RESPONSE OF TOMATO TO CALCIUM AND BORON IN THE *ONATTUKARA* TRACT OF ALAPPUZHA DISTRICT

by

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(2015-11-018)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"RESPONSE OF TOMATO TO CALCIUM AND BORON IN THE *ONATTUKARA* TRACT OF ALAPPUZHA DISTRICT"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

I, hereby declare that this thesis entitled **"RESPONSE OF TOMATO TO CALCIUM AND BORON IN THE *ONATTUKARA* TRACT OF ALAPPUZHA DISTRICT"** is a bonafide record of research work done independently by Ms. Aswathy Mohan (2015-11-018) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or associateship to her.

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Aswathy Mohan

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
$\mu S\ m^{-1}$	Micro Siemens per metre
@	At the rate of
°C	Degree Celsius
AEU	Agro Ecological Unit
ATP	Adenosine Tri Phosphate
B	Boron
BER	Blossom End Rot
B:C	Benefit : Cost
Ca	Calcium
CD	Critical difference
CEC	Cation Exchange Capacity
Cl	Chlorine
cm	Centimeter
$cmol\ kg^{-1}$	Centi mol per kilogram
Cu	Copper
cv	Cultivar
EC	Electrical conductivity
et al.	And co workers
Fe	Iron
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
ie	That is
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram

Kg ha^{-1}	Kilogram per hectare
KSPB	Kerala State Planning Board
LR	Lime Requirement
MAP	Month After Planting
mg	Milligram
mg/kg	Milligram per kilogram
Mg	Magnesium
mM	Milli molar
Mn	Manganese
MSL	Mean Sea Level
N	Nitrogen
Na	Sodium
No.	Number
OC	Organic carbon
P	Phosphorus
pH	Negative logarithm of hydrogen ions
POP	Package of practices
ppm	Parts per million
RBD	Randomized Block Design
RDF	Recommended Dose of Fertilizers
S	Sulphur
SEm	Standard errors of means
Sl.	Serial
TSS	Total Soluble Solids
viz.,	Namely
Zn	Zinc

Introduction

1. INTRODUCTION

Kerala, god's own country, blessed with a wide variety of climate and soils, on which a large number of crops can be cultivated. From a time of near self-sufficiency in food production, Kerala now depends on neighboring states for its food needs especially vegetables. Efforts are being made from various angles to encourage farmers to increase the area under vegetable cultivation, which are the vital component of our daily food. For the cultivation of vegetables a net area of 17472 acres are utilized out of the total 48153 acres of agricultural land possessed by the farmers i.e. only 36.28 per cent of the total land owned by them is utilized for vegetable cultivation. According to estimates, the state produces only about five lakh of tonnes of vegetables out of a total annual requirement of around 25 lakh tonnes. Around Rs. 1,000 crore worth of vegetables are imported into Kerala yearly. To feed the tremendously growing population, it requires several million tonnes additional food grains each year and the only way to solve this issue is to produce more from the same or even less land holding. For that, effective balanced plant nutrition using fertilizers of secondary and micronutrients along with NPK should be adopted. Thus, our aim, additional food grain production has to come through judicious, efficient and balanced use of fertilizers.

After the advent of green revolution, farmers started intensive cultivation of early maturing, high yielding varieties. They paid less or no attention towards soil health. Continuous cultivation of crops without paying much attention has resulted in decrease in yield, reduction in soil and crop quality and so many environmental hazards such as pollution. This has also resulted in huge depletion of soil available secondary and micronutrients because, traditional fertilizer practices were designed to meet these needs for only the major nutrients like N, P and K. That is, deficiency of micronutrients and secondary nutrients has become a limiting factor for sustainable crop productivity across the country.

Balanced nutrition is the application of fertilizers in optimum quantities and in right proportion through appropriate methods, which in turn results in sustenance of crop productivity and soil fertility. Application of balanced plant nutrition is the key in enhancing nutrient use efficiency of the applied plant nutrients for maintaining soil productivity. It also leads to building up of soil health, while imbalanced nutrition leads to soil deterioration and soil sickness. Without proper supply of secondary and micronutrients, it is not possible to obtain maximum benefits from the applied N, P and K fertilizers even by the cultivation of high yielding varieties.

