MANAGEMENT Of CALCIUM, MAGNESIUM AND BORON DEFICIENCIY FOR ENHANCING YIELD AND QUALITY IN CHILLI (*Capsicum annuum* L.)

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by

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THESIS

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KERALA, INDIA

2022

DECLARATION

I, hereby declare that this thesis entitled **"Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for award to me any degree, diploma, associate, fellowship or other similar title, of any other University or society.

Anjitha

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CERTIFICATE

Certified that this thesis entitled "**Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)**" is a record of research work done independently by Ms. Anjitha K (2019-11-247) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

Padannakkad
28|04|2022

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We, the undersigned members of the advisory committee of Ms. Anjitha K (2019-11- 247), a candidate for the degree of **Master of Science in Agriculture** with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled **"Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)"** may be submitted by Ms. Anjitha K, in partial fulfilment of the requirement for the degree.

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Anjitha

Dedicated to
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LIST OF ABBREVIATIONS

%	-	per cent
@	-	at the rate of
B	-	Boron
Ca	-	Calcium
$CaCl_2$	-	Calcium chloride
$Ca(NO_3)_2$	-	Calcium nitrate
CD	-	Critical difference
cm	-	Centimetre
Cu	-	Copper
$CuSO_4$	-	Copper Sulphate
DAP	-	Days after planting
$dS\ m^{-1}$	-	Deci Siemens per meter
EC	-	Electrical Conductivity
et al	-	And others
Fe	-	Iron
$FeSO_4$	-	Iron Sulphate
Fig.	-	Figure
FYM	-	Farm Yard Manure
g	-	Gram
g/L	-	Gram per litre
K	-	Potassium
KAU	-	Kerala Agricultural University
Kg	-	Kilogram
$kg\ ha^{-1}$	-	Kilogram per hectare
m	-	Metre
$meq\ 100g^{-1}$	-	Mili-equivalence per 100 gram

Mg	-	Magnesium
mg/ kg	-	Milligram per Kilogram
$MgSO_4$	-	Magnesium Sulphate
ml	-	Millilitre
ml/L	-	Millilitre per Litre
mM	-	Milli molar
Mn	-	Manganese
$MnSO_4$	-	Manganese Sulphate
Mo	-	Molybdenum
MT	-	Million Tonne
N	-	Nitrogen
NAA	-	Naphthalene Acetic Acid
NaOH	-	Sodium hydroxide
$NaCl_2$	-	Sodium chloride
NS	-	Non significant
P	-	Phosphorus
pH	-	Soil reaction
ppm	-	Parts per million
POP	-	Package of Practice Recommendation
RARS	-	Regional Agricultural Research Station
Rs ha^{-1}	-	Rupees per hectare
S	-	Sulphur
SE(m)	-	Standard error mean
T	-	Treatment
t ha^{-1}	-	Tonnes per hectare
TSS	-	Total Soluble Solids
Zn	-	Zinc
$ZnSO_4$	-	Zinc Sulphate

Introduction

1. INTRODUCTION

Chilli (*Capsicum annuum*) is one of the most valuable commercial crops grown in India which belongs to the family solanaceae and introduced to India in 1584 through Portuguese traders. Chilli is known as universal spice of India and it plays an important role in Indian diet. Capsaicin is the principal compound contributing unique pungent taste and capsanthin contributes the red colour. It is highly nutritious, rich in vitamins and are enriched with potassium, magnesium and iron. They boost immune system and lower cholesterol (GO1, 2009).

India is the largest producer, exporter and consumer of chilli. Area under chilli cultivation in India is 316.47 thousand hectares with a production of 3633.99 thousand MT followed by China, Thailand, Ethiopia and Indonesia. In India major chilli producing states are Andra Pradesh, Telangana, Madhya Pradesh, Karnataka and West Bengal (Gade *et al*., 2020). In Kerala, during 2018-19 largest area under chilli production was in Palakkad which accounts 224.89 hectare with a production of 227.589 tonnes followed by Kollam and Thiruvananthapuram (GOK, 2020).

Nutrient management in chilli is very important for enhancing yield and quality. Secondary and micronutrients are necessary for proper plant growth and yield. Among these nutrients calcium, magnesium and boron plays a major role. Calcium is third in abundance in plant tissue (Prasad and Shivay, 2020). It is a multifunctional nutrient in plants required for proper growth and can enhance crop quality also. It has a major role in post harvest quality as it delays senescence by reducing respiration and ethylene synthesis which increases storage life of fruits and vegetables (Gao *et al*., 2019). Magnesium is another important secondary nutrient required for several physiological and biochemical activities in plants including chlorophyll formation, phloem loading, carbohydrate partitioning, photosynthesis and photophosphorylation (Cakmak and Yazici, 2010). Under Kerala condition heavy rainfall and soil acidity aggravates deficiency of calcium and magnesium. Boron is a non metal micronutrient which plays a vital role in cell division and cell elongation and improves growth, yield and quality of crops. It is also involved in defence mechanism of plants through phenol production (Shireen *et al*., 2018).

Secondary and micronutrients are highly essential for crop growth because they are involved in several physiological and biochemical processes in plants. However wide spread deficiencies of secondary nutrients Ca and Mg and micronutrient B have been observed in major crops of Kerala. About 60% of soils were deficient in Ca and 75% soils were deficient in Mg. Boron deficiency accounts around 40% in soil. Calcium deficiency was severe in Onattukara sands and Wayanad Plateau. In case of Mg and B widespread deficiency was reported in many areas. Low boron status in soil also induces calcium deficiency (Rajasekharan *et al*., 2014). High rainfall and soil acidity also aggravate nutrient deficiency. In Kerala 94.7 % soils were acidic (Maji *et al*., 2012). Amelioration of soil acidity has to be given more priority for increasing the crop productivity during cultivation. Liming is the most important practice adopted for ameliorating soil acidity and lime and dolomite are the most popular and commonly used ameliorants. So proper management of these secondary and micronutrients along with soil amelioration is essential for ensuring better crop yield and quality. Low soil pH and resultant problems like availability of nutrients and Fe toxicity are the important yield limiting factors in acid soils (Devi *et al.*, 2017).

Nutrients can be applied through soil or as foliar spray. Foliar application is an effective method since it reduce nutrient loss and rapidly corrects nutrient deficiency. Deficiency occurs not only due to lack of nutrients in soil, but sometimes plants are unable to absorb it from soil which may induce nutrient deficiency. Foliar application is a best alternative to overcome induced deficiency. Source of nutrients and method of application are important factors which decide availability of nutrients in soil. Lime and gypsum are the most widely used calcium sources applied in soil. Gypsum is inexpensive, non toxic and relatively soluble compound supplying around 23% calcium (Walworth, 2012) and magnesium sulphate is a highly soluble source of magnesium. Several studies revealed the positive effect of foliar spray of borax on crop yield and quality.

Chilli being an important vegetable crop which is cultivated throughout Kerala, present study is carried out with following objectives

1. Development of nutrient management practices for mitigating calcium, magnesium and boron deficiencies in chilli

2. To evaluate its effect on growth, yield and quality parameters

Review of Literature

2. REVIEW OF LITERATURE

Chilli is an important vegetable cum spice crop valued for its aroma, taste, flavour and pungency. It is grown largely for its fruit all over India and it has great nutritional value and medicinal properties. India is the world's largest producer, consumer and exporter of chilli and in India it is cultivated mainly in the states of Andra Pradesh, Maharashtra, Gujarat, Tamil Nadu, Karnataka and Orissa. Andra Pradesh is leading in area and production (Gade *et al*., 2020). Nutrient management in chilli gains much importance because of higher nutrient removal and uptake. Balanced nutrition is essential for ensuring higher yield. Secondary and micronutrients are necessary for enhancing yield and quality in crops. Neverthless they are highly deficient in soil. The present investigation was carried out with an aim of effective management of calcium, magnesium and boron deficiency in chilli to enhance yield and quality.

2.1 IMPORTANCE OF SECONDARY AND MICRONUTRIENTS

Secondary nutrients are essential for plant growth, required relatively small amount (Singh, 1996) and micronutrients are also important in plant nutrition which occurs in much lower concentration (Havlin *et al*., 2016).

Calcium, magnesium and sulphur are secondary nutrients. According to Bhaduri *et al*. (2014), dolomite is the major source for supplementing Ca and Mg whereas gypsum, potassium and magnesium sulphate are major source of S.

Micronutrients are required in less quantity but they are highly important for plant growth. They catalyse redox processes, form enzyme-substrate complexes and enhance enzyme reactions by influencing the molecular configuration of an enzyme or substrate. There are 6 metal micronutrients such as Fe, Mn, Zn, Cu, Mo, Ni and 2 non metal nutrients B and Cl (Romheld and Marschner, 1991).

Gupta *et al.* (2008) reported that in most of the soil total quantity of micronutrients is not an indicator of its potential availability to plants. Only a small portion is available to plants even if they are present in higher concentration.

2.1.1 Calcium

Calcium is the fifth most abundant mineral in the earth crust and contributes to 3.64% of earth crust (Mengel and Kirkby, 1982).

Bache (1984) reported that Ca is generally present in higher quantity than any of the other cations both in the cation exchange site and also in the soil solution.

Calcium plays several important roles in plants. It is a constituent of cell wall and membrane. It acts as a counter cation for inorganic and organic anion in the vacuole and as an intracellular messenger in the cytosol (Marschner,1995).

Calcium is one of the most important secondary nutrient, required for the growth and strength of the plants. Lack of Ca leads to a general breakdown of cell membrane structures and results in flower and fruit drop (Jadhav *et al*., 2019).

Mc Laughlinl and Wimmer (1999) reported that Ca plays an important regulatory role in several processes such as phosphorylation of nuclear proteins, cell division, cell wall and membrane synthesis, intra and intercellular signaling, stomatal regulation and carbohydrate metabolism.

Calcium interacts with pectic acid in the cell walls to form calcium pectate and thereby helps in maintaining the cell wall structure of fruits (Poovaiah, 1986).

Calcium is involved in the defence mechanism of plants through imparting disease resistance in plants. Cell wall became more resistant to the action of pectolytic enzyme produced by pathogens. Calcium forming cross bridges between adjacent pectic acid or between pectic acid and other polysaccharides and become more resistant to pathogens (Conway *et al*., 1994).

Volpin and Elad (1991) reported that Ca is an important nutrient in plant disease resistance. Increased calcium content in plant tissue inhibits some diseases in plants.

2.1.2 Magnesium

Magnesium is a constituent of many minerals, contributing 2 per cent of the Earth's crust. Primary and secondary minerals are important sources of Mg for plant nutrition. Magnesium is located both in clay minerals and associated with cation exchange sites on clay surfaces (Mikkelsen, 2010).

Magnesium (Mg) is the eighth most abundant element in the Earth's crust, and also the second most abundant cation in plant (Chen *et al*., 2017).

According to Rajasekharan *et al.* (2014), highly weathered tropical soils are deficient in Mg and 75% of soils are deficient in Mg indicating wide spread deficiency in Kerala soil.

Magnesium plays an important role in alleviating Al toxicity in acid soil. Cakmak and Yazici, (2010) reported that plants growing in acid soils has ability to release organic acid anions from roots. Organic anion released from roots will chelate toxic Al ions and Mg is necessary for effective release of organic anions from roots (Yang *et al*., 2007).

Magnesium is a primary constituent of chlorophyll and accounts for 15 to 20 per cent of the total Mg content of plants (Bybordi and Shabanov, 2010).

Magnesium serves as a structural component in ribosome and it is required for enhancing the activity of phosphorylating enzymes involved in carbohydrate metabolism (Havlin *et al*., 2016). It is also involved in photosynthesis, protein synthesis, phloem loading, partitioning and utilization of photo assimilates, generation of reactive oxygen species and photo oxidation in leaf tissue (Cakmak and Yazici, 2010).

Magnesium plays a role in plant disease resistance which may be direct effect on plant health or indirect effect on various physiological process. As a constituent of middle lamella Mg impart resistance to cell wall degradation by various pathogens. Increased Mg content in plant provide resistance to tissue against degradation by pectolytic enzyme (Huber and Jones, 2012).

2.1.3 Sulphur

Sulphur is an essential macronutrient necessary for plant growth which is recognised as 4th major plant nutrient after N, P and K (Zenda *et al*., 2021).

Sulphur plays several roles in plants. It is a constituent of S containing amino acids and involved in chlorophyll synthesis, synthesis of oil in oil seeds and activates several enzymes (Rai *et al*., 2020).

Rajasekharan *et al.* (2014) reported that available S is sufficient in Kerala soil and deficiency noticed only in coastal sandy soils.

2.1.4 Iron

Iron is an essential micronutrient playing a vital role in respiration and photosynthesis. It is involved in chlorophyll synthesis and necessary for maintenance of chloroplast structure and function. Approximately 50 per cent Fe is present in photosynthetic cells (Rout and Sahoo, 2015).

In soil greatest part of the Fe is present in crystal lattices of numerous minerals. Primary source of iron in soil is ferromagnesium silicates (Mengal and Kirby, 2001).

Iron is involved in oxidation reduction reactions of respiration and photosynthesis as it is a structural component of porphyrin molecules cytochrome, hemes, hematin, ferrichrome and leg haemoglobin (Borlotti *et al*., 2012).

2.1.5 Manganese

Manganese content in Indian soil varies from 37 to 11500 mg $kg^{-1}$and highest in arid and semi-arid areas. Water soluble and exchangeable Mn is around 5 to 20 mg kg^{-1}, about 3 per cent of total Mn in soil (Tandon, 2003).

Manganese plays several vital roles in plants. It is involved in photosynthesis as a structural component in water splitting protein and it is a part of an antioxidant, superoxide dismutase which protects cell from free radicle (Mousavi *et al*., 2011). It activates several important metabolic processes, accelerates germination and maturity and increasing the availability of phosphorus and calcium. It is involved in root growth, fruit development and imparts disease resistance (Sidhu *et al*., 2019).

2.1.6 Zinc

Zinc is an important micronutrient playing several vital roles in plants. It is an important component of different enzymes catalysing many metabolic processes. It is involved in plant defence mechanism, photosynthesis, cell membrane integrity, protein synthesis and pollen formation (Rudani *et al*., 2018). It also promotes starch formation, seed maturation, enhances seed viability and seedling vigour. It is necessary for various enzymatic activities and is involved in sulphur and nitrogen metabolism (Pandav *et al*., 2016).

According to Tandon (2003), Zn is highly deficient in Indian soil. Total Zn in Indian soil varies from 2 to 1600 mg kg^{-1} and plant available Zn is around 1.5 per cent of total zinc.

2.1.7 Copper

In soil Cu occurs as divalent cation and largest fraction is present in the crystal lattice of primary and secondary minerals. Copper content in soil ranges from 2 to 100 mg kg^{-1} (Das, 2000).

Copper nutrient plays a vital role in the growth and development of plants and it is involved in variety of processes such as respiration, photosynthesis and detoxification of superoxide radicals (Harris and Lavanya, 2016). It also participates in lignin formation, protein and carbohydrate metabolism and sometimes in symbiotic nitrogen fixation (Tandon, 2003).

2.1.8 Boron

Boron is an important micronutrient required for plant growth. In soil B is distributed in various components like organic matter, soil solution and minerals. B in soil solution is easily available to plants but it constitutes only small fraction less than 3 per cent of total soil boron (Jin *et al*., 1987).

Boron is a unique non metal micronutrient required for normal growth, development and optimum yield of crops. Ahmed *et al.* (2009) reported that yield in boron deficient soil can be increased with B application at proper time, rate and method and also by maintaining proper balance with other nutrients.

Boron is the second most deficient micronutrient in soil after Zn. Its deficiency was reported in more than 80 countries and on 132 crops over last 60 years (Shorrocks, 1997).

In India, about one third of the cultivated soils are deficient in boron. The total boron content in Indian soils varied from 7 to 630 mg kg^{-1} and available boron content ranged from 0.75 to 8.0 mg kg^{-1} of soil (Prasad *et al*., 2014).

Availability of B in soil is mainly determined by factors such as pH, soil texture, moisture content, temperature and presence of other ions (Goldberg, 1997).

According to Jokanovic (2020), cell wall synthesis and maintaining its structure and integrity is the primary function of B in plants.

Boron is highly essential for plants which is involved in various metabolic processes such as cell wall synthesis, lignification, carbohydrate metabolism and phenol metabolism (Marshner, 2012).

Adequate B in plants increases flower production, retention, fruit set and seed development. It is required for pollen tube growth, transport of water, nutrients and sugars to growing meristematic tissue. It is also needed for normal development of legume root nodules (Havlin *et al*., 2016).

2.2 EFFECT OF SECONDARY AND MICRONUTRIENTS IN GROWTH AND YIELD PARAMETERS OF VEGETABLES

Combined foliar application of Mg and B had a significant effect on growth and fruit yield in chilli. Foliar application of magnesium and boron at the rate of 100 ppm resulted increased plant height, number branches, number of flowers, number of fruits and fruit weight in chilli (Harris *et al*., 2018).

Boron nutrition had a significant effect on flowering and fruit set. Suganiya and Kumuthini, (2014) reported that application of 150 ppm boric acid showed positive response to number of flower buds, flowers per cluster, percentage of flower set, number of fruits and fruit set percentage in ratoon crop of brinjal.

Foliar application of boron at the rate of 6 ppm resulted minimum days to 50 per cent flowering in female and male flowers of bitter gourd (Gedam *et al*., 1998).

Pandav *et al*. (2016) reported that fruit parameters such as fruit length, fruit diameter and fruit weight was improved significantly with application of borax in egg plant.

Calcium nutrition has a positive effect on bulb yield and quality of onion. Ghoname *et al.* (2007) reported that soil application of $Ca(NO_3)_2$ gave highest yield, bulb weight and TSS content. It also concluded that soil application of calcium had an effect on reducing flaking of onion bulb during storage but there is no significant effect while foliar application.

An experiment was carried out to study the interactive effect of calcium and magnesium in tomato and result revealed that there is a significant effect on growth and yield of tomato. Application of 0.3 percent calcium and 0.08 percent magnesium increases plant height, number of flowers, number of fruit and total yield in tomato (Ilyas *et al*., 2016).

Application of B had a significant effect on growth, nutrient uptake and quality of tomato. Davis *et al.* (2003) reported that application of B increased plant growth, total yield and uptake of nutrients like N, K, Ca and B in tomato. It also improved shelf life and fruit firmness.

Naz *et al*. (2012) reported that application of B at the rate of 2 kg per ha increased number of flower cluster, fruit set percentage, total yield and decreased weight loss in tomato.

Kumar (2011) reported that sulphur application showed significant positive response in garden pea. Application of S at the rate of 40 kg per ha resulted increased plant height, number of leaves, number of branches and number of nodules in garden pea.

An experiment was carried out to study the effect of nitrogen levels and boron on growth, yield and quality of radish. Application of nitrogen along with boron resulted increased root length, root shoot ratio, root yield, ascorbic acid content and TSS in radish (Rampal *et al*., 2019).

Foliar application of 0.2 percent borax or in combination with Zn resulted increased plant height, number of fruits per plant, fruit length and improved seed quality in okra (Rahman *et al*., 2020).

An investigation was carried out to study effect of different levels of nitrogen and sulphur on the growth, yield and quality of cabbage and result revealed that application of S at the rate of 60 kg per ha significantly improved width of head, length of head, dry weight of leaves and yield (Verma and Nawange, 2015).

