71cm), stem girth (2.61cm) and number of branches per plant (10.78) in brinjal (Reddy and Reddy, 1986).

Hazra *et al.* (1987) found that in okra foliar application of zinc at 0.2% resulted in highest plant height (114.96 cm) and number of primary branches (423).

Jana and Kabir (1987) reported that maximum growth of French bean cv.Contender was obtained when the plants were sprayed with B + Cu + Mo + Fe + Zn + Mn + Mg at 0.1 per cent concentration.

Hussain *et al.* (1988) noticed increase in Zn concentration from 0.001 to 0.1 ppm in nutrient solution, increased the internodal length, leaf area and leaf chlorophyll content in French bean.

In chilli, spraying of 0.2 per cent $ZnSO_4$ at full bloom stage increased plant height, plant spread, number of branches, stem diameter and leaf area (Dod *et al.*, 1989).

Singh *et al.* (1989) noticed highest plant height (40.47 cm) and number of effective branches per plant (7.52) at 20 kg $ZnSO_4$ /ha + 0.5% as a foliar spray before flowering in chilli.

Levchenko *et al.* (1989) reported that spraying of magnesium-zinc dihydrophosphate at 0.02% improved the root development in tomato.

Maximum plant height (88.69, 89.18 cm) and number of branches per plant (14.65, 13.29) were noticed in tomato by the application of 10 kg $ZnSO_4$ / ha (Singh and Verma, 1991).

Highest cauliflower leaf size index (736.70 cm^2) and curd size index (166.77 cm^2) were recorded by zinc application at 4.2 kg/ha and highest leaf curd ratio of 1.25 was recorded at 2.1 kg Zn/ha (Balayan and Singh, 1994).

Bose and Tripathy (1996) reported that combined foliar application of zinc, manganese, iron and boron increased the number of branches in tomato.

Kumar *et al.* (1996) reported that number of leaves per plant, leaf and root size parameters, top and root weights per plant, total plant weight / ha and root quality (in terms of sugar and vitamin C content, acidity and organoleptic rating) were greatest with 0.1 % foliar nutrition of borax on radish.

Saha *et al.* (1999) reported that boron in the form of borax per cent 5 kg/ha increased its concentration and uptake and significantly improved the growth and yield of yellow sarson. Foliar application of sodium molybdate resulted in maximum concentration of Mo in plants.

Choudhary and Mukherjee (1999) found highest cauliflower plant height (38.60 cm) and number of leaves (26.48) by foliar application of 6 ppm of zinc at 30 days after transplanting.

Sharma (1999) reported that boron and calcium carbonate application had exhibited pronounced effect in improving the vegetative growth of bell pepper. There was significant increase in the growth parameters like plant height and number of branches per plant.

Soil application of 10 ppm of zinc in tomato showed the highest no. of secondary branches per plant, leaf area and total chlorophyll content (Yadav *et al.*, 2001).

Hatwar *et al.* (2003) found that all the treatments with micronutrients Zn, B and Fe exerted significantly positive influence on the plant height. The combined spraying of Zn, B and Fe @ 0.1 % gave maximum height of the plant, number of branches, diameter of stem and spread of plant in chilli.

Singh *et al.* (2003) reported that foliar application of borax, $CuSO_4$ and $ZnSO_4$ significantly enhanced plant height in tomato var. Hisar Arun.

Highest plant height of 69.3 cm in tomato, 69.5 cm in okra, 48.7 cm in pea by basal application of 40 kg $ZnSO_4$ ha^{-1} was reported by Raghav and Sharma (2003).

In cucumber, highest vine length (167.80 cm) and leaf area (105.22 cm^2) were noticed by soil application of 25 kg $ZnSO_4$ ha^{-1} + $ZnSO_4$ at 0.50 per cent foliar application (Sudhan and Shakila, 2003).

Sarma *et al.* (2003) observed highest root length (20.67 cm) of cabbage at 0.5 per cent zinc sulphate spray at 40 days after transplanting.

Patil (2004) found that foliar spraying of multiplex gave the maximum number of leaves per plant, number of fruits per plant and fruit yield in okra.

Bhatt *et al.* (2004) studied that application of mixture of micronutrients such as B, Zn, Cu, Fe, Mn at 100 ppm and Mo at 50 ppm in tomato recorded highest number of primary branches per plant (9.11), no. of leaves per plant (132.16), leaf area (82.83 cm^2) and fresh weight of plant (785 gm).

In potato, highest plant height (45.6 cm), no. of haulms/plant (4.3) and No. of leaves per plant (35.8) were recorded by application of 8 kg Zinc/ha (Raghav and Singh, 2004)

Kumar and Sen (2005) in okra reported highest plant height (148.77 cm) and number of branches per plant (2.70) at 45 kg $ZnSO_4$/ha and recorded highest number of nodes on main axis (18.35) at 30 kg $ZnSO_4$ /ha.

Srivastava *et al.* (2005) reported highest plant height of 47.93 cm by application of 0.6% $ZnSO_4$ and highest number of leaves/ plant (7.33) and leaf length (39.93 cm) in onion at 90 DAT.

2.3 Effect of micronutrients on yield and quality of vegetables crops

Govindan (1950) and Verma *et al.* (1973) observed increase in ascorbic acid and total soluble solids in tomato fruits raised in calcareous soils receiving boron application.

Chowdary (1960) mentioned that application of mixture of 75 kg NPK in ratio of 18:2:3 plus 5 kg boron, zinc, molybdenum produced maximum amount of allyl propyl disulphide in garlic.

Application of Zn at 20 ppm in brinjal at the end of flowering improved the fruit weight (Nagarajan and Sundaram 1961).

Application of 10kg of $CuSO_4$, $ZnSO_4$ and $MgSO_4$ to soil gave higher yield in chilli variety Sathur Sambha rather than foliar application (Pillai and Vadivelu, 1966).

Red beet seeds soaked in 0.003-0.05 per cent solution of Cu, Zn, Mn, $AlSO_4$ (or) ammonium molybdate, boric acid (or) potassium iodide increased emergence and yield by 8-16 per cent (Smagina, 1970).

Foliar spray at 2.24 kg $ZnSO_4$ /ha resulted in maximum fruit production and enhanced P and K absorption by tomato plant. Soil treatment at 22.40 kg $ZnSO_4$/ ha was as effective as the foliar sprays in increasing yield and Zn uptake (Mohapatra and Kibe, 1971).

Pandey *et al.* (1974) in cauliflower reported that application of 20 and 50 kg $ZnSO_4$/ha resulted in white coloured compact curd and $ZnSO_4$ at 20 kg resulted in less (16.6 per cent) of abnormal heads and highest fresh curd yield (503.4 q/ha). $ZnSO_4$ at 50 kg resulted in highest fresh weight of curd / plant (1.140 kg) and fresh weight of leaves / head (0.797 kg).

Maurya and Lal (1975) reported that application of Zinc at 1, 2 and 3 ppm increased the yield of onion bulbs.

El-Beheidi *et al.* (1978) reported that spraying of cucumber plants with 0.01 per cent borax and zinc sulphate stimulated growth, advanced flowering, enhanced production of male and female flowers and improved seed yield and quality. Seed yield and seed content of carbohydrates, N and protein were highest with Zn treatment.

Under zinc deficiency in cowpea genotypes reduction in yield was noticed by Ghildiyall *et al.* (1978).

In tomato cv. Roma, micro element (Mn, Zn and Fe) sprays along with foliar fertilizer containing NPK tended to lower the K, acid and Sucrose content of juice (Silva and Fontana 1979).

In cabbage cv. Pride of India, application of Zn at 10 kg/ha or 2 foliar application of 0.25 per cent $ZnSO_4$ solution enhanced the yield similarly and this marked an increase in carbonic anhydrase activity, especially with foliar application of Zn (Iyengar *et al.*, 1979)

Application of 2 ppm zinc increased the number of fruits, fresh and dry weight of fruits and yield per plant in okra (Singh and Maurya 1979).

Khadr (1980) observed that in pea, application of Zn EDTA or $ZnSO_4$ @ 5 ppm increased plant dry weight and leaf Zn, Fe, Mn and Mg but decreased leaf Ca. The chelated Zn gave better results.

Reddy *et al.* (1980) in tomato found that application of 75Kg $ZnSO_4$/ha resulted in highest number of fruits per plant (31), fruit length (6.98 cm), fruit breadth (5.83 cm), average fruit weight (63 g) and fruit yield (202.1 q/ha) and ascorbic acid content (15.90 mg/100 g).

Mallick and Muthukrishnan (1980), in tomato noticed that Zn, Cu, Fe and Mn had pronounced effect in increasing the ascorbic acid content from 2 to 7 mg/100 g of the fruits and causing reduction in TSS. Such an effect was marked with Zn treatments at 5-10 ppm of soil application and 3000 and 5000 ppm of foliar sprays.

Hemphill *et al.* (1982) reported that boron and phosphorus did not affect yield but boron application reduced incidence of root canker in table beet.

Singh and Kothari (1982) reported that on non calcic brown soil, guar yield was increased by the application of Mn + Zn + B, Zn + B or Mn alone but Zn, B, Zn + Mn and Mn + B gave no response.

Gupta *et al.* (1983) noticed increase in onion bulb yield by 30 and 67 per cent over the control in plant received Zn at 5 and 10 ppm respectively.

Guzman and Bornemisza (1983) in tomato cv. Tropic reported that Zn application increased Zn absorption but had no effects on dry matter yields.

Zhang and Wu (1983) reported that in tomato absorbed Zn was mainly distributed in roots and conducting tissues of aerial parts. Absorption of Zn by normal plant was promoted by light treatment.

Abed *et al.* (1984) noted that cucumber Cv. Beta-alfa seeds soaked for 24 hours in 500 ppm of Cu and Zn recorded seed germination of 94.5-96.5 per cent and 99 per cent by Mn at 2000 ppm, but yields were highest (1.16-2.22 t/ha) after treatment at 500 ppm with all 3 elements.

In capsicum Cv. Yolowonder plants treated with Irral (containing NPK + Mg, Fe, Zn, Mn B and Cu) at 0.2 per cent spray for 3 times at 21 days intervals starting 30 days after transplanting gave the highest total yields (Alla *et al.*, 1984).

Seeds of *cucurbita pepo* were soaked for 24 hours in 0.05 per cent Zn, Mn and /or B solutions and found best effect on the number of female flowers/plant (180% increase over water treated control) and total yield (69.3%) over control (Almishaal *et al.*, 1984).

Application of B, Cu, Fe, Mn, Mo or Zn at 30 days after transplanting and again15 days later increased the yield of tomato and chilli but Zn at 0.5 per cent having most beneficial effect .The treatments significantly increased the total sugar content in fruit, except Mo, which significantly reduced (Rawat and Mathpal, 1984).

Misra *et al.* (1984) in trials with the cabbage Cv. Pride of India, NAA at 100ppm with 0.2 or 0.3 per cent Zn applied one month after transplanting greatly increased the yield and also ascorbic acid and vitamin C content of heads.

Boyle and Smith (1985) in snap bean reported the application of Zn at 11.2 kg/ha as sulphate or chloride form is more effective in increasing leaf Zn content followed by Zinc oxide while, Zinc chelate did not increase leaf Zn.

Jawaharlal *et al. (1986) noticed in onion that soil application of* $ZnSO_4$ at 50 kg/ha as a basal dose resulted in highest foliage yield (1.18 t/ha), bulb yield (17.16 t/ha), foliage dry matter production (0.840 t/ha) and bulb dry matter production (1.745 t/ha).

Sukhina and Petrosova (1986) observed in cucumber improved vitamin C accumulation and fruit acidity in cucumber by optimal top dressing treatment was 2.9 g B, 0.2 g Zn and 0.2 g Cu / liter of nutrient solution. The top dressing of cucumber with 2.9 g B, 0.2 g Zn and 0.2 g Cu/ liter of nutrient solution helped in advanced bud development, flowering and fruiting.

Highest yield in french bean was reported by foliar spray of micronutrients (Jana and Kabir, 1987). This spraying resulted in increased number and length of pods.

It was observed that application of higher doses of Tracel – 2 and borax gave maximum yield of marketable beetroots as compared to other treatments. Lower doses of molybdenum, zinc and manganese increased the yield of beet as compared to control (Jana, 1987).

Foliar application of zinc at 0.1 per cent in okra resulted in highest fruit length (14.25 cm); fruit weight (16.83 g), fruit yield (125q/ha) compared to 0.2 per cent Zn (Hazra *et al.*, 1987).

Sharma *and* Sharma (1987) noticed in tomato that restoration of Zn as $ZnCl_2$ to deficient plant increased stomatal aperture and transpiration in leaves and carbonic anhydrase activity within 2 hours.

In cauliflower variety Snowball-16, maximum yield of 238 q/ha was recorded with 160 kg N + 50 kg P_2O_5 + 20 kg $ZnSO_4$ /ha (Balayan *et al.*, 1988).

Bhaghel and Sarnaik (1988) noted that combined foliar spray of zinc (0.5%) and boron (0.2%) gave higher yield in onion.

Among trace elements used, only the application of 20 ppm $CuSO_4$ or of 20 ppm $ZnSO_4$ + 10 ppm H_3BO_3 + 5 ppm Mo had significant positive effect on fresh weight yields of garlic bulbs (Gaudi *et al.*, 1988).

Cakmak and Marschener (1988) in tomato Cv. Super Marmande reported the Zn deficiency increased root exudation of K^+, amino acids, sugars and phenolics. Re-supply of Zn to deficient plant for 8, 12 or 27 hours increased Zn concentration in the roots and simultaneously decreased root exudation.

Balayan and Dhankar (1988) found that application of 20 kg $ZnSO_4$/ha recorded highest curd size index (189.1 sq.cm) and marketable yield (201.6 q/ha). However application of 30 kg $ZnSO_4$/ha adversely affected the growth and development of the cauliflower plant.

Application of Zn (0, 5 or 10 mg kg^{-1} soil) without P application had no effect on dry matter yield of french bean plants. However, Zn application in combination with P application resulted in significant in case of dry matter yield was increased (Singh *et al.*, 1988).

Spraying of 0.2 per cent of $ZnSO_4$, $MnSO_4$ and $CuSO_4$ on capsicum cultivar Jwala at full blossom stage reduced the incidence of flower drop, advanced the date of harvesting and improved the fruit yield (Dod *et al.*, (1989).

Significantly higher yield and yield components in chilli were recorded by foliar application of 0.1 per cent zinc or boron or in a combination of zinc, boron and iron each at 0.1 per cent compared to control. Also application of commercial compound Devimicrosakti containing zinc, boron, manganese, iron, copper and sulfur at 5kg per hectare at 0.1 per cent spray was found to yield similar (Hussain *et al.*, 1989).

Highest seed yield of radish (625.8 kg/ha in 1983-84 and 600 kg/ha in 1984-85) was recorded by application of Zn, Cu, B and Mn to soil or as a foliar spray (Mishra and Yadav, 1989).

In onion highest yield (275 q/ha) was noticed in plots received 2 sprays of 1 ppm Cu + 3 ppm of Zn + 0.5 ppm of B + 100 ppm Fe and control yield was 204-211 q/ha (Sindhu and Tiwari, 1989).

Singh and Dhankhar (1989) found in onion that higher bulb yield when zinc sulphate was applied at 25 kg/ha alone or in combination with 100 kg K_2O/ha.

In chilli (*Capsicum frutescens*), application of $ZnSO_4$ at 20 kg/ha + 0.5 per cent as a foliar spray before flowering, showed highest value for number of healthy fruit per plant (44.25%), dry weight of fruits per plant (29.46 gm), number of seeds per fruit (36) and seed yield (61.77 q/ha) (Singh *et al.*, 1989).

Dakshinamoorthy and Krishnamoorthy (1989) reported that there was a significant increase in fruit yield (17.5%) by the application of Zn in brinjal.

Maurya (1990) in coriander reported that per cent of essential oil was maximum (0.726%) in 0.25% spray of $CuSO_4$ treated plot followed by 0.5% $ZnSO_4$ spray (0.710%) while minimum (0.612%) was recorded under tracel-2 (0.5%). But the total yield per hectare of essential oil was maximum (7.56 kg/ha) under $CuSO_4$ followed by 7.27 kg/ha under $ZnSO_4$ and minimum (5.61 kg/ha) under control.

El-sherif *et al.* (1990) found that increase in dry matter content in tomato up to 5.3 per cent for foliar treatment of 0.5 per cent zinc and 94.7 per cent for soil mixed with 10 kg $ZnSO_4$/ha. The total uptake and concentration of K, Ca, Fe and Zn by tomato seedlings were increased with Zn application, whereas Na and Mn were decreased.

Dwivedi and Dwivedi (1991) studied the micronutrient application in potato wherein Fe, Mn, Cu and Zn as sulphate and sodium tetraborate were applied @ 10, 10, 10, 15 and 20 kg/ha respectively and foliar spray of 0.2% solution of each micronutrient sprayed on standing crop at 60 and 90 days after planting and for seed soaking, the tuber were soaked in 0.05% solution of each micronutrient for 3 hours before planting. Micronutrient applied alone or mixture significantly increased the tuber yield of potato over control soil application was superior to other two methods.

Hattab and Ramanathan (1991) reported that application of 100 kg K_2O and $ZnSO_4$ was found to be adequate for obtaining higher yield in tomato.

It was found that both micronutrient treatments and methods of P application had significantly increased the yield in cowpea var. Co.3

(Krishnasamy *et al.*, 1991). The application of $ZnSO_4$ had a greater influence in increasing the uptake of four micronutrients Fe, Cu, Zn and Mn.

Foliar spray of 200 ppm $ZnSO_4$ increased French bean seed yield (Soliman *et al.*, 1991).

Carvajal *et al.* (1992) observed that titanium treatments had no effect on red capsicum fruit mineral composition, except for a general increase in Fe and for N and P increase in cv. Negral. These increases did not result in any nutrient imbalance and a general improvement in nutrient uptake was observed.

Mondy *et al.* (1993) found higher ascorbic acid content of potato tubers with the application of 11.2 kg/ha $ZnSO_4$ treatment. Zinc fertilization resulted in higher Zn concentration in tubers.