As per the study of the state planning board 88 percent of Kerala soils are acidic in nature and there is very high deficiency of calcium, magnesium and boron. Around 50 per cent of soil samples had calcium deficiency, 80 per cent had magnesium deficiency and 70 per cent had boron deficiency (KSPB, 2013). Micronutrients are present only in lower concentrations in soil compared to macronutrients but are equally significant in plant nutrition, since, the plants grown in micronutrient-deficient soils show similar reductions in productivity and quality as those grown in macronutrient-deficient soils (Havlin *et al.*, 2004). Sureshkumar *et al.* (2013) found that the availability of calcium is very low in Kerala soils due to leaching under heavy rainfall. In laterite soils of Kerala, having low pH, boron is lost by leaching as the boron retention capacity of soil is very low (KSPB, 2013).

Calcium is a very important secondary nutrient which plays a key role in the structure of cell wall and cell membranes, fruit growth and development as well as fruit quality (Kadir, 2004). Symptoms of deficiency include death of growing points, premature shedding of buds and blossoms, bitter pit, blossom end rot and tip burn. Without adequate level of calcium, shelf life of fruits can be reduced significantly.

Boron is a micronutrient required in very minute quantities, though it plays a vital role in physiology of plants. It is responsible for formation and stabilization of cell wall, lignification and xylem differentiation. It helps to imparts drought tolerance and plays an important role in pollen germination. Boron deficiency results in a reduced number of flowers per plant, empty pollen grains, poor pollen viability and stunted root growth.

Tomato (*Solanum lycopersicum* L.), the second important vegetable after potato is a well-known crop grown all over the world. It is grown extensively throughout India for fresh consumption and commercial processing. Tomato as vegetable and fruit occupy an important place in healthy daily diet and is an excellent source of many nutrients and secondary metabolites that are important for human health.

Onattukara is a unique agro-ecological situation characterised by loamy sand texture, low organic matter content and water holding capacity, low nutrient retention capacity and poor fertility. Research work to evaluate the response of tomato to different levels of calcium and boron in sandy tract of *Onattukara* is meagre (Mini, 2015). Hence there is a need to determine the optimum quantity of calcium and boron for tomato. Tomato is the most popular vegetable crop among Kerala farmers in view of its consumer acceptance. Hence the present study on the "Response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district" was formulated with the following objectives.

- To find out the effect of calcium and boron on yield and quality of tomato
- To develop a recommendation for calcium and boron to optimize the productivity

Review of Literature

2. REVIEW OF LITERATURE

The aim of the farmers is to get maximum yield from his holdings. In earlier times, the cultivation of traditional varieties helped to meet the nutritional needs and the soils were also rich in nutrients. The traditional practices helped in maintaining optimum physical and chemical properties of the soil as well as nutrient supplying ability of the soil. But with the advent of green revolution, farmers started intensive cultivation of early maturing, high yielding varieties without paying much attention to soil health and quality. Continuous cultivation without balanced nutrition has resulted in decrease in yield, reduced crop quality, soil health and many environmental problems. So it is very important to pay close attention to nutrient management.

There are 17 essential elements that are required for a successful crop. Even though N, P and K are the primary nutrients, a plant can't complete its life only with these nutrients. Without adequate supply of secondary and micronutrients, it is impossible to get maximum yield and productivity from applied NPK fertilizers. Nowadays, due to more concentration and application of primary nutrients, soils developed deficiency symptoms for secondary and micronutrients. The understanding on the requirement of all the essential nutrients was developed in 1840 by the German chemist, Justus Von Liebig, by proposing the 'Law of Minimum' which describes the effect of every individual nutrient on crops. Liebig's law of minimum is a principle developed in agriculture which states that if one of the nutritive element is deficient, plant growth is restricted and not in its full potential even when all the other elements are abundant. Hence deficient elements must be supplied to the soil along with NPK to get higher yields in crops. Hence the "Response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district" was conducted via the present investigation and the literature pertaining to the review is presented in the following paragraphs.