Petchhong and Khurnpoon (2017) reported that a commercial formulation named Magic, contain calcium-boron solution applied at the rate of 0.5 per cent significantly increased fruit setting percentage, number of fruit per plant, fruit firmness and ascorbic acid content in cherry tomato.

According to Usha *et al.* (2019), sulphur had significant effect on growth and yield contributing characters of French bean. Increased plant height, number of pods, number of seeds per pods, length of pod and grain yield was obtained from the application of S at the rate of 15 kg per ha.

Combined application of P at the rate of 30 kg per ha and S at the rate 20 kg per ha resulted maximum number of seeds, test weight and grain yield in soyabean (Akter *et al*., 2013).

Application of B at the rate of 0.6 kg per ha increased plant height, fruit weight and total fruit yield in tomato (Haque *et al*., 2011).

Combined application of Ca and B recorded superior effect on growth, yield and quality parameters of tomato over single application of these nutrients. Application of 0.6 per cent $CaCl_2$ along with 0.2 per cent borax resulted increased plant height, number of branches, number of flower and fruit per plant, fruit weight, fruit firmness and TSS content when compared to single application of $CaCl_2$ and borax (Rab and Haq, 2012).

An experiment was carried out to study the effect of Ca, B and Zn foliar application on growth and fruit production in tomato. Result revealed that calcium boron interaction had significant effect on plant height. Maximum plant height (95.33cm) was recorded with foliar application of 0.6 per cent $CaCl_2$ and 0.25 per cent boric acid (Haleema *et al.*, 2018).

Calcium is a constituent of cell wall and has a role in cell lengthening of root and shoot. So, Ca treatment had a significant effect on plant height. Sajid *et al.* (2020) reported that application of $CaCl_2$ in tomato increased plant height. Increasing calcium level from 0 to 1.5 per cent, increased plant height from 90 cm to 97.53cm.

Hassan *et al.* (2018) observed that there is a positive correlation between B treatment and plant height in cauliflower. Application of B at the rate of 2 kg per ha resulted increased plant height.

An experiment was done to study the effect of boron on growth, quality and fruit yield of tomato. Result revealed that highest plant height was recorded with application of borax at the rate of 20 kg per ha at vegetative, flowering and harvesting stage (Sathya *et al.*, 2010).

Micronutrients, B and Mo play a major role in better production of broccoli. An experiment was carried out to study the effect of B and Mo on growth, yield and quality of broccoli. Result revealed that application of borax at the rate of 18 kg per ha and ammonium molybdate at the rate of 1.8 kg per ha recorded maximum head diameter, head weight, number of sprouts and head and sprout yield in broccoli (Thapa *et al*., 2016).

Davis *et al.* (2003) concluded that soil or foliar applied boron improved fruit set, total yield, firmness, shelf life and plant uptake of nutrients in fresh market tomato.

El-Tohamy *et al*. (2009) reported that foliar application of micronutrients such as Fe, Mn and Zn significantly improved vegetative and yield parameters in onion. Increased plant height, number of leaves, bulb diameter, fresh weight of bulb and total yield was obtained.

Combined application of Ca and B in cucumber resulted maximum plant height, stem diameter, number of leaves, number of nodes per plant, number of pickings, number of fruits per plant and total yield compared to all other treatments (Yadav *et al*., 2020).

2.3 EFFECT OF SECONDARY AND MICRONUTRIENTS ON QUALITY PARAMETERS OF VEGETABLES

Calcium treatment increases shelf life of fruit and vegetables. Diana *et al.* (2006) reported that lettuce treated with calcium lactate reduced weight loss during storage and maintained crispiness.

Swetha *et al.* (2018) reported that increased availability of micronutrients mainly B and Zn enhanced fruit quality in tomato.

Karthick *et al*. (2018) reported that foliar spray of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ at a concentration of 0.5 per cent along with 0.1 per cent $CuSO_4$ and 0.3 percent boric acid at two times interval recorded highest TSS, ascorbic acid and iron content in bitter gourd.

Calcium treatment has a significant effect on shelf life, physiological weight loss and total soluble salt content of tomato. Tomato fruits treated with 1 per cent $CaCl_2$ extended shelf life of tomato and minimize the physiological weight loss by making the membrane strong and rigid. Increased storage period resulted higher TSS content in tomato (Bhattarai and Gautam, 2006).

According to Panda *et al.* (2019), application of B at the rate of 1.5 kg per ha every year significantly improved firmness, ascorbic acid content, dry matter content, TSS and shelf life of knol khol.

A study was carried out to know the quality of tomato as influenced by B and Zn under different levels of NPK fertilizers. Results revealed that combined application of B at the rate of 2.5 kg per ha and Zn at the rate of 6 kg per ha increased TSS, acidity, ascorbic acid and lycopene content in tomato (Salam *et al*., 2010).

An experiment was conducted to study the effect of Mg nutrition in onion and results found that there is a positive effect on yield and quality. Soil application of Mg resulted increased nutrient content in leaves and bulb, chlorophyll, ascorbic acid and soluble sugars (Kleiber *et al*., 2012).

An experiment was done to study the effects of NAA and $CaCl_2$ application on nutrient uptake, growth, yield and post-harvest performance of tomato fruit. The results obtained showed that application of 1 per cent $CaCl_2$ in combination with 0.02 per cent NAA recorded increased ascorbic acid content, shelf life and reduced weight loss (Abbassi *et al*., 2013).

In tomato, maximum vegetative growth along with increased firmness, reduced weight loss, fruit cracking and physiological disorders were reported with combined application of Ca at the rate of 30 kg per ha and B at the rate of 10 kg per ha along with recommended dose of fertilizers (Kumar *et al*., 2020).

Gonzales and Quevedo (2017) studied about respiration rate and shelf life of radish (*Raphanus sativus* L.) as influenced by postharvest application of $Ca(NO_3)_2$ and humic acid concentration. Results revealed that application of 0.6 per cent $Ca(NO_3)_2$ or combined application of 0.6 per cent $Ca(NO_3)_2$ and 0.6 per cent humic acid significantly increased shelf life of radish.

Naveena and Immanuel (2017) reported that pre-treatment of cucumber with $CaCl_2$ and $NaCl_2$ resulted promising effect on shelf life and weight loss. $CaCl_2$ treated cucumber with a steeping time of 5 min and 10 min recorded maximum shelf life of about 19 and 22 days respectively and minimum weight loss when compared to control.

Islam *et al.* (2016) conducted an experiment to study the cherry tomato quality affected by foliar spraying of Ca and B. Result revealed that treated fruits showed superior quality over the control. Tomato treated with Ca + B had increased firmness, vitamin C content, shelf life and reduced weight loss.

Khan *et al*. (2018) reported that application of S at the rate of 45 kg per ha and gypsum as a source resulted best quality of cauliflower compared to other sources. Highest ascorbic acid content, crude protein and reduced free N content was recorded.

Tomato dipped in 2 per cent $CaCl_2$ recorded superior result on firmness, ascorbic acid, lycopene content, shelf life and physiological weight loss over control (Gharezi *et al*., 2012).

An investigation was carried out to study the effect of S on growth, yield and quality of garlic and results revealed that application of gypsum at the rate of 45 kg per ha recorded maximum TSS content, pyruvic acid and shelf life in garlic (Chattoo *et al.*, 2018).

Nasef (2019) reported that 1 per cent $CaCl_2$ in combination with short hot water treatment in cucumber considerably reduced weight loss during storage and improved quality and shelf life.

According to Pramanik *et al.* (2018), application of micronutrients had a positive impact on better bulb quality in onion. Maximum TSS content, ascorbic acid, total protein and total sugar was recorded from foliar application of micronutrient mixture at the rate of 0.5 per cent at two times interval.

2.4 EFFECT OF SECONDARY AND MICRONUTRIENTS ON PEST AND DISEASE INCIDENCE IN VEGETABLES

Application of gypsum at the rate of 50 kg per ha as basal dose and two weeks after planting significantly reduced anthracnose and bacterial bulb rot in onion (Fernando *et al.*, 2021).

There is a positive correlation between calcium content and soft rot incidence in potato tuber. Khlaif and wreikat (2018) reported that bacterial soft rot in potato was reduced from an initial 43 per cent to 4 per cent with calcium fertilizer within 3 years. Highest rotting percentage was reported in tubers with low calcium content.

A study conducted by Elad and Violpin (1993) concluded that application of 1Mm $CaCl_2$ or 3Mm $Ca(NO_3)_2$ in bean and single soil application of $Ca(NO_3)_2$ or $CaSO_4$ in tomato significantly reduced the severity of grey mould and ghost spot incidence.

Low soil pH has a significant effect on disease incidence. Addition gypsum as a soil ameliorant reduced scab incidence in potato. Lambert and Manzer (1991) reported that tuber calcium content in potato increased more substantially while using gypsum than lime.

A study was conducted to know the effect of Ca amendments on phenolic compounds and soft rot resistance in potato. Result showed that antimicrobial compounds present in potato such as chlorogenic acid and caffeic were increased in the presence of Ca and also the enzymatic activity of peroxidase, poly phenol oxidase and phenylalanine ammonia lyase which were involved in plant defense mechanism (Ngadzea *et al*., 2014).

Application of $Ca(NO_3)_2$ at the rate of 0.3 g/L through foliar spray or soil drenching effectively control soft rot disease in chineese cabbage (Felix *et al*., 2015).

Jiang *et al*. (2013) conducted an experiment to study the effect of Ca nutrition on resistance of tomato against bacterial wilt disease. Results revealed that Ca nutrition considerably reduced bacterial wilt in tomato. Increased Ca content in root and shoot tissue resulted from Ca nutrition improved rate of accumulation of H_2O_2 and increased activity of peroxidase and polyphenol oxidase in plant, there by reduced disease severity in tomato.

2.5 EFFECT OF SECONDARY AND MICRONUTRIENTS IN NUTRIENT CONTENT IN VEGETABLES

Turkmen *et al.* (2004) reported that application of Ca at the rate of 100 and 200 mg kg^{-1} significantly affected N, Ca and S content in shoot and K content in root of tomato seedling under salinity.

According to Dong *et al.* (2005), foliar application and root application of Ca markedly increased fruit Ca and decreased the concentrations of K, Mg, P and several micronutrients in the fruit of tomato.

Application of $ZnSO_4$ at the rate of 40 kg per ha in vegetable pea significantly increased Zn and N content in grain and plant (Kumar and Sharma, 2015).

2.6. EFFECT OF RATE OF APPLICATION OF SECONDARY AND MICRONUTRIENTS

Gypsum is an emerging fertilizer material and is not only important as a source of calcium and sulphur, also improves soil structure. Soils with high subsoil acidity, gypsum application helps in eliminating toxicity associated with exchangeable aluminium (Batte and Forster, 2015).

Ain *et al.* (2016) found that foliar application of borax at the rate of 0.25 % in broccoli significantly increased plant height when compared to 0.5 % and 1 % concentrations.

According to Uddin *et al.* (2021), application of different doses of gypsum had significant effect on growth and yield of kohlrabi. Maximum plant height, knob length, root length and yield were recorded with application of gypsum at the rate of 150 kg ha^{-1} when compared to 100 kg ha^{-1} and 125 kg ha^{-1} concentrations.

Application of gypsum and boron significantly influenced the nutrient concentration in haulm and tuber of potato. Combined application of gypsum at the rate of 150 kg ha^{-1} and foliar application of borax at the rate of 0.5 % showed significantly higher content of calcium, magnesium, sulphur and boron and also uptake of these nutrients (Shirur *et al.*, 2021).

2.7. EFFECT OF SECONDARY AND MICRONUTRIENTS IN CHILLI

2.7.1 Growth characters

2.7.1.1 Plant height

Combined application of Mg and B had significant effect on growth parameters of chilli. An experiment was carried out to study the effect of foliar application of Mg and B in growth and yield of chilli and result revealed that combined application of boric acid and $MgSO_4$ at the rate of 100 ppm increased plant height, number of branches and leaves in chilli (Harris *et al*., 2018).

Salim *et al.* (2019) reported that foliar application of $CaCl_2$ and boric acid individually and in combination significantly increased plant height in chilli.

Foliar feeding of Ca sources significantly improved vegetative growth components in chilli. Among the various Ca sources, Ca complex with B recorded maximum plant height in both season (Swelam and El-Basir, 2021).

2.7.1.2 Root Characteristics

Azam *et al.* (2016) carried out an experiment to assess the effect of foliar application of micro-nutrient and soil condition on growth and yield of sweet pepper (*Capsicum annuum* L.). and results revealed that foliar application of $CaCl_2$ increased root length in pepper. Maximum root length was recorded with foliar application of 10mM $CaCl_2$ when compared to control.

2.7.1.3 Days to 50% flowering

Micronutrient, B and Zn has significant effect on growth of chilli. Kumar *et al*. (2020) concluded that there is a positive correlation between flowering and boron treatment in chilli. Treatment which contains foliar application of 0.25 per cent borax recorded minimum days to flowering.

Devi *et al.* (2013) conducted an experiment to study the effect of foliar feeding of micronutrients on growth and yield of chilli and results revealed that application of 0.2 per cent boric acid recorded minimum days to 50% flowering.

Kadam (2006) conducted an experiment to study the effect of plant growth regulators and micronutrients on growth and yield of chilli during summer season and results revealed that treatment application of 0.5 per cent $ZnSO_4$ recorded least number of days to 50% flowering compared to control.

2.7.1.4 Total dry matter production

An experiment was carried out to study the response of hot pepper to interactive effect of salinity and B. Results showed a negative correlation between plant dry matter production and B content under salinity. As the B content increases, dry matter of plants get decreased (Supanjani and Lee, 2006).

Nabi *et al.* (2006) reported that application of low levels of B increased dry matter yield of sweet pepper. Application of 2 mg kg^{-1} B in soil resulted 54 per cent increase in dry matter production over control.

Total dry matter yield of plant was positively responded to boron. Application of B at the rate of 0.5 kg ha^{-1} along with vermicompost recorded highest dry matter yield in chilli (Nawrin *et al.*, 2020).

2.7.2 Yield parameters

Dursun *et al.* (2010) studied the effect of boron fertilizers on tomato, pepper and cucumber yield and chemical composition and revealed that boron application had a significant effect on yield. Application of B at the rate of 2 kg per ha recorded maximum yield in pepper, tomato and cucumber.

An experiment conducted by Salim *et al*. (2019) reported that application of $CaCl_2$ and boric acid individually or in combination resulted highest fruit weight, number of fruit per plant, fruit yield per plant and total fruit yield in pepper compared to control.

An investigation was carried out to study the response of chilli to Zn and B application and result revealed that single or combined application of these nutrients had a positive impact on yield components of chilli. Application of borax at the rate of 1 kg per ha increased fruit yield, fruit breadth and fresh fruit weight (Shil *et al*., 2013).

Singh and Sharma (2019) carried out an investigation to study the effect of micronutrients and bio inoculants (*Trichoderma viride* and PGPR) on yield parameters of chilli (*Capsicum annum L*.) and observed that application of $ZnSO_4$ at the rate of 0.2 per cent recorded maximum fruit yield per ha followed by borax at the rate of 0.1per cent.

Foliar feeding of chilli with 0.6 per cent boric acid considerably increased number of fruits per plant, fruit weight per plant, fresh weight of individual fruits and total yield compared to other treatments (Devi *et al*., 2013).

Dongre *et al.* (2000) reported that in a field experiment highest yield was recorded with application 0.5 per cent $ZnSO_4$ followed by 0.5 per cent boric acid and highest fruit length was recorded with 0.1 percent boric acid in chilli.

Application of secondary nutrients calcium, magnesium and sulfur each at the rate of 25 kg per ha resulted maximum dry fruit yield, chilli (Kurubetta *et al.*, 2021).

Zeist *et al.* (2018) reported that B alone or in combination with Ca significantly increased photosynthetic yield and yield of marketable bell pepper.

2.7.3 Quality parameters

2.7.3.1 Ascorbic acid

Calcium and boron had a positive correlation with ascorbic acid content in fruits. Foliar application of 2000 ppm $CaCl_2$ and 400 ppm boric acid recorded highest vitamin C content in pepper (Salim *et al*., 2019).

Ascorbic acid is one of the important nutritious compounds related to quality of sweet pepper (Iqbal *et al*., 2004). A study done by Buczkowska *et al*. (2016) concluded that Ca had a positive effect on ascorbic acid content in chilli. Application of calcium nitrate resulted about 27 per cent increase in ascorbic acid content when compared to control.

Michaaoju and Dzida (2012) found out that Ca treatment had a positive effect on ascorbic acid content in pepper. Results stated that higher Ca concentration enhanced vitamin C content which might be due to stimulation of ascorbic acid synthesis by Ca.

An experiment was carried out on a topic of pre-harvest $CaCl_2$ and GA_3 treatments improve postharvest quality of green bell peppers (*Capsicum annum* L.) during storage period and result showed that treatments contain $CaCl_2$ and GA_3 significantly increased ascorbic acid content over the control (Bagnazari *et al*., 2018).

Pre-harvest foliar application of Ca and ascorbic acid in sweet pepper improved quality attributes such as vitamin C, firmness and antioxidant activity (Mahsa *et al*., 2019).

2.7.3.2 Oleoresin

Calcium treatment had a significant effect on chilli oleoresin content. Jadhav *et al.* (2020) reported that treatment which contain three times sprays of $Ca(NO_3)_2$ at the rate of 1.5 per cent recorded highest oleoresin content in chilli.

Malik *et al.* (2020) claimed that Ca and B content had influence on chilli oleoresin. In an experiment, highest oleoresin was recorded in a treatment which contain combined application of $Ca(NO_3)_2$ and $FeSO_4$ at the rate of 0.2 per cent and borax at the rate of 0.1 per cent.

According to Malawadi (2003), oleoresin content in chilli was highly affected by secondary and micronutrients. Combined application of Ca, S and Fe along with NPK recorded highest oleoresin content in the experiment.

2.7.3.3 Capsaicin

B has an effect on formation of capsaicin. B stimulates formation of phenyl alamine which is a component of capsaicin compound (Sardar, 1983).

An investigation was carried out to study the effect of secondary nutrients on yield, quality and economics of dry chilli and effect of treatments on capsaicin content was found non significant. Highest capsaicin was recorded in treatment contain application Ca, Mg and S at the rate of 25 kg per ha (Kurubetta *et al*., 2021).

Boron treatment showed positive effect on capsaicin content in chilli. Treatments with application of B or combined application of B and humic acid resulted increased capsaicin content compared to control (Manas *et al*., 2014).

Silva *et al*. (2021) reported capsaicin and dihydrocapsaicin content in chilli was reduced under N and S deficiency, because S had a role in its biosynthesis pathway as a constituent of acetyl COA molecules.

2.7.3.4 Shelf life

A study was carried out to assess the effect of postharvest treatments and storage temperatures on the quality and shelf life of sweet pepper. Result revealed that longer shelf life (30.27 days) was recorded in treatment T_6 which contain fruit dipping in $CaCl_2$ at a concentration of 1.5 per cent for 15 minutes (Rao *et al.*, 2011).

Bagnazari *et al.* (2018) stated that pre harvest treatment of green bell pepper with calcium and gibberellin improved shelf life of fruit.

Toivonen *et al*. (1999), studied the effect of pre harvest foliar sprays of Ca on quality and shelf life of two cultivars of sweet bell peppers (*Capsicum annuum* L.) grown in plasticulture and result obtained was Ca treatment increased firmness and reduced post-harvest decay.