Zinc application at 4.2 kg/ha in cauliflower variety Snowball-16, recorded highest curd weight (482.96 g) and marketable yield of 198.57 q/ha (Balayan and Singh, 1994).

Increased ascorbic acid and acidity content of tomato fruits var. Pusa Ruby were recorded under 10 kg zinc application with the advancement of stages where as, TSS, total sugars, reducing and non reducing sugars were significantly reduced (Verma *et al.*, 1995). Highest values of ascorbic acid and acidity were found with the application of 2 kg boron /ha and it was increased with the advancement of stages. TSS, total sugars, reducing and non-reducing sugars were reduced at later stages, which was maximum under 2 kg boron/ ha. The highest marketable fruit yields of 285.88 and 275.51 q/ha were recorded under 10 kg zinc and 2 kg boron/ha respectively.

Naruka and Gujar (1996) in okra found the highest number of fruits per plant (15.03), length of fruits (13.50 cm), diameter of fruits (6.54 cm) and yield (180.79 q/ha) by foliar application of Zn at 0.6% at 3-4 leaf stage.

Meena *et al.* (1998) found that sulphur dose of 20mg/kg on S deficient soils and 10mg S with 5mg Zn kg^{-1} for low S soils was appropriate for better onion yields.

In tomato Balasubramaniam *et al.*(1999) reported that the treatment combination involving 100 per cent soil test based NPK + 50 kg of $ZnsO_4$ + 10 kg of Borax along with 5 t/ha of composted coir pith registered the highest yield of 1487g/plot and yield improvement of 232 per cent over control.

Less number of days taken for curd initiation (67.43), curd maturity (79.79) and highest biological yield per plant (1.202 kg), average weight of curd per plant (0.706 kg) and total marketable yield per ha (243.60 q) in cauliflower were reported by foliar application of 6 ppm of zinc at 30 DAT (Choudhary and Mukherjee 1999).

Yadav *et al.* (2001) reported that tomato yield was increased with application of zinc and boron. Maximum yield was obtained with application of 7.5 ppm zinc and 1 ppm boron. Highest concentration and uptake of zinc and boron in tomato plants was with application of 10 ppm zinc and 1 ppm boron respectively.

Devi *et al.* (2000) found that with soil and foliar application of boron, molybdenum and zinc individually and in combination on cabbage, there was significant effect on nitrogenous fractions, concentrations of total nitrogen, soluble nitrogen and insoluble nitrogen at early stage of plant growth.

Dongre *et al.* (2000) found that application of micronutrients Fe, Zn and B was effective in increasing fruit set and reducing fruit drop in chilli.

Foliar application of 10 ppm of zinc in tomato showed significantly highest fruit length, fruit breadth and number of fruits per plant when compared to control (Yadav *et al.*, 2001).

Tomato plants treated with 0.15 ppm Zn in nutrient solution and higher levels of zinc (3.5 ppm) applied as a foliar spray showed significant decrease in the production of dry matter, chlorophyll and green fruit yield as compared to that treated with 7.70 ppm zinc in nutrient solution (Kaya and Higgs, 2001).

Raj *et al.* (2001) reported that combined application of zinc @ 12.5 kg $ZnSO_4$/ha soil initially along with three sprays of 0.2 per cent $ZnSO_4$ and 0.5 per cent $FeSO_4$ thrice at weekly interval at later stages recorded significantly highest fruit yield with 23.6 per cent increase over control in brinjal. Zn and Fe contents in index leaves were significantly more in the treatments where zinc and iron applied as foliar spray.

Patnaik *et al.* (2001) reported that application of zinc through $ZnSO_4$ either soil or as foliar spray and iron as foliar spray through $FeSO_4$ had resulted in significant increase in the fruit yield of tomato accompanied by increased concentration of respective elements in index leaves.

Hatwar *et al.* (2003) found that combination of Zn + Fe + B at 0.1 per cent each along with recommended dose of NPK induced sufficient flowers, maximum fruit setting and negligible flower and fruit drop in chilli. Thus, micronutrient treated plants retained more flowers and heavy fruit set. Plants supplied with micronutrients enhanced the photosynthetic activity resulting in the production and accumulation of carbohydrates and increased number of fruits per plant.

Moreno *et al.* (2003) reported that promotion of phytoaccumulation of Fe and Mn, and accumulation of Cu, Zn and Cl in fruits of cucumber.

Singh *et al.* (2003) reported that in tomato var. Hisar Arun maximum number of flowers per inflorescence was recorded with the foliar application of borax. The same trend was observed in case of total number of inflorescence per plant. Number of fruits per plant was increased significantly with all the treatments with micronutrients except molybdate.

Highest weight of tomato fruit of 210.3 g, okra fruit of 21.3 g and pea pod of 22.3 g by basal application of 40 kg $ZnSO_4$ ha^{-1} was reported by Raghav and Sharma (2003).

Sudhan and Shakila (2003) in cucumber noticed the highest dry matter production (671.93 g) by soil application of 25 kg $ZnSO_4$ ha^{-1} plus foliar application of 0.50 per cent $ZnSO_4$ ha^{-1}. In cucumber highest number of female flowers produced per vine (16.10), fruit set percentage (90.06%), number of fruits per vine (14.50), single fruit weight (49.02 g), yield per vine (710.79 g) and lowest value for number of days taken for first female flower appearance (32.25) and sex ratio (6.13) were by soil application of 25 kg $ZnSO_4$ ha^{-1} plus foliar application of 0.50% $ZnSO_4$ ha^{-1}.

Paithankar *et al.* (2004) observed in tomato that foliar application of boron significantly increased fruit size. The treatment of 0.3 % borax recorded maximum fruit length and breadth. The treatment recorded maximum ascorbic acid content. The foliar application of boron at higher concentration either alone or in combination with DAP reduced the percentage of cracked fruits.

Pal *et al.* (2004) reported that foliar application of 1000-ppm boron or zinc increased physical attributes where as 2000 ppm boron enhanced the quality traits when sprayed thrice at 10 days intervals commencing from 50 days after transplanting in bell pepper. Foliar application of magnesium sulphate produced maximum fruit length but zinc application (1000 ppm) enhanced the fruit base diameter. The average fruit weight was found maximum when plants sprayed with

1000-ppm boron in which pericarp thickness was also be enhanced. The biochemical attributes like TSS, ascorbic acid, acidity, carotene and total chlorophyll were significantly influenced by micronutrient application.

Raghav and Singh (2004) noticed highest numbers of potato tubers per plant, weight of tubers per plant and tuber yield per ha by application of 8kg zinc/ha.

In onion highest seed yield recorded by application of 1 per cent and 0.5 per cent $ZnSO_4$ (Khalate *et al.*, 2004).

Highest dry matter content of shoot (27.58 %) and fruit (6.27%) was noticed in tomato by application of mixture of all (Bo, Zn, Cu, Fe, Mn at 100 ppm and Mo at 50 ppm), followed by 25.55 per cent and 5.90 per cent by Zn application at 100 ppm. (Bhatt *et al.*, 2004). The application of mixture of micronutrients (Bo, Zn, cu, Fe, Mn at 100 ppm and Mo at 50 ppm) in tomato resulted in highest fruit yield (266.6 q/ha).

Srivastava *et al.* (2005) found highest TSS (18.67%) by foliar application of 1.2 per cent $ZnSO_4$ and highest per cent marketable onion bulbs after 60 days of storage (85.50%) by foliar application of 0.2 per cent $ZnSO_4$ twice at 45 and 60 DAT. Highest bulb yield (798.33 g/plot), bulb weight (34g) and bulb diameter (4.50 cm) reported by foliar application of 0.6% $ZnSo_4$ twice at 45 and 60 DAT.

Bhatt and Srivastava (2005) reported that foliar spray of most of micronutrient treatments significantly increased the uptake of N, P, K, S, Zn, Fe, Cu, Mn and B in fruits and shoots of tomato. The application of mixture of micronutrients was found to be best treatment for improving nutrient uptake and ultimately improving the yield.

Sarma *et al.* (2005 a.) reported that application of 0.5 per cent borax recorded the highest yield and harvest index of cabbage. The highest quantity of protein and ascorbic acid content were found by spraying 0.5 per cent borax and ammonium molybdate respectively. Foliar application of 0.5 per cent manganese sulphate recorded the highest chlorophyll content of head.

Sarma *et al.* (2005 b.) reported that weight loss was greatest with copper sulphate and lowest with zinc sulphate after 12 days of storage in cabbage. In terms of the maintenance of head colour, zinc sulphate was superior among the treatments. On the other hand, rapid change was recorded for copper sulphate and head compactness was greatest with borax.

Available nutrient status (N, P, K, Ca, Mg, S, Fe, Zn, Cu and Mn) in brinjal plants and fruits significantly increased with different nutrient management practices including foliar nutrition of micronutrients (Srijaya and Sitaramayya, 2006).

2.4 Effect of micronutrients by soil and foliar application in other crops.

Savithri *et al.* (1984) reported that foliar sprays in soybean with 1 per cent $MnSO_4$ or 0.5 per cent $ZnSO_4$ significantly increased the grain yield and uptake of Mn in black soil, while in red soil application of 25 kg/ha of $MnSO_4$ or $ZnSO_4$ resulted in marked increase in grain yield. The influence of $FeSO_4$ fertilization was not marked in both the soils.

Duraisamy *et al.* (1990) reported that foliar feeding of micronutrients such as Zn at lower concentrations, B and Mo at higher concentrations was beneficial in increasing the foliage and oil yield in mint. Among the micronutrients tried, Zn spray at 0.25 per cent in the form of $ZnSO_4$ was found to be optimum for maximising yield.

Prasad (1991) reported that the uptake of magnesium by greengram was significantly affected by application of $ZnSO_4$ and $CuSO_4$.

Gill and Pandey (1991) reported that application of $ZnSO_4$ and $FeSO_4$ increased the uptake of N, P and K in greengram.

Both micronutrient treatment and P application had increased the grain yield in greengram var.Co.4 (Krishnasamy and Kothandaraman, 1991).

Sharma *et al.* (1993) reported that different levels of GA and zinc sulphate produced significant effect on fruit yield in guava. The yield response of $ZnSO_4$ (0.06%) was superior to its lower concentrations.

Gowda *et al.* (1994) found that yield of pod and haulm of groundnut increased significantly with increasing levels of soil applied zinc sulphate. The yield response to Zn was further enhanced when combined with molybdenum. The result indicates that groundnut in zinc deficient light textured soils will respond to Zn when applied as $ZnSO_4$ and application of Mo enhance the beneficial effect.

Singh and Singh (1995) reported that the grain yield, Mo content and its uptake increased while Mn content and its uptake decreased consistently with Mo application in pea.

Singh and Ahlawat (1996) found that plant growth in terms of height, spread and shoot length increased and maximum growth was observed where 2.0 per cent of urea and 1 per cent zinc sulphate was sprayed in ber. Leaf area and number of branches were also found maximum in tree receiving 2 per cent urea or 1 per cent zinc sulphate spray.

Devi *et al.* (1996) reported that soil application at 50g/ plant each of zinc sulphate, ferrous sulphate and manganese sulphate combined with three foliar sprays of 0.5 per cent each of the above resulted in higher fruit yield in *Citrus sinensis.* cv. Sathgudi. The micronutrient application increased leaf micronutrient and chlorophyll content and photosynthetic activity followed by recovery from chlorosis in contrast to control trees. The fruit yield was also increased due to micronutrient application.

Chahil *et al.* (1996) reported that copper sulphate application at 0.2 per cent alone and with combinations of increasing doses of zinc sulphate improved copper concentration in leaves of plum. Fruit yield was increased significantly with 0.2 per cent $CuSO_4$ application. The fruit retention was increased with zinc and copper application.

Borax 0.4 per cent spray was the most effective in enhancing fruit set, retaining more number of fruits and minimizing the cracking of fruits in litchi (Brahmachari and Kumar, 1997). Total soluble solids, ascorbic acid, reducing and total sugars of fruits increased, however acidity reduced considerably by this foliar spray.

Singh and Vashishta (1997) reported that by a study on response of foliar application of zinc sulphate, potassium sulphate, borax and urea on yield and quality in ber cv. Seb, two sprays of zinc sulphate (0.5 – 1 per cent), borax (0.5 per cent) and urea 1 per cent at fruit setting stage were found suitable for fruit retention and increased fruit yield and quality in semi arid region.

Yield and quality of Kinnow improved with soil and foliar application of zinc. However, foliar application of 0.75 per cent was found to be more effective in kinnow mandarin (Wali and Sharma, 1997).

Purakayastha and Nad (1997) reported that in wheat, application of only N, P and K resulted in accumulation of NO_3 nitrogen in straw that was appreciably reduced with the application of S, Mg or Mo over NPK. Both S and Mo were more effective when applied alone or in combinations. The reduction in NO_3 nitrogen in straw was followed by an overall increase in uptake of N, P and S by grain and increased protein yield.

In an experiment application of S, Mg and Mo to mustard and wheat grown in an ustochrept soil in pot culture produced more grains and dry matter (Purakayastha and Nad, 1998). Response of mustard to S was relatively higher than that of wheat. The effect of S got enhanced when it was added along with Mg or Mo. Uptake of N, P and K in mustard and that of N only in wheat were substantially higher with the increase in sulphur level.

Tripathy *et al.* (1999) reported that soil application of Zn, B and Mo singly or in combination improved nodulation and nitrogenase activity in groundnut. But the dry matter and leaf area index increased only when these micronutrients were applied in combination of any two or all the three.

Ali and Mishra (2001) reported that in kabuli chickpea foliar spray of 0.2 per cent borax at 50 and 60 days after sowing increased the grain yield significantly in both the years of study to the highest levels of 1796 and 1590 kg/ha. A significant response to foliar spray of 0.1 per cent ammonium molybdate was also observed.

Thiyageswari and Ramanathan (2001) found that application of micronutrients singly and in combination either as soil application or foliar sprays had a significant influence on uptake of nitrogen, phosphorus, potassium and micronutrients by soybean at different growth stages viz. vegetative, flowering and harvest stage. The foliar application of all micronutrients appreciably enhanced nitrogen uptake.

The studies on response of macro and micro nutrients in combination with organic matter on yield of sesame revealed that use of organic matter in combination with chemical fertilizers recorded significantly more grain yield. It recorded the higher gross monetary returns and benefit cost ration over both control and the treatments of chemical fertilizer in combination with micronutrients (Narkhede *et al.*, 2001).

Thalooth *et al.* (2001) reported that spraying the plants with the different micronutrients or their mixture with soil P application increased seed weight. The ratio of weight of pods to whole plant was increased due to foliar spraying with micronutrient elements. Shelling percentage was not affected by neither spraying with different micronutrients nor method of P application. The highest seed yield was obtained by foliar spraying with Fe or Mo when either foliar or soil applied in broad bean

El-Fouly *et al.* (2001) reported that application of micronutrients showed positive effects on growth and nutrient uptake either before or after the salinization treatments in faba bean. It also showed that the foliar application of micronutrients could induce increases in tolerance to salinity.

The use of sulphur and some micronutrients such as Zn, B, Mo, and Fe had improved the productivity of pulse crops considerably (Thiyagarajan *et al.*, 2003).

Mankar *et al.* (2004) reported that application of 1 per cent $ZnSO_4$ significantly increased oil and protein content in seeds of mustard. Viability was not affected due to the application. Germination and dormancy were adversely affected by the spraying of $ZnSO_4$.

In mungbean at maturity significant increase in dry matter accumulation and various growth parameters (LAI, CGR, NAR and SLW) were noticed with the soil application of 25 kg $FeSO_4$ as well as with the foliar application of 0.5 per cent $FeSO_4$ + 0.1 per cent citric acid at both pre flowering and flowering as compared to other iron treatment (Kumawat *et al.*, 2005).

Materials and Methods

III. MATERIALS AND METHODS

The present investigation was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2006-2007 with an objective to study the response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients.

The site is located at 10°31' N and latitude, 76°13' E longitude and at an altitude of 22.25 m above MSL. The area experiences a typical warm humid tropical climate and receives average rainfall of 2663 mm per year. The soil of the experiment site is lateritic in origin coming under the textural class of sandy clay loam and is acidic in reaction.

3.1 Season of Experiment

The crop was raised during the Rabi season from September to January, 2006-07.

3.2 Variety

The high yielding variety Saras, developed by Kerala Agricultural University was selected for study.

3.3 Treatments

The treatments consist of foliar application of six micronutrients along with multiplex, a commercial formulation (Table 1).

Three foliar sprays of micronutrients and multiplex were given at three times starting from 40 days after sowing, at an interval of 10 days.

Table 1. Different treatments and dosage

Treatment	Chemicals	Dosage
T1	FYM & NPK as per POP recommendation (KAU, 2002)	
	Farm Yard Manure	20-25 t/ha
	Nitrogen	70 kg/ha
	Phosphorus	25 kg/ha
	Potassium	25 kg/ha
T2	T1 + Boron (Boric acid)	100 ppm
T3	T1 + Zinc (Zinc sulphate)	100 ppm
T4	T1 + Molybdenum (Ammonium molybdate)	50 ppm
T5	T1 + Copper (Copper sulphate)	100 ppm
T6	T1 + Iron (Ferrous sulphate)	100 ppm
T7	T1 + Manganese (Manganese sulphate)	100 ppm
T8	T1 + Mixture of all	In equal proportion
T9	T1 + Multiplex (Commercial formulation)	100 ppm
T10	NPK alone (Soil application)	70:25:25 kg/ha

3.4 Methods

3.4.1 Layout and experiment design

The experiment was laid out in Randomized Block Design (RBD) with ten treatments in three replications. There were twenty plants per plot in four rows of five plants each. Spacing adopted was 4.5 X 0.5 m. The plot size was 18 X 2.5 m. The layout of the experiment is given in Fig 1.

The manures and fertilizer doses were based on the POP recommendation (KAU, 2002) for pumpkin.

3.4.2 Application of Micronutrients

The micronutrient formulations and multiplex were sprayed on the leaves and branches after thoroughly mixing with water.