2.1. STATUS OF CALCIUM AND BORON IN SOILS OF INDIA

Available B status of loamy sandy soils of Bihar ranges from traces to 1.05 ppm and 11.0 ppm B is critical for wheat in those soils (Singh and Sinha, 1976).

A critical limit of B in the soils of texture varying from sandy loam to silty clay loam is 0.5 ppm (Bhandari and Randhawa, 1978).

Liu *et al.* (1983) reported that laterite, lateritic and red soils of china derived from gneiss, granite and other igneous rocks contain less than 0.4 ppm water soluble boron. Under humid tropical climatic conditions, soils dominated by kaolinitic clays readily leaches out Ca^{2+}, thus causing its deficiency (Sims and Ellis, 1983).

Narayan *et al.* (1989) found that the silt loam soils were reported to have an available B status of 0.42 ppm. The available B status in the sandy loam soils of Forzepur and Faridkot districts of Punjab ranged from 0.22 to 3.85 ppm, where the critical limits being 0.52 to 1.0 ppm in them (Singh and Nayyar, 1999).

It is reported that 33% of Indian soils are deficient in B. Total B contents in Indian soils vary from 7 to 630 mg /kg of soil. Available B in Indian soils ranges from 0.75 to 8.0 mg /kg. Soils in the arid and semi-arid tropical regions have the highest contents of B (Brar *et al.*, 2008).

Worldwide crop responses to applied Ca (lime) varied from 20 to 635% (Prochnow, 2014).

2.2. STATUS OF CALCIUM AND BORON IN SOILS OF KERALA

Nowadays, problems due to deficient amount of secondary and micronutrients have been reported from so many parts of Kerala.

Regions having humid tropical climate receives rainfall which is characterized by high intensity, short duration and large year-to-year variations in total rainfall (Sivakumar, 1987) and that cause the leaching of nutrients from the soil which makes the soil acidic in reaction. And also due to long term continuous application of straight fertilizers alone, deficiency of nutrients are widespread and their application often get neglected; resulting severe impacts in present day agriculture.

Several reports suggest that there exist only a narrow range between the deficient and toxic level of B and the application of B may prove extremely toxic at concentration slightly above the optimum level (Das, 2000). In general, available B of 0.5 ppm is considered to be low or deficient level of B in soils.

Critical of level of Ca in soil is 300 ppm. That is, above this value is toxic and below denotes deficient condition (KAU, 2011).

The soil samples from 14 districts of Kerala showed that there was a very high deficiency of Ca and B. Around 50% soil samples had Ca deficiency and 70% had B deficiency (Viju, 2012).

Sureshkumar *et al.* (2013) reported that the availability of Ca is very low in Kerala soils due to leaching under heavy rainfall.

As per the report of Kerala State Planning Board (2013), about 45 per cent of the Kerala soils were deficient in Ca. *Onattukara* sands (AEU 3) and the Wayanadu plateau (AEU 20 and AEU 21) were showing very high deficiency of Ca and the deficiency was negligible in Kumily Hills (AEU 16), Attappady (AEU 18 and 19), Marayur Hills (AEU 17), central Palakkad (AEU 22) and eastern Palakkad (AEU 23).

A study by KSPB confirmed wide spread deficiency of B, with about 66% of the soil samples testing inadequate level. In laterite soils of Kerala, having low pH, B is lost by leaching as the B retention capacity of soil is very low. In Attappady hills and coastal low lands subjected to sea water inundation, the deficiency was not pronounced (KSPB, 2013).

2.3. CALCIUM

Calcium (Ca) is a very important secondary nutrient essential for plant growth and development. It plays a vital role in cell division and cell enlargement. Ca also takes part in the development of root system and storage organs. Main sources of Ca in soil are soil solution Ca and exchangeable Ca. Ca bearing minerals that contribute to soil solution include, liming agents, fertilizers, etc. Soil solution Ca is the one which is readily available for plant uptake. Depending upon the nature of parent material, degree of weathering and the prevailing climatic conditions, Ca content of different soil types varies significantly. Ca content of the soils derived from limestone is usually higher and is in the range of 100-700 g Ca/kg soil. A healthy soil has 40-50% Ca in its exchange complex.