2.7.4 Nutrient content in plants

An experiment was conducted to study the effect of humic acid and $Ca(NO_3)_2$ on nutrient contents in pepper (*Capsicum annuum*) seedling under salt stress and results revealed that $Ca(NO_3)_2$ significantly increased nutrient content in plant compared to control except Mn and Zn (Sonmez and Gulser, 2016).

Dursun *et al.* (2010) reported that B fertilization significantly increased shoot and leaf tissue concentration of P, K, Fe, Zn, Mn, Cu and B and decreased N, Ca and Mg in tomato, pepper and cucumber.

Leaf nutrient concentration in chilli was positively responded to foliar application of calcium chloride and boric acid which significantly increased N, P and K content (Salim *et al*., 2019).

Nawrin *et al*. (2020) reported that application of 0.5 kg B per ha along with vermicompost recorded maximum amount of macro and micro nutrient in chilli fruit.

Foliar application of $Ca(NO_3)_2$ increased the concentration of Ca and N in leaves of chilli and uptake of K by plant roots (Jadhav *et al*., 2019).

2.7.5 Disease resistance

Le, (2014) reported that Ca and B nutrition significantly reduced grey mould in capsicum. Soil application of $Ca(NO_3)_2$ at the rate of 4mM or foliar application at the rate of 1 per cent reduced grey mould in capsicum var Aries.

According to Kamara *et al.* (2016), $CaCl_2$ was most effective against grey mould development in all tested pepper cultivars and significantly decreased diameter of rotting area.

An experiment was carried out to study the antifungal potential of zinc against leaf spot disease in chili pepper caused by *Alternaria alternata* and results found that increasing concentration of $ZnSO_4$ significantly reduced growth of Alternaria causing leaf spot in chilli. *In vivo* foliar spray of $ZnSO_4$ exhibit a stimulatory effect on growth along with reducing disease severity. As the concentration of $ZnSO_4$ increases from 0.25 to 10.50 mM considerably reduced growth of organism (Shoaib *et al*., 2021).

Materials and Methods

3. MATERIALS AND METHOD

A research study entitled "Management of calcium magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)" was carried out at Instructional farm, Nileswar, College of Agriculture, Padannakkad. The objective of the study was to develop nutrient management practices for mitigating calcium, magnesium and boron deficiency in chilli and to evaluate its effect on growth, yield and quality parameters.

3.1 FIELD EXPERIMENT

Field experiment was carried out at Instructional farm, Nileswar, Kasaragod during the period from December to May 2021 using chilli as a test crop. The experiment was carried out in randomized block design with ten treatments and three replications. Seedlings were raised in pot trays and transplanted to the main field. All the cultural practices were done as per KAU POP (2016).

3.1.1 Location

Geographically, the experiment site was located at 12˚14'44" N latitude and 75˚8'6" E longitude and at an altitude of 5-8m above mean sea level.

3.1.2 Crop and Variety

Experiment was done using chilli as a test crop and the variety used was Anugraha. It was developed by Kerala Agriculture University. The plants of chilli variety Anugraha are of medium height with attractive long green, medium pungent fruits. The main advantages of this variety are early maturing and bacterial wilt resistance.

3.1.3 Climate and Soil type

The field experiment was conducted during 10th December to 5th May, 2021. The region mostly experiences a warm humid tropical climate. The meteorological data during the period are summarized in appendix 1. Soil type in that region is red sandy loam.

3.1.4. Design and Layout

Crop	: Chilli
Variety	: Anugraha
Design	: RBD
Spacing	: 45 × 45 cm
Plot size	: 2.7 × 1.5 m
Treatments	:10
Replication	: 3

The chilli seeds were collected from RARS farm Pilicode.

3.1.5. Treatments Details

T_1	: KAU POP + lime (based on soil test) (350 kg per hectare)
T_2	: T_1 + 125 kg gypsum per hectare
T_3	: T_1 + 80 kg magnesium sulphate per hectare
T_4	: T_1 + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare
T_5	: T_1 + foliar application of borax (0.2%)
T_6	: T_2 + foliar application of borax (0.2%)
T_7	: T_3 + foliar application of borax (0.2%)
T_8	: T_4 + foliar application of borax (0.2%)
T_9	: KAU POP + dolomite (based on soil test)(350 kg per hectare)
T_{10}	: T_9 + foliar application of borax (0.2%)

Lime was applied in each plot except T_9 and T_{10} after land preparation, based on soil test value and dolomite was applied in T_9 and T_{10}. FYM was applied one week after lime application. Gypsum and magnesium sulphate were applied as single dose at one month after transplanting. In the treatments with combined application of gypsum and magnesium sulphate, magnesium sulphate was applied one week after the application of gypsum. Foliar application of borax was done one month after transplanting. Three more sprays were given at 20 days interval.

Neutralizing value of liming materials were analysed in the lab. Neutralizing value of lime and dolomite were 123.9 and 106.5 respectively.

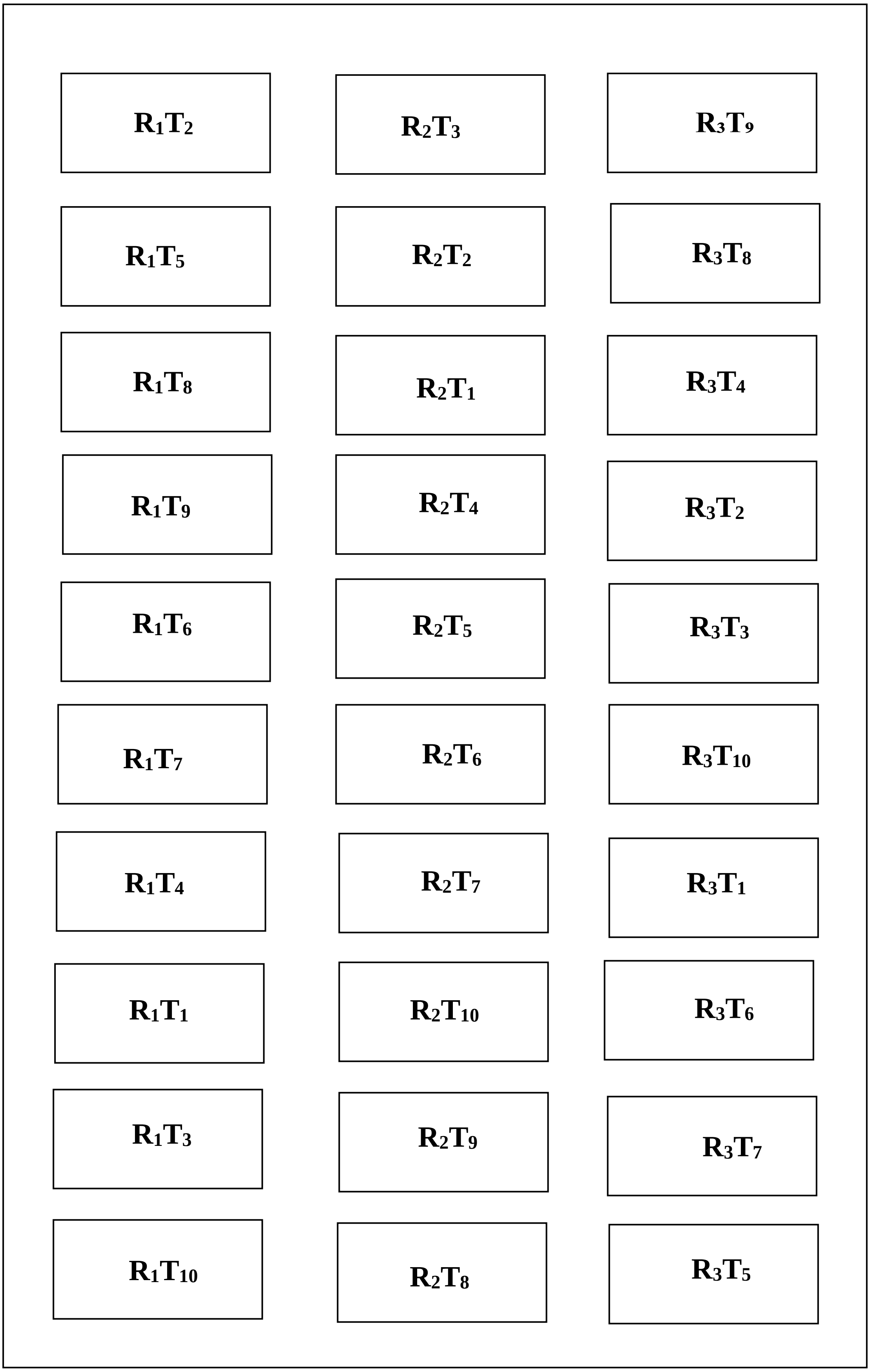

Plate 1. Layout of the experimental plot

3.1.6. Cultural Practices

3.1.6.1. Raising seedlings

Seedlings were raised in pot trays. Each tray was filled with potting mixture and seeds were sown. One month old seedlings were transplanted to the main field.

3.1.6.2. Land preparation

Land was ploughed two times with a tractor to a fine tilth. Experimental plot was laid out after removing stubbles from the field. Field was divided into 3 blocks each containing 10 plots with a plot size of 2.7 m ×1.5 m and separated by a distance of 60 cm. Lime as per soil test basis was applied in furrows in each plot and after one week FYM at the rate of 25 t ha^{-1} was applied.

3.1.6.3. Transplanting

One month old seedlings were transplanted in the field at a spacing of 45 cm × 45 cm. 20 plants were transplanted in each plot with 4 plants per furrows. Coconut fronds were used for shading. Gap filling was done three times.

3.1.6.4. Manures and fertilizers

Fertilizer NPK was given as per POP recommendation through urea, rajphos and muriate of potash. Gypsum, $MgSO_4$, dolomite and borax were given as per treatments.

3.1.6.5. After cultivation

Hand weeding was carried out and earthing up was done two times.

3.1.6.6. Plant protection

White flies in the field were controlled by spraying with Nimbicidin @ 5 ml L^{-1} during the early stages of crop growth (1 week after transplanting) and Oberon @ 1 ml L^{-1} was sprayed during the end of crop growth for controlling mite. For the management of bacterial wilt Copper oxychloride 2 g L^{-1} was drenched in the field 20 days after transplanting.

3.1.6.7. Harvesting

Green chillies were harvested (70 days after transplanting) when it reached maximum fruit size with light green colour. Harvesting was started from second week of March and continued till first week of May.

3.2. BIOMETRIC OBSERVATION

Biometric observations like days to 50% flowering, plant height, fruit weight, total fruit yield, total dry matter production, root characters, incidence of pest and disease were measured and recorded. Observations are made from tagged plants in each treatment throughout the period.

3.2.1. Days to 50% flowering

Number of days taken from first flowering to 50% of total plants flowering in each treatment was recorded.

3.2.2. Plant height

Plant height from ground level to tip of fully opened leaves of five observational plants from each treatment were measured using a scale and average was taken and expressed in centimeter. Measurements were taken at an interval of 45,75 and 105 days after transplanting.

3.2.3. Fruit weight

Fruits were harvested separately from five tagged plants in each treatment and five fruits were selected randomly, weight was recorded and average was taken.

3.2.4. Total fruit yield

Fresh green chilli yield obtained from each plot was recorded separately at different picking. Then total fruit yield per plot was calculated. On the basis of yield per plot, yield per hectare was computed.

3.2.5. Total dry matter production

Randomly selected five plants were uprooted from each plot at harvest and fresh weight was recorded. Collected samples were air dried and later dried in an oven at 60° C and total dry weight was recorded.

3.2.6. Root characters

Root characters like root volume, root - shoot ratio and taproot length were measured. Root volume was measured by dipping roots in a beaker filled with water and record the amount of water displaced and expressed in cm^3.

Length of the taproot was measured from collar region to the tip of taproot and expressed in cm at harvest.

The tagged plants from each treatment were pulled out and dry weight of roots and shoots were measured. From this value root-shoot ratio was calculated.

3.2.7. Incidence of pest and diseases

Occurrence of pest and disease during the crop period were monitored regularly and recorded.

3.3. QUALITY PARAMETERS

3.3.1. Capsaicin

Capsaicin content was estimated by colorimetric method. 0.5g dry chilli powder was taken and mixed with 10 mL dry acetone (25 g anhydrous sodium sulphate in 500 mL acetone) and centrifuged. Pipette out 1mL supernatant and evaporate to dryness and the residue is dissolved in 5mL of NaOH (0.4%) solution. Then 3mL of phosphomolybdic acid (3%) added to the solution, shaked and centrifuged. Read the intensity of blue colour at 650 nm (Sadasivam and Manickam, 1991).

3.3.2. Oleoresin

Oleoresin was analyzed using soxhlet apparatus. 2 g of dried chilli powder was packed in filter paper and the oleoresin was extracted using solvent acetone.

3.3.3. Ascorbic acid

Ascorbic acid content of fresh chilli fruit was estimated by crushing 5g chilli with oxalic acid (4%) and taking 5 mL aliquot from a 100 mL of solution and titrated against 2,6 dichloro phenol indophenol dye until the appearance of a pink colour which persists for a few minutes (Sadasivam and Manickam, 1991).

3.3.4. Shelf life

Chilli fruit samples were collected from each treatment separately and number of days from harvest to stage at which fruits become shrunken and lost firmness were recorded.

3.4. SOIL ANALYSIS

Soil samples were collected before the field experiment for initial analysis. Samples were collected for nutrient analysis from each treatment at flowering and harvesting stage also. Samples were analyzed for bulk density, particle density, texture, pH, EC, organic carbon, available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B as per standard procedure given in table 1. Properties of initial soil samples are given in table 2.

3.5. PLANT ANALYSIS

Index leaves (fully opened youngest leaves) were collected at flowering stage and total plant collected after harvest were dried, powdered and analyzed separately. Plant analysis were carried out as per standard procedure given as table 3.

3.6. FRUIT ANALYSIS

After harvest, fruits from each treatments were collected, dried, powdered separately and analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B content as per standard procedure given in table 3 and also for capsaicin, oleoresin and ascorbic acid content.

3.7. BENEFIT COST RATIO

The benefit cost ratio of cultivation in respect of all the treatments were calculated using the formula

$$BCR = \frac{\text{Gross return ha}^{-1}\text{ (Rs.)}}{\text{Cost of cultivation ha}^{-1}\text{ (Rs.)}}$$

3.8. STATISTICAL ANALYSIS

The data obtained from the experiment was analyzed using Analysis of Variance (ANOVA) for randomized block design and significance was tested as per the 'F' test (Snedecor and Cochran, 1967).

Table 1. Analytical method followed for soil analysis

Sl. No.	Parameter	Method	Reference
1	pH	pH meter (1:2.5)	Jackson (1958)
2	EC	Conductivity meter	Jackson (1958)
3	Textural Analysis	International Pipette method	Robinson (1922)
4	Bulk density	Undisturbed core sample	Black *et al*. (1965)
5	Particle density	Pycnometer method	Black *et al*. (1965)
6	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1934)
7	Available N	Alkaline permanganate Method	Subbiah and Asija (1956)
8	Available P	Bray extraction and Photoelectric colorimetry	Jackson (1958)
9	Available K	Flame photometry	Pratt (1965)
10	Available Ca	Atomic absorption Spectroscopy	Jackson (1958)
11	Available Mg	Atomic absorption Spectroscopy	Jackson (1958)

12	Available S	Photoelectric colorimetry	Massouni and Cornfield (1963)
13	Available Fe	Atomic absorption Spectroscopy	Sims and Johnson (1991)
14	Available Mn	Atomic absorption Spectroscopy	Sims and Johnson (1991)
15	Available Zn	Atomic absorption Spectroscopy	Emmel *et al.* (1977)
16	Available Cu	Atomic absorption Spectroscopy	Emmel *et al.* (1977)
17	Available B	Photoelectric colorimetry	Binghum (1982)

Table 2: Properties of initial soil sample

Sl.No	Parameter	Value
Physical property		
1	Particle density (Mg/m^3)	2.4
2	Bulk density (Mg/m^3)	1.35
3	Texture	Sandy Loam
Chemical properties		
1	pH	5.08
2	EC (dS/m)	0.14
3	Organic carbon (%)	0.42
4	Available N (kg/ha)	156.80
5	Available P (kg/ha)	60.80
6	Available K (kg/ha)	217.80
7	Available Ca (mg/kg)	140.00
8	Available Mg (mg/kg)	48.00
9	Available S (mg/kg)	1.26
10	Available Fe (mg/kg)	106.71
11	Available Mn (mg/kg)	24.3
12	Available Zn (mg/kg)	3.257
13	Available Cu (mg/kg)	1.07
14	Available B (mg/kg)	0.194

Table 3. Analytical method followed for plant and fruit analysis

Sl. No.	Parameter	Method	Reference
1	Total N	Modified Kjeldhal digestion method	Jackson (1958)
2	Total P	Vanadomolybdate yellow colour method	Piper (1966)
3	Total K	Flame photometry	Jackson (1958)
4	Total Ca	Atomic absorption Spectroscopy	Issac and Kerber (1971)
5	Total Mg	Atomic absorption Spectroscopy	Issac and Kerber (1971)
6	Total S	Turbidimetric method	Bhargava and Raghupathy (1995)
7	Total Fe	Atomic absorption Spectroscopy	Piper (1966))
8	Total Mn	Atomic absorption Spectroscopy	Piper (1966)
9	Total Zn	Atomic absorption Spectroscopy	Emmel *et al.* (1977)
10	Total Cu	Atomic absorption Spectroscopy	Emmel *et al.* (1977)
11	Total B	Azomethane - H colorimetric method	Binghum (1982)

Plate 2A. Seedling stage

Plate 2B. Transplanting stage

Plate 2C. Flowering stage

Plate 2D. Fruit formation stage

Plate 2E. Field view

Plate 2. Field view of experimental plot at Instructional Farm 2, Karuvachery

Results

4. RESULTS

A field experiment was carried out at Instructional farm, Nileshwar, College of Agriculture, Padannakkad on a research topic 'Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)'. The data obtained from various biometric observation, soil, plant and fruit analysis after statistical analysis are presented here.

4.1. FIELD EXPERIMENT

Experiment was carried out at Instructional farm, Nileshwar and results of various biometric observation, soil analysis, plant analysis and fruit analysis were statistically analyzed and are given below.

4.1.1. Effect on growth and yield characters of chilli

4.1.1.1. Plant height

Observation on plant height was recorded periodically at 45,75 and 105 days after planting to analyze the effect of treatments. Results obtained from statistical analysis are presented in the table 4. Treatments were found to be non significant.

4.1.1.2. Total dry matter production (kg ha^{-1})

Effect of treatments on dry matter production of chilli after harvest was recorded and presented in table 4. A significant effect on dry matter production was observed among different treatments. Maximum dry matter production (2694.65 kg ha^{-1}) was recorded in T_8 (T_4 + foliar application of borax (0.2%)) which was superior to all other treatments followed by T_5 (T_1 + foliar application of borax (0.2%)) and was on par with T_7 (T_3 + foliar application of borax (0.2%)). Minimum dry matter production (1018.83 kg ha^{-1}) was observed in T_2 (T_1 + 125 kg gypsum per hectare).