3.5 Field experiment

3.5.1 Land Préparation and sowing

In the experimental field, weeds were removed by sickle weeding and weedicide was sprayed. After weeding, the plot was laid out. After the land preparation, seeds were sown in trenches at a spacing of 50 cm.

3.5.2 After cultivation

The trenches were hand weeded regularly to keep the field free of weeds. Earthing up was done along with the application of remaining half dose of N in two equal splits at vining and-full blooming stages. Irrigation was given on alternate days. For trailing the seedlings, dried twigs and coconut leaves were spread on the ground.

N

45m

28m

B	B	B	B	B	B	B	B	B	B	B	B	B	B
R1T2	R1T3	R1T4	R1T9	R1T7	R2T9	R2T3	R2T6	R2T1	R2T10	R3T3	R3T2	R3T4	R3T7
R1T2	R1T3	R1T4	R1T9	R1T7	R2T9	R2T3	R2T6	R2T1	R2T10	R3T3	R3T2	R3T4	R3T7
B	B	B	B	B	B	B	B	B	B	B	B	B	B
R1T8	R1T6	R1T5	R1T1	R1T10	R2T2	R2T5	R2T4	R2T7	R2T8	R3T10	R3T9	R3T6	R3T1
R1T8	R1T6	R1T5	R1T1	R1T10	R2T2	R2T5	R2T4	R2T7	R2T8	R3T10	R3T9	R3T6	R3T1
B	B	B	B	B	B	B	B	B	B	B	B	B	B

B	R3T8	R3T8	B	R3T5	R3T5	B

Figure 1. Lay out of the experimental plot

3.5.3 Plant protection

Plant protection chemicals were applied as and when required.

3.5.4 Harvesting

Fruits were harvested at vegetable maturity.

3.6 Observations

The observations were recorded on five plants per plot selected at random.

3.6.1 Biometrical and biochemical characters

3.6.1.1 Vine length

Vine length of the plant, after harvesting the fruits, was recorded on five plants per plot and the average was taken. Measurement was taken from base of the vine to the growing tip of the plants.

3.6.1.2 Primary branches per plant

Numbers of primary branches of each plant was recorded at 90 days after sowing and average was worked out.

3.6.1.3 Days to first female flower

The number of days taken from sowing to opening of first female flower in each plant of five observation plants per plot was recorded and average was worked out.

3.6.1.4 Nodes to first female flower

The number of node to first female flower in each observation plant of each plot was recorded and average was taken.

3.6.1.5 Sex ratio

Sex ratio (between male and female flowers) for each observation plant was calculated.

3.6.1.6 Days to first harvest

The number of days taken from sowing to first harvest of the fruits in five plants of each plot was recorded and mean was calculated.

3.6.1.7 Number of fruits per plant

Total number of fruits from five plants was counted and the average was calculated.

3.6.1.8 Average fruit weight (g)

Total weight of fruits from five plants was divided by total number of fruits to get the average fruit weight.

3.6.1.9 Average flesh thickness (cm)

Flesh thickness of three fruits of each plot was recorded and average was taken.

3.6.1.10 Fruit yield per plant (kg)

Total weight of fruits from five plants of all the harvests of each plot was recorded and average was calculated to get fruit yield per plant.

3.6.1.11 Fruit yield per plot (kg)

Weight of fruits from each plot after each harvest including yield of labelled plants were added to get the total yield per plot.

3.6.1.12 Shelf life (Days)

Fruits were harvested at vegetable maturity and kept at room temperature under open condition. The number of days for which the fruits remained intact under ambient conditions was recorded as the shelf life in days. Then the average was worked out.

3.6.2 Biochemical parameters

3.6.2.1 Vitamin C content

Vitamin C content of fruit at vegetable harvest stage was estimated by titration with 2,6 – dichlorophenol indophenol dye (Sadasivam and Manickam, 1992).

Five gram of the fresh sample was extracted in four per cent oxalic acid using a mortar and pestle and made up to 100 ml. Five ml of the extract was pipetted, added 10 ml of 4 per cent oxalic acid and titrated against the dye. Ascorbic acid content of the fresh sample was calculated from the titrated value and the value was expressed as mg per 100g of fresh fruit.

3.6.2.2 β - Carotene content

β - Carotene content of fruit at vegetable harvest stage was estimated using n-butanol (A.O.A.C., 1970)

5g of powdered and dried sample were placed in a 125 ml glass flask and added 50 ml water saturated n- butanol from pipette. The flask was stoppered tightly. Shake well for one minute and kept overnight protected from sunlight. Decant the supernatant. Pippetted 0.5 ml of supernatant and diluted with 10ml water to saturated butanol and read the colour intensity in a spectrophotometer at 435.8 nm. β - Carotene content of the sample was calculated from spectrophotometer reading and converted to fresh weight basis.

3.6.3 Mineral nutrients status

3.6.3.1 Availability of Organic C, P, K, S, Fe, Cu,, Zn, and Mn in soil

For nutrient analysis of soil, three sets of soil samples were prepared in which each sample included soil collected from 8 different locations of the experimental field before the crop. After the harvest of crop, soil samples were taken from each plot (10treatments). The methods used for the analysis of different nutrients are given in table 2.

3.6.3.2 N, P, K, S, Fe, Cu, Zn, and Mn in plant

For chemical analysis index leaves (fully opened fifth leaf from the tip of the plant) were collected from the observation plants of each plot. Plant samples were collected before and after application of the treatments. After cleaning, the leaves were dried in a hot air oven at 70± 5° , powdered well and analysed for different nutrients N, P, K, S, Fe, Cu,, Zn, and Mn. The methods used for the analysis of different nutrients are given in the table 3.

Table.2 Methods used for soil chemical analysis

Sl. No.	Nutrient	Method	Reference
1	Organic Carbon	Walkely and Black method.	Walkely and Black, 1934
2	Available P	1. Extracted with Bray No. 1 reagent 2. Estimated by Ascorbic acid reduced molybdo phosphoric blue colour method.	1.Bray and Kurtz, 1945 2.Watanabe and Olsen, 1965.
3	Available K	Available K was extracted using neutral normal ammonium acetate and its content in the extract was estimated by flame photometry	Jackson, 1958.
4	Available S	Available S was extracted using $CaCl_2$ and its content in the extract was estimated by turbidimetry.	Chesnin and Yein, 1951.
5	Available Fe, Cu, Zn and Mn	Available Fe, Cu, Zn and Mn was extracted using 0.1m HCl and its contents were estimated using atomic absorption spectrometer	Sims and Johnson, 1991.

Table.3 Methods used for plant nutrient analysis

Sl. No.	Nutrient	Method	Reference
1	N	Micro Kjeldhal digestion and distillation method	Jackson, 1958.
2	P	Vanadomolybdate yellow colour method using Spectronic 20	Koenig and Johnson, 1942.
3	K	Diacid extract using flame photometer	Cheng and Bray, 1951.
4	S	Turbidimetric method	Williams and Steinbergs, 1959.
5	Fe	Diacid extract using atomic absorption spectrometer	Sims and Johnson, 1991.
6	Mn	Diacid extract using atomic absorption spectrometer	Sims and Johnson, 1991
7	Cu	Diacid extract using atomic absorption spectrometer	Sims and Johnson, 1991
8	Zn	Diacid extract using atomic absorption spectrometer	Sims and Johnson, 1991

For the estimation of P, K, S, Mn, Fe, Zn & Cu the plant samples were digested with nitric – perchloric acid (9:4) mixture (Wilde et al., 1972.)

3.7 Incidence of pest and diseases

Observations on the incidence of major pest and diseases viz., red pumpkin beetle, epilacna beetle, fruit fly and diseases like powdery mildew, downy mildew, bacterial wilt and mosaic were recorded.

3.8 Statistical analysis

Data were analyzed as per MSTATC package.

Results

IV. RESULT

The results of the study entitled "Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients" are presented under the following headings.

4.1 Biometrical and biochemical characters

4.2 Availability status of organic C, P, K, S, Fe, Cu, Zn and Mn in soil

4.3 N, P, K, S, Fe, Cu, Zn and Mn content in plant

4.4 Incidence of pest and disease

4.1 Biometrical and biochemical characters

The results of various biometrical and biochemical characters are presented in tables 4a and 4b. Vine length, sex ratio, flesh thickness, shelf life, vitamin C and β-Carotene content differed significantly between the treatments.

4.1.1 Vine length.

Vine length differed significantly between the treatments. The highest vine length (4.25 m) was observed in T_6 (T_1 + Iron 100 ppm) and was minimum where NPK alone (T_{10}) was applied through soil.

4.1.2 Primary branches per plant.

Primary branches per plant were maximum (3.27) in T_4 (T_1 + Molybdenum 50 ppm). The application of manures and fertilizers as per PoP (T_1) resulted in lowest number of branches per plant.

4.1.3 Days to first female flower

The plants which received foliar application of Multiplex 100 ppm along with recommended manures and fertilizers (T_9) flowered earlier (61.9 days) than other treatments. The application of NPK alone through soil (T_{10}) resulted in delay in flowering (68 days). The result was on par with T_2, T_3 and T_4 where boron, zinc and molybdenum were applied respectively.

4.1.4 Nodes to first female flower

The node to first female flower was minimum (21.8) in T_4 (T_1 + Molybdenum 50 ppm). Application of NPK alone (T_{10}) produced first female flower on later nodes (28.87). The result was on par with other treatments except T_1 and T_{10}.

4.1.5 Sex ratio

The sex ratio (male to female) was minimum (16.19) in T_1 (application of manures and fertilizers as per PoP). But it was very high (23.55) in T_{10} (application of NPK alone). The results show a significant difference between the treatments.

4.1.6 Days to first harvest.

Application of recommended manures and fertilizers along with foliar spray of manganese 100 ppm (T_7) resulted in minimum number of days (84.33) to first harvest. Maximum number of days (92.73) to first harvest was in T_{10} (application of NPK alone).

Table 4 a. Effect of different treatments on biometrical and biochemical characters.

	*Vine length(m)	Primary branches per plant(No.)	Days to first female flower	Nodes to first female flower	**Sex ratio	Days to first harvest	Fruits per plant
T1	4.12a	2.33c	64.53ab	26.20ab	16.19e	89.00ab	1.20b
T2	4.16a	2.47bc	62.00b	23.47b	16.59de	86.67b	1.33ab
T3	3.88a	2.80abc	63.4 ab	23.07b	17.30cde	86.67b	1.20b
T4	3.87a	3.27a	63.27b	21.80b	18.44bcd	85.27b	1.47a
T5	3.95a	2.87abc	63.60ab	24.47b	18.63bcd	89.00ab	1.33ab
T6	4.25a	2.67abc	64.13ab	23.27b	20.16b	85.27b	1.40ab
T7	4.15a	3.07ab	64.53ab	23.53b	17.14cde	84.33b	1.33ab
T8	3.97a	2.60bc	65.13ab	23.93b	18.85bc	87.13ab	1.20b
T9	3.84a	2.60bc	61.93b	22.20b	19.99b	88.53ab	1.47a
T10	3.32b	2.60bc	68.00a	28.87a	23.55a	92.73a	1.27ab
CD at 5%level	0.44	0.55	3.97	4.14	1.99	5.30	0.22

*Significance at 5% level; **Significance at 1% level; Same alphabets shows homogenous effect.

Table 4 b. Effect of different treatments on biometrical and biochemical characters.

	Yield per plant(kg)	Yield per plot (kg)	Average fruit weight (kg)	**Flesh thickness (cm)	**Shelf life (days)	**Vitamin C (mg/100g)	**β Carotene ((µg/g)
T1	2.41a	51.22ab	2.01a	2.35bc	41.67c	1.77ef	166.67d
T2	2.61a	55.05a	1.99a	2.74a	61.67a	2.92bc	188.67bc
T3	2.07a	44.33ab	1.73a	2.14cd	61.67a	1.77ef	168.22d
T4	2.79a	54.67ab	1.88a	2.64ab	52.33b	2.50cd	189.33bc
T5	2.54a	49.38ab	1.91a	2.35bc	50.00b	3.23ab	168.81d
T6	2.50a	48.43ab	1.78a	2.49ab	51.33b	3.65a	208.25a
T7	2.65a	51.07ab	1.99a	2.34bc	51.33b	2.09def	184.46c
T8	2.32a	46.78ab	1.96a	2.35bc	51.33b	2.29de	192.59b
T9	2.79a	46.78ab	1.78a	2.41abc	53.33b	2.19def	170.29d
T10	2.21a	40.52ab	1.77a	2.00c	39.33c	1.67f	134.78e
CD at 5%level	0.66	12.46	0.41	0.30	4.60	0.53	6.86

**Significance at 1% level; Same alphabets shows homogenous effect.

4.1.7 Fruits per plant

There was no significant difference between treatments for fruits per plant. However the treatments T_4 (T_1 + Molybdenum 50 ppm) and T9 (T_1 + Multiplex 100 ppm) gave highest number of 1.47 fruits per plant.

4.1.8 Yield per plant

The mean yield per plant was highest (2.79 kg) in T_4 (T_1 + Molybdenum 50 ppm) and it was lowest in T_3 (T_1 + Zn 100 ppm).

4.1.9 Yield per plot

The yield per plot varied from 40.52 kg to 55.05 kg. It was highest in T_2 where 100 ppm boron was applied as foliar spray along with the recommended dose of manures and fertilizers. The yield per plot was lowest wherein recommended NPK alone was applied (T_{10}).

4.1.10 Average fruit weight

The average fruit weight was highest (2.01 kg) in T_1 (application of recommended manures and fertilizers). It was lowest (1.73 kg) in T_3 (T_1 + Zn 100 ppm).

4.1.11 Flesh thickness

There was significant difference between treatments for flesh thickness. The fruits of treatment T_2 (T_1 + Boron 100 ppm) had maximum flesh thickness (2.74 cm) and T_{10} had lowest flesh thickness (2cm).

4.1.12 Shelf life

There was a significant effect on shelf life of pumpkin fruits among the treatments. The shelf life of pumpkin fruits harvested at vegetable maturity varied from 39.33 days (T_{10} – recommended NPK alone) to 61.67 days in T_2 (T_1 + Boron 100 ppm) and T_3 (T_1 + Zn 100 ppm). The shelf life of the fruits of other treatments was on par.

4.1.13 Vitamin C content

Foliar application of micronutrients had a significant effect in vitamin C content in pumpkin fruits at vegetable maturity. The vitamin C content of the fruits at vegetable maturity was highest 3.65 mg $100g^{-1}$ in T_6 (T_1 + Iron 100 ppm). The lowest vitamin C content (1.67 mg $100g^{-1}$) was observed in fruits where the treatment was recommended NPK alone (T_{10}).

4.1.14 β-Carotene content

The β-carotene content of the fruits at vegetable maturity was highest (208.25 μg g^{-1}) in T_6 (T_1 + Iron 100 ppm) and was lowest (134.78 μg g^{-1}) in T_{10}. The result shows a significant effect between the treatments in β – carotene content of pumpkin fruits.

4.2 Availability status of Organic C, P, K, S, Fe, Cu, Zn and Mn in soil

There was an increase in soil organic carbon content from 0.86% before to 1.15% after the harvest of the crop.

There was significant difference in the available nutrient content in the soil of the experimental field before and after the crop (Table 5).

Plate 1. Field photo of T6 (T1+ Fe100ppm)

Plate 2. Fruits of T6 (T1+ Fe100ppm)

Plate 3. Field photo of T4 (T1+ molybdenum 50ppm)

Plate 4. Fruits of T4 (T1+ molybdenum 50ppm)

Table 5. Nutrient content in soil before and after treatment

	Organic C %	P_2O_5 kg ha $^{-1}$	K_2O kg ha $^{-1}$	S kg ha $^{-1}$	Fe mg kg $^{-1}$	Cu mg kg^{-1}	Zn mg kg $^{-1}$	Mn mg kg $^{-1}$
Before treatment	0.86	80.76	173.97	66.27	9.93	2.35	1.98	22.50
After treatment	1.15	292.33*	252.37	103.60**	22.33*	11.90**	4.66*	53.13*

* Significance at 5% level ** Significance at 1% level

The available P content was 80.76 kg ha^{-1} before the experiment and it got increased to 292.33 kg ha^{-1} after the experiment (Figure 2)

There was an increase in available S content from 66.27 kg ha^{-1} (before the experiment) to 103.60 kg ha^{-1} after the experiment.

The available content of micronutrients like Fe, Cu, Zn and Mn also increased from 9.93 to 22.33 mg kg^{-1}; 2.35 to 11.90 mg kg^{-1}; 1.98 to 4.66 mg kg^{-1} and 22.5 to 53.13 mg kg^{-1} respectively before and after raising the crop (Figure 3).

4.3 Nutrient content in plants

4.3.1 N, P, K, S, Fe, Cu, Zn and Mn content in plant before treatment

The results of analysis of plant samples before treatment are given in Table 6.

The nitrogen content varied from 2.66 per cent in T_{10} (soil application of recommended NPK alone) to 3.38 per cent in T_5 (T_1 + copper 100 ppm) (Figure 4).

There was significant difference in phosphorus content of plants which varied from 0.07 per cent to 0.23 per cent. It was highest in T_8 (T_1 + mixture of all) and lowest in T_{10} (recommended NPK alone).

The potassium content was maximum (2.32 %) in T_8 (T_1 + mixture of all) and minimum 1.99 per cent in T_9 (T_1 + Multiplex 100 ppm).

There was no significant difference between the treatments for the S content in plant. It varied from 0.09 per cent in T_2 (T_1 + boron 100 ppm) to 0.79 per cent in T_{10} (recommended NPK alone).