2.3.1. Calcium Deficiency in Plants

Ca deficiency in plants decreases plant height by decreasing the mitotic activity in the terminal meristem (Nelson and Niedziela, 1998).

Pan (2000) reported that low supply of Ca to the soil inhibits nodulation, growth and nitrogen fixation of bacteria associated with the root of legumes.

Deficiencies of Ca are most likely to occur on acidic, sandy soils from which available Ca has been leached by irrigation water or rain and also on muck soils and strongly acid peat where total soil Ca is low. High exchangeable soil Na may depress plant uptake of Ca (Ganeshamurthy and Hegde, 2009).

Deficiency symptoms of Ca nutrition first appear on the growing apices and young regions of plants. Deficiency is characterized by marginal chlorosis of leaves which later changes to necrotic patches. Leaves become small and stunted, splitting and curling of leaf tips, edges and distal end of midrib (Bhattacharya, 2013).

2.3.2. Role of Calcium in Plant Nutrition

Ca is reported to exert significant positive effect on plant vigour and stiffness of straw and also on grain and seed formation in cereals (Follett *et al.*, 1981).

Ca acts as a mediator ion in the translocation of carbohydrates through its effect on the cell walls and cells (Bennett, 1993).

Ca as second messenger is involved in a large number of cellular functions which are regulated in plant cells by changes in cytosolic Ca^{2+} concentrations, such as gene expression, ionic balance, mitosis, carbohydrate metabolism and secretion (Bush, 1995).

Ca is a very important element required for structural roles in the cell wall and membranes, as an intracellular messenger in the cytosol and as a counter-cation for inorganic and organic anions in the vacuole (Marschner, 1995). It plays a key role in maintenance of membrane permeability and a major role in cell division and cell elongation (Fageria et al., 1997).

Fageria and Gheyi (1999) found that Ca is an indispensible nutrient for the germination of pollen tube in plants.

Ca has the potential to protect the plasma membrane from the deleterious effects of hydrogen ions at lower pH and also reduces harmful effects of Na^{+} in saline soils. It is also take part in the regulation of stomatal aperture (Epstein and Bloom, 2005).

Ca is not just a macronutrient but also a major controller of plant metabolism and development since it is an integral component in calmodulin (Jha, 2006).

Under Ca deficient conditions banana exhibits interveinal chlorosis near the leaf margins and towards the leaf tip. Later these patches create a serrated necrosis along the leaf edge. A temporary shortage of Ca causes the 'spike-leaf' symptom, in which the lamina on new leaves is deformed or almost absent (Robinson, 2010).

Ca plays an important role in chlorophyll components, enhancing pollen germination and growth, cell wall and membrane integrity and activators of several enzymes

2.3.3. Effect of Calcium on Content and Uptake of Nutrients

Increasing application of Ca caused gradual reduction in P and Mg concentrations and positively influenced the micronutrients such as Fe, Mn, Zn, Cl and B. it was also found that there exist a synergistic relationship between Ca and B (Romero and Ruiz, 2001).

2.3.4. Effect of Calcium on Yield and Yield Attributes

Nambiar *et al.* (1978) studied the effect of graded doses of lime on growth and yield of banana var. Zanzibar at Banana Research Station, Kannara and reported that application of lime contributed significantly to an increase in bunch weight, number of hands and number of fingers per bunch.

Nutritional studies on banana carried out by Rajeevan (1985) at Kannara on the effects of split application of fertilizers, nutrient uptake and translocation found that Ca were significant in the pseudostem and leaves.

Addition of Ca as gypsum increased the vigour and seed filling in sunflower in addition to seed yield (Ahmedkhan *et al.* 1990).

Prema (1992) observed that yield of banana crop was positively correlated with per cent Ca present in leaves. Moreno *et al.* (1999) studied the effect of Ca, K and Mg on banana yield and found that Ca application in banana significantly increased its yield.

Even though the effect of Ca is not significant on pollen germination and tube growth in mango, it induced more fruit set in mango cv. Namdokmai (Jutamanee *et al.*, 2002).

Sharma and Sarkar (2005) observed that conjunctive use of lime along with recommended level of fertilizers on acid soils has increased yield's of a variety of crops by about 49-189% over farmer's practice.