4.1.1.3. Root characters

Effect of treatments on root parameters such as taproot length, root volume and root shoot ratio were recorded and presented in table 5. Treatments had a significant effect on root characters. Maximum tap root length (13.50 cm) was recorded inT_8 (T_4 + foliar application of borax (0.2%)) which was significantly superior to all other treatments and minimum (9.95 cm) was recorded in T_1 (KAU POP + lime (based on soil test)) which was inferior to all.

Root volume also gave similar results. Maximum root volume (23.23 cm^3) was recorded in T_8 (T_4 + foliar application of borax (0.2%)) and minimum (14.03 cm^3) was recorded in T_1 (KAU POP + lime (based on soil test)). Treatment T_8 was on par with T_7 (T_3 + foliar application of borax (0.2%)).

Among the various treatments, T_8 (T_4 + foliar application of borax (0.2%)) recorded highest (0.165) root shoot ratio which was significantly on par with T_4 (T_1 + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare), T_{10} (T_9 + foliar application of borax (0.2%)) and T_9 (KAU POP + dolomite (based on soil test). Lowest (0.11) shoot root ratio recorded in T_1 (KAU POP + lime (based on soil test)).

4.1.1.4.Days to 50 % flowering

Days taken for 50 % flowering as affected by treatments were presented in the table 6. Treatments showed non significant effect on days to 50 % flowering. Minimum number of days to 50 % flowering (17 days) was recorded in T_5 (T_1 + foliar application of borax (0.2%)) and maximum days (23.66) was recorded in T_1 (KAU POP + lime (based on soil test)).

4.1.1.5. Fruit weight (g)

The data on single fruit weight (g) of chilli was recorded and presented in table 6. The results revealed that treatments had a significant effect on fruit weight. Highest fruit weight (7.43 g) was recorded with treatment T_8 which was on par with T_{10} (7.22 g). Lowest fruit weight (5.60 g) was recorded in T_1.

4.1.1.6. Total fruit yield (kg ha^{-1})

The data on total fruit yield obtained from different pickings were recorded and presented in table 6. Significant difference among the treatments were noticed. Highest yield (4456.79 kg ha^{-1}) was recorded in T_8 and lowest yield (2659.25 kg ha^{-1}) was recorded in T_1.

4.1.1.7.Incidence of pest and diseases

Incidence of pest and disease were monitored regularly and recorded. During the initial period mild infestation of whitefly and aphids were noticed. At the end of crop period mite attack was also became prominent. Some plants experienced bacterial wilt too. Management measures were taken uniformly throughout the field.

Table 4: Effect of treatments on plant height and total dry matter production

Treatments	Plant height (cm)			Total dry matter production (kg ha^{-1})
	45 DAP	75 DAP	105 DAP	
T_1	27.85	36.27	43.96	1087.73^{de}
T_2	26.85	37.79	40.12	1018.83^{e}
T_3	24.31	35.18	44.90	1020.59^{e}
T_4	24.45	33.50	39.91	1306.66^{cde}
T_5	28.83	43.54	46.16	2121.31^{b}
T_6	25.27	36.08	41.36	1439.88^{cd}
T_7	30.80	39.03	52.07	2062.55^{b}
T_8	32.66	40.17	48.01	2694.65^{a}
T_9	31.62	39.71	50.53	1344.97^{cde}
T_{10}	26.46	36.57	42.32	1572.18^{c}
CD (0.05)	NS	NS	NS	372.051
SE(m)	1.946	2.065	2.940	124.258

Table 5: Effect of treatments on root characters of chilli

Treatments	Root volume (cm^3)	Taproot length (cm)	Root shoot ratio
T_1	14.03^{e}	9.95^{f}	0.110^{f}
T_2	16.20^{cde}	11.49^{cd}	0.136^{cde}
T_3	16.12^{cde}	11.13^{cde}	0.122^{def}
T_4	14.80^{de}	11.64^{cd}	0.159^{ab}
T_5	18.35^{c}	10.69^{e}	0.115^{ef}
T_6	14.90^{de}	11.80^{c}	0.140^{bcd}
T_7	21.41^{ab}	11.55^{cd}	0.132^{cdef}
T_8	23.23^{a}	13.50^{a}	0.165^{a}
T_9	18.88^{bc}	11.01^{de}	0.144^{abc}
T_{10}	17.17^{cd}	12.60^{b}	0.146^{abc}
CD (0.05)	3.065	0.732	0.023
SE(m)	1.024	0.244	0.008

Table 6: Effect of treatments on days to 50% flowering, fruit weight, total fruit yield

Treatment	Days to 50% flowering	Fruit weight (g)	Total fruit yield (kg ha^{-1})
T_1	23.6	5.60^{d}	2659.26^{d}
T_2	18.33	6.22^{cd}	2864.20^{cd}
T_3	22.67	6.69^{bc}	2703.70^{d}
T_4	20.67	6.45^{c}	2882.31^{cd}
T_5	17.00	6.48^{c}	3459.26^{bc}
T_6	18.00	6.45^{c}	3546.50^{bc}
T_7	19.33	6.62^{bc}	3718.44^{b}
T_8	17.33	7.43^{a}	4456.79^{a}
T_9	20.67	6.50^{bc}	2948.15^{cd}
T_{10}	19.67	7.22^{ab}	3420.58^{bc}
CD (0.05)	NS	0.733	703.909
SE(m)	1.938	0.247	235.093

4.2. SOIL CHARACTERISTICS

The results of soil analysis carried out at flowering and harvesting stage for parameters such as pH, EC, OC, available N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B were presented below.

4.2.1. pH

The effect of treatments on pH at flowering and harvesting stage were analyzed and presented in table 7. Treatments showed significant effect on soil pH. At flowering stage highest pH (5.53) was recorded in T_8 which was on par with T_9 (5.41), T_4 (5.41) and T_{10} (5.38). Lowest (5.18) pH was recorded in T_1.

At harvesting stage there were significant difference among treatments. The highest value (5.79) was recorded in T_8 and lowest value (5.02) was recorded in T_7.

4.2.2.EC (dS m^{-1})

EC of soil at flowering and harvesting stage were analyzed and presented in table 7. The data indicated that treatments showed significant difference. At flowering, T_8 (0.213 dS m^{-1}) recorded highest EC and was on par with T_4 (0.210 dS m^{-1}), T_9 (0.173 dS m^{-1}), T_{10} (0.190 dS m^{-1}). Lowest value was recorded in treatment T_3 (0.133 dS m^{-1}).

At harvest, highest value was recorded in treatment T_4 (0.165 dS m^{-1}) which was on par with treatment T_8 (0.155 dS m^{-1}) and lowest value was recorded in T_1 (0.100 dS m^{-1}).

4.2.2. Organic Carbon (%)

Organic carbon status of soil at two stages of crops were analysed and presented in table 7. The effect of treatments were significant at flowering stage whereas, found to be non significant at harvesting stage. Highest organic carbon content was recorded in T_6 (0.737 %) which was superior to all other treatments and lowest value was recorded in T_2 (0.433 %). Treatment T_6 was on par with T_7 (0.617 %), T_{10} (0.600 %) and T_4 (0.580 %).

Table 7: Effect of treatments on pH, EC and organic carbon content in soil

Treatments	pH		EC (dS m^{-1})		OC (%)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	5.18^{d}	5.12^{c}	0.150^{cd}	0.100^{f}	0.457^{bc}	0.540
T_2	5.32^{bcd}	5.45^{b}	0.147^{cd}	0.140^{bc}	0.433^{c}	0.600
T_3	5.20^{cd}	5.47^{b}	0.133^{d}	0.125^{cde}	0.507^{bc}	0.570
T_4	5.41^{ab}	5.43^{b}	0.210^{a}	0.165^{a}	0.580^{abc}	0.660
T_5	5.18^{d}	5.40^{b}	0.157^{cd}	0.105^{ef}	0.473^{bc}	0.643
T_6	5.35^{bc}	5.07^{c}	0.167^{bcd}	0.140^{bc}	0.737^{a}	0.613
T_7	5.31^{bcd}	5.02^{c}	0.157^{cd}	0.135^{bcd}	0.617^{ab}	0.570
T_8	5.53^{a}	5.79^{a}	0.213^{a}	0.155^{ab}	0.573^{abc}	0.613
T_9	5.41^{ab}	5.55^{b}	0.173^{abcd}	0.115^{def}	0.547^{bc}	0.480
T_{10}	5.38^{ab}	5.39^{b}	0.190^{abc}	0.125^{cde}	0.600^{ab}	0.553
CD (0.05)	0.155	0.175	0.045	0.024	0.161	NS
SE (m)	0.052	0.058	0.015	0.008	0.054	0.083

4.2.3. Available N (kg ha^{-1})

Available nitrogen in soil at flowering and harvesting stage were analyzed and presented in table 8. Treatments were found to be non-significant both at flowering and harvesting stage.

4.2.4. Available P (kg ha^{-1})

The available phosphorus content in soil at two stages of crop were statistically analyzed and given in table 8. Available phosphorus content in soil was not significantly influenced by treatments.

4.2.5. Available K (kg ha^{-1})

The data on available potassium status in soil at flowering and harvesting stage were statistically analyzed and presented in table 8. Treatments were statistically significant at both stages. Results revealed that highest potassium content was recorded in treatment T_8 (295.60 kg ha^{-1}) followed by T_3 (273.84 kg ha^{-1}) and T_{10} (272.86 kg ha^{-1}). Lowest potassium content was recorded in T_1 (228.21 kg ha^{-1}).

Among the treatments, T_8 (200.31 kg ha^{-1}) recorded highest potassium content in soil which was on par with T_4 (194.32 kg ha^{-1}) at harvest. Lowest value was recorded in T_5 (146.04 kg ha^{-1}).

Table 8: Effect of treatments on available N, P and K content in soil

Treatments	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	236.24	140.49	67.02	60.18	228.21^{e}	156.96^{ef}
T_2	250.88	141.12	67.65	61.35	249.46^{cd}	182.61^{bcd}
T_3	244.60	153.66	64.95	61.03	273.84^{b}	180.93^{bcd}
T_4	248.78	144.25	68.20	59.81	261.48^{bc}	194.32^{ab}
T_5	236.24	151.78	68.71	59.30	236.39^{de}	146.04^{f}
T_6	244.60	143.94	65.66	60.22	268.57^{bc}	178.08^{cd}
T_7	225.79	152.09	63.80	61.10	257.93^{bc}	185.24^{bc}
T_8	229.97	150.52	68.04	60.11	295.60^{a}	200.31^{a}
T_9	246.69	147.39	69.10	63.76	251.88^{cd}	170.46^{de}
T_{10}	242.51	153.66	68.65	63.18	272.86^{b}	178.36^{cd}
CD (0.05)	NS	NS	NS	NS	21.117	14.137
SE(m)	5.540	6.551	1.361	1.239	7.053	4.721

4.2.6. Available Ca (mg kg^{-1})

Available calcium status of soil at flowering and harvesting stage were analyzed and presented in table 9. Treatments were statistically significant at flowering stage. Highest Ca content was recorded in T_8 (179.85 mg kg^{-1}) which was on par with T_2 (179.38 mg kg^{-1}), T_6 (176.83 mg kg^{-1}) and T_4 (175.33mg kg^{-1}). Treatment T_9 (162.83 mg kg^{-1}) was inferior to all other treatments.

4.2.7. Available Mg (mg kg^{-1})

The data on available magnesium in soil at flowering and harvesting stage were statistically analyzed and given in the table 9. The treatments were statistically significant. Among the treatments, T_9 (54.18 mg kg^{-1}) recorded highest Mg content in soil and on par with T_{10} (53.26 mg kg^{-1}), T_7 (52.58 mg kg^{-1}), T_3 (52.50 mg kg^{-1}), T_8 (52.31 mg kg^{-1}) and T_4 (51.450 mg kg^{-1}). Lowest Mg content was recorded in T_5 (48.05 mg kg^{-1}).

At harvest, treatment T_{10} (48.80 mg kg^{-1}) recorded highest Mg content which was on par with T_7 (47.20 mg kg^{-1}), T_9 (46.80 mg kg^{-1}), T_3 (45.20 mg kg^{-1}), T_8 (44.40 mg kg^{-1}) and T_6 (43.20 mg kg^{-1}). T_1 (35.20 mg kg^{-1}) was inferior to all other treatments.

4.2.8. Available S (mg kg^{-1})

Effect of treatments on available sulphur in soil at two stages of crops were analyzed and presented in table 9. Treatments were statistically significant. Highest value was recorded in treatment T_4 (15.08 mg kg^{-1}) and was on par with T_8 (13.90 mg kg^{-1}) and lowest value was recorded in T_1 (4.24 mg kg^{-1}).

At harvesting stage, treatment T_4 (8.95 mg kg^{-1}) showed superior effect over all other treatments and T_5 (2.24 mg kg^{-1}) was inferior to all. T_4 was followed by T_8 (7.00 mg kg^{-1}).

Table 9: Effect of treatments on available Ca, Mg and S content in soil

Treatments	Available Ca (mg kg^{-1})		Available Mg (mg kg^{-1})		Available S (mg kg^{-1})	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	163.50^{c}	132.66	48.11^{bc}	35.20^{e}	4.24^{f}	2.56^{g}
T_2	179.38^{a}	146.66	46.56^{c}	39.20^{cde}	8.32^{bc}	4.80^{de}
T_3	164.75^{c}	136.66	52.50^{a}	45.20^{abc}	7.74^{bcd}	4.02^{ef}
T_4	175.33^{ab}	139.33	51.45^{ab}	41.60^{bcde}	15.08^{a}	8.95^{a}
T_5	164.50^{c}	143.33	48.05^{bc}	37.20^{de}	4.63^{ef}	2.24^{g}
T_6	176.83^{a}	152.66	47.96^{bc}	43.20^{abcd}	9.52^{b}	5.86^{c}
T_7	166.50^{bc}	145.33	52.58^{a}	47.20^{ab}	7.06^{cd}	3.45^{f}
T_8	179.85^{a}	149.33	52.31^{a}	44.40^{abc}	13.90^{a}	7.00^{b}
T_9	162.83^{c}	156.66	54.18^{a}	46.80^{ab}	4.86^{ef}	3.74^{f}
T_{10}	163.16^{c}	150.66	53.26^{a}	48.80^{a}	6.38^{de}	4.99^{cd}
CD (0.05)	9.167	NS	3.610	7.152	1.915	0.891
SE(m)	3.062	10.642	1.206	2.389	0.640	0.297

4.2.9. Available iron (mg kg^{-1})

The data on available iron content in soil at flowering and harvesting stage were statistically analyzed and given in table 10. At flowering stage, treatments showed significant difference. Lowest Fe content was recorded in T_8 (70.76 mg kg^{-1}) followed by T_2 (88.16 mg kg^{-1}) and T_4 (92.56 mg kg^{-1}). Highest Fe was observed in T_5 (146.33 mg kg^{-1}).

At harvest treatments were found to be non significant.

4.2.10. Available manganese (mg kg^{-1})

Available Mn in soil at flowering and harvesting stage were statistically analyzed and presented in table 10. Treatments were found to be significant at both stages of analysis. Highest Mn content was recorded in T_4 (28.73 mg kg^{-1}) at flowering and lowest value was recorded in T_7 (11.91 mg kg^{-1}).

Among the treatments, T_5 (23.48 mg kg^{-1}) recorded highest Mn content at harvesting stage whereas T_{10} (13.89 mg kg^{-1}) recorded lowest content.

4.2.11. Available zinc (mg kg^{-1})

Effect of different treatments on soil available Zn status at flowering and harvesting stage were analyzed and presented in table 10. Treatments were found to be significant. At flowering T_{10} (4.20 mg kg^{-1}) recorded highest zinc content which was on par with T_8 (4.19 mg kg^{-1}), T_6 (4.13 mg kg^{-1}), T_7 (3.97 mg kg^{-1}), T_2 (3.95 mg kg^{-1}), T_4 (3.70 mg kg^{-1}) and T_5 (3.63 mg kg^{-1}). T_1 (3.63 mg kg^{-1}) recorded lowest Zn content.

At harvest, treatments were found to be non significant.

4.2.12. Available copper (mg kg^{-1})

Effect of treatments on available copper content in soil was analyzed at flowering and harvesting stage. Treatments were found to be not significant in both stages.

4.2.13. Available boron (mg kg^{-1})

The data on available boron status in soil at different stages of crop were analyzed and presented in table 11. Available boron content was not significantly influenced by treatments.

Table 10: Effect of treatments on available Fe, Mn and Zn content in soil

Treatments	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	123.70^{bc}	89.96	28.00^{ab}	16.66	3.23^{c}	1.95
T_2	88.16^{ef}	87.63	24.81^{bc}	18.73	3.95^{ab}	1.49
T_3	109.93^{cd}	88.56	16.85^{d}	22.69	3.38^{bc}	1.50
T_4	92.56^{de}	78.53	28.73^{a}	18.01	3.70^{abc}	1.98
T_5	146.33^{a}	82.63	28.01^{ab}	23.48	3.63^{abc}	2.08
T_6	114.16^{cd}	87.80	22.11^{c}	14.19	4.13^{a}	1.99
T_7	142.66^{ab}	77.76	11.91^{e}	14.13	3.97^{ab}	1.97
T_8	70.76^{f}	68.68	26.96^{ab}	19.74	4.19^{a}	1.85
T_9	113.30^{cd}	71.46	17.18^{d}	18.24	3.24^{c}	1.43
T_{10}	99.80^{de}	76.80	26.96^{ab}	13.89	4.20^{a}	2.06
CD (0.05)	21.870	NS	3.610	6.553	0.677	NS
SE(m)	7.304	5.375	1.206	2.189	0.226	0.239

Table 11: Effect of treatments on available Cu and B content in soil

Treatments	Available Cu (mg kg^{-1})		B (mg kg^{-1})	
	Flowering	Harvest	Flowering	Harvest
T_1	2.700	1.290	0.243	0.195
T_2	2.887	1.325	0.252	0.207
T_3	2.367	1.957	0.251	0.209
T_4	2.933	1.545	0.261	0.220
T_5	2.928	1.287	0.285	0.249
T_6	2.964	1.988	0.283	0.224
T_7	2.773	1.380	0.295	0.218
T_8	2.670	1.950	0.277	0.242
T_9	2.560	1.823	0.252	0.237
T_{10}	2.953	1.619	0.286	0.266
CD (0.05)	NS	NS	NS	NS
SE(m)	0.261	0.188	0.015	0.014

4.3. NUTRIENT CONTENT IN PLANT

Index leaves (fully opened leaves) at flowering and total plant after harvesting were analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B and the results after subjected to statistical analysis was presented below.

4.3.1. Nitrogen (%)

Plant nitrogen content at flowering and harvesting stage were analyzed and presented in table 12. Treatments were not statistically significant in both stages.

4.3.2. Phosphorus (%)

Effect of treatments on plant phosphorus content at flowering and harvest were analyzed and presented in table 12. Treatments were found to be statistically non significant in both stages.

4.3.2. Potassium (%)

Data on plant potassium content at flowering and harvesting stage were statistically analyzed and presented in table 12. Treatments were statistically significant at harvest. Treatment T_8 (3.53 %) showed superior effect over all other treatments which was on par with T_2 (3.45 %). Lowest value was recorded in T_5 (2.68 %) which was inferior to all other treatments.

Table 12: Effect of treatments on N, P and K content in plant.