Table 6. Nutrient content in plant before treatment

	N %	*P %	*K %	*S %	Fe mg kg^{-1}	Cu mg kg^{-1}	*Zn mg kg^{-1}	Mn mg kg^{-1}
T1	3.1 a	0.19 ab	2.8 ab	0.32 bc	1118.33 a	51.83 b	48.67 a	666.17 a
T2	2.91 a	0.13 abc	2.16 ab	0.09 c	343.33 a	25.17 b	39.50 ab	570.50 a
T3	2.84 a	0.08 bc	2.12 ab	0.34bc	460.00 a	46.67 b	46.67 ab	845.17 a
T4	2.74 a	0.18 ab	2.15 ab	0.47 abc	315.00 a	27.17 b	37.17 ab	430.17 a
T5	3.38 a	0.09 bc	2.31 a	0.14 bc	808.00 a	42.17 b	41.50 ab	380.00 a
T6	3.29 a	0.16 abc	2.16 ab	0.43abc	381.67 a	120.33 ab	43.00 ab	592.17 a
T7	2.99 a	0.15 abc	1.99 b	0.56 ab	501.67 a	303.83 a	45.17 ab	580.33 a
T8	3.19 a	0.23 a	2.32 a	0.51 abc	565.00 a	101.33 ab	32.17 bc	756.33 a
T9	2.66 a	0.18 ab	1.99 b	0.45 abc	2278.33 a	135.17 ab	33.83 abc	628.83 a
T10	3.36 a	0.07 c	2.25 ab	0.79 a	1706.67 a	57.67 b	20.17 c	772.83 a
CD at 5% level	1.72	0.10	0.28	0.37	1819.99	197.68	14.29	845.86

*Significance at 5% level Same alphabets shows homogenous effect

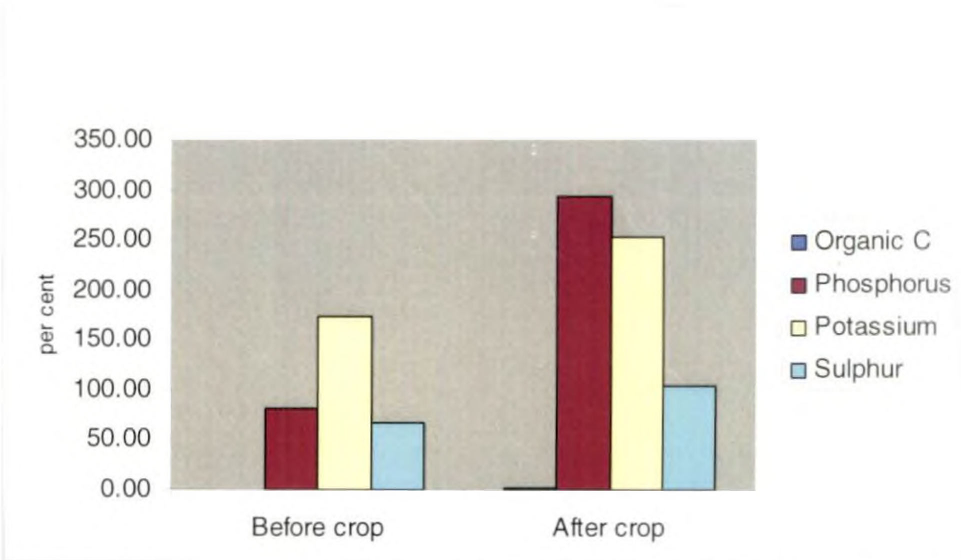

Figure 2. Effect of different treatments on available content of organic C, P, K and S in soil (%)

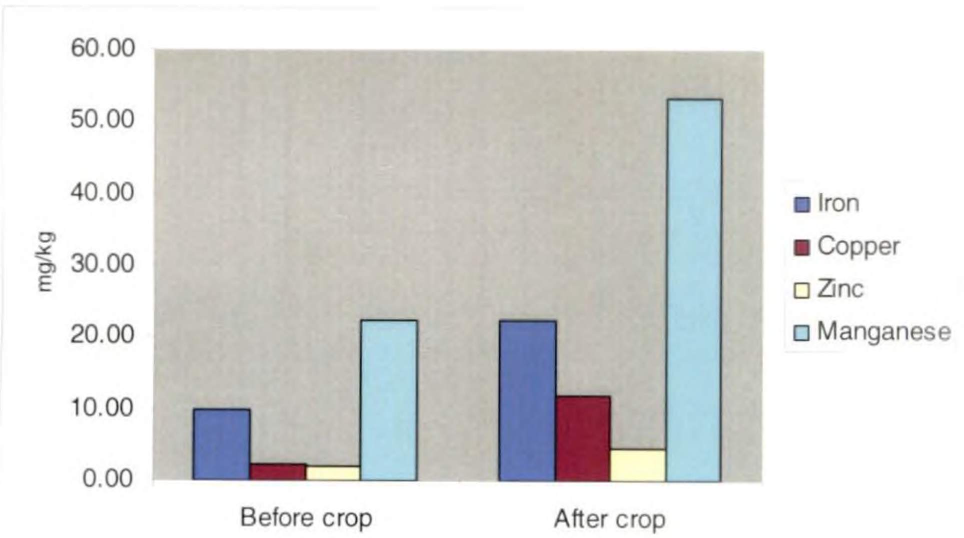

Figure 3. Effect of different treatments on available Fe, Cu, Zn and Mn in soil (mg kg^{-1})

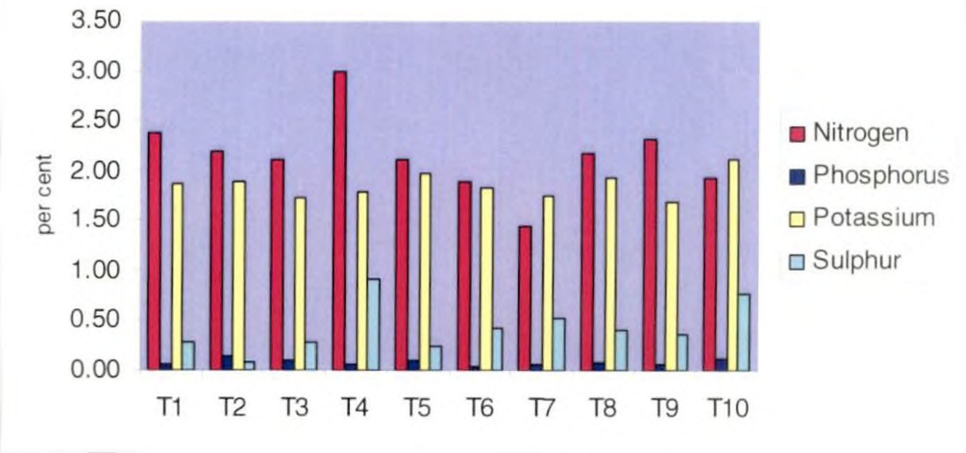

Figure 4. Effect of different treatments on N, P, K and S content in plant before the application of nutrients (%)

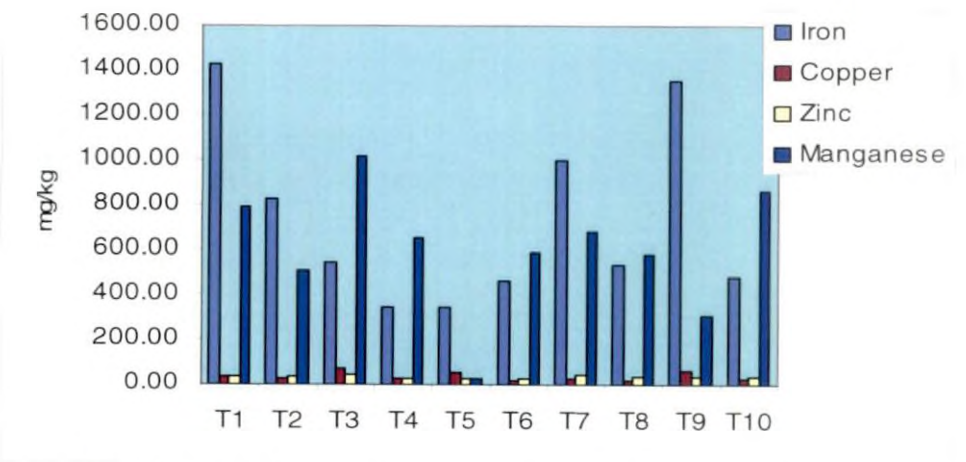

Figure 5. Effect of different treatments on Fe, Cu, Zn and Mn content in plant before treatment (mg kg^{-1})

The Fe content varied from 315 mg kg $^{-1}$ in T_4 (T_1 + molybdenum 50 ppm) to 2278.33 mg kg $^{-1}$ in T_9 (T_1 + Multiplex 100 ppm).

The copper content in plant varied from 25.17 mg kg $^{-1}$ in T_2 (T_1 + boron 100 ppm) to 308.83 mg kg $^{-1}$ in T_7 (T_1 + manganese 100 ppm).

The Zn content was lowest (20.17 mg kg $^{-1}$) in T_{10} (recommended NPK alone). It was highest (48.67 mg kg $^{-1}$) in T_1 (recommended manures and fertilizers as per PoP).

The Mn content varied from 380 mg kg $^{-1}$ in T_5 (T_1 + copper 100 ppm) to 845.17 mg kg $^{-1}$ in T_3 (T_1 + zinc 100 ppm) (Figure 5).

4.3.2 N, P, K, S, Fe, Cu, Zn and Mn content in plant after treatment

The results of analysis of plant samples before treatment are given in Table7.

The nitrogen content varied from 1.45 per cent in T_7 (T_1 + manganese 100 ppm) to 2.99 per cent in T_4 (T_1 + molybdenum 50 ppm) (Table 7).

The content of phosphorus varied from 0.05 per cent in T_6 (T_1 + iron 100 ppm) to 0.15 per cent in T_2 (T_1 + boron 100 ppm).

The potassium content varied from 1.73 per cent in T_3 (T_1 + zinc 100 ppm) to 2.09 per cent in T_{10} (recommended NPK alone) (Figure 6).

The sulphur content varied from 0.19 per cent in T_2 (T_1 + boron 100 ppm) to 0.89 per cent in T_4 (T_1 + molybdenum 50 ppm).

Table 7. Nutrient content in plant after treatment

	N %	P %	K %	S %	Fe mg kg $^{-1}$	Cu mg kg $^{-1}$	Zn mg kg $^{-1}$	Mn mg kg $^{-1}$
T1	2.38 ab	0.07 a	1.85 ab	0.32 bc	1411.67 a	36.33 a	31.00 a	774.33 ab
T2	2.19 ab	0.15 a	1.90 ab	0.19 c	911.67 a	22.50 a	32.33 a	528.50 abc
T3	2.10 ab	0.10 a	1.73 b	0.31 bc	312.50 a	67.83 a	40.50 a	937.17 a
T4	2.99 a	0.07 a	1.80ab	0.89 a	431.67 a	24.17 a	29.50 a	718.83 ab
T5	2.15 ab	0.10 a	1.94ab	0.33 bc	365.00 a	50.83 a	31.00 a	114.67 c
T6	1.91 ab	0.05 a	1.83 ab	0.41 bc	1618.33 a	20.83 a	27.50 a	603.67 abc
T7	1.45 b	0.06 a	1.81 ab	0.48 abc	1061.67 a	45.17 a	41.00 a	694.67 ab
T8	2.19 ab	0.10 a	1.90 ab	0.38 bc	586.67 a	23.33 a	35.33 a	539.17 abc
T9	2.29 ab	0.07 a	1.74 b	0.36 bc	1180.00 a	65.33 a	33.33 a	308.33 bc
T10	1.96 ab	0.11a	2.09 a	0.66 ab	388.33 a	25.33 a	42.17 a	808.33 ab
CD at 5% level	1.05	0.08	0.29	0.40	1056.66	46.62	14.69	840.68

Same alphabets shows homogenous effect

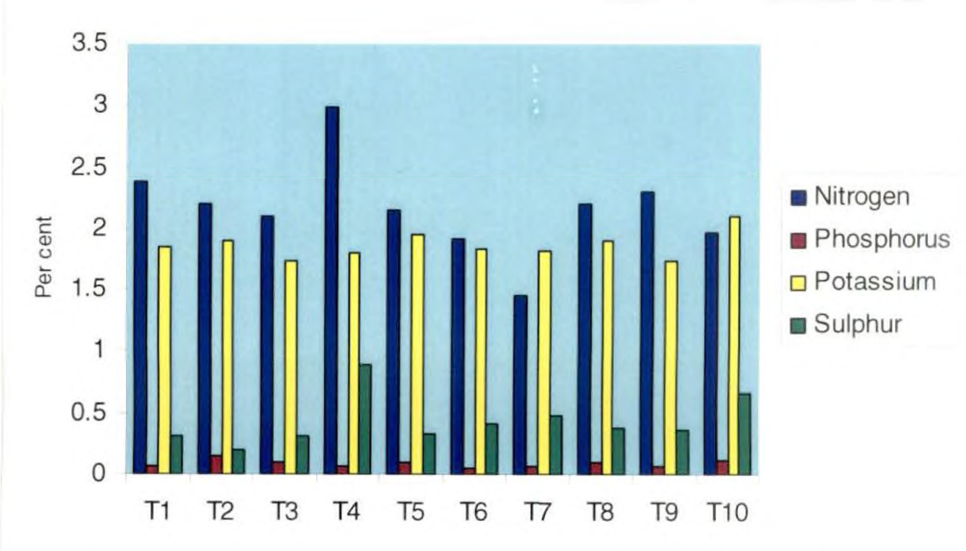

Figure 6. Effect of different treatments on N, P,K and S content in plant after the application of nutrients (%)

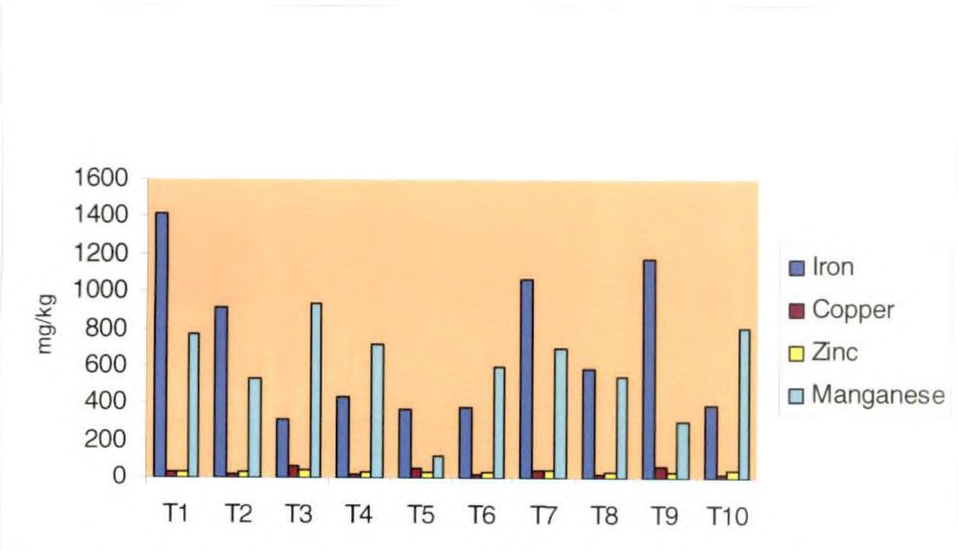

Figure 7. Effect of different treatments on Fe, Cu, Zn and Mn content in plant after treatment (mg kg^{-1})

The highest value for Fe content (1618.33 mg kg $^{-1}$) was in T_6 (T_1 + Fe 100ppm) and minimum (312.50 mg kg $^{-1}$) in T_3 (T_1 + zinc 100 ppm).

The highest copper content (67.83 mg kg $^{-1}$) was recorded in T_3 (T_1 + Zinc 100 ppm) and minimum value of 20.83 mg kg $^{-1}$ recorded in T_6 (T_1 + iron 100 ppm).

The maximum zinc content (42. 17 mg kg $^{-1}$) was recorded in T_{10} (recommended NPK alone) and minimum 27.5 mg kg $^{-1}$ in T_6 (Figure 7).

The highest manganese content (937.17 mg kg $^{-1}$) was recorded in T_3 (T_1 + Zinc 100 ppm) and minimum (114.67 mg kg $^{-1}$) in T_5.

4.3.3 Correlation studies.

The vine length of plant was negatively correlated with days to first harvest (-0.40*) and it was positively correlated with vitamin C (0.43*) and carotene content (0.57**) in fruits at vegetable maturity. Number of primary branches in plant had a negative correlation (-0.46**) with days taken to first harvest. Number of days taken for first female flower was positively and significantly correlated with nodes to first female flower (0.61**) and sex ratio (0.52**) (Table8).

Number nodes to first female flower had a positive correlation with days to first harvest (0.42*) and a negative correlation with flesh thickness (-0.43*), shelf life (-0.56**) and carotene content (-0.52**). Sex ratio was negatively correlated with yield per plant (-0.39*), flesh thickness (-0.39*), shelf life (-0.42*) and to carotene content (-0.39*).

Days taken to first harvest had a negative correlation with carotene content (-0.40*) in fruits. Number of fruits per plant was positively correlated with yield per plant (0.5**). The yield per plant was correlated with yield per plot (0.80**) and average fruit weight (0.68**). The yield per plot was positively correlated with average fruit weight (0.61**), flesh thickness (0.55**) and carotene content (0.38*). Flesh thickness showed correlation with shelf life (0.34*), vitamin C (0.45*) and carotene content (0.62**). Carotene content of fruit was significantly correlated with shelf life (0.46*) and vitamin C content (0.61**).

The content of N in plant before the foliar application of micronutrients was positively and significantly correlated with vine length (0.37*). The P content in plant before the treatment was positively correlated with iron content after the treatment (0.43*) and carotene content in fruits (0.37*) at vegetable maturity. The potassium content in plant before the treatment was negatively correlated with number of primary branches in the plant (-0.44*). The available content of S in plant before the treatment was positively correlated with Cu content in plant before the treatment (0.54**), Mn content in plant after treatment (0.37*), sex ratio (0.56**) and negatively correlated with vine length (-0.63**), shelf life (-0.43*) and vitamin C content (-0.41*).

The Fe content in plant before the treatment was positively and significantly correlated (0.43*) with the Mn content in plant before the treatment. The Cu content in plant before the treatment was positively correlated Fe (0.45*) and Cu (0.38*) content in plant after the treatment. The available Zn content in plant before the treatment was negatively and significantly correlated with sex ratio (-0.50**) and positively correlated with yield per plant (0.46*) and flesh thickness (0.41*).