Rahman (2006) observed that Ca as a nutrient significantly influenced plant height and number of branches per plant in tomato that maximum values were obtained from the 150 kg/ha Ca while the shortest were from the control plot.

Foliar application of Ca nitrate at 1.5% in gooseberry increased the volume, weight and pulp weight of the fruit and reduced the stone weight (Tripathi and Shukla, 2011).

According to Rab *et al.* (2012) foliar application of 0.3% $CaCl_2$ has increased the plant height, branches per plant, yield and reduced the blossom end rot disorder in tomato.

Spraying Ca chloride (15 mM) either alone or in combination with 30 ppm humic acid affected vegetative and reproductive growth and yield of tomato positively (Kazemi, 2014).

According to Ilyas *et al.* (2014), 6% Ca application showed significant increase in plant height, number of branches per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit weight, yield/ ha and low percentage of blossom end rot fruits in tomato.

According to Prochnow (2014) a sound liming program improves physical, chemical and biological properties of the soil, positively influence the availability of plant nutrients, symbiotic N fixation by legumes and reduced toxicities to crops.

2.3.5. Effect of Calcium on Quality Parameters

Hartmond *et al.* (1993) reported a significant positive correlation between the percentage of locules that are filled and shelling percentage; confirming the value of shelling percentage as an index of Ca deficiency in plants.

Fertilization with Ca improved fruit storage life by reducing the incidence of internal browning associated with refrigerated storage and increased fruit Ca levels (Herath *et al.,* 2000).

Application of Ca at preharvest or postharvest stages can prevent postharvest disorder and fruit ripening in many crop species (Aguayo *et al.*, 2006).

Postharvest vacuum infiltration of papaya fruits in 2.5% $CaCl_2$ positively influence storage life capacity, control disease incidence and maintains quality characteristics such fruit firmness (Raqeeb *et al.,* 2008).

There were no significant effects of Ca treatments on plant growth, fruit size distribution, fruit weight or most indices of fruit quality of pineapple (Silva *et al.*, 2006). Ca application @ 100 kg ha^{-1} increased the number of filled pods, shelling percent, 100 seed weight, seed yield, calcium content, germinability, vigour and the oil content in groundnut (Kamara, 2010).

In sweet cherry, Ca treatment improved the amount of chlorophyll a and chlorophyll b content. The mass of carotenoid pigments were also increased in close connection with Ca sprays (Thurzo *et al.,* 2010).

Tripathi and Shukla (2011) reported that foliar application of Ca nitrate at 1.5% increased the TSS, ascorbic acid, total sugar and reduced titratable acidity content of fruits as compared to the control in gooseberry.

Herrera *et al.* (2012) postulated that in Cape gooseberry, the per cent fruit cracking was 38%, when Ca was not applied while with a dose of 100 kg ha^{-1}, the cracking was only 27%.

Spraying Ca chloride (15 mM) either alone or in combination with 30 ppm humic acid improved the chlorophyll content, TSS, vitamin C, nitrate reductase activity, fruit firmness, fruit lycopene content and lowest blossom end rot incidence (Kazemi, 2014).

2.3.6. Effect of calcium on disease resistance

Nutrition of plants has a substantial effect on the predisposition of plants to attack by pests and diseases. By affecting the growth pattern, the morphology and anatomy and particularly the chemical composition, the nutrition of plants may contribute either to an increase or decrease the tolerance and/or resistance to pests and diseases.

A review on Ca metabolism and its relationship with "maturity bronzing" in banana fruits by Cayon *et al.* (2007) reported that the incidence of maturity bronzing in dry season can be reduced to some extent by Ca nitrate fertilization.

Application of 4% $CaCl_2$ in banana delayed the onset of finger drop by 2 to 4 days, and hence extended shelf life of the fruit. The treatment was also found to reduce the incidence of finger drop to a great extent (Esguerra *et al.,* 2009).

Poovarodom and Boonplang (2010) reported that soil Ca together with pre-harvest spray of Ca and B is found to be useful for reducing the number of gamboge disorder and translucent flesh disorder fruits in mangosteen.