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	3.01	2.14	0.30	0.24	3.05	2.92[f]
T_2	3.43	2.24	0.34	0.30	3.38	3.45[ab]
T_3	3.22	2.42	0.32	0.30	3.44	3.03[ef]
T_4	3.15	1.77	0.34	0.27	3.25	3.35[bc]
T_5	3.08	1.96	0.28	0.31	3.10	2.68[g]
T_6	3.29	2.14	0.35	0.30	3.35	3.21[d]
T_7	3.15	2.05	0.30	0.31	3.19	3.28[cd]
T_8	3.08	2.33	0.29	0.37	3.49	3.53[a]
T_9	3.08	2.05	0.31	0.30	3.26	3.25[cd]
T_{10}	3.36	1.49	0.33	0.37	3.48	3.15[de]
CD (0.05)	NS	NS	NS	NS	NS	0.134
SE(m)	0.108	0.205	0.016	0.017	0.107	0.045

4.3.3. Calcium (%)

Plant calcium content at flowering and harvesting stage were analyzed and presented in table 13. Treatments were statistically significant. At flowering stage, highest calcium content was recorded in treatment T_8 (1.260 %) and was on par with T_6 (1.25 %), T_2 (1.16 %) and T_4 (1.15 %). Lowest value was recorded in T_5 (0.927 %).

At harvesting stage also treatments showed significant difference. Treatment T_2 (1.24 %) recorded highest Ca content which was on par with T_6 (1.14 %). Treatment T_1 (0.77 %) was inferior to all other treatments.

4.3.4. Magnesium (%)

Magnesium content in plant at flowering and harvesting stage were statistically analyzed and presented in table 13. Significant difference were observed among treatments. Treatments T_{10} (0.74 %) recorded highest content and on par with T_7 (0.73 %), T_8 (0.72 %) and T_9 (0.70 %). Treatment T_1 (0.56%) was inferior to all other treatments.

Treatments were found to be significant at harvest. Highest value was recorded in T_7 (0.71 %) which was on par with T_8 (0.70 %), T_{10} (0.68 %), T_9 (0.67 %), T_3 (0.64 %) and T_4 (0.61 %). T_1 (0.44 %) was inferior to all other treatments.

4.3.5. Sulphur (%)

Data on plant sulphur content at flowering and harvesting stage were statistically analyzed and presented in table 13. Treatments were significant at both stages. At flowering stage, treatment T_8 (0.61 %) recorded highest value which was superior to all other treatments and T_5 (0.41 %) showed inferior effect over all other treatments. T_8 was on par with T_4 (0.60 %), T_6 (0.59 %), T_2 (0.57 %), T_3 (0.53 %) and T_7 (0.52 %).

At harvest highest sulphur content was recorded in treatment T_4 (0.66 %) which was on par with T_8 (0.64 %) and followed by T_6 (0.56 %). Lowest value was recorded in T_9 (0.42 %).

Table 13: Effect of treatments on Ca, Mg and S content in plant.

Treatments	Calcium (%)		Magnesium (%)		Sulphur (%)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	1.08^{bc}	0.773^{d}	0.568^{ef}	0.440^{e}	0.450^{cd}	0.432^{d}
T_2	1.16^{ab}	1.24^{a}	0.512^{g}	0.568^{bcd}	0.572^{ab}	0.549^{c}
T_3	1.00^{cd}	0.963^{c}	0.664^{bc}	0.648^{ab}	0.528^{abc}	0.541^{c}
T_4	1.15^{ab}	1.02^{bc}	0.628^{cd}	0.616^{abc}	0.595^{a}	0.665^{a}
T_5	0.92^{d}	0.880^{cd}	0.604^{de}	0.528^{cde}	0.410^{d}	0.445^{d}
T_6	1.25^{a}	1.14^{ab}	0.536^{fg}	0.472^{de}	0.591^{a}	0.561^{bc}
T_7	1.08^{bc}	0.960^{c}	0.732^{a}	0.712^{a}	0.522^{abc}	0.555^{c}
T_8	1.26^{a}	1.04^{bc}	0.720^{a}	0.704^{a}	0.609^{a}	0.641^{ab}
T_9	1.07^{bc}	0.933^{cd}	0.700^{ab}	0.672^{ab}	0.456^{cd}	0.421^{d}
T_{10}	1.09^{bc}	0.98^{bc}	0.736^{a}	0.688^{a}	0.500^{bc}	0.495^{cd}
CD (0.05)	0.121	0.170	0.056	0.107	0.090	0.083
SE(m)	0.040	0.057	0.019	0.036	0.030	0.028

4.3.6. Iron (ppm)

Effect of treatments on plant iron content at flowering and harvesting stage were analyzed and given in table 14. Treatments were statistically significant at flowering stage. Lowest iron content was recorded in T_4 (175.12 ppm). Highest iron content was recorded in T_1 (234.83 ppm).

4.3.7. Manganese (ppm)

Manganese content in plant was analyzed at flowering and harvesting stage and results were presented in table 14. Treatments were found to be significant at both stages. At flowering stage, highest Mn content was recorded in T_6 (167.95 ppm) which was superior to all other treatments. T_6 was on par with T_4 (166.17 ppm), T_7 (147.42 ppm), T_3 (145.89 ppm), T_5 (138.65 ppm) and T_9 (138.02 ppm). Treatment T_8 (103.56 ppm) was inferior to all other treatments.

At harvest, T_7 (122.79 ppm) recorded highest Mn content and on par with T_4 (117.85 ppm) and T_4 (108.43 ppm)

Zinc (ppm)

Data on zinc content in plant at flowering and harvesting stage were statistically analyzed and given in table 14. Treatments showed significant effect. Treatment T_8 (72.46 ppm) recorded highest Zn content at flowering and lowest value was recorded in T_1 (54.30 ppm). Treatment T_8 was on par with T_9 (70.26 ppm), T_4 (67.60 ppm), T_2 (66.03 ppm), T_5 (63.40 ppm) and T_{10} (62.83 ppm).

At harvest, treatments were also showed significant effect. Treatment T_8 (53.20 ppm) was superior and on par with T_6 (52.60 ppm), T_9 (50.70 ppm), T_3 (48.83 ppm), T_{10} (48.36 ppm), T_1 (47.90 ppm), T_7 (47.53 ppm) and T_2 (45.96 ppm). Treatment T_5 (40.23 ppm) was inferior to all other treatments.

Table 14: Effect of treatments on Fe, Mn and Zn content in plant

Treatments	Fe (ppm)		Mn (ppm)		Zn (ppm)	
	Flowering	Harvest	Flowering	Harvest	Flowering	Harvest
T_1	234.83^{a}	187.00	115.60^{bc}	95.13^{cd}	54.30^{d}	47.90^{ab}
T_2	186.17^{cd}	173.44	129.36^{bc}	90.11^{de}	66.03^{abc}	45.96^{abc}
T_3	208.11^{abc}	180.11	145.90^{ab}	108.44^{abc}	59.73^{bcd}	48.83^{a}
T_4	175.12^{d}	175.77	166.18^{a}	117.85^{ab}	67.60^{ab}	41.36^{bc}
T_5	222.50^{a}	194.11	138.65^{abc}	102.00^{bcd}	63.40^{abcd}	40.23^{c}
T_6	186.28^{cd}	183.88	167.95^{a}	93.93^{cde}	60.33^{bcd}	52.60^{a}
T_7	205.04^{abcd}	176.11	147.42^{ab}	122.80^{a}	55.96^{cd}	47.53^{abc}
T_8	188.28^{cd}	180.22	103.57^{c}	94.62^{cde}	72.46^{a}	53.20^{a}
T_9	195.11^{bcd}	192.55	138.03^{abc}	78.73^{e}	70.26^{ab}	50.70^{a}
T_{10}	194.88^{bcd}	176.44	113.55^{bc}	93.30^{cde}	62.83^{abcd}	48.36^{ab}
CD (0.05)	32.830	NS	35.997	16.270	11.241	7.418
SE(m)	10.965	11.414	12.022	5.434	3.754	2.477

4.3.8. Copper (ppm)

Copper content in plant was analyzed at flowering and harvesting stage and results were given in table 15. Treatments were statistically significant. At flowering stage, highest value was obtained in treatment T_8 (47.93 ppm) and it was significantly superior to all other treatments.

Treatments showed significant effect at harvest also. Maximum copper content was recorded in treatment T_8 (27.60 ppm). Minimum copper content was recorded in T_4 (16.33 ppm).

4.3.9. Boron (ppm)

Boron content in plant at flowering and harvesting stage were analyzed and presented in table 15. Treatments were found to be statistically significant. Highest value was recorded in T_6 (24.10 ppm) which was superior to all other treatments and lowest value was recorded T_3 (17.58 ppm) which was inferior to all other treatments. Treatments T_8 (23.20 ppm), T_5 (23.19 ppm), T_{10} (22.75 ppm) and T_7 (22.66 ppm) were on par with T_6.

At harvest, maximum boron content was recorded in T_{10} (29. 71 ppm) which was on par with T_8 (29.29 ppm), T_5 (29.18 ppm), T_7 (28.81 ppm) and T6 (27.26 ppm). Minimum value was recorded in T_4 (21.43 ppm).

Table 15: Effect of treatments on Cu and B content in plant.

Treatments	Cu (ppm)		B (ppm)	
	Flowering	Harvest	Flowering	Harvest
T_1	28.56^{cd}	18.13^{c}	19.30^{bc}	21.99^{c}
T_2	36.06^{bc}	17.86^{c}	19.94^{b}	23.11^{c}
T_3	30.76^{cd}	17.20^{c}	17.58^{c}	22.91^{c}
T_4	28.50^{cd}	16.33^{c}	18.45^{bc}	21.43^{c}
T_5	24.33^{de}	22.93^{b}	23.19^{a}	29.18^{ab}
T_6	39.13^{b}	16.46^{c}	24.10^{a}	27.26^{ab}
T_7	34.13^{bc}	17.10^{c}	22.66^{a}	28.81^{ab}
T_8	47.93^{a}	27.60^{a}	23.20^{a}	29.29^{ab}
T_9	23.90^{de}	19.20^{bc}	18.74^{bc}	22.68^{b}
T_{10}	16.60^{e}	18.23^{c}	22.75^{a}	29.71^{a}
CD (0.05)	7.806	4.270	2.242	2.450
SE(m)	2.607	1.426	0.749	0.818

4.4. FRUIT ANALYSIS

Total nutrient analysis of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B in fruit and quality parameters such as capsaicin, oleoresin, ascorbic acid and shelf life were analyzed and results were presented below.

4.4.1 Nutrient Analysis

4.4.1.1. Nitrogen (%)

Fruit nitrogen content was statistically analyzed and recorded in table 16. Treatments were found to be significant. Treatment T_8 (2.98 %) recorded highest N content which was superior to all other treatments and on par with T_{10} (2.89 %), T_6 (2.80 %), T_9 (2.52 %) and T_5 (2.42 %). Treatment T_1 (1.21 %) showed inferior effect over all other treatments.

4.4.1.2. Phosphorus (%)

The effect of treatments on phosphorus content was statistically analyzed given in table 16. Treatments were found to be statistically non-significant.

4.4.1.3. Potassium (%)

The data on fruit potassium content was statistically analyzed and presented in table 16. Treatments were statistically significant. Treatment T_{10} (3.83 %) recorded highest potassium content which was superior to all other treatments and T_1 (3.01 %) recorded lowest potassium content. T_{10} was on par with T_9 (3.67 %), T_3 (3.60 %), T_2 (3.54 %) and T_8 (3.43 %) followed by T_4 (3.21 %) and T_5 (3.20 %).

4.4.1.4. Calcium (%)

Fruit calcium content was statistically analyzed and recorded in table 16. Treatments varied significantly. Highest value was recorded in T_8 (0.330 %) which was on par with T_6 (0.290 %) and followed by T_{10} (0.280 %). Lowest value was recorded in T_1 (0.190 %).

4.4.1.5. Magnesium (%)

The data on magnesium content in chilli fruit was statistically analyzed and given in table 16. Treatments were found to be significant. Maximum value was recorded in treatment T_3 (0.672 %) and minimum value was recorded in T_1 (0.492 %). Treatment T_3 was on par with T_9 (0.660 %), T_4 (0.660 %), T_8 (0.648 %) and T_{10} (0.624 %).

4.4.1.6. Sulphur (%)

Effect of treatment application on sulphur content in chilli was analysed and presented in table 16. Treatments were statistically significant. Highest value was obtained in T_6 (0.228 %) which was on par with T_9 (0.181 %) and T_4 (0.179 %). Lowest value was obtained in T_1 (0.084 %).

Table 16: Effect of treatments on N, P, K, Ca, Mg and S content in fruit

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)
T_1	1.21^{d}	0.217	3.01^{d}	0.190^{d}	0.492^{f}	0.084^{c}
T_2	2.05^{b}	0.287	3.54^{abc}	0.250^{bc}	0.588^{cde}	0.156^{b}
T_3	1.31^{cd}	0.264	3.60^{abc}	0.200^{d}	0.672^{a}	0.151^{b}
T_4	2.05^{b}	0.280	3.22^{bcd}	0.230^{cd}	0.660^{ab}	0.179^{ab}
T_5	2.43^{ab}	0.256	3.21^{bcd}	0.220^{cd}	0.564^{de}	0.138^{b}
T_6	2.80^{a}	0.249	3.14^{cd}	0.290^{ab}	0.552^{ef}	0.228^{a}
T_7	1.96^{bc}	0.229	3.09^{cd}	0.250^{bc}	0.600^{bcde}	0.166^{b}
T_8	2.99^{a}	0.281	3.43^{abcd}	0.330^{a}	0.648^{abc}	0.163^{b}
T_9	2.52^{ab}	0.265	3.68^{ab}	0.260^{bc}	0.660^{ab}	0.181^{ab}
T_{10}	2.89^{a}	0.288	3.83^{a}	0.280^{b}	0.624^{abcd}	0.149^{b}
CD (0.05)	0.705	NS	0.528	0.045	0.069	0.053
SE(m)	0.236	0.022	0.176	0.015	0.023	0.018

4.4.1.7. Iron (ppm)

Iron content in fruit was analyzed and recorded in table 17. Significant difference was noticed among treatments. Maximum iron content in fruit was recorded in T_7 (88.77 ppm) which was on par with T_9 (86.193 ppm) and T_3 (82.91 ppm) whereas minimum value was recorded in T_2 (50.77 ppm).

4.4.1.8. Manganese (ppm)

Fruits were analyzed for its Mn content and data was given in table 17. Treatments were statistically significant. Highest value was recorded in T_2 (21.08 ppm) followed by T_9 (17.20 ppm) and lowest value was recorded in T_3 (8.89 ppm).

4.4.1.9. Zinc (ppm)

The data on Zn content in fruit was statistically analyzed and presented in table 17. Treatments were found to be statistically significant. Among the treatments T_4 (30.10 ppm) recorded highest Zn content and was on par with T_2 (28.01 ppm), T_8 (25.26 ppm), T_6 (24.91 ppm) and T_3 (23.90 ppm). Lowest value was recorded in T_{10} (19.48 ppm).

4.4.1.10. Copper (ppm)

The data on copper content in plant was analyzed and presented in table 17. Treatment application showed statistically significant effect on Cu content in fruit. Maximum value was obtained in T_2 (6.25 ppm) and on par with T_3 (5.42 ppm). Treatment T_7 (1.36 ppm) recorded minimum value.

4.4.1.11. Boron (ppm)

Boron content in fruit was analyzed and was found to be statistically significant. Among the treatment T_6 (25.22 ppm) recorded highest B content which was on par with T_7 (22.83 ppm), T_{10} (22.60 ppm), T_5 (22.24 ppm) and T_8 (20.96 ppm).

Table 17: Effect of treatments on Fe, Mn, Zn, Cu and B content in fruit

Treatment	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	B (ppm)
T_1	72.54^{bc}	14.36^{c}	20.07^{c}	1.56^{d}	17.03^{c}
T_2	50.77^{e}	21.09^{a}	28.02^{ab}	6.25^{a}	18.96^{bc}
T_3	82.92^{ab}	8.90^{f}	23.90^{abc}	5.43^{ab}	18.77^{bc}
T_4	63.06^{cd}	12.93^{cde}	30.10^{a}	4.83^{b}	19.21^{bc}
T_5	58.33^{de}	14.50^{c}	19.60^{c}	3.07^{c}	22.24^{ab}
T_6	65.17^{cd}	11.07^{ef}	24.92^{abc}	4.55^{b}	25.23^{a}
T_7	88.78^{a}	13.74^{cd}	23.37^{bc}	1.36^{d}	22.84^{ab}
T_8	65.61^{cd}	13.37^{cd}	25.27^{abc}	3.30^{c}	20.96^{abc}
T_9	86.19^{a}	17.21^{b}	21.22^{c}	1.38^{d}	19.15^{bc}
T_{10}	66.39^{cd}	12.03^{de}	19.48^{c}	2.83**c**	22.60^{ab}
CD (0.05)	12.333	2.216	6.519	1.150	4.577
SE(m)	4.119	0.740	2.177	0.384	1.529

4.4.2. Quality Parameters

4.4.2.1.Capsaicin (%)

Effect of various treatments on capsaicin content in chilli was analyzed and presented in table 18. Treatments were found to be significant. Highest capsaicin content was recorded in treatment T_8 (0.352 %) and was on par with T_4 (0.345 %). Lowest value was recorded in T_1 (0.210 %).

4.4.2.2.Oleoresin (%)

Data on oleoresin content was statistically analyzed and given in table 18. Treatments showed significant difference. Treatment T_8 (11.00 %) was superior over all other treatments which was on par with T_4 (10.5 %), T_6 (9.00 %) and T_2 (8.73 %). Treatment T_1 (6.26 %) was inferior to all.

4.4.2.3.Ascorbic acid (mg100 g^{-1})

Data on ascorbic acid content in chilli was analyzed and recorded in table 18. Treatments were statistically significant. Maximum ascorbic acid content was obtained in treatment T_8 (96.83 mg 100 g^{-1}) which was on par with T_6 (94.03 mg 100 g^{-1}), T_{10} (91.63 mg 100 g^{-1}), T_5 (83.26 mg 100 g^{-1}), T_4 (80.53 mg 100 g^{-1}) and T_7 (80.53 mg 100 g^{-1}). Treatment T_1 (61.06 mg 100 g^{-1}) recorded minimum ascorbic acid content.

4.4.2.4.Shelf life

Effect of calcium, magnesium and boron on shelf life of chilli was statistically analyzed and given in table 18. Treatments were found to be significant. Longest shelf life was obtained in treatment T_8 (13.66) and shortest shelf life was recorded in treatment T_1 (8.66). Treatment T_8 was on par with T_{10} (13.33), T_6 (13.33), T_5 (12.66) and T_7 (12.66) followed by T_2 (12.33).