The N content in plant after the treatment was negatively correlated with Zn content (-0.39*) in plant after the treatment. The content of P in plant after the treatment was positively correlated with K content (0.39*) and Cu content (0.44*) in plant after the treatment and to number of days taken for first harvest (0.54**). The K content in plant after the treatment was positively correlated with days taken for opening of first female flower (0.47**) and number of nodes to first female flower (0.36*).

Fe content in plant after the treatment was positively correlated with Cu content in plant after treatment (0.53**) and days taken to first harvest (0.48**). Cu content in plant after treatment was positively correlated with the first harvest of fruits (0.41*). The available Zn content in plant after treatment was negatively correlated with number of fruits per plant (-0.38*), yield per plant (-0.38*), flesh thickness (-0.36*) and vitamin C content in fruit (-0.37*). Mn content in plant after treatment had a negative correlation with vitamin C content (-0.38*) in fruits at vegetable maturity.

4.4 Incidence of pest and diseases

During the crop period, incidence of bacterial wilt caused by *Ralstonia solanacearum* (Yabucchi *et al.*) was observed in all the treatments and was comparatively free from pests.

Table 8. Correlation studies

	N(b)	P(b)	K(b)	S(b)	Fe(b)	Cu(b)	Zn(b)	Mn(b)	N(a)	P(a)	K(a)	S(a)
N(b)	1											
P(b)	-0.289	1										
K(b)	-0.102	0.028	1									
S(b)	-0.289	0.135	0.004	1								
Fe(b)	-0.024	0.162	0.14	0.209	1							
Cu(b)	-0.301	0.191	-0.147	.540(**)	0.278	1						
Zn(b)	-0.101	0.292	0.063	-0.339	-0.085	-0.008	1					
Mn(b)	0.341	-0.027	0.154	0.043	.434(*)	0.173	0.125	1				
N(a)	0.035	-0.154	0.081	-0.117	-0.073	-0.107	-0.098	0.171	1			
P(a)	-0.13	0.075	0.181	-0.118	-0.043	-0.089	0.164	-0.162	-0.049	1		
K(a)	-0.076	-0.081	0.136	0.119	0.022	0.108	-0.345	-0.109	0.045	.385(*)	1	
S(a)	-0.007	0.015	-0.089	0.264	-0.092	-0.04	0.012	-0.147	0.327	0.176	0.205	1
Fe(a)	-.365(*)	.429(*)	-0.106	0.254	0.14	.450(*)	0.289	-0.053	0.015	0.265	0.118	0.074
Cu(a)	-0.244	0.153	0.076	0.206	0.268	.381(*)	0.219	-0.076	0.013	.437(*)	-0.017	0.025
Zn(a)	0.094	-0.254	-0.103	0.173	-0.201	0.115	-0.301	-0.048	-.388(*)	0.09	0.191	-0.097
Mn(a)	-0.165	-0.079	-0.119	.374(*)	-0.334	0.084	-0.05	-0.234	0.111	0.167	0.078	0.261
Vine length	.373(*)	0.09	-0.242	-.627(**)	-0.096	-0.019	0.334	0.195	0.103	-0.212	-0.213	-0.251
Pri.branches	-0.017	-0.009	-.438(*)	0.15	-0.356	0.197	-0.211	-.375(*)	-0.053	-0.027	0.056	0.316
Days to first f.flower	0.115	-0.135	0.296	0.067	0.068	-0.165	-0.134	-0.046	0.121	0.337	.467(**)	0.325
Node to fisrt f.flower	0.184	-0.233	0.361	0.189	0.257	0.019	-0.238	0.284	0.153	0.176	.361(*)	0.062
Sex ratio	0.065	-0.18	0.103	.559(**)	0.357	0.086	-.503(**)	0.204	-0.015	-0.056	0.262	0.222
Days to first harvest	-0.148	0.059	0.306	0.137	0.252	-0.043	0.193	0.081	0.051	.537(**)	0.302	0.318
Fruits per plant	-0.05	0.045	-0.307	0.077	0.31	0.203	-0.024	-0.027	0.133	-0.197	-0.177	0.093
Yield per plant	0.164	0.082	-0.184	-0.033	-0.061	0.039	0.121	-0.099	0.137	-0.258	-0.036	0.176
Yield per plot	0.16	0.217	-0.033	-0.258	-0.029	-0.06	.461(*)	0.132	0.201	-0.08	-0.19	0.153
Aver.fruit wt.	0.188	0.15	0.021	-0.129	-0.312	-0.14	0.164	-0.092	-0.005	-0.129	0.064	0.083
Flesh thickness	-0.097	0.288	-0.157	-0.329	-0.25	-0.101	.414(*)	-0.259	0.238	0.294	-0.189	0.278
Shelf life	-0.085	0.008	-0.305	-.429(*)	-0.289	-0.061	0.283	-0.078	-0.038	0.215	-0.343	-0.225
Vitamin C	0.039	-0.07	-0.035	-.407(*)	-0.059	-0.109	0.062	-0.256	0.07	-0.029	0.029	-0.101
β-Carotene	-0.065	.373(*)	-0.094	-0.208	-0.183	0.157	0.311	-0.119	0.015	-0.12	-0.325	-0.077

(b)-before treatment *Correlation is significant at the 0.05 level

(a)-after treatment * *Correlation is significant at the 0.01 level

Fe(a)	Cu(a)	Zn(a)	Mn(a)	Vine length	Pri.branches	Days to first f.Flower	Node to fisrt f.flower	Sex ratio	Days to first harvest	Fruits per plant	Yield per plant	Yield per plot	Aver.fruit wt.	Flesh thickness	Shelf life	Vitamin C	β-Carotene
1																	
.532(**)	1																
-0.181	-0.018	1															
0.065	0.233	0.273	1														
-0.074	-0.311	-0.247	-0.282	1													
-0.13	0.011	0.302	0.19	-0.063	1												
0.146	0.021	-0.009	0.182	-0.124	-0.338	1											
0.176	0.077	0.027	0.044	-0.204	-0.279	.610(**)	1										
-0.156	-0.07	0.006	-0.065	-.497(**)	-0.047	0.206	0.299	1									
.476(**)	.414(*)	-0.044	-0.012	-.402(*)	-.463(**)	.524(**)	.417(*)	0.268	1								
0.038	0.102	-.375(*)	-0.185	-0.07	0.112	-0.238	-0.313	0.183	-0.058	1							
0.031	-0.176	-0.2	-0.08	0.135	0.115	0.005	-0.338	-0.17	-0.205	.499(**)	1						
0.151	-0.108	-.384(*)	-0.169	.365(*)	-0.217	0.054	-0.282	-.391(*)	0.04	0.297	.791(**)	1					
-0.002	-0.298	0.08	-0.001	0.198	0.026	0.128	-0.147	-0.314	-0.192	-0.257	.682(**)	.609(**)	1				
0.145	-0.066	-.362(*)	-0.083	0.361	0.008	-0.048	-.429(*)	-.389(*)	0.048	0.251	0.338	.546(**)	0.189	1			
0.052	0.197	-0.024	-0.055	0.303	0.162	-0.349	-.564(**)	-.423(*)	-0.23	0.104	-0.043	0.11	-0.135	.385(*)	1		
-0.265	-0.281	-.370(*)	-.380(*)	.425(*)	0.085	-0.028	-0.27	-0.052	-0.202	0.264	0.295	0.262	0.105	.449(*)	0.219	1	
-0.019	-0.162	-0.356	-0.122	.576(**)	0.114	-0.26	-.521(**)	-.387(*)	-.397(*)	0.238	0.274	.376(*)	0.101	.622(**)	.459(*)	.609(**)	1

Discussion

5. DISCUSSION

The present experiment is conducted to study the "Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients". The results of the investigation are discussed under the following headings.

5.1 Biometrical and biochemical characters

5.2 Availability status of N, P, K, S, Fe, Cu, Zn and Mn in soil and plant

5.1 Biometrical and biochemical characters

In general the results indicate that the morphological characters are not significantly influenced by the application of micronutrients. The micronutrients serve as co-factors in the enzyme catalysed biochemical reactions associated with plant metabolism. The lack of response to foliar spray of micronutrients may be because the plants are provided with optimum level of micronutrients as co-factors in anabolic reactions responsible for the synthesis of protoplasm and consequent vegetative growth.

There was significant difference between the treatments for vine length. It was minimum (3.32 m) where NPK alone was applied through the soil (T_{10}) and maximum in T_6 (T_1 + Fe 100ppm) (Figure 9). The nitrogen content in the plant before the foliar application of nutrients is positively and significantly correlated with vine length. This is probably because the N content in the early phase of the crop was responsible for the increased vine length. Here the results showed *significant and homogenous effect in available Zn content in plant samples* after the foliar spray treatment. The low level of Zn in T_6 is probabaly due to its interaction with Fe and also that it might have been utilized for increasing the vine length. Zinc has role in growth as it is reported to promote synthesis of indole acetic acid through tryptophan which serve as a precursor for auxin synthesis and directly affect the growth parameter. Due to enhanced availability of auxin the leaf area might have increased, thereby increasing photosynthesis and production of metabolites required for plant growth and development.

Highest value (3.27) for primary branches per plant was obtained from the treatment T_4 (T_1 + Mo 50ppm). Similar result was reported by Singh *et al.* (2003) for number of branches in tomato.

The number of days taken for production of first female flower and node to first female flower was positively correlated with the plant content of potassium after the application of treatments. This is probably because potassium helps in the *translocation of metabolites in the reproductive phase. The treatment* T_9 (T_1 + Multiplex 100ppm) resulted in earliest flowering (Figure 11). The result was on par with T_2, T_3 and T_4 where boron, zinc and molybdenum were applied respectively. It may be due to increased availability of micronutrients in required proportion indicating that these elements have similar role in inducing earliness. B and Mo in lower concentration induce female flower production and fruit setting.

The nodes (21.8) to first female flower was minimum in T_4 (T_1 + Mo 50ppm) and was on par with other treatments except T_1 and T_{10}. Here also the results shows the importance of micronutrients Mo, B, Cu, Zn and Fe in producing first female flower in earliest nodes and there by inducing in earliness in flowering. In cucumber Sukhina and Petrosova (1986) reported advanced bud development, flowering and fruiting as a result of top dressing with micronutrient solutions. Hatawar *et al.* (2003) reported similar results in chilli plants with micronutrients. These findings shows that micronutrients are effective in advancing the number of nodes to first female flower production. Maximum number of nodes to first female flower in T_{10} was probably because of enhanced vegetative growth where NPK alone was applied.

Sex ratio (male: female) was minimum (16.19) when the recommended dose of organic manures and fertilizers (T_1) were added followed by 16.59 in T_2 (T_1 + B100ppm) and significantly differed between the treatments. It was maximum (23.55) in T_{10} (Figure 10). This wide difference in sex ratio indicates the requirement of organic manures in promoting femaleness. This result was similar to findings of Pandita *et al.* (1976) and Singh *et al.* (2003) in tomato where foliar application of B as borax resulted in increased number of flower formation. This might be due to enhancement in the translocation of carbohydrates from the sight of synthesis to the reproductive tissues in plants.

The number of days taken to first harvest was minimum (84.33 days) in T_7 (T_1 + Mn 100ppm) and was on par with T_2, T_3, T_4 and T_6 (Figure 11). This may be due to hastening of fruit set by Mo and probable role of Fe in synthesis of chlorophyll and photosynthesis and also expected since the same treatments induced early flowering. The more number of days (92.73) required in T_{10} is may be due to the delayed flowering. The positive correlation between days to first female flower and days to first harvest also indicates the same. Choudhary and Mukherjee (1999) reported similar results in cauliflower. This might be due to better absorption of nutrients resulting in efficient physiological activities in plant which was governed by Mo and Zn in relation to nutrition and availability of other macro and micro nutrients.

The maximum number of fruits per plant was obtained in T_4 and T_9 (1.47) (Figure 12). This is probably due to the role of micronutrients in chlorophyll synthesis, photosynthesis and resultant translocation of carbohydrates to the reproductive parts. Here also the role of Mo in fruit setting might lead to the formation of maximum number of fruits per plant. Boron and zinc are associated with fruit set because they are involved with pollen germination, pollen tube growth and ovule fertilization. Longbottom (2004) found that pollen tube growth, ovule penetration and fertilization were increased when supplemental molybdenum was applied, but only if the vines were deficient in the first place. Molybdenum is

Plate 5. Fruits of T1 (recommended manure & fertilizers as per PoP)

Plate 6. Field photo of T1 (recommended manure & fertilizers as per PoP)

Plate 7. Field photo of T9 (T1+ Multiplex 100ppm)

Plate 8. Field photo of T2 (T1+ boron 100ppm)

known to be a cofactor for some enzymes, including nitrate reductase. It is also involved in synthesis of some plant hormones, specifically indole-3-acetic acid (IAA) and abscisic acid (ABA). Molybdenum is a micronutrient involved in the conversion of nitrate nitrogen, taken up by the roots, into form that the vine can use. It is also involved in enzymatic reactions essential for growth and reproduction in plants. Recent research indicated that molybdenum plays an important role in grapevine fruit set, seed formation, berry formation and development and yield (Williams *et al.*, 2004). Alla *et al.* (1984) observed increased yield in capsicum by foliar application of 0.2 per cent Irral (commercial formulation containing NPK and micronutrients). Application of micronutrients in chilli enhanced the photosynthetic activity and resulted in production and accumulation of carbohydrates and increased the number of fruits (Hatawar *et al.*, 2003). Sudhan and Shakila (2003) in cucumber noticed the highest dry matter production by soil and foliar application of micronutrients. In cucumber they got highest number of female flowers produced per vine, fruit set percentage, number of fruits per vine, single fruit weight, yield per vine and lowest value for number of days taken for first female flower appearance and sex ratio by soil and foliar application of micronutrients.

The highest yield per plant was observed in T_4 (T_1 + Mo 50ppm) (Figure 8). The positive correlation between fruits per plant and yield per plant shows the relation between number of fruits per plant and yield per plant. The increase in number of fruits per plant leads to increased yield per plant. The increase in fruit yield might be due to rapid uptake, translocation and assimilation of photosynthates to sink (fruit). The results are in line with the findings of Singh and Verma (1991), Yadav *et al.*(2001), Raghav and Sharma (2003), Bhatt *et al.*(2004) in tomato and Singh *et al.* (1989) in chilli.

The yield per plot (55.05 kg) was highest when 100 ppm B applied as foliar spray. These results are similar to the findings of Pal *et al.* (2004) in bell pepper and Paithankar *et al.* (2004) in tomato. Boron is said to function in carbohydrate

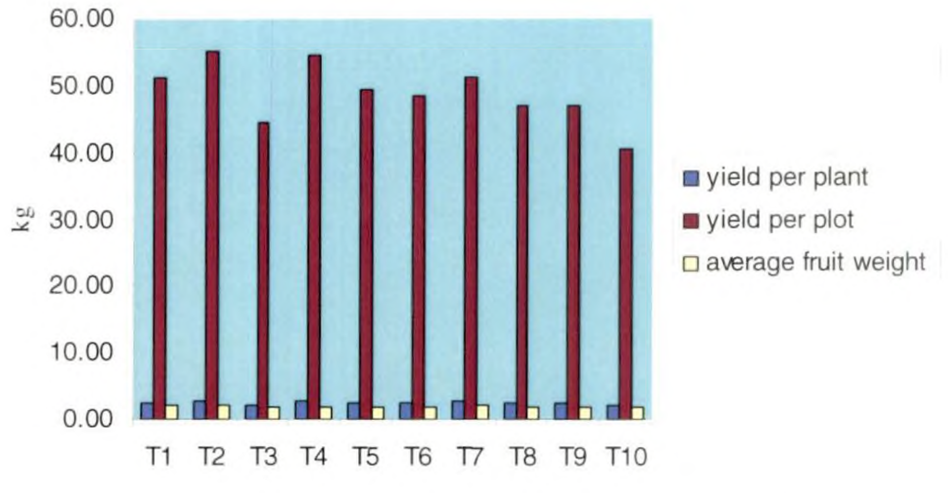

Figure 8. Effect of different treatments on yield per plant, yield per plot and average fruit weight.

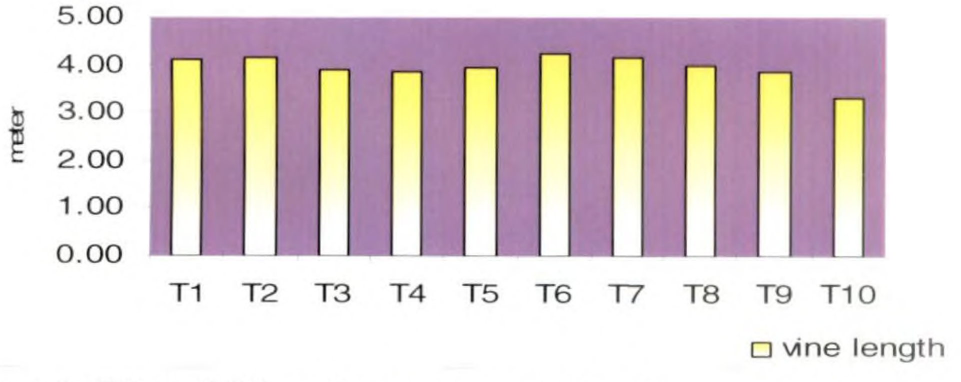

Figure 9. Effect of different treatments on vine length.