Foliar application of $CaCl_2$ @ 0.3% reduced the blossom end rot disease in tomato (Rab *et al.,* 2012).

Higher the concentration of Ca in the tissue, the greater is the plants ability to reduce fungal infection, since Ca is an integral part of Ca pectate (KSPB, 2013).

2.4. BORON

Boron (B) is an element which is unique not only in chemical properties but also in its role in biology. It occurs in low concentrations in the earth crust and in most igneous rocks and soils. The concentration of B in the earth's crust is 10 mg/kg and it ranges from 5 to 15 mg/kg in igneous rocks. Most soil B is unavailable to plants, the available B fraction ranging from 0.4 to 5 mg/ kg. B is mainly contributed from tourmaline and fluorine boro silicate minerals. Besides, B is also contributed by organic matter, irrigation water and different fertilizers containing B. Deficiency of B is the most widespread and common micronutrient deficiency which badly affect the crop growth and yield. Continuous supply of B is essential to get a normal healthy plant growth. Hence, adequate B supply must be ensured to obtain high yields and good quality of agriculture produce.

2.4.1. Boron Availability in Soils

Highly weathered soils of humid regions are often absolutely low in B and crops may suffer from B deficiency (Ellis *et al.,* 1982). On such sites B can easily be leached out from the root zone. The soluble form of B in soil is boric acid.

Availability of B in soils depends on the factors such as soil texture, liming, pH, soil moisture, organic matter content and relationship with certain anions and cations in soils (Tisdale *et al.,* 1985).

A substantial portion of B will get bound as ester to soil organic matter in sandy soils (Goldberg and Glaubig, 1986). Widespread B deficiency occurs in highly weathered red acid soils, soils derived from igneous rocks and sandy rice soils (Doberman and Fairhurst, 2000).

Available form of B in soil is derived from the decomposition of organic matter and release from clay minerals. H_3BO_3 is the highly mobile form of B in soils (Dunn *et al.*, 2005).

A positive correlation exists between the uptake of B and the concentration of boric acid in soil solution. A linear increase in leaf B is observed as the concentration of the nutrient in soil solution increased (Tariq *et al.*, 2005). Application of B in soil leads to fixation and thus unavailability (Rao *et al.,* 2013).

2.4.2. Boron Deficiency in Plants

Since B plays a key role in reproductive growth, poor fruit set and reduced fruit yield are the first visual symptoms of its deficiency (Loomis and Durst, 1992).

Since B is immobile in plants, the deficiency symptoms appear firstly on young leaves with marginal, dull yellow chlorosis at the tip. Due to the important role of B on elongation of leaves and stem, B deficient plants are short and stout. In severe cases, tillers may die before maturity (Bell, 1997).

Disruption of the normal functioning of the apical meristem with changes in cell wall synthesis, membrane structure, metabolisms of auxin, carbohydrate and RNA, phenol accumulation and transport of sucrose are the primary effect of B deficiency (Brown *et al.*, 2002).

According to Benton (2003), B deficiency, the most common and widespread micronutrient problem which vary between crop species, but generally occur in the growing points or flower or fruiting parts of the plant.

Characteristic symptoms of B deficiency include death and discolouration of apical meristems with consequent thickening of stems and multiple shooting of axillary buds, thickening of roots with multiple lateral apices close to the tip, youngest leaves become misshaped, wrinkled and often thickened with a darkish blue colour. Fruit formation is also affected (Bhattacharya, 2013).

2.4.3. Effect of Boron on Plant Nutrition

B has a functional role in the transport of carbohydrate and translocation of sugar, which is enhanced by the synthesis of borate- sugar complexes (Marcus-Wyner and Rains, 1982; Katyal and Singh, 1983).

B is a very essential micronutrient that directly or indirectly involved in several physiological and biochemical activities during plant growth. It is required only in very small quantities for successful crop production. The improvement in growth attributes as a result of B application is due to the enhanced photosynthetic and metabolic activity which leads to an increase in various plant metabolic pathways responsible for cell division and elongation (Barman *et al.*, 1987).

B plays an important role in flowering and fruit formation (Nonnecke, 1989). According to Tariq *et al.* (1993), B has a unique role in seed production. Plants will fail to produce flowers and any seeds even under moderate deficiency.