Table 18: Effect of treatments on capsaicin, oleoresin, ascorbic acid and shelf life of fruit

Treatments	Capsaicin (%)	Oleoresin (%)	Ascorbic acid (mg 100 g^{-1})	Shelf life
T_1	0.210^{e}	6.26^{c}	61.07^{d}	8.67^{f}
T_2	0.317^{b}	8.73^{ab}	77.73^{bcd}	12.33^{bc}
T_3	0.318^{b}	8.13^{bc}	66.63^{cd}	9.67^{ef}
T_4	0.345^{a}	10.50^{a}	80.53^{abc}	10.67^{de}
T_5	0.249^{d}	6.93^{bc}	83.27^{abc}	12.67^{ab}
T_6	0.310^{bc}	9.00^{ab}	94.03^{ab}	13.33^{ab}
T_7	0.292^{c}	7.30^{bc}	80.53^{abc}	12.67^{ab}
T_8	0.352^{a}	11.00^{a}	96.83^{a}	13.67^{a}
T_9	0.261^{d}	7.00^{bc}	77.73^{bcd}	11.33^{cd}
T_{10}	0.316^{b}	7.23^{bc}	91.63^{ab}	13.33^{ab}
CD (0.05)	0.022	2.317	18.719	1.073
SE(m)	0.007	0.774	6.252	0.358

Plate 3A

Plate 3B

Plate 3. Fruits from the best treatments

Plate 4A. Bacterial Wilt

Plate 4B. Aphid

Plate 4C. Mite

Plate 4. Pest and disease observed during crop period

Discussion

5. DISCUSSION

Results obtained from the investigation on ‘Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.)’ are discussed below.

5.1. FIELD EXPERIMENT

5.1.1. Effect on growth parameters

Analysis was carried out to study the effect of various treatments on growth parameters of chilli such as plant height, tap root length, root volume, root shoot ratio and total dry matter production. Significant influence of treatments was observed in root characteristics and total dry matter production.

The treatment application did not significantly influence plant height whereas root characters showed significant positive response to various treatments. Highest root length was recorded in T_8 (KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)). Both calcium and boron had a major role in cell division and cell elongation promoting root elongation and root growth. Magnesium also might have played a vital role in photosynthesis and transport of carbohydrate to sink organs like root and is involved in root growth. All these might have contributed to increase in root length. Maximum root volume was also obtained in T_8 but was on par with T_7 (KAU POP + lime (based on soil test) + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)). Combined application of magnesium and boron showed significant increase in root volume. Similar result was reported by El-Hamd and Esmail (2008) in sugar beet. Among the various treatments, highest root shoot ratio was recorded in T_8 which was on par with T_4, T_{10} and T_9. Addition of gypsum decreases concentration of soluble Al and increases Ca content in subsoil which promote root growth (Radcliffe *et al*., 1986). Incorporation of dolomite in soil enhance downward movement of Ca and Mg into the deeper layer (Caires *et al*., 2002) and it helps in enhanced root growth. Similar result was reported by Cristancho *et al*. (2014) in oil palm.

Dry matter production was significantly influenced by various treatments. Maximum dry matter production was recorded in T_8 (KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) and it was significantly superior to all other treatments. It might be due to the interactive effect of Ca, Mg and B. Calcium, magnesium and boron had a significant role in photosynthesis. Calcium increases the leaf area by activating enzymes and improves photosynthesis. Similar results of positive influence of B foliar spray on dry matter production of sunflower was reported by Al -Amery *et al*. (2011). Boron is involved in cell division, cell elongation and nucleic acid metabolism. It also might have played a role in increasing leaf area which improved photosynthetic activities in plants and thereby increased dry matter production. The findings are in accordance with findings by Dell and Huang (1997). Magnesium is involved in carbohydrate partitioning and transportation, hence it enhances the growth and increases dry matter production.

5.1.2. Effect of treatments on yield attributes

The effect of treatments on yield attributes of chilli such as days to 50% flowering, fruit weight and total fruit yield was analysed and results showed a significant difference among the treatments with respect to fruit weight and total fruit yield.

Days to 50% flowering was not significantly influenced by various treatments. Even though there was no significant effect, borax treated plots showed early flowering. Minimum number of days to 50% flowering was observed in T_5 (KAU POP + lime (based on soil test) + foliar application of borax (0.2%)) and maximum days to 50 % flowering was recorded in T_1 ((KAU POP + lime (based on soil test).

Significantly higher fruit yield was recorded in treatment T_8 ((KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)). Combined application of Ca, Mg and B significantly increased total fruit yield. Higher yield might be due to the effect of these nutrients on physiological function, growth parameters and nutrient uptake. Nitrogen is an important primary nutrient contributing to the vegetative growth of plants and is involved in photosynthesis. Increased Ca content in plant enhances the uptake of N and it contributes to chlorophyll synthesis leading to increased photosynthesis and results higher yield. These findings are in accordance with the findings by Jadhav *et al.* (2019). Magnesium is a constituent of chlorophyll and increased Mg content in plants contributing to increased photosynthesis and involved in carbohydrate partitioning which may also lead to higher yield. Boron had a role in flowering, fruit setting and pollen tube growth. It also contributes to increased yield. Similar results of significant increase in yield of wheat with combined soil application of lime, magnesium and boron was reported by Hossain *et al.* (2011) and with addition of gypsum in cauliflower and broccoli was reported by Sanderson (2003). Combined application of boron and magnesium recorded higher fruit weight (Harris *et al*., 2018) and calcium and boron recorded higher fruit yield (Salim *et al*., 2019) in chilli.

Among the various treatments, T_8 (KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) recorded highest fruit weight. T_8 was on par with T_{10} and all the treatments which contain Mg was significantly superior than T_1 (KAU POP + lime (based on soil test). Similar results were reported by Kasinath *et al.* (2015) and stated that application of $MgSO_4$ significantly increased fruit weight in tomato.

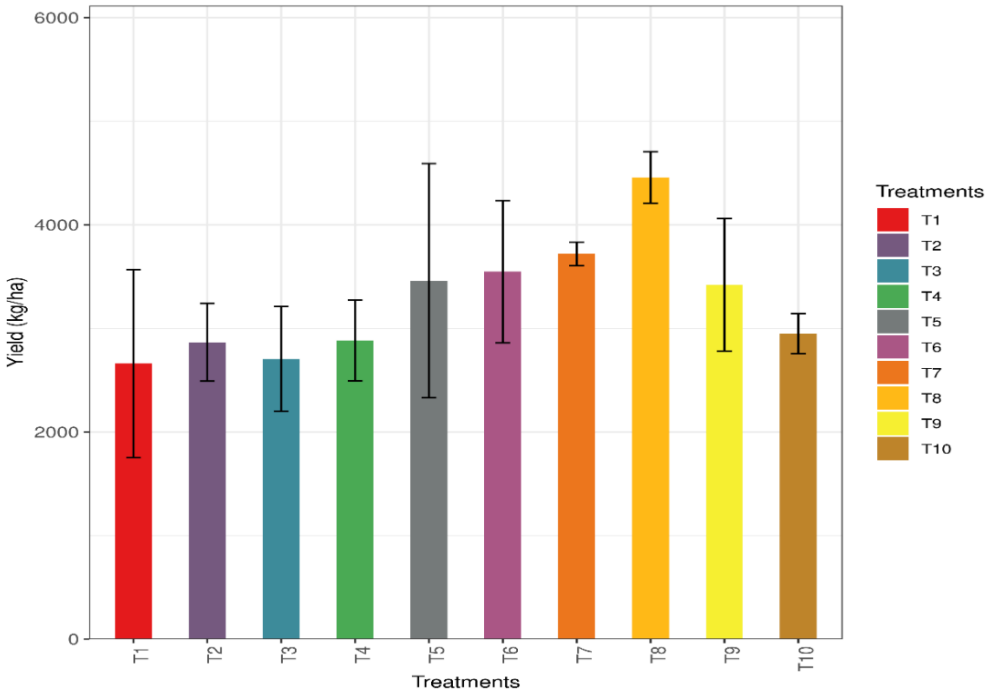

Fig 1. Effect of treatments on total fruit yield

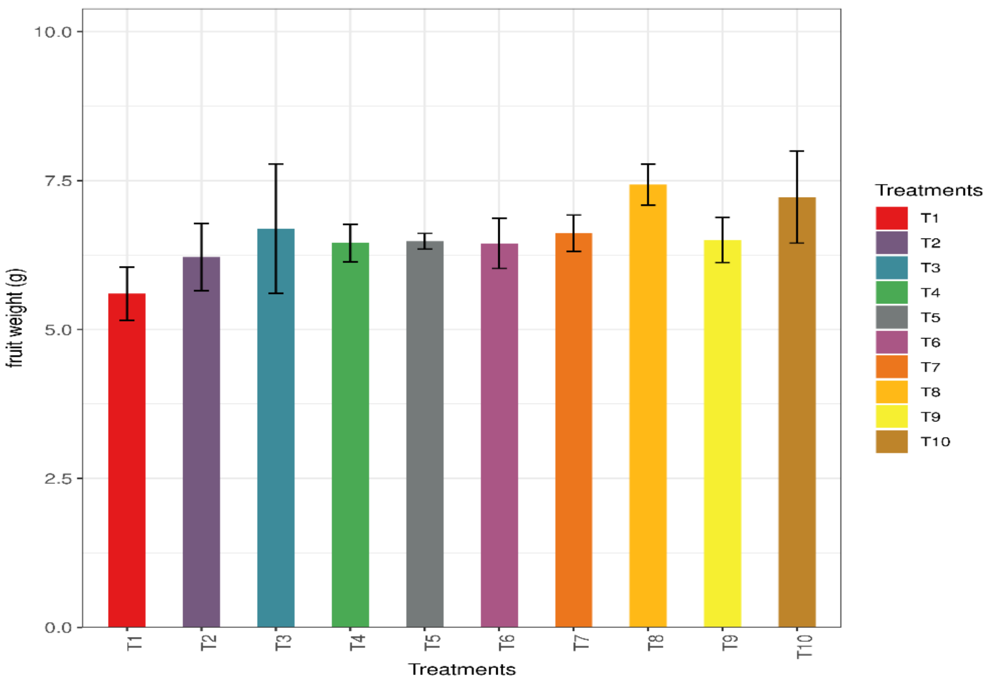

Fig 2. Effect of treatments on fruit weight

5.1.3. Effect of treatments on soil nutrient status

Effect of treatments on soil nutrient status was analysed and found that all the soil parameters were significantly affected by treatments whereas N at flowering and OC, Ca and B at harvest were found to be non significant.

Soil pH and EC responded positively to treatments at both stages of analysis. At flowering and harvest highest pH was recorded in T_8. Application of gypsum and $MgSO_4$ which are highly soluble, release Ca and Mg into the soil and replace the Fe and Al in the exchange site. These findings are in conformity with the findings by Rampim and Lana (2015) that application of calcium sources like gypsum reduces sub soil acidity and increases basic cations like K, Ca and Mg. Application of lime in all treatments slightly increased soil pH. Similar result was reported by Murata *et al*. (2002) that application of limestone significantly increased soil pH. Gypsum is highly soluble in nature and it release Ca and SO_4 which rapidly leached into the subsoil layer where it replace Al^{3+} ions (Anderson *et al*., 2021). Increased soil pH resulting from the addition of gypsum might be due to the release of hydroxyl ion by the SO_4 adsorption (Curtin and Syers, 1990). Among the treatments, T_8 recorded highest EC at flowering stage and T_4 recorded highest EC at harvest. It might be due to the increase in concentration of salts like Ca and Mg in soil.

Effect of treatments on soil organic carbon was found to be significant at flowering stage and non significant at harvesting stage. At flowering stage, highest organic carbon content was recorded in T_6 which was on par with T_7, T_{10}, T_4 and T_8.

Among the major nutrients, available N and P content in soil was found to be non significant at flowering and harvesting stage whereas available potassium content at both stages were found to be significant. Maximum content of soil available potassium was observed during flowering stage. Treatment T_8 recorded highest available potassium at flowering and harvesting stage. This might be due to the addition of lime along with gypsum, magnesium sulphate and foliar application of borax. Lime application increases soil pH and gypsum reduces the sub soil acidity thereby increases the availability of nutrients. Similar result was reported by Prabhakar (2015) that increasing the levels of Ca, Mg and B in soil increases the K levels.

Soil available calcium was significantly influenced by various treatments at flowering stage and maximum value was recorded in T_8 (KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)). Lowest calcium content was recorded in T_9. This might be due to the addition of gypsum which was highly soluble in nature and release Ca into the soil and increasing its availability.

Significant effect of treatments on available magnesium content in soil at flowering and harvesting stage were observed. Treatment T_9 and T_{10} recorded maximum value at flowering and harvesting stage respectively. This might be due to the addition of dolomite and $MgSO_4$ in soil, which are good source of Mg. This is in accordance with the findings by Cristancho *et al.* (2014). Application of gypsum along with lime also increased Mg level in soil (Murata *et al.*, 2002). Similar results were observed in T_2 and T_6 treatments.

Available S content in soil showed positive response to treatments. Among the treatments T_4 recorded highest S content at flowering stage and was on par with T_8. Whereas at harvest T_4 recorded highest S content. This might be due to combined application of gypsum and $MgSO_4$ which are good sources of sulphur. Gypsum is highly soluble in nature and rapidly release sulphur into soil. Dash and Kosh (2012) reported that application of gypsum and magnesium sulphate in rape seed grown in lateritic soils significantly increased S content. Similar result was reported by Turan *et al.* (2013) that gypsum application increased sulphate content in soil.

The effect of various treatments on soil available micronutrient at flowering and harvesting stage were also studied. Lowest Fe content was recorded in T_8 followed by T_2. Application of soil ameliorants increase soil pH and results in low Fe availability. Similar results were reported by Bhindhu *et al.* (2018).

The effect of treatments on Mn content in soil at both stages of analysis were found to be significant. Highest manganese content was recorded in T_4 at flowering stage whereas T_5 recorded highest content at harvest. Akbari *et al.* (2003) reported that availability of nutrients increases with addition gypsum, because it creates more favourable environment in which nutrients are in more available form.

Significant difference was noticed among treatments in case of available Zn in soil at flowering stage. Highest Zn content was recorded in T_{10} and lowest zinc content was observed in T_1. Das (2000) reported that B and Mg exhibited a synergistic interaction with Zn. Since Mg and Zn have almost similar ionic diameter, Mg^{2+} react with relatively insoluble Zn compounds and release Zn in more available form. This might be contributed to increased Zn content with application of dolomite.

The available copper and boron content in soil were not significantly influenced by various treatments at both stages of analysis.

5.1.4. Effect of treatments on nutrient content in plants

Analysis of index leaves (fully opened leaves) and total plants were carried out at flowering and harvesting stage respectively. Significant effect of various treatments on N, K, Ca, Mg, S, Fe, Mn, Zn and Cu content of plant except P was observed.

Among the major nutrients, significant effect of treatments on plant K was observed whereas treatments showed non significant effect on plant nitrogen and phosphorus content. At harvest, maximum content of potassium was observed in T_8. This was on par with T_2.

Effect of treatments on plant Ca content at both stages of flowering and harvest were found to be significant. At flowering stage, highest calcium content was recorded in T_8 and was on par with T_6, T_4 and T_2. This might be contributed by the increased Ca content in soil and B also enhances Ca uptake from soil. Treatment T_2 recorded highest Ca content at harvesting stage.

The treatments showed positive effect on Mg content in plant at both stages of analysis. Treatment T_{10} recorded highest Mg content in plant at flowering stage and was on par with T_7, T_8 and T_9 whereas at harvest T_7 recorded highest Mg content and was on par with T_8, T_{10}, T_9, T_3 and T_4. This might be due to the increased Mg content in soil which was available for plant uptake. Similar results were reported by Mondy *et al.* (1987) and stated that application of $MgSO_4$ resulted in increased Mg content in potato tubers.

The plant S content at both stages were found to be significant. T_8 recorded highest S content at flowering and T_4 recorded highest S at harvesting stage. Treatment application with gypsum and $MgSO_4$ recorded increased plant S content. Similar result was reported by Caires *et al.* (2002) and stated that increased S concentration in wheat leaves were brought by soil application of gypsum. This might be the reason for increased S content in plants.

The effect of treatments on Fe content in plant found to be significant at flowering. Lowest iron content was recorded in T_4 (T_1 +125 kg gypsum per ha + 80 kg $MgSO_4$ per ha) followed by T_2 (T_1 + 125 kg gypsum per hectare), T_6 (T_2 + foliar application of borax (0.2%)) and T_8 (T_4 + foliar application of borax (0.2%)). This might be due to the addition of Ca and Mg in soil that reduces the availability of Fe**.**

Mn content in plants showed significant response to treatment application. Among the treatments, T_6 recorded highest Mn content at flowering stage which was on par with T_4 whereas at harvesting stage T_7 recorded highest Mn content.

Significant difference was noticed among treatments in case of Zn content of plants. At flowering stage, T_8 recorded highest Zn content followed by T_9, T_4, T_2, T_5 and $T_{10.}$ At harvest also T_8 recorded highest Zn content in plants. This might be due to increased concentration of available Zn in soil. Takkar and Nayyar, (1981) reported that application of gypsum increased Zn absorption by plant roots. Synergistic interaction of Zn with Mg and B was also reported by Prasad *et al.* (2016) and Sinha *et al.* (2000) respectively. S application also showed positive response to Zn uptake in groundnut leaves (Singh, 1999). The results obtained from this study was in conformity with these findings.

Copper uptake by plants were significantly affected by treatment application at both stages of analysis. At flowering stage, T_8 recorded highest Cu content followed by T_6 which was on par with T_2. At harvesting stage also T_8 was found to be highest in Cu content followed by T_5. This might be due to the synergistic interaction between S and Cu. The results were in conformity with the findings by Sreemannarayana and Srinivasa Raju (1995) and reported that Cu uptake by sunflower plant was positively influenced by S addition.

Significant difference was observed in treatments in case of B content in plants. Highest boron content was recorded in T_6 at flowering stage. B content in plants of boron treated plots showed increased boron concentration towards the harvest. Highest value was recorded in T_{10} which was on par with T_8, T_5, T_7 and T_6. Periodic foliar application of boron increases the B content in plant tissue. Similar result was reported by Davis *et al*. (2003) that application of B increased uptake and tissue concentration of B in tomato.

5.1.5. Effect of treatments on fruit characteristics

The effect of treatments on total fruit nutrient content, ascorbic acid, capsaicin, oleoresin and shelf life were analysed.

Total nutrient analysis was carried for estimation of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B content in fruits. Treatments showed significant effect on all nutrients except phosphorus.

The effect of treatments on fruit nitrogen content was found to be significant. Highest value was recorded in T_8 which is on par with T_{10}, T_6, T_9 and T_5. This might be due to the synergistic effect of Ca and B in N uptake by plants. Results were supported by the conclusion of Anil *et al.* (2020) that application of Ca and B had significant response to N uptake by tomato plants.

The treatments showed non significant effect on P content in fruits whereas K content was significant. The treatments had positive effect on fruit K content. Maximum potassium content was recorded in T_{10} which was on par with T_9, T_3, T_2 and T_8. High calcium content in leaves enhance K uptake by plants and B is also involved in translocation of K to fruit and thereby increases its concentration in fruit. These findings are in accordance with the findings by Jadhav *et al.* (2019) and Davis *et al.* (2003).

The effect of treatments on fruit Ca content was found to be significant. Highest value was recorded in T_8 which was on par with T_6. Lowest value was recorded in T_1. This might be due to the effect of high Ca concentration in leaves. Similar result was reported by Islam *et al*. (2016). Boron helps in translocation of absorbed Ca in plants, it also supports the findings.

The treatments showed significant effect on Mg and S content in fruits. Highest Mg content was observed in T_3 and on par with T_9, T_4, T_8 and T_{10}. Treatment application of KAU POP + lime (based on soil test) + 125 kg gypsum per ha + foliar application of borax (0.2%) recorded maximum S in fruit which was on par with T_9 and T_4. It might be due to the addition of Mg and S sources in soil, increase its uptake and translocation in various plant parts.