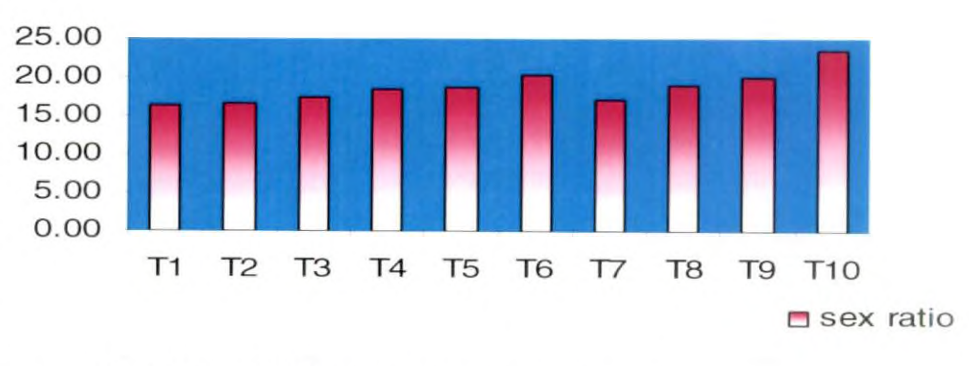

Figure 10. Effect of different treatments on sex ratio

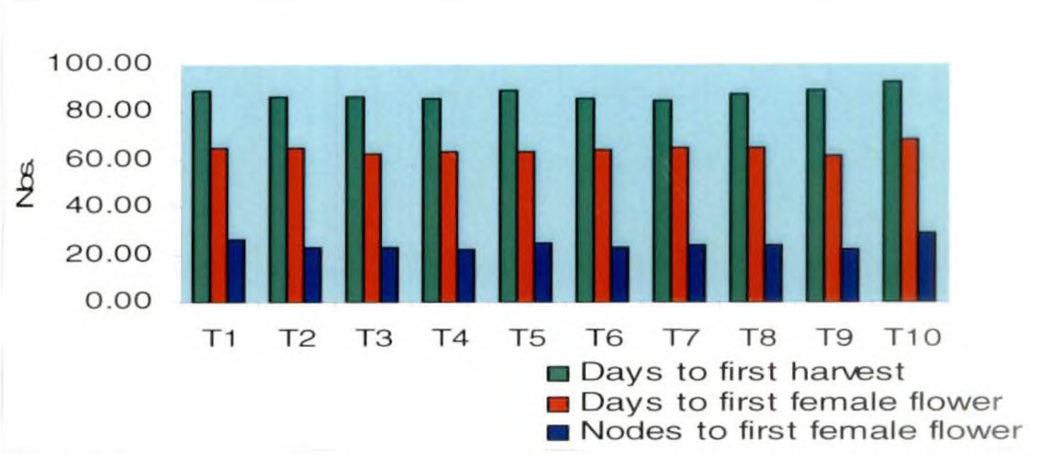

Figure 11. Effect of different treatments on days to first harvest, days to first female flower and nodes to first female flower.

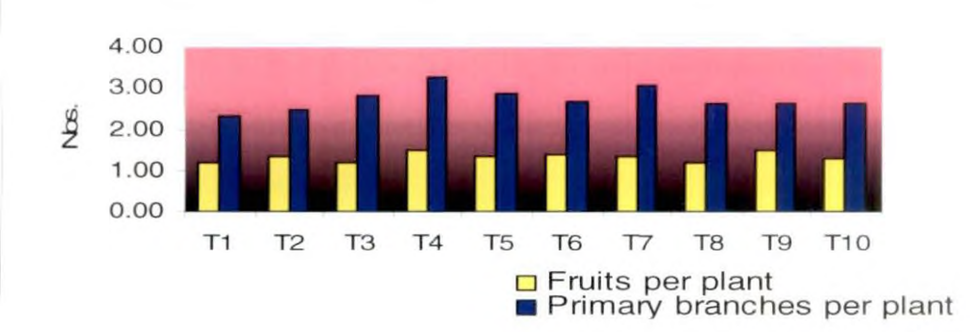

Figure 12. Effect of different treatments on fruits per plant and primary branches per plant.

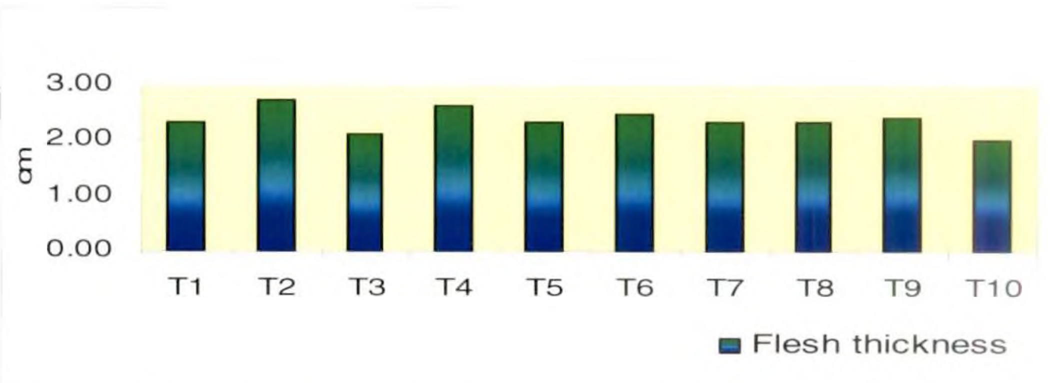

Figure 13. Effect of different treatments on flesh thickness of fruits.

metabolism and to facilitate the movement of sugars by forming permeable boron – sugar complex or by joining the cell membrane which make it more permeable to sugars. It is also believed to influence cell development by its control over the polysacharide formation. The rate of cell division in plants considered as function of B content. Thus the increased availability of boron by foliar spray would have resulted in enhanced cell development all together lead to increased yield. The effect of boron on female flower induction and Mo on fruit setting have accounted for highest yield per plot by application of these nutrients.

The highest average fruit weight (2.01 kg) was in T_1 followed by T_2 (T_1 + B 100ppm) and T_7 (T_1 + Mn 100ppm) with 1.99 kg. Similar findings were reported by Singh *et al.* (2003) and Pandita *et al.* (1976) in tomato.

There was significant difference between treatments for flesh thickness at vegetable maturity. The highest flesh thickness (2.74 cm) was observed in T_2 (Figure 13). Its positive correlation with shelf life, vitamin C and carotene content indicate that various quality parameters will increase with flesh thickness. These results are in relation to the findings of Paithankar *et al.* (2004) where fruit size in tomato was increased by 0.3per cent borax spray. Growth promoting and stimulating effect of boron is reflected here which lead to increase in flesh thickness. The function of sugar boron complex might have helped in increasing the flesh thickness.

Shelf life differed significantly between the treatments. The minimum shelf life was in T_{10} (39.33days) and was on par with T_1 (Figure 14). The maximum shelf life was observed in T_2 and was on par with T_3. The shelf life of the fruits of other treatments was on par. It shows the probable role of micronutrients in enhancing the shelf life. This is probably due to performance of boron and other micronutrients in protective function in plants in that it prevent the excessive polymerization of sugars at the site of sugar synthesis and accumulation.

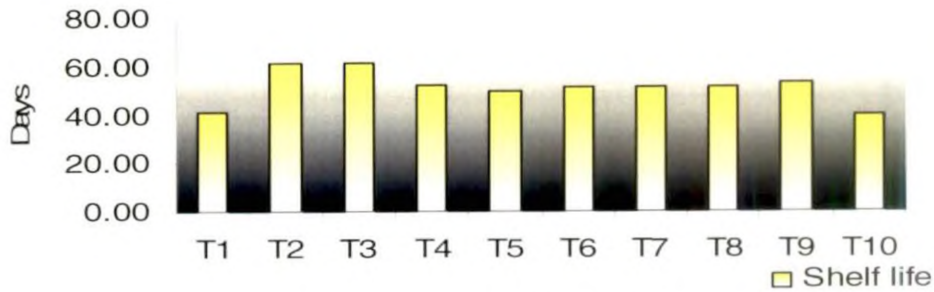

Figure 14. Effect of different treatments on shelf life of fruits.

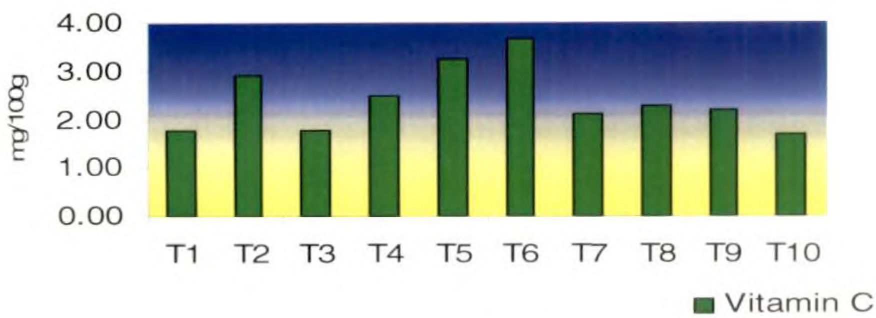

Figure 15. Effect of different treatments on vitamin C content (mg/100g).

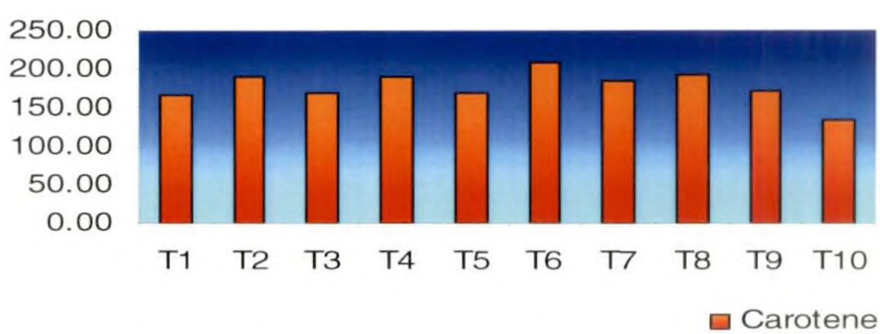

Figure 16. Effect of different treatments on β Carotene content (μg/g).

A significant difference was observed between the treatments for vitamin C content of the fruits at vegetable maturity. The highest vitamin C content of 3.65 mg/100g was observed in T_6 (T_1 + Fe 100ppm) followed by T_5 (T_1 + Cu 100ppm) (Figure 15). This may be due to the role of these nutrients as part of ascorbate peroxidase which is responsible for the vitamin C synthesis. Sukhina and Petrosova (1986) had observed improved vitamin C accumulation in cucumber by topdressing with micronutrient solution. The carotene content was highest (208.25 μg/g) in T_6 and minimum in T_{10} (Figure 16). This is probably due to the role of Fe in enzymes involved in photosynthesis and β carotene synthesis. There was positive correlation between vitamin C and β carotene content indicating that as vitamin C increases β carotene also increases.

The positive correlation between number of fruits per plant, yield per plant, average fruit weight, yield per plot and flesh thickness indicate that when the number of fruits per plant increases the total yield increases and when the flesh thickness increases the average fruit weight and the consequent yield per plant and yield per plot also increases.

5.2 Availability status of N, P, K, S, Fe, Cu, Zn and Mn in soil and plant

The available nutrient content in soil before and after the application of foliar spray of micronutrients indicates that the soil is enriched with the nutrients after the cropping period. This is probably due to that the applied nutrient elements directly or indirectly enriched the soil. Translocation of nutrients from plants to soil may also be caused for enrichment of soil. There was no significant increase in nutrient content after the treatments. The P content in plant after the treatment was minimum when T_6 (T_1 + Fe 100ppm) was applied. This is because either the physiological availability of P in the plant is blocked by Fe or the absorption itself is hindered.

The role of micronutrients in pumpkin nutrition has not been reported from India. Therefore, the present investigation provides valuable information on micronutrients in the nutrition of pumpkin. It can be seen that three foliar sprays of Boron (100ppm) and Molybdenum (50ppm) starting 40 days after sowing helps to increase the yield. The quality parameters like β carotene and vitamin C were improved by spraying of iron (100ppm) and copper (100ppm). In addition, the comparison of results, obtained between the treatments where NPK alone and NPK along with farmyard manure were applied, showed the importance of FYM in pumpkin nutrition.

Future line of work

- The reasons for increased content of nutrients in soil after the experiment should be investigated.
- The plant nutrient status should be taken into account considered while fixing the concentration of micronutrients to be sprayed.
- The micronutrient concentration required for enhancing the yield, vitamin C and β carotene content and shelf life of pumpkin at vegetable maturity should be standardised.

Summary

VI. SUMMARY

A study entitled 'Response of pumpkin (*Cucurbita moschata* Poir.) to foliar application of micronutrients' was carried out at Department of Olericulture, College of Horticulture, Vellanikkara, during September 2006 to January 2007 to study the effect of micronutrients on the growth, yield and quality of pumpkin and also to study the available content of N, P, K, Fe, Cu, Mn, Zn and S in soil and plant. The study revealed the following information.

1. The vine length of plants differed significantly among the treatments. The highest vine length (4.25 m) was observed in T_6 (T_1 + Iron 100 ppm) followed by T_2 (T_1 + boron 100ppm).

2. The highest number of primary branches per plant (3.27) was obtained for the treatment T_4 (T_1 + Molybdenum 50 ppm).

3. The plants which received foliar application of Multiplex 100 ppm along with recommended manures and fertilizers (T_9) flowered earlier (61.9 days) than other treatments.

4. The node to first female flower was minimum (21.8) in T_4 (T_1 + Molybdenum 50 ppm).

5. There was significant difference for sex ratio among the treatments. The sex ratio was minimum (16.19) in T_1 (application of manures and fertilizers as per PoP) and was maximum (23.55) with T_{10} (application of NPK alone).
6. Foliar spray of manganese 100 ppm with recommended manures and fertilizers (T_7) resulted in minimum number of days (84.33) to first harvest.

7. The highest number of fruits per plant (1.47) was obtained from the treatments T_4 (T_1 + Molybdenum 50 ppm) and T_9 (T_1 + Multiplex 100 ppm).

8. The mean yield per plant was highest (2.79 kg) in T_4 (T_1 + Molybdenum 50 ppm).

9. The yield per plot varied from 40.52 kg to 55.05 kg. It was highest in T_2 where 100 ppm boron was applied as foliar spray along with the recommended dose of manures and fertilizers.

10. The highest average fruit weight (2.01 kg) was obtained in T_1 (application of recommended manures and fertilizers).

11. It was seen that there was significant difference among the different treatments for flesh thickness of the fruits. The fruits of treatment T_2 (T_1 + Boron 100 ppm) had maximum flesh thickness (2.74 cm).

12. There was a significant effect on shelf life of pumpkin fruits among the treatments. The shelf life of pumpkin fruits harvested at vegetable maturity varied from 39.33 days (T_{10} – recommended NPK alone) to 61.67 days in T_2 (T_1 + Boron 100 ppm) and T_3 (T_1 + Zn 100 ppm).

13. Foliar application of micronutrients had a significant effect on vitamin C content in pumpkin fruits at vegetable maturity. The Vitamin C content of the fruits at vegetable maturity was highest 3.65 mg $100g^{-1}$ in T_6 (T_1 + Iron 100 ppm).
14. The carotene content of the fruits at vegetable maturity was highest (208.25 $\mu g\ g^{-1}$) in T_6 (T_1 + Iron 100 ppm) and there was a significant difference between the treatments for β-Carotene content.

15. There was significant difference in the available nutrient content in the soil of the experimental field before and after the crop. There was significant increase in available P content after the experiment. The P content was ranged from 80.76 kg ha^{-1} to 292.33 kg ha^{-1}. The available S content was increased from 66.27 kg ha^{-1} (before the experiment) to 103.60 kg ha^{-1} after the experiment. The available content of micronutrients like Fe, Cu, Zn and Mn also increased from 9.93 to 22.33 mg kg^{-1}; 2.35 to 11.90 mg kg^{-1}; 1.98 to 4.66 mg kg^{-1} and 22.5 to 53.13 mg kg^{-1} respectively before and after raising the crop.

16. There was significant and positive correlation between number of days to first female flower and nodes to first female flower and sex ratio. The number of fruits per plant is positively correlated with yield per plant and yield per plot. The carotene content is correlated with shelf life and vitamin C content at vegetable maturity.

17. The P content in plant after the treatment is positively correlated with K content (0.39*) and Cu content (0.44*) in plant after the treatment and to number of days taken for first harvest (0.54**). The K content in Plant after the treatment is positively correlated with days taken for opening of first female flower (0.47**) and number of nodes to first female flower (0.36*).

References

REFERENCES

A.O.A.C. 1970. *Official methods of Analysis.* 11th ed. Association of Official Analytical Chemists, Washington D.C.

Abed, T.A., Sharbash, M.T.M. and Gabal, M.R. 1984. Effect of soaking of seeds in different concentration of Cu, Mn or Zn on cucumber plant (*Cucumis sativus*). *Ann. Agric. Sci.* 21 (3): 837-853.

Ali, M. and Mishra, J.P. 2001. Efect of foliar nutrition of boon and molybdenum on ckickpea. *Indian J. Pulses Res.* 14(1): 41-43

Alla, I.M.A., Abed, T.A. and Shafshak, N.S. 1984. The response of summer sweet pepper plants to micronutrients foliar sprays. *Ann. agric. Sci.* 21 (3): 897-912.

*Almishal, A.J.J., Buhairi, A.G. and Gallum, A.A.A. 1984. Effect of soaking of seeds with some micronutrient on the flowering and fruit yield of squash cv. Eskandarany grown under plastic houses. *Iraqi J. agric. Sci.* 2(4): 59-64.

Arora, S.K., Pandita, M.L. and Pandey, S.C. 1983. Effect of PCPA and micronutrient on the fruit set, early and total yield of tomato variety HS – 102. *Haryana J. hort. Sci.* 12 (3/4): 212-217

Attia, K.K. and El-Dsousky, M.M. 2001. Effect of farmyard manure aplication and late foliar nutrition with nitrogen during the pod filling stage on yield and some nutrients content in seeds of faba bean. *Assiut J. agric. Sci.* 32(2): 277-291

Balasubramaniam, P., Mani, A.K., Duraisamy, P. and Kandaswami. M. 1999. Efect of organic and inorganic nutrients on the yield and uptake of tomato *(Lycopersicon esculentum)* in alfisols. *South Indian Hort.* 46 (3&4): 143-147.