Involvement of B in hormone synthesis and translocation, carbohydrate metabolism and DNA synthesis contributes to additional growth and yield in crop plants (Kalyani *et al.*, 1993).

Obermeyer *et al.* (1996) suggested that the B as a nutrient has the ability to stimulate H^+ transport activity and ATP hydrolysis and control membrane voltage charging.

B is an essential micronutrient required for successful plant growth and its deficiency symptoms will appear when the plants suffer reduced supply of boron. Severe deficiency will lead to abnormal development of reproductive organs (Huang *et al.*, 2000).

Oosterhuis (2001) postulated that B has a very important role in cell wall synthesis. The primary cell walls of B deficient cells are not smooth but characterized by irregular depositions of vesicular aggregations intermixed with membraneous material. It also takes part in tissue differentiation and phenol and auxin metabolism, root cell elongation, seed germination, pollen tube growth and pollen germination.

Due to the lack of B, there is hypertrophy, disintegration and degeneration of cambium cells in the meristematic tissues. Its deficiency may cause sterility, small fruit size, poor yield and affects translocation of starches, sugar, N and P, synthesis of protiens and amino acids (Davis *et al.*, 2003).

Soil B application has increased the total soluble solids and total acidity, which can be attributed to the transportation of higher amount of assimilates into fruit tisses. It is also important for pollen tube growth and pollen germination, that likely to increase the fruit set. Hence, B fertilization will increase the yield particularly when grown on sandy soils having low amount of available B (Wojcik *et al.*, 2008).

Increase in the amount of photosynthetic pigments such as chlorophyll and carotenoid was noticed as result of foliar application of B in sweet cherry (Thurzo *et al.*, 2010).

B helps in the absorption of water and carbohydrate metabolism translocation of carbohydrates in plants, cell division and elongation, DNA synthesis in meristems, active salt absorption, fertilization, photosynthesis and involves indirectly in metabolism of N, P, hormones and fat (Haque *et al.*, 2011).

2.4.4. Effect of Boron on Content and Uptake of Nutrients

Band or foliar application of B in corn resulted in higher uptake in plants than B applied by broadcast (Touchton and Boswell, 1975). Foliar application of B in early growth stages results in greater absorption of B than when applied at later stages of growth (Gupta and Cutcliffe, 1972; 1975).

B fertilization increased the K uptake and its availability in soil by reducing the leaching losses (Soundararajan *et al.,* 1984).

Das (2000) reported that the application of B and K significantly increased each other concentration in rice crop grown in sandy soils.

According to Debnath and Ghosh (2012) increased levels of B application has increased the B concentration in rice shoots.

2.4.4.1. Macronutrients

B application in rice increases the uptake of N and K (Rakshit *et al.*, 2002). According to Yu and Bell (2002) application of B at the tillering stage of rice increased Ca and Mo in new leaves but it decreased Cu, Fe, K and S content.

Kabir *et al.* (2007) found that the application of 2 kg/ha of B produced highest straw and grain yield in rice and maximum uptake of N, P and K by rice plants.

Application of B (20 mg/kg) and lime (1/3 LR) has increased the concentration of N, K, Ca, Mg and S in rice plants (Barman *et al.,* 2014).

2.4.4.2. Micronutrients

Bhutto *et al.* (2013) observed that the application of Zn and B at 10 and 2 kg/ha to rice in addition to recommended dose of N and P improved the nutritional contents within grains.

Application of B (20 mg/kg) and lime (1/3 LR) reduced the concentration of Fe, Mn and Cu concentration in plants ((Barman *et al.,* 2014).

2.4.5. Effect of Boron on Yield and Yield Attributes

Many investigations reported that the application of B through different sources either through soil or foliar spray was found beneficial in stimulating plant growth and in increasing yield of various crops such as cereals, vegetables, fruit crops, etc.

Application of B @ 1.0 kg/ ha in combination with P in French bean induced early flowering and fruiting and got additional pod yield of 7.38 q/ ha (Singh and Singh, 1990).

The yield and yield attributes of crop cowpea, a very good source of vegetable protien are significantly benefited by the application of B especially during rabi season of the year (Dwivedi *et al*., 1993).