Fe and Mn content showed significant response to treatment application. Treatment T_7 recorded highest Fe content. In case of Mn highest value was observed in T_2.

The effect of treatments on fruit Zn and Cu content was found to be significant. T_4 recorded highest Zn content in fruit which was on par with T_2, T_8, T_6 and T_3. This might be due to increased Zn uptake by plants and translocation within plants. Maximum Cu content was obtained in T_6 followed by T_2 which was on par with T_3. Islam (2012) reported that S application showed significant increase in uptake of Zn and Cu by plants. These findings supported the results.

Boron content in fruit was significantly affected by treatments. Maximum value was recorded in T_6 and was on par with T_7, T_{10}, T_5 and T_8. Increased S in soil enhanced boron uptake. The findings are in line with the findings of Das (2000).

Chilli oleoresin content was significantly influenced by various treatments. Treatment T_8 recorded maximum oleoresin content and was on par with T_4, T_6 and T_2 whereas treatment T_1 recorded minimum content. It might be due to the effect of secondary and micronutrients in growth and yield in chilli. Addition of Ca, Mg and B increased photosynthetic activities in plants which contributes to increased fruit weight. Malawadi, (2003) reported that Ca and K had close relation to oleoresin content in chilli. These results are also in conformity with the findings of Bidari (2000) that presence of higher K, Ca and S content in chilli favours increased oleoresin content.

The treatments showed significant difference in the capsaicin content of fruit. Maximum capsaicin content was recorded in T_8 was on par with T_4. Murugan (2001) reported that capsaicin content in chilli increases with increasing N concentration when compared to control. This indicated the positive effect of N on capsaicin content of chilli. Calcium enhances the N uptake by plants and this might be contributed to increased capsaicin content in treatments. This might be the reason for increased capsaicin content in treated plot.

Various treatment application showed significant response to ascorbic acid content in chilli. Among the treatments, highest ascorbic acid content was recorded in treatment T_8 which was on par with treatments T_6, T_{10}, T_5, T_4 and T_7 and lowest ascorbic acid content was recorded in T_1. All the treatments where boron was sprayed showed significant increase in ascorbic acid. Calcium and boron played a vital role in increasing the ascorbic acid content in fruit. High Ca content was observed in fruits of Ca treated plot. When fruit Ca level increases it will reduce respiration. During the respiration processes, consumption of organic acids like ascorbic acid will increase thus its concentration in fruit will reduces. As the respiration decreases it may increase the ascorbic acid content. These findings are in accordance with the findings by Abbasi *et al*. (2013) and Bagnazari *et al.* (2018). Micronutrients have a major role in enhancement of enzymatic activity of ascorbic acid oxidase which increases the ascorbic acid content. Similar results were reported by Dixit *et al*. (2017) and Salim *et al*. (2019).

Shelf life of chilli was significantly influenced by various treatments. In the present study maximum shelf life was recorded in T_8 which was on par with T_{10}, T_6, T_5 and T_7 whereas minimum shelf life was recorded in T_1. Fruit softening mainly occurs due to the degradation of middle lamella. Calcium application increases Ca content in tissue thus it reducing the deterioration of fruits. Boron enhances cell wall integrity along with promoting the calcium metabolism. Calcium - boron interaction stabilizes Ca complexes in middle lamella which makes cells compact and increase the shelf life by reducing weight loss and maintaining its firmness. These findings are in accordance with the findings of Kumar *et al.* (2000). Similar results were reported by Islam *et al*. (2016), Naveena and Immanuel, (2017) and Ghazeri *et al.* (2012).

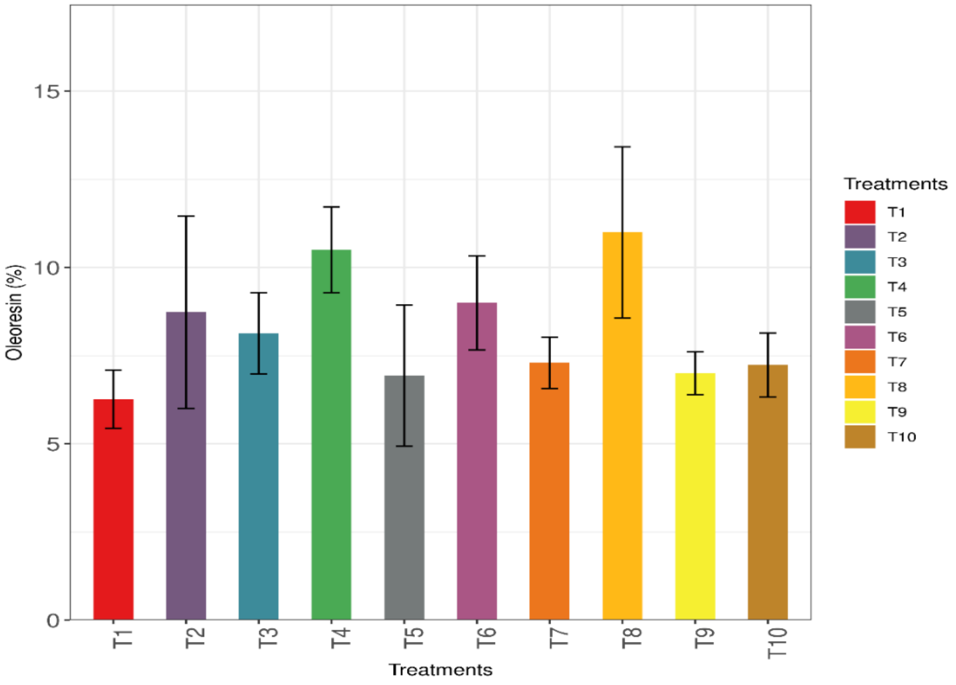

Fig 3. Effect of different treatments on oleoresin content in chilli

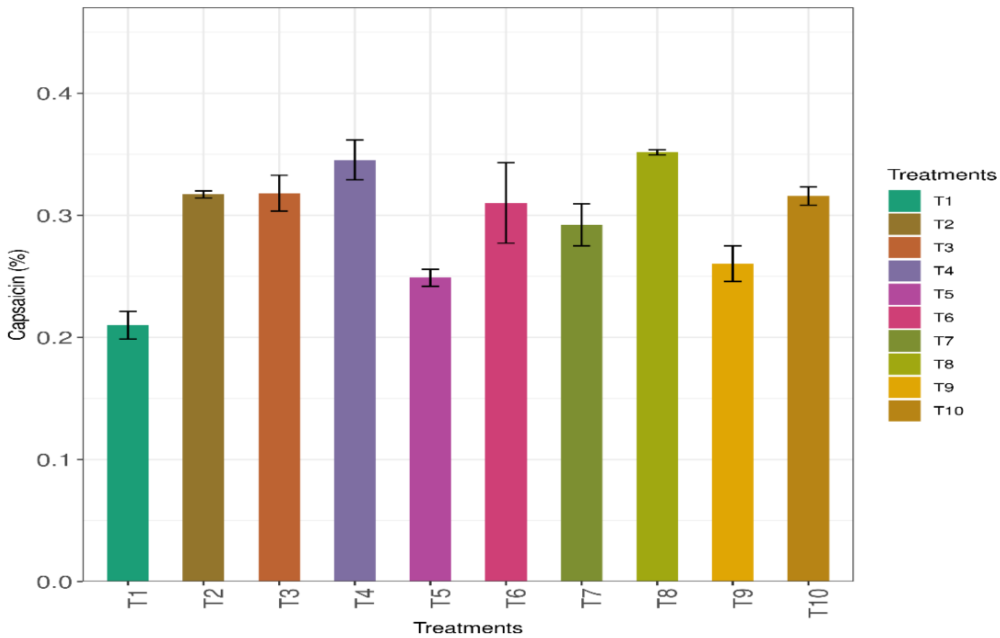

Fig 4. Effect of different treatments on capsaicin content in chilli

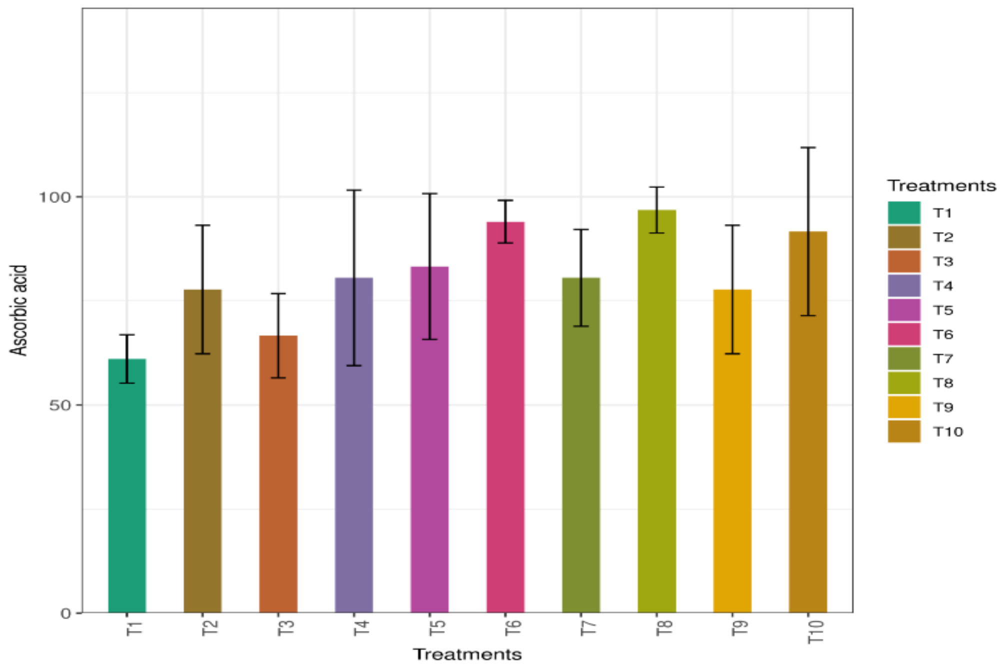

Fig 5. Effect of different treatment on ascorbic acid content in chilli

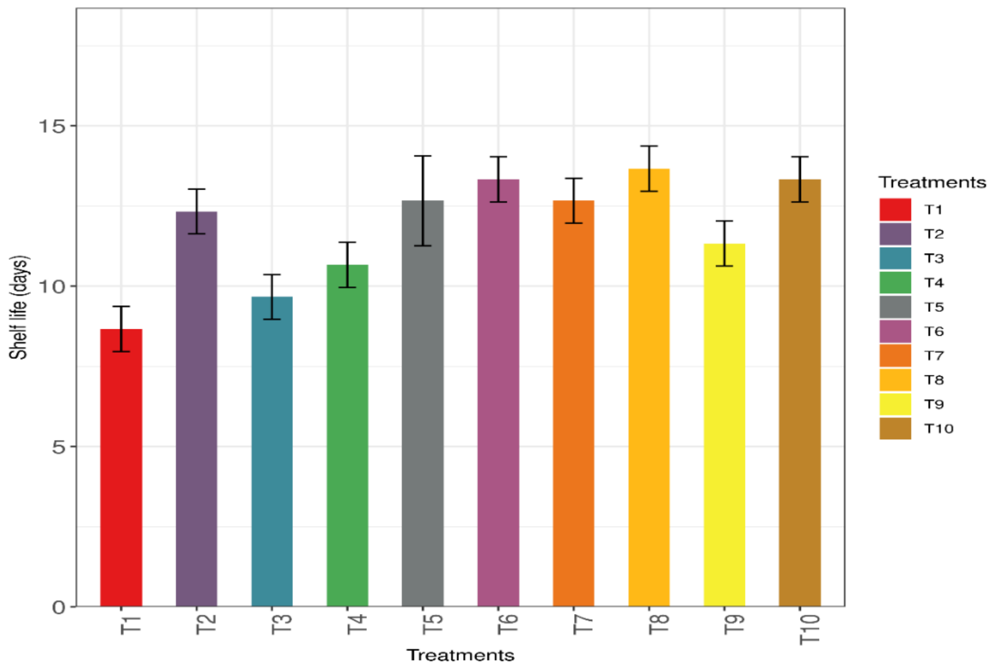

Fig 6. Effect of different treatments on shelf of chilli

Summary

6. SUMMARY

The salient findings of present investigation entitled "Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli (*Capsicum annuum* L.) are summarized here.

The field experiment was carried out at instructional farm, Nileswar during December to May, 2021 to study the effect of calcium, magnesium and boron in chilli with an objective to develop nutrient management practices for mitigating calcium, magnesium and boron deficiencies and to evaluate its effect on growth, yield and quality parameters. The experiment was done in randomized block design with ten treatments and three replications with twenty plants per plot. Chilli variety released by KAU Anugraha, was used as test crop. All the management practices were carried out as per POP recommendation.

The treatments consisted of soil application of gypsum, $MgSO_4$ and dolomite in single dose and foliar spray of borax four times in 20 days interval. Treatment combinations were T_1 (KAU POP + lime (based on soil test),T_2 (T_1 + 125 kg gypsum per hectare), T_3 (T_1 + 80 kg magnesium sulphate per hectare), T_4 (T_1 + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare), T_5 (T_1 + foliar application of borax (0.2%)), T_6 (T_2 + foliar application of borax (0.2%)), T_7 (T_3 + foliar application of borax (0.2%)), T_8 (T_4 + foliar application of borax (0.2%)), T_9 (KAU POP + dolomite (based on soil test)), T_{10} (T_9 + foliar application of borax (0.2%)). Observations on yield, quality and growth parameters of chilli along with nutrient aspects of soil and plant were studied.

Results revealed that treatment application showed significant effect on growth and yield characters of chilli. The effect of treatments was not significant with respect to plant height and days to 50 % flowering, even though minimum number of days to flowering was recorded in T_5 with foliar application of borax. Root characters and total dry matter production were significantly influenced by various treatments. Treatment T_8 ((KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) was significantly superior to all other treatments with respect to tap root length and total dry matter production. In case of root volume also T_8 was significantly superior but on par with T_7 whereas highest root shoot ratio was recorded in T_8. Significantly higher fruit yield was recorded in treatment T_8 ((KAU POP + lime (based on soil test) + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) which was significantly superior to all other treatments.

Among the various treatments, maximum fruit weight was obtained in T_8 and was on par with T_{10}. Results clearly indicated that combined application of calcium, magnesium and boron has significant effect on yield in chilly. In the case of pest and disease incidences, mild attack of white fly, mite and incidence of bacterial wilt were observed which was completely managed in the initial stage itself.

Soil analysis was carried out at flowering and harvest and treatments showed significant effect on soil pH, EC, available potassium, calcium, magnesium, sulphur, iron, manganese and zinc content whereas available nitrogen, phosphorus, copper and boron were not influenced by treatments. Among the various treatments, T_8 recorded highest pH both at flowering and harvest whereas EC was highest in T_8 and T_4 at flowering and harvesting stage respectively. Treatment T_6 recorded increased organic carbon content at flowering stage whereas available K was highest in T_8 at both stages of analysis. Addition of calcium and magnesium sources significantly increased available calcium and magnesium content in soil. Among the various treatments highest available calcium was recorded in T_8 and was on par with T_2, T_6 and T_4 at flowering stage. Highest magnesium content was recorded in T_9 and T_{10} at flowering and harvest respectively. In case of available S, T_4 recorded highest S content both at flowering and harvesting stage. Among the micronutrients, at flowering stage treatment T_8 recorded lowest Fe content followed by T_2 and T_4 while T_{10} recorded highest available Zn content.

Index leaf analysis at flowering and total plant analysis at harvesting stage were carried out and found that plant nutrient content was significantly influenced by treatments. Significant effect of various treatments on plant nutrients except nitrogen and phosphorus was observed. Among the treatments, plant K and Ca content was found to be highest in T_8. Highest Mg was recorded in T_{10} and T_7 at flowering and harvesting stage respectively. Highest plant S content was recorded in T_8 at flowering and T_4 at harvest. Foliar application of borax significantly improved boron content in plants. Highest boron content was observed in T_6 and was on par with T_8, T_5, T_{10} and T_7.

In case of nutrient content in fruit, all the nutrients except P content was found to be non significant. Treatment T_8 recorded highest content of N and Ca whereas K was highest in T_{10}. Maximum content of Mg and S was recorded in T_3 and T_6 respectively. Highest Fe was recorded in T_7 and was on par with T_3 and T_9. Among the treatments, T_2 recorded highest Mn content whereas Zn content was highest in T_4 and was on par with T_2, T_3, T_6 and T_8. Treatment T_6 recorded highest boron content and was on par with T_7, T_{10}, T_5 and T_8 were borax where applied through foliage.

All the fruit quality attributes are significantly influenced by various treatments. Treatment T_8 (KAU POP + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) recorded highest capsaicin, oleoresin, ascorbic acid and shelf life in chilli.

The results of the study clearly indicated that combined application of lime, gypsum, $MgSO_4$ and borax had significant effect on yield and quality of chilli. Treatment application of KAU POP + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%) was proved as a best treatment for increasing yield and quality in chilli.

Future Line of Work

- Effect of various levels of deficient secondary and micro nutrients on yield and quality parameters are to be studied.
- More studies are needed to know the effect of various levels of the deficient nutrients on pest and disease management and post harvest quality

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Abstract

MANAGEMENT Of CALCIUM, MAGNESIUM AND BORON DEFICIENCIY FOR ENHANCING YIELD AND QUALITY IN CHILLI (*Capsicum annuum* L.)

by

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8. ABSTRACT

The investigation entitled 'Management of calcium, magnesium and boron deficiency for enhancing yield and quality in chilli' was carried out at Instructional farm, Nileshwar, College of Agriculture Padannakkad, with an objective to develop nutrient management practices for mitigating calcium, magnesium and boron deficiency and to evaluate its effect on growth, yield and quality parameters. The field experiment was carried out during December 2020 to May 2021.

The experiment was carried out with chilli variety Anugraha, in randomized block design with ten treatments and three replications. Treatment combinations were T_1(KAU POP + lime (based on soil test)), T_2 (T_1 + 125 kg gypsum per hectare), T_3 (T_1 + 80 kg magnesium sulphate per hectare), T_4 (T_1 + 125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare), T_5 (T_1 + foliar application of borax (0.2%)), T_6 (T_2 + foliar application of borax (0.2%)), T_7 (T_3 + foliar application of borax (0.2%)), T_8 (T_4 + foliar application of borax (0.2%)), T_9 (KAU POP + dolomite (based on soil test)) and T_{10} (T_9 + foliar application of borax (0.2%)). Soil application of amendments were done as a single dose and foliar nutrition was given four times in a 20 days interval.

Analysis of experimental results showed that various treatments showed significant effect on growth characters, fruit quality parameters as well as nutrient content in both soil and plant, over KAU POP recommendation. Significant positive effect of treatments on plant root characters and total dry matter production was observed whereas plant height and days to 50% flowering were found to be non significant. Among the treatments, maximum tap root length (13.50 cm), root volume (23.23 cm^3), root shoot ratio (0.16) and total dry matter production (2694.65 kg ha^{-1}) were recorded in T_8 (KAU POP + lime application based on soil test) +125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%). Various treatments showed significant influence on yield and yield attributes. Maximum fruit weight (37.16 g) and total fruit yield (4456.79 kg ha^{-1}) was also observed in T_8 and in case of fruit yield, it was significantly superior to all other treatments. Combined application of gypsum, magnesium sulphate and borax were effective and maximized fruit yield.