Balayan, D.V. and Dhankar, B.S. 1988. Studies on the effect of nitrogen, phosphorus and zinc on growth and yield of cauliflower. *Haryana agric. Univ.J.Res.* 18(3): 220-223.

Balayan, D.S. and Singh, J. 1994. Effect of nitrogen and zinc on production of cauliflower variety Snowball-16. *Haryana agric. Univ. J. Res.* 24: 88-92.

Balayan, D.S., Dhankar, B.S., Ruhal, D.S. and Singh, K.P. 1988. Growth and yield of cauliflower variety snowball-16 as influenced by nitrogen, phosphorus and zinc. *Haryana J. hort. Sci.* 17 (3-4): 247-254.

*Barcel, J., Gunse, B. and Poschenrider, C. 1986. Chlorophyll and carotenoid content of phaseolus vulgaris L., In relation to mineral nutrition disorder induced by dhromium VI supply. *Photosynthetica.* 20(3): 249-255.

Bhagel, B.S. and Sarnaik, D.A. 1988. Comparative study of soil and foliar application of zinc and boron on growth, yield and quality of onion (*Allium cepa* L.) Cv.Pusa red. *Res. Devel. Rep.* 5(1-2): 76-79.

Bhatt, L. and Srivastava, B.K. 2005. Effect of foliar application of micronutrients on nutrient uptake in tomato. *Veg. Sci.* 32(2): 158-161.

Bhatt, L., Srivastava B.K. and singh, M. P. 2004. Studies on the effect of foliar application of micronutrient on growth, yield and economics of tomato (*Lycopersicon esculentum* mill.). *Progressive Hort.* 36(2): 331-334.

Boliglowa, E. 1996. The influence of foliar nutrition on the content of some micronutrients in potato tubers. *Zeszyty Problemowe Postepow Nauk Rolniczych.* 434(1): 163-168.

Bose, U.S. and Tripathy, S.K. 1996. Effect of micronutrients on growth, yield and quality of tomato cv. Pusa Ruby in M.P. *Crop Res.* 12 (1): 61-64.

*Boyle, J.F. and Smith, C.B. 1985. Growth and leaf elemental composition of snap beans as affected by applied zinc and interacting fertilizer. *Commun. Soil Sci. and Plant Analysis*. 6(5): 501-507.

Brahmachari, V.S. and Kumar, R. 1997. Effect of foliar sprays of mineral nutrients on fruit set, retension and cracking of litchi fruits. *Haryana J. hort. Sci.* 26(3-4): 177-180.

Bray, R.H. and Kurtz, L.T. 1945. Determining total, organic and available forms of phosphate in soils. *Soil Sci.* 59: 39-45.

Cakmak, I. and Marschner, H. 1988.Increase in membrane permeability and exudation in roots of zinc deficient plant. *J. Plant Physiol.* 132(3): 356-361.

Carvajal, M., Frutos, M.J., Gimenez, J.L., Alcaraz, C.F. and Martinez, S.F. 1992. Foliar application of titanium to red capsicum: Influence on the nutrient balance in fruit pericarp. *Sue- lo-y- Planta*. 2(4): 551-562.

Chahil, B.S., Sidhu, B.S. and Tomer, N.S. 1996. Effect of foliar application of zinc and copper on leaf compostion, fruit composition, fruit yield and quality of titron plum (*Prunus salicina* Linn.). *Haryana J. hort. Sci.* 25(3): 116-121.

*Cheng, K.L. and Bray, R.H. 1951. Determination of calcium and magnesium in soils and plant materials. *Soil Sci.* 72: 449-458

Chesnin, L. and Yien, C.R. 1951. Turbidimetric determination of available sulphates. *Proc. Soil Sci.Soc.Am.* 15: 149-151.

Choudhary, D. and Mukherjee. 1999. Effect of boron and zinc concentration on growth and yield of cauliflower (*Bassica oleracea* var *Botrytis* Linn.) Cv. Snowball-16. *Haryana J. hort. Sci.* 28 (1&2): 119-120.

Chowdary, S.K. 1960. Allyl sulphide content of garlic. *Curr. Sci.* 29: 351-352.

Dakshinamoorthy, M. and Krishnamoorthy, K.K. 1989. Studies on the effect of zinc and copper on the yield and quality of brinjal. *Madras agric. J.* 76(6): 345-347

De, N. and Rai, M. 2005. Micronutrient disorders and management in vegetable crops: a review. *Veg. Sci.* 32(1): 1-10.

Devi, D.D., Srinivasan, P.S. and Balakrishnan,K. 1996. Influence of Zn, Fe and Mn on photosynthesis and yield of *Citrus sinensis*. *Indian J. Plant Physiol.* 2(2): 174-176.

Devi, W. I., Singh, P. K. and Devi, G. A. S. 2000. Role of boron, molybdenum and zinc on various nitrogenous fractions of cabbage (*Brassica oleracea* var. capitata L.). *J. Veg. Crop Prod.* 5(2): 45-57.

*Dod, V.N., Kale, PB. and Ranotokar, R.S. 1989. Effect of foliar application of auxins and micronutrient on growth and yield of chilli. *PKV Res. J.* 13(1): 29-33.

Dongre, S.M., Mahorkar, V.K., Joshi, P.S. and Deo, D.D. 2000. Effect of micronutrient spray on the fruit drop and fruit retention of chilli cv. Jayanti. *J. Soils and Crops*. 10(1): 156-157.

Duraisamy, P., Mani, A.K. and Sampath, V. 1990. Effect of foliar feeding of micronutrients on bergamot mint (*Mentha citrata* Ehrh.). *Madras agric. J.* 77(1): 41-43.

Dwivedi, G.K. and Dwivedi, M. 1991, Mode of application of micronutrients to potato in acid soil of garhwal himalaya. *Indian J. Hort.* 48(3):258-263.

Edward and Muhammed, A.K. 1973 Reduction in carbonic anhydrase activity in zinc deficiency leaves of *phaseolus vulgaris* L. *Crop Sci.* 13 (3): 351.

*El-Sherif, A.F., Shata, S.M. and Youssef, R.A. 1990. Effect of rates and method of zinc application on growth and nutrient uptake of tomato plants. *Egypt. J. Hort.* 17(2): 123-129.

El-Beheidi, M., El-Mansi, A.A., Abd –Alla, I.L. and Hewedy, A.M. 1978. Effect of some micro element on the growth and seed yield of cucumber. *Res. Bull*, Faculty of Agriculture Ain Shams Univ. NO.909, 18 PP.

El-Fouly, M. M., Zeinab, M. M. and Zeinab, A. S. 2001. Micronutrient sprays as a tool to increase tolerance of faba bean and wheat plants to salinity. pp.422-423.

*Ghildiyall, M.C., Tomarl, O.P.S. and Sirohil, G.S. 1978. Response of cowpea genotypes to zinc in relation to photosynthesis, nodulation and dry matter distribution. *J. Plant and Soil.* 49(3): 505-516.

Gill, A.S. and Pandey, R.K. 1991. Effect of potassium with micronutrients on yield and uptake of N, P, K in green gram cv. Co. 4. *Madras agric. J.* 78(16): 300-301.

Govindan, K. and Thirumurugan, V. 2000. Response of greengram to foliar nutrition of potassium. *Maharashtra agric. Univ.* 25(3): 302-303.

Govindan, R. 1950. A note on the influence of boron on the yield and ascorbic acid content in the tomato fruit. *Curr. Sci.* 19: 319-320.

Gowda, N.G., Shivaraj, B. and Gowda, A. 1994. Effect of zinc and molybdenum application on yield and uptake of zinc by groundnut. *J. Res. APAU.* 22(1&2): 40-42.

*Guadi, N., Suwandi and Hilman, Y. 1988. The effect of the application of stable manure and different trace elements on garlic. *Bull. Penelition Horticultura.* 16 (4): 5-13.

Gupta, V.K., Raj, H., Gupta, S.P. 1983. A Note on effect of zinc application on the yield and zinc concentration of onion. *Haryana J. hort. Sci.* 12 (1/2): 141-112.

*Guzman, E. and Bornemisza, E. 1983. Phosphorus –Zinc relationships in three acid soils of Costa Rica. II. Element absorption by green house tomatoes. *Turrialba,* 33 (3): 265-270.

Hattab, K.O. and Ramanathan, K.M. 1991. Effect of potassium and zinc on the yield of tomato under varied soil groups of Tamil Nadu. *Madras agric. J.* 78(5-8): 161-164.

Hatwar, G.P., Gondane, s.U. Urkude, S.M. and Gahukar, O.V. 2003. Effect of micronutrients on growth and yield of chilli. *J. Soils and Crops.* 13(1):123-125.

Hazra, P., Maity, T.K. and Mandal, A.R. 1987. Effect of micronutrients on growth and yield of okra (*Abelomoschus esculentus* L.). *Prog. Hort.* 19(3-4): 219-222.

Hemphill, D. D. Jr., Webber, M. S. and Jackson, T. L. 1982. Table beet yield and boron deficiency as influenced by lime, nitrogen and boron. *Soil Sci. Soc. Am. J.* 46: 1190-1192.

Hussain, S.A., Mohammed, S. and Rao, B.V.R. 1989. Response of chilli (*Capsicum annuum* L.) to micronutrients. *Indian J.Agron.* 34(1): 117-118

Hussain, I.S.A., Rao, S.R. and Setty, T.A.S. 1988. Zinc nutrition in French beans. *South Indian Hort.* 36(1-2): 21-26.

Iyengar, B.R.V., Pal, D.K. and Selvaraj, Y. 1979. Zinc anhydrase activity as index of zinc nutrition in cabbage. *Curr. Sci.* 48(19): 867-868.

Jackson, M.L. 1958. *Soil chemical analysis.* Prentice Hall Inc. Eagle wood. Cliffs, N.J., U.S.A. Indian reprint (1973) by Prentice Hall of India (Pvt) Ltd., New Delhi, p.498.

Jana, B.K. 1987. Response of micronutrients on yield and quality of beet root cv. Sutton's Globe. *Veg. Sci.* 14(2): 115-119.

Jana, B.K. and Kabir, J. 1987. Influence of micronutrients on growth and yield of French bean cv. Contender under polyhouse conditions. *Veg. Sci.* 14(2): 124-127.

Jawaharlal, S., Sundarrajan and Veeraragavathatham, D. 1986. Studies on the mode of application of zinc and iron on the growth and yield of onion (*Allium cepa var cepa*). *South Indian Hort.* 34 (4): 236-239.

Kalloo, G. 2006. Strategies for research and development in vegetable crops for sustainable production. *Indian Hort.*51 (3): 2

Kaya, C. and Higgs, D. 2001. The role of zinc in auxin synthesis in the tomato plant. *Am. J. Bot.* 35. (3): 172-179.

Khadr, A.A. 1980. Chelated and unchelated iron and zinc influence on growth and chemical composition of pea seedling grown in soil mixed with calcium carbonate. *Ann. agric. Sci.* 12: 147-156.

Khalate,S.P., Sanghavi, K.U. and Kadam, J.R. 2004. Effect of some micronutrients on seed yield and seed quality of onion (Cv.Basawant-780). *South Indian Hort.* 50(1-3): 248-250.

Kim, S.J., Matsuo, T., Watanabe, M. and Watanabe, Y. 2002. Effect of nitrogen and sulphur application on the glucosinate content in vegetable turnip rape (*Brassica rapa* L.). *Soil Sci. Pl. Nutri.* 48(1): 43-49.

Koenig, H.A. and Johnson, G.R. 1942. Colourimetric determination of phosphorus in biological materials. Ind. Eng.Chem (Anal.). 14: 155-156.

Kolota, E. and Osinska, M. 2000. The effect of foliar nutrition on yield of greenhouse tomatoes and quality of the crop. EUCARPIA TOMATO' 2000. XIV meeting of the EUCARPIA Tomato Working Group, Warsau, Poland, 20-24 August 2000. *Acta Physiologiae Plantarum* 2000. 22(3): 373-376.

Kolota, E. and Osinska, M. 2001. Efficiency of foliar nutrition of field vegetables grown at different nitrogen rates. *Acta Horticulturae*. 563: 87-91.

Krishnasamy, R. and Kothandaraman, G.V. 1991. Effects of P with micromutrients on the yield and uptake of N, P and K in greengram var. CO. 4. *Madras agric. J.* 78(5-8): 300-301.

Krishnasamy, R., Manickam, T.S., Kothandaraman, G.V. and Ramanathan, G. 1991. Influence of P and micronutrients on the yield and uptake of micronutrients in cowpea var.CO. 3. *Madras agric. J.* 78(5-8): 298-299.

Kumar, B. N. A., Halepyati, A.S., Desai, B.K. Koppakar, B.G. and Pujari, B.T. 2002. Response of Indian mustard to foliar nutrition. *Karnataka J. agric. Sci.* 15(3):573-574.

Kumar, M. and Sen, N. L. 2005. Effect of zinc, boron and gibberellic acid on growth and yield of okra (*Abelomoschus esculentus* L.,). *The Orissa J. Hort.* 33(2): 46-48.

Kumar, R., Singh, M. and Singh, A. R. 1996. Effect of foliar nutrition of boron on growth, yield and quality of radish (*Raphanus sativus* Linn.). *Recent Hort.* 3(1): 93-97.

Kumawat, R.N., Rathore, P.S. and Talwar, H.S. 2005. Effect of sulphur and iron on crop growth attributes in summer green gram. *Indian J. Plant Physiol.* 10(1): 86-89.

Lateef, E.M., Ashour, N.I. and Farrag, A.A. 1998. Effect of foliar spray with urea and some micronutrients on mungbean (*Vigna radiata* (L) Wilazek) growth, yield and seed chemical composition. *Bull. Natl. Res. Centre*, Cairo. 23(2a): 219-232.

Lester, G. E. 2004. Foliar applied potassium: effects on cantaloupe quality, sugar content and related compounds. International Congress on Plant Nutrition Proceedings. pp.49-57.

Lester, G.E., Jifon,J.L. and Makus, D.J. 2006. Supplemental foliar potassium application with or without a surfactant can enhance netted muskmelon quality. *Hort. Sci.* 41(3): 741-744.

*Levchenko, L.A., Antrapsteva, N.M. and Scherov, L.N. 1989. The regulating action of binary magnesium - zinc dihydrophsphate for optimizing tomato nutrition in protected cultivation. *Fiziologiya i biokhimiya kul'turnykh Rasteni.* 21(3): 273-278.

Longbottom, M. 2004. Foliar application of molybdenum pre-flowering: effect on yield of merlot. *The Australian & New Zealand Grapegrower and Winemaker.* 491:36-39.

Mallick, F.R.M. and Muthukrishnan, C.R. 1980. Effect of micronutrient on the quality of tomato (*Lycopersicon esculentum* mill.). *Veg. Sci.* 7(1): 6-13.

Mallick, F.R.M.. and Muthukrishnan, C.R. 1980. Effect of micronutrients on tomato (*Lycopersicon esculentum* Mill.) I: effect on growth and development. *South Indian Hort.* 28(1): 121-124.

Mankar, S.M., Deotale, R.D., Wandile, R.m. and Dighe, R.S. 2004. Postharvest studies in mustard as influenced by foliar application of zinc sulphate. *J. Soils and Crops.* 14(1): 83-86.

Maurya, A.N. and Lal, S.S. 1975. Response of onion (*Allium cepa*) to zinc feeding. *Punjab hort. J.*: 61-64.

Maurya, K.R. 1990. Effect of micronutrients on yield and essential oil content of coriander. *Indian Perfume*. 34(4): 263-65.

*Meena, O.S. and Singh, D. 1998. Effect of sulfur and zinc application on onion yield and sulfur and zinc uptake in three soil orders. *J. Indian Soc. Soil Sci.* 46(4): 636-640.

*Mishra, H.P. and Yadav, K. 1989. Relative effectiveness of various micronutrient and their methods of application on seed production of radish (*Raphanus sativus* L.) root crop grown in calcareous soil. *Seed and farms.*15(1): 14-17.

Misra, S.G., Gupta, A.K., Varshney, M.L. and Sharma, K.N. 1984. Effect of napthalein acetic acid and chelated zinc on vitamin c content and yield of cabbage (*Brassica oleracea var. capitata*). *Progressive Hort.* 16(1/2): 92-94.

Mohapatra, A.R. and Kibe, M.M., 1971, Response of tomato to zinc fertilization in a zinc deficient soil of Maharastra. *Indian J. agric Sci.* 41(8): 650-654.

Mondy, N.I., Chandra, S. and Munshi, C.B. 1993. Effect of zinc fertilization on ascorbic acid and mineral concentration of katadhin potato. *J. Food. Sci.* 58(6): 1375-1377.

Moreno, D.A., Villora, G. and Romero, L. 2003. Variations in fruit micronutrient contents associated with fertilization of cucumber with macronutrients. *Scientia Horticulturae* 97: 121-127.

Nagarajan, S.S. and Sundaram, S. S.1961. Studies on micronutrient on crop plants.1. Foliar nutrient studies on brinjal. *Madras agric. J.* 418(2): 22-23.

Nandan, R., Sharma, H.M. and Singh, R.N.P. 1998. Response of late sown chickpea to irrigation and foliar nutrition in calcareous soil. *J. appl. Biol.* 8(2): 5-8.

Neri, D., Lodolini, E.M., Muthuchelian, K., Bonanomi,G. and Zucconi, F. 2002. Physiological responses to several organic compounds applied to primary leaves of cowpea (*Vigna sinensis* L.). *Acta Horticulturae.* 594: 309-314.

Narkhed, T.N., Wadile, S.C., Attarde, D.R., Suryawanshi, R.T. and Deshmukh, A.S. 2001. Integrated nutrient management in rainfed sesamum (*Sesamum indicum* L.) in assured rainfall zone. *J. Soils and Crops.* 11(2): 203-205.

Naruka, I.S. and Gujar, K.D. 1996. Effect of foliar spray of micro- nutrients on growth and yield of okra (*Abelomoschus esculentus* (L.) MONECH) Cv. Pusa Sawani. *Prog.Hort.* 28(3-4): 107-110.