Kalyani *et al.* (1993) found that boric acid as a boron source increased the relative growth rate, plant height, net assimilation rate and leaf area index in pigeon pea.

Sharma (1995) observed that application of borax at 20 kg/ha and calcium carbonate at 10 kg/ha alone or in combination showed the best results in for plant height and number of branches per plant, number of fruits per plant, fruit yield and seed yield in Tomato.

From the studies of Sakal and Singh (1995) it was observed that a spectacular response of cereals, oilseeds, pulses and cash crops to the application of B (0.5 to 2.5 kg ha^{-1}) had largely been observed on B deficient soils of Bihar, West Bengal, Orissa, Assam and Punjab.

Application of borax 20 kg/ha gave the maximum plant height and number of branches per plant, while the control registered the least plant height and number of branches per plant (Sharma, 1999).

Meerabai (2001) reported B @ 2 kg/ha has the capacity to increase the ginger yield and application of B @ 4kg/ha has increased turmeric yield.

Rashid and Yasim (2002) reported that, due to the application of B, the yield of Basmathi rice was increased 25% over control.

Foliar spraying of 0.5% B at 50 per cent flowering period was found beneficial in increasing the number of fruits per plant, fruit weight and total fruit yield in tomato (Hamsaveni *et al.*, 2003).

In acid soils of Jharkhand, application of B @ 1.0 kg/ha alone or 0.5kg/ha along with 250 kg lime/ ha was found optimal for maximum production of gram (Singh *et al.*, 2004).

Karuppaiah (2005) noticed that the foliar application of 0.5% borax at 35, 50 and 65 days after transplanting to be the best in terms of number of flowers per plant, number of productive flowers per plant, individual fruit weight , number of fruits per plant and fruit yield in brinjal crop.

Kumar *et al.* (2006) observed that priming of pea seeds with 0.5% B solution increased the plant height, fruiting and pod yield with a simultaneous reduction in number of days to 50% flowering.

B application through seed treatment (4g/kg of seed) in Pigeon pea was more economical and effective in increasing the seed yield by 10.53% when compared with the control treatment (Malla *et al.,* 2007).

Uddin *et al.* (2008) reported that application of B @ 2kg/ha in Wheat increased the number of tillers per plant, spike length, spikelets per spike, grains per spike, grain and straw yield.

According to Jyolsna and Mathew (2008), B significantly increased plant height and number of primary branches. It also reduced the days to flowering and increased fruit set (12.5 to 20% more at the highest level) both with and without FYM. Benefit-cost ratio was 40% greater for the highest level of B when applied in conjunction with RDF compared with RDF alone (no B).

Soil application of B @ 20 kg/ha in tomato resulted in the highest fruit yield (Sathya *et al.*, 2010).

Patil *et al.* (2010) reported that application of boric acid @ of 100 ppm resulted in maximum number of primary branches, yield per plant and fruit yield in tomato var. Megha.

Foliar application of borax at 0.5% has the ability to result in significantly highest number of fruits and fruit yield per plant in bell pepper (Malabasari, 2011).

Mathew and George (2011) reported that the inclusion of B at 2.5 kg/ha along with sulphur at 30 kg/ ha within the Kerala State fertilizer recommendation has the ability to improve yield, harvest index and economics of growing sesame in Kerala.

In tomato, Rab and Haq (2012) noticed that foliar application of borax alone efficiently increased the number of flowers per cluster, fruits per cluster, fruit weight, fruit firmness, fruits per plant and total soluble solids content in the fruits.

Soil application of B @ 2 kg ha^{-1} resulted in maximum number of flower clusters per plant, fruit set percentage, and total yield. It was observed from the study that 2 kg B ha^{-1} significantly affected flowering and fruiting of tomato (Naz *et al.,* 2012).

According to Hussain *et al.* (2012) foliar applied B (1.5% B) and soil applied B (1.5 kg/ha) at different growth stages substantially improved the rice growth and yield. However, soil application was found better in improving the number of grains per panicle, grain yield, 1000 grain weight and harvest index.

B fertilization in apple in sandy soils having low B status increased the fruit set