Soil analysis was carried out at flowering and harvest wherein, the treatments showed significant effect on soil pH, EC, available potassium, calcium, magnesium, sulphur, iron, manganese and zinc content whereas available nitrogen, phosphorus, copper and boron were not influenced by treatments. Addition of calcium and magnesium sources significantly increased available calcium and magnesium content in soil. Among the various treatments, the highest available calcium was recorded in T_8 and was on par with T_2, T_6 and T_4 at flowering. Highest available magnesium content was recorded in T_9 and T_{10} at flowering and harvest respectively.

Analysis of Index leaves at flowering and total plant analysis at harvest were carried out and it was found that plant nutrient content was significantly influenced by treatments. Significant effect of various treatments on plant nutrients except nitrogen and phosphorus was observed. Foliar application of borax significantly improved boron content in plants. Fruit quality parameters such as capsaicin, oleoresin, ascorbic acid and shelf life and total nutrient content were analysed and results showed significant positive response to treatments. Analysis of nutrient content in fruits showed that primary nutrients mainly, nitrogen and potassium, secondary nutrients and micronutrients in fruits were significantly influenced by various treatments. The treatment, T_8 (KAU POP + lime based on soil test) +125 kg gypsum per hectare + 80 kg magnesium sulphate per hectare + foliar application of borax (0.2%)) recorded highest capsaicin (0.352 %), oleoresin (11.00 %), ascorbic acid (96.83 mg 100 g^{-1}) and maximum shelf life (13.66 days) in chilli.

The results obtained from the experiment revealed the significant influence of soil amendments over KAU POP recommendation and it can be concluded that combined application of gypsum, magnesium sulphate and borax was effective for increasing fruit yield and quality in chilli.

സംക്ഷിപ്തം

‘മുളക് കൃഷിയുടെ വിളവും ഗുണനിലവാരവും മെച്ചപ്പെടുത്തുന്നതിനായി കാൽസ്യം, മഗ്നീഷ്യം, ബോറോൺ മൂലകങ്ങളുടെ പരിപാലനമുറകൾ’ എന്ന വിഷയത്തിൽ പടന്നക്കാട് കാർഷിക കോളേജ്, ഇൻസ്ട്രക്ഷണൽ ഫാം നീലേശ്വരം എന്നീ കേന്ദ്രങ്ങളിലായി ഡിസംബർ 2020 - മെയ് 2021 കാലയളവിൽ പഠനം നടത്തി. കാൽസ്യം മഗ്നീഷ്യം ബോറോൺ എന്നീ മൂലകങ്ങളുടെ അഭാവം ലഘുകരിക്കുന്നതിനുള്ള പോഷക പരിപാലനമുറകൾ വികസിപ്പിച്ചെടുത്ത് ഫലം വളർച്ചയിലും വിളവിലും ഗുണനിലവാരത്തിലും വിലയിരുത്തുക എന്നതായിരുന്നു പഠനത്തിന്റെ പ്രധാന ലക്ഷ്യം.

കാർഷിക സർവകലാശാല പുറത്തിറക്കിയ അനുഗ്രഹ ഇനം മുളകിൽ പത്തു ട്രീട്മെന്റ്സ് മൂന്നു ആവർത്തനങ്ങളിലായാണ് പരീക്ഷണം നടത്തിയത്. ട്രീട്മെൻറ്സ്കൾ T_1 - കാർഷിക സർവകലാശാല കൃഷി പരിപാലന ശുപാർശകൾ + കുമ്മായം (മണ്ണ് പരിശോധന അടിസ്ഥാനത്തിൽ), T_2 - T_1 + 125 കി.ഗ്രാം ജിപ്സം 1 ഹെക്ടറിൽ എന്ന തോതിൽ , T_3 - T1 + 80 കി. ഗ്രാം മഗ്നീഷ്യം സൽഫയിറ്റ് 1 ഹെക്ടറിൽ എന്ന തോതിൽ, T_4 - T_1 + 125 കി.ഗ്രാം ജിപ്സം 1 ഹെക്ടറിൽ എന്ന തോതിൽ + 80 കി. ഗ്രാം മഗ്നീഷ്യം സൽഫയിറ്റ് 1 ഹെക്ടറിൽ എന്ന തോതിൽ, T_5 - T_1 + ബോറാക്സ് പർണപോഷണം (0.2 %), T_6 - T_2 + ബോറാക്സ് പർണപോഷണം (0.2 %), T_7 - T_3 + ബോറാക്സ് പർണപോഷണം (0.2 %), T_8 - T_4 + ബോറാക്സ് പർണപോഷണം (0.2 %), T_9 - കാർഷിക സർവകലാശാല കൃഷി പരിപാലന ശുപാർശകൾ + ഡോളോമൈറ്റ് (മണ്ണ് പരിശോധന അടിസ്ഥാനത്തിൽ), T_{10} - T_9 +

ബോറാക്സ് പർണപോഷണം (0.2 %). മണ്ണിലൂടെയുള്ള വളപ്രയോഗം ഒറ്റ തവണയായും പർണപോഷണം ഇടവേളകളിൽ നാല് തവണകളായും നൽകി.

പരീക്ഷണ ഫലങ്ങളുടെ വിശകലനങ്ങളുടെ അടിസ്ഥാനത്തിൽ വിവിധ ട്രീട്മെൻറ്സ്സൾ, കാർഷിക സർവകലാശാല കൃഷി പരിപാലന ശുപാർശകളെക്കാൾ ചെടിയുടെ വളർച്ച സ്വഭാവത്തിലും മുളകിന്റെ ഗുണനിലവാരത്തിലും മണ്ണിലെയും ചെടിയിലെയും മൂലകങ്ങളുടെ അളവിലും കാര്യമായ സ്വാധിനം ചെലുത്തിയതായി കാണിച്ചു. ചെടിയുടെ വേരിൻറ്റെ സ്വഭാവത്തിലും ആകെ ഡ്രൈ മാറ്റർ പ്രൊഡക്ഷൻ അനുകൂലമായ ഫലങ്ങൾ ഉണ്ടാക്കിയെങ്കിലും ചെടിയുടെ നീളത്തിലും 50 % പൂക്കാൻ ആവശ്യമായ ദിവസങ്ങളുടെ എണ്ണത്തിലും കാര്യമായ മാറ്റമൊന്നും ഉണ്ടാക്കിയില്ല. വിവിധ ട്രീട്മെന്റ്സുകളിൽ, T_8 (T_4 + ബോറാക്സ് പർണപോഷണം (0.2 %)) ലാണ് പരമാവധി തായ്‌വേരിന്റെ നീളം, വ്യാപ്തം,വേര് തണ്ടു ആനുപാതം, ആകെ ഡ്രൈ മാറ്റർ പ്രൊഡക്ഷൻ എന്നിവ രേഖപ്പെടുത്തിയത്. അതുപോലെ തന്നെ വിളവിലും വിളവിന്റെ ഗുണവിശേഷങ്ങളിലും ട്രീട്മെന്റ്സുകൾ സ്വാധിനം ചെലുത്തി. പരമാവധി മുളകിന്റെ തൂക്കവും ഏറ്റവും കൂടുതൽ വിളവും ലഭിച്ചത് T8- ൽ തന്നെയായിരുന്നു. വിളവിന്റെ കാര്യത്തിൽ ട്രീട്മെൻറ് T8 മറ്റു ട്രീട്മെന്റ്സുകളെക്കാൾ ഗണ്ണ്യമായി ഉയർന്നുനിന്നു. മുളകിന്റെ വിളവ് വർധിപ്പിക്കുന്നതിനായി ജിപ്സവും മഗ്നീഷ്യം സൾഫയിറ്റും ബോറാക്സും കുടിച്ചേർത്തുള്ള പ്രയോഗം വളരെ ഫലപ്രദമാണ്.

ചെടിയുടെ പൂവിടുന്ന സമയത്തും വിളവെടുക്കുന്ന സമയത്തും മണ്ണ് പരിശോധന നടത്തുകയും അതിന്റെ

അടിസ്ഥാനത്തിൽ മണ്ണിന്റെ പി എച്, വൈദുദ ചാലകാത, ലഭ്യമായ പൊട്ടാഷ്യം, കാൽസ്യം, മഗ്നീഷ്യം, സൾഫർ, ഇരുമ്പ്, മംഗനീസ് എന്നിവയിൽ ട്രീട്മെന്റ്സുകൾ കാര്യമായ സ്വാധിനം ചെലുത്തിയെങ്കിലും നൈട്രജൻ, ഫോസ്ഫറസ്, കോപ്പർ, ബോറോൺ എന്നിവയിൽ കാര്യമായ മാറ്റമൊന്നും ഉണ്ടാക്കിയില്ല. കാൽസ്യം, മഗ്നീഷ്യം സ്രോതസുകൾ മണ്ണിൽ ചേർക്കുന്നത് വഴി മണ്ണിലെ കാൽസ്യത്തിൻറെയും മഗ്നീഷ്യൻറ്റെയും അളവിൽ കാര്യമായ വർധനവുണ്ടായി. ട്രീട്മെൻറ് T_8 ലാണ് ഏറ്റവും കൂടുതൽ കാൽസ്ത്തിൻറെ അളവ് രേഖപ്പെടുത്തിയത്. അതോടൊപ്പം തന്നെ T_2, T_4, T_6 എന്നിവയും തുല്യ ഫലം കാണിച്ചു. ട്രീട്മെൻറ്സ് T_8 ലും T_9 ലുമാണ് ഏറ്റവും കൂടുതൽ മഗ്നീഷ്യത്തിന്റെ അളവ് രേഖപ്പെടുത്തിയത് അത് യഥാക്രമം പൂവിടുന്ന സമയത്തും വിളവെടുപ്പിന്റെ സമയത്തുമായി.

പൂവിടുന്ന സമയത്തും വിളവെടുപ്പിന്റെ സമയത്തും ചെടിയിലെ മൂലകങ്ങളുടെ അളവ് പരിശോധിച്ചതിന്റെ അടിസ്ഥാനത്തിൽ വിവിധ ട്രീട്മെൻറ്സ് കാര്യമായ സ്വാധിനം ചെലുത്തിയതായി കാണപ്പെട്ടു. ചെടിയിലെ നൈട്രജനും ഫോസ്ഫറസും ഒഴികെ മറ്റു മൂലകങ്ങളിൽ ഗണ്യമായാ മാറ്റം വന്നതായി നിരീക്ഷിച്ചു.

മുളകിന്റെ ഗുണനിലവാര ഘടകങ്ങളായ കാപ്സൈസിൻ, ഒലിയോറെസിൻ, വിറ്റാമിന് സി, സംഭരണ കാലാവധിയും കൂടാതെ മൂലകങ്ങളുടെ തോതും പരിശോധിച്ചു. പരിശോധനയുടെ അടിസ്ഥാനത്തിൽ മുളകിലെ പ്രാഥമിക മൂലകങ്ങളായ നൈട്രജനും പൊട്ടാഷ്യവും ദ്യുതിയ മൂലകങ്ങളും സൂഷ്മമൂലകങ്ങളും ട്രീട്മെന്റ്സിനാൽ വ്യതാസപ്പെട്ടിരുന്നു. ഏറ്റവും കൂടുതൽ കാപ്സൈസിന്റെയും ഒലിയോറെസിന്റെയും വിറ്റാമിന് സിയുടെയും തോത്

രേഖപ്പെടുത്തിയ ട്രീട്മെൻറ് T_8 -ൽ തന്നെയാണ് പരമാവധി സംഭരണ ശേഷിയും രേഖപ്പെടുത്തിയത്.

കാർഷിക സർവകലാശാല ശുപാർശകളോടൊപ്പം ജിപ്സം മഗ്നീഷ്യം സൽഫയിറ്റും ബോറാക്സും ഒരുമിച്ച് ചേർത്ത് പ്രയോഗിക്കുന്നത് മുളകിന്റെ വിളവും ഗുണനിലവാരവും വർദ്ധപ്പിക്കുവാൻ ഫലപ്രദമാണെന്ന് കണ്ടെത്തി.

Appendices

APPENDIX I

Daily average weather parameters of RARS, Pilicode

Date	Temperature		Relative Humidity		Rainfall (mm)
	Max	Min	I	II	
10-12-2020	33	23.5	96	61	0.2
11-12-2020	33	24	92	61	0
12-12-2020	34	24.5	92	72	0
13-12-2020	34	22	96	67	92
14-12-2020	34	23.5	88	67	0
15-12-2020	34	22	96	67	0
16-12-2020	34	22	91	67	0
17-12-2020	34	23.5	96	73	0
18-12-2020	34	23.5	96	61	0
19-12-2020	33	20.5	96	68	0
20-12-2020	34	20.8	91	48	0
21-12-2020	33	19	96	76	0
22-12-2020	32	20	91	76	0
23-12-2020	32	20	91	54	0
24-12-2020	34	23.5	91	61	0
25-12-2020	34	23.5	92	61	0
26-12-2020	34	22.5	96	61	0
27-12-2020	32	20	83	83	0
28-12-2020	32	19	92	64	0
29-12-2020	32	21.5	91	56	0
30-12-2020	32	21.5	100	73	0
31-12-2020	33	22.5	91	67	0
01-01-2021	32	23	91	61	0
02-01-2021	34	19.5	91	50	0
03-01-2021	33	24	91	57	0
04-01-2021	33	19	83	61	0
05-01-2021	33	23	96	67	22
06-01-2021	32	23	93	61	0
07-01-2021	32	22	96	79	20
08-01-2021	32	23	96	72	36.6
09-01-2021	32	23	91	70	1.4
10-01-2021	32	23	96	67	0
11-01-2021	32	23	91	66	0
12-01-2021	32	22.5	96	60	0
13-01-2021	33	22	91	59	0

14-01-2021	32	22	96	66	0
15-01-2021	31	24	88	57	0
16-01-2021	32	23	96	65	0
17-01-2021	32	23	96	67	0
18-01-2021	32	23	91	67	0
19-01-2021	31	22.5	96	61	0
20-01-2021	31	21	93	61	0
21-01-2021	34	21	96	61	0
22-01-2021	34	22	96	55	0
23-01-2021	34	24	88	61	0
24-01-2021	34	24	96	64	0
25-01-2021	34	22	96	67	0
26-01-2021	33	20.5	95	56	0
27-01-2021	33	20	91	66	0
28-01-2021	33	20	91	50	0
29-01-2021	32	20.5	91	50	0
30-01-2021	32	20.8	91	50	0
31-01-2021	32	23	92	57	0
01-02-2021	35	20	91	51	0
02-02-2021	33	20	91	59	0
03-02-2021	33	20	94	50	0
04-02-2021	33	22	91	58	0
05-02-2021	32	22.6	95	56	0
06-02-2021	33	21.3	94	64	0
07-02-2021	33	20.9	94	46	0
08-02-2021	33	18	95	32	0
09-02-2021	33	18.2	90	37	0
10-02-2021	33	18.4	91	58	0
11-02-2021	33	19.5	91	61	0
12-02-2021	33	21	93	61	0
13-02-2021	33	22	91	58	0
14-02-2021	33	22	91	64	0
15-02-2021	33	22.3	96	58	0
16-02-2021	33	22	96	58	0
17-02-2021	32	21.5	96	51	0
18-02-2021	33	21	91	53	0
19-02-2021	33	22.5	87	56	0
20-02-2021	33	21	64	61	0
21-02-2021	33	21	91	58	5.8
22-02-2021	33	21.5	87	61	6
23-02-2021	33	21	91	59	0
24-02-2021	34	23	91	56	0
25-02-2021	33	19	92	58	0
26-02-2021	33	22.5	92	64	0
27-02-2021	33	25	92	67	0
28-02-2021	32	25	92	67	0

01-03-2021	33	25	92	64	0
02-03-2021	33	23.5	97	59	0
03-03-2021	34	23	91	67	0
04-03-2021	34	22	92	68	0
05-03-2021	34	21	91	61	0
06-03-2021	37	22.5	87	64	0
07-03-2021	36	23	84	62	0
08-03-2021	35	24.3	93	62	0
09-03-2021	35	24	92	55	0
10-03-2021	34	24.5	88	59	0
11-03-2021	34	24	91	56	0
12-03-2021	34	23.5	89	61	0
13-03-2021	34	24	92	67	0
14-03-2021	34.5	27	85	57	0
15-03-2021	34	24.5	92	59	0
16-03-2021	34	24.5	88	62	0
17-03-2021	34	24	88	62	0
18-03-2021	34	24.5	88	62	0
19-03-2021	34.5	25	88	77	0
20-03-2021	34	25	88	67	0
21-03-2021	34.2	22.8	89	59	1.8
22-03-2021	34	22.8	90	57	0
23-03-2021	34	24.7	88	61	0
24-03-2021	34.5	25.5	85	62	0
25-03-2021	34.7	25.5	88	71	0
26-03-2021	33.8	25.5	90	71	0
27-03-2021	34.6	25.5	88	68	0
28-03-2021	34.5	26	81	68	0
29-03-2021	34.5	26	85	65	0
30-03-2021	34.5	25	51	65	0
31-03-2021	34.5	25	88	62	0
01-04-2021	34	27	88	62	0
02-04-2021	35	24	92	62	0
03-04-2021	33.5	24	92	68	0
04-04-2021	34	24	84	57	0
05-04-2021	35	24	92	73	0
06-04-2021	34	23.5	81	66	0
07-04-2021	34.5	22	75	79	0
08-04-2021	34	28	85	79	0
09-04-2021	34	25	88	63	0
10-04-2021	35	25	88	63	0
11-04-2021	35	28	78	57	0
12-04-2021	35	25	84	57	0
13-04-2021	34.5	24	96	60	0
14-04-2021	34.5	26	78	57	0
15-04-2021	34.5	26	85	64	0

16-04-2021	33	25	85	74	0
17-04-2021	34	24.5	84	55	0
18-04-2021	34.5	26	85	65	0
19-04-2021	34	24.5	100	68	52
20-04-2021	34	24.5	92	81	0
21-04-2021	35	26	92	62	0
22-04-2021	33.5	24.5	92	62	5.6
23-04-2021	32.5	26	88	62	0.2
24-04-2021	33	25.5	92	57	0
25-04-2021	34	26	88	68	0
26-04-2021	35.5	25.7	92	68	0
27-04-2021	34.9	26.5	81	62	0
28-04-2021	34.4	26.2	96	65	0
29-04-2021	35.2	26.2	82	60	0
30-04-2021	35	24.5	88	62	6.2
01-05-2021	35.5	25.5	88	51	0
02-05-2021	35.5	25	78	65	0
03-05-2021	35.5	25	92	63	10.7
04-05-2021	35.5	25.5	92	73	26.8
05-05-2021	35.5	24.5	92	68	0
06-05-2021	34.5	24.5	96	70	44.8

APPENDIX II

Effect of treatments on B:C Ratio

Treatments	Cost of Cultivation (Rs ha^{-1})	Gross income	Net income	BCR
T_1	90194	132963	42768.96	1.47
T_2	90944	143209.9	52265.88	1.57
T_3	95394	135185.2	39791.19	1.41
T_4	96144	144115.2	47971.23	1.49
T_5	95794	172963	77168.96	1.80
T_6	96544	177325.1	80781.1	1.83
T_7	100994	185922	84928	1.84
T_8	101744	222839.5	121095.5	2.19
T_9	88619	147407.4	53188.41	1.56
T_{10}	94219	171028.8	82409.81	1.92