Nowosielski, O. and Bartkowski, K. 1993. Influence of substrate liming and foliar nutrition on tomato yield in tray container technique (TCT). Proceedings of the 8th international congress on soilless culture, Hunters Rest, South Africa, 2-9 Oct. 1992. pp325-333

Osinska, M. and Koota,E. 2002. The effect of foliar applied polycompound fertilizers on yield of iceberg lettuce. *Folia Horticulturae.* 14(1):171-176.

Osinska,M. and Kolota, E. 1998. Utilization of Ekolist in foliar nutrition of field vegetable crops grown at different nitrogen rates. *Folia Universitatis Agriculturae, Stetinensis Agricultura* 1998, No.72: 247-252.

Paithankar, D.H. Sadawarte, K.T., Mahorkar, V.K. and Deo, D.D. 2004. Effect of foliar application of boron and DAP fertilization on quality of tomato (*Lycopersicon esculentum*, Mill.). *J. Soils and Crops.* 14(1): 46-49.

Pal, R.K., Behera, T.K., Sen, N. and Singh, M. 2004. Response of bellpepper cultivars to foliar application of magnesium, boron and zinc. *Veg. Sci.* 31(1): 40-44.

Pandey, U.C., Shula, U.C. and Singh, K. 1974. Effect of zinc and boron on yield and quality of cauliflower (*Brassica oleracea* var Botrytis). *Haryana J. hort. Sci. (3&4): 201-206.*

Pandita, M.L., Arora, S.K. and Singh, K. 1976. Effect of plant regulators on the fruit set, early and total yield of tomato variety HS – 101 (*Lycopersicon esculentum* Mill.) during summer season. *Haryana J. hort. Sci.* 8 (3-4): 112-116.

Patil, K.B. 2004. Effect of micronutrients on growth and yield of okra. *J. soils and Crops.* 14(1): 211-212.

Patnaik, M.C., Raj, G.B., and Reddy, I.P. 2001. Response of tomato to zinc and iron. *Veg. Sci. 28(1): 78-79.*

Pillai and Vadivelu. 1966. Effect of certain micro nutrient combination on growth and yield of chilli under field condition. *Ind. J. Agron.* 12:358-362.

Prakash, V. and Bhardwaj, S.N. 1965. Influence of foliar application of molybdenum and cobalt on growth of cabbage. *Indian J. Hort.* 22(3&4): 349-350.

Prasad, J. 1991. Effect of zinc and copper and rhizobium inoculation on magnesium uptake in greengram (*Phaseolus radiatus*). *Madras agric. J.* 78(5-8): 285-286.

Purakayastha, T.J. and Nad, B.K. 1997. Effect of sulphur, magnesium and molybdenum on mustard (*Brassica juncea* L.) and wheat (*Triticum aestivum*): nitrate nitrogen accumulation and protein yield. *Indian J. Plant Physiol.* 2(2): 110-113.

Purakayastha, T.J. and Nad, B.K. 1998. Effect of sulphur, magnesium and molybdenum on mustard (*Brassica juncea* L.) and wheat (*Triticum aestivum*): yield and uptake of macronutrients. *Indian J. Plant Physiol.* 3(2): 112-115.

Raghav, M and Singh, N.P. 2004. Effect of zinc application on growth and yield of potato. *Progressive Hort.* 36 (1): 135-137.

Raghav, M. and Sharma, R.D. 2003. Growth and yield in tomato-okra –vegetable pea cropping sequence as affected by levels and methods of zinc application. *Progressive Hort.* 35(1): 96-99.

Rai, M. 2006. Research and development in vegetable crops: present status and future strategies. *Indian Hort.* 51 (3): 4-7.

Raj, G.B., Patnaik, M.C., Reddy, I.P. and Rao, A.P. 2001. Response of brinjal to zinc and iron. *Veg. Sci.* 28(1): 80-81

Rajendran, R. 1991. Response of green gram (Co 4) to soil and foliar nutrition. *Madras agric. J.* 78(9-12): 453-457.

Ramesh, K. and Thirumurugan, V. 2001. Effect of seed pelleting and foliar nutrition on growth of soybean. *Madras agric. J.* 88(7/9): 465-468.

Randhawa, K.S. and Bhail, A.S. 1976. Growth, yield and quality of cauliflower (Brassica oleracea Var. botrytis) as influenced by nitrogen, phosphorus and boron. *Indian J. Hort.* 33(1): 83-91.

Rawat, P.S. and Mathpal, K.N. 1984. Effect of micronutrient on yield and sugar metabolism of some of vegetable under humaun hill condition. *Sci. and Culture.* 50(8): 243-244.

Reddy, B.K. and Reddy, N.E. 1986. Effect of plant nutrient on growth and yield of brinjal (*Solanum melongena* L.,). *South Indian Hort.* 34(2): 100-104.

Reddy, S.P., Reddy, R.M.G., Veerarghavaiah, H., Subramanyam and Satyanarayan, D. 1980. Response of tomato to micronutrients. *South Indian.Hort.* 28: 14-20.

Rydz, A. 2001. The effect of foliar nutrition with urea on yield quality of broccoli cv. Lord F1. *Veg. crops res. Bull.* 54(1): 61-64.

Sadashivam, S. and Manickam, A. 1992. *Biochemical methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi and Tamil Nadu Agricultural University, Coimbatore, p.256

Saglam, N., Gebologlu, N., Ylmaz, E. and Brohi, A. 2002. The effects of different plant growth regulators and foliar fertilizers on yield and quality of crisp lettuce, spinach and pole bean. *Acta Horticulturae.* 579:619-623.

Saha, A., Mandal, B.K. and Mukhopadhyay, P.K. 1999. Boron and molybdenum uptake by yellow sarson as influenced by their fertilization in different levels and models. *Indian J. Plant Physiol.* 4(2):114-116.

Sarma, P., Goswami, R.K. and Deka, B.C. 2005. a. Effect of foliar application of micronutrients on yield and quality of cabbage. *Crop Res.* Hisar. 30(1): 68-72.

Sarma, P., Goswami, R.K. and Deka, B.C. 2005. b. Effect of foliar application of micronutrients on shelf life of cabbage. *Indian J. Hort.* 62(2): 160-162.

Sarma, P., Goswami R.K. and Deka, B.C. 2003. Effect of foliar application of micronutrients on growth character of cabbage (*Brassica oleraceae capitata*) under Assam condition. *The Orissa J. Hort.* 31(2): 51-53.

Savithri, P., Boshani, N.K., Manickam, T.S. and Kothandaraman, G.V. 1984. Response of soyabean to micronutrient application. *Madras agric. J.* 71(5): 299-301.

Sharma, C.P. and Sharma, P.N. 1987. Mineral nutrient deficiencies affect plant water relation. *J.plant Nutr.* 10(9/10): 1637-1643

Sharma, S.K. 1999. Effect of boron and calcium on seed production of bell pepper. *Veg. Sci.* 26(1): 87-88.

Sharma, R.K., Thakur, S. and Kumar, R. 1993. A note on the effect of foliar feeding of zinc and GA on fruiting of guava trees (*Psidium guajava* L.). *Haryana J. hort. Sci.* 22(3): 207-208.

Singh, S. and Ahlawat, V.P. 1996. Effect of various concentrations of urea and zinc sulphate on vegetative growth of ber cv. Umran. *Haryana J.hort. Sci.* 25(1): 41-43.

*Silva, S. and Fontana, P. 1979. Interaction between macro element and micro element in the foliar feeding of tomatoes. *Annali della facolta di agrarian.* 19(1): 63-78.

Sims, J.T. and Johnson, G.V. 1991. *Micronutrient Soil Tests. Micronutrient in Agriculture.* 2nd Edn. (Ed. Mortvedt, J.J., Cox, F.R., Shuman, L.M. and Welch, R.M.). SSSA Madison USA, pp.427-472.

Sindhu, S.S., Tiwari, R.S. 1989. Effect of Micronutrient on The growth characters of onion (*Allium cepa.*) Cv. Pusa red. *Haryana J. hort. Sci.*18(1-2): 1 46-149.

Singh, G.P. and Singh, V. 1995. Effect of molybdenum and manganese on their uptake and yield in pea (*Pisum sativum* L.). *Indian J. Plant Physiol.* 38(1): 85-87.

Singh, J. and Dhankar, B.S. 1989. Effect of nitrogen, potash and zinc on growth, yield and quality of onion. *Veg.sci.* 12:136-144.

Singh, J.P., Karmonas, R.E. and Stewart, S.J.W.B. 1988.. The mechanism of phosphorus induced zinc deficiency in bean (*Phaseolus vulgaris* L.). *Can. J. Soil Sci.* 68(2): 345-358.

Singh, M., Batra, V.K., Bhatia, A.K., Singh, V. and Arora, S.K. 2003. Response of foliar application of micronutrients on tomato variety Hisar Arun. *Veg. Sci.* 30(2): 182-184.

Singh, R.S. and Vashishtha, B.B. 1997. Effect of foliar spray of nutrients on fruit drop, yield and quality of ber cv. Seb. *Haryana J. hort. Sci.* 26(1-2): 20-24.

Singh, S.S. and Maurya, A.N. 1979. Anote on the effect of zinc application on the growth, yield and quality of okra. *Haryana J. hort. Sci.* 8(3-4): 258-259.

Singh, S.S. and Verma, S.K. 1991. Influence of potassium, zinc and boron on growth and yield of tomato (*Lycopersicon esculentum* mill.). *Veg. Sci.* 18(2): 122-129

Singh, S.B., Singh, B.N. and Singh, S.S. 1989. Growth and yield of chilli (*Capsicum fruitescense* L.) in relation to zinc levels and number of seedlings / hill. *Haryana J. hort. Sci.* 18(1-2): 113-118

Singh, B. and Kothari, M.L. 1982. Response of some micronutrients, fertilization on the yield of guar grown in non calcareous brown soil of Rajasthan. Transaction of Indian society of desert technology and university center of desert studies. *Hort. Abst.* 54: 868.

*Smagina, V.N. 1970. The effect of microelements on red beet yield. *Refrativnyl zhurnal.* 55: 555-562.

Soliman, M.M., El-oksh, I.I. and El-gizy, S.M.H. 1991. Effect of organic manure, P, Zn and Mo on growth and yield of common bean *Phaseolus vulgaris* L., *Ann. agric. Sci.* 36(2): 589-598.

Srijaya, T. and Sitaramaya, M. 2006. Effect of nutrient management on yield and nutrient content of brinjal grown in an alfisol, Ranga Reddy district, A.P. *J. Soils and Crops.* 16(2): 264-269.

Srinivasan, K. and Ramasamy, M. 1992. Effect of foliar nutrition of urea and diammonium phosphate on rainfed cowpea (*Vigna unguiculata*). *Indian J. Agron.* 37(2): 265-267.

Srivastava, R., Agarwal, A., Tiwari, R. S. and Kumar, S. 2005. Effect of zinc and boron on yield, quality and storability of onion (*Allium cepa* L.). *Progressive Hort.* 37(2): 466-471.

Sudhan N. M. and Shakila, A. 2003. Effect of zinc on growth, flowering and yield of cucumber (*Cucumis sativus* L.). *South Indian Hort.* 51(1-6): 195-198.

Sukhina, Z.D. and Petrosova, L.A. 1986. Effect of some micro elements on marphogenesis and physiological process in cucumber. *Referativenyl zhurnal.* 86-89.

Suryanarayana, V. and Reddy, E.P. 1979. Effect of growth regulants and micronutrients on french bean. *Veg. Sci.* 6: 130-134.

Thalooth, A.T., Yakout, G.M. and Saad, A.O.M. 2001. Response of broad bean (*Vicia faba*) to method of phosphorus application and foliar nutrition of micronutrients. Plant nutrition: food security and sustainabilty of agro ecosystems through basic and applied research. 14th International Plant Nutrition Colloquium, Hannover, Germany. pp 794-795.

Thiyagarajan, T.M., Bakiyavathy, M.R. and Savithri, P. 2003. Nutrient management for pulses - a review. *Agric. Rev.* 24 (1): 40-48.

Thiyageshwari, S. and Ramanathan, G. 2001. Uptake of nutrients as influenced by application of micronutrients and cytozyme to soybean in incepyisol. *J. Soils and Crops.* 11(1):1-6.

Tripathy, S.K., Patra, A.K. and Samui, S.C. 1999. Effect of micronutrients on nodulation, growth, yield and nutrient uptake by groundnut. *Indian J. Plant Physiol.* 4(3):207-209.

Verma, A.N., Ram, K. and Sharma, R.K. 1973. Growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.) as affected by boron in sand culture. *Mysore J. agric. Sci.* 7(1): 130-132.

Verma, S.K., Singh, S.S. and Awasthi, C.P. 1995. Response of zinc and boron fertilization on yield and quality of tomato fruits at different stages of picking. *Veg. Sci.* 22(1): 5-8.

Wali, P. and Sharma, O.N. 1997. Effect of soil and foliar application of zinc on yield and quality in kinnow – a mandarin hybrid. *Haryana J. hort. Sci.* 26(3-4):213-215.

*Walkely, A. and Black, C.A. 1934. An examination of Degtareff methods for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil. Sci.* 39: 29-38

*Watanabe, P.S. and Olsen, S.R. 1965. Test of an acid method for determining phosphate in water and NH_4HCO_3 extracts from soil. *Pro. Soil Sci. Am.* 29: 677-678.

Wilde, S.A., Voigt, G.K. and Iyer, J.G. 1972. *Soil and Plant Analysis for Tree Culture.* 4th ed. (ed. Chesters, G.) Oxford and IBH Publishing Co.pp.111-123.

Williams, C.H. and Steinbergs, A. 1959. Soil sulpher fractions as chemical indices of available sulpher in some Australian soils. *Aust. J. agric. Res.* 10: 340-352.

Williams, C.M.J., Maier, N.A. and Bartlett, L. 2004. Effect of molybdenum foliar sprays on yield, berry size, seed formation and petiolar nutrient composition of Merlot grapevines. *J. Plant Nutr.*27: 1891-1916.

Witek, A. 1999. Foliar nutrition of potato crops. *Problemy Inzynierii Rolniczej.* 7(4):13-18.

Yadav, P.V.S., Tikoo, A. and Sharma, N.K. 2001. Effect of zinc and boron application on growth, flowering and fruiting of tomato (*Lycopersicopn esculentum* Mill). *Haryana J. hort. Sci.* 30(1&2): 105-107.

Yakout, G.M. and Greish, M.H. 2001. Response of faba bean crop to phosphatic, foliar and bionutrition under new reclaimed sandy soil conditions. Plant nutrition: food security and sustainabilty of agro ecosystems through basic and applied research. 14th International Plant Nutrition Colloquium, Hannover, Germany. pp850-851.

Zhang, G.C. and Wu, Z.M. 1983. Absorption and distribution of zinc in relation to light. *Plant phisiologia communications.* No-6: 20-23.

* Originals not seen

Abstract

RESPONSE OF PUMPKIN (*Cucurbita moschata* POIR.) TO FOLIAR APPLICATION OF MICRONUTRIENTS

By

VINESH KUMAR K. V.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2007

ABSTRACT

The study on Response of (*Cucurbita moschata* Poir.) pumpkin to foliar application of micronutrients was carried out at Department of Olericulture, College of Horticulture, Vellanikkara, during September 2006 to January 2007 under field conditions. The experiment was laid out in Randomized Block Design (RBD) with three replications. High yielding variety Saras developed by the Kerala Agricultural University was used for the study.

The investigation revealed that the plants treated with Fe 100ppm by foliar spray along with soil application of recommended manures and fertilizers recorded highest vine length of 4.25m. The maximum number of branches per plant (3.27) was recorded in treatment T_4 which include the soil application of recommended manures and fertilizers along with foliar spray of Mo 50 ppm.

The days to first female flower (61.93) was earliest in foliar spray of Multiplex along with recommended manures and fertilizers. The treatment T_4 which include the soil application of recommended manures and fertilizers along with foliar spray of Mo 50 ppm recorded minimum number of nodes to produce first female flower (21.80). The minimum sex ratio (male: female) (16.19) obtained in treatment where recommended manures and fertilizers were applied in soil.

Among different treatments studied application of recommended manures and fertilizers as per PoP along with foliar spray of Mn 100ppm resulted in minimum number of days (84.33) to first harvest of fruits. Plants treated with Mo 50 ppm and Multiplex 100ppm along with soil application of manures and fertilizers recorded highest number of fruits per plant (1.47). The mean yield per plant was highest (2.79) in treatment T_4. The highest yield per plot (55.05kg) was obtained in foliar spray of B 100ppm followed by foliar spray of Mo 50 ppm. The

highest value 2.01kg for average fruit weight was obtained in soil application of recommended manures and fertilizers as per PoP.

Regarding the flesh thickness B100 ppm foliar spray with soil application of manures and fertilizers recorded highest value of 2.74 cm followed by 2.64 in T_4. The fruits of plants treated with B 100 ppm and Zn 100 ppm along with soil application of manures and fertilizers could be stored for maximum days. For *vitamin C and β-Carotene content in pumpkin fruits harvested at vegetable* maturity, foliar spray of Fe100ppm along soil application of recommended manures and fertilizers recorded highest values of 3.65 mg $100g^{-1}$ and 208.25 μg g^{-1} respectively.

It can be concluded that foliar spray of micronutrients on pumpkin enhanced the growth, yield and quality parameters. The importance of FYM in crop production was also observed between the treatments. Among different treatments T_2 and T_4 was found better for yield when compared with other treatments. The treatments T_6 (T_1 + Iron 100 ppm) was found to be the best for quality parameters like vitamin C and β-Carotene content.

Appendices

Appendix- I.

Weather data of Vellanikkara (2006 September to 2007 January)

Weather parameter	September	October	November	December	January
Relative humidity (%)	84	79	72	57	54
Rain fall (mm)	522.2	323.7	79	0	0
Rainy days	17	11	5	0	0
Sunshine hours	3.9	4.8	6.5	7.8	8.7
Maximum temperature(^{0}C)	29.6	31.0	31.7	31.5	32.5
Minimum temperature(^{0}C)	23.0	23.0	23.7	23.6	22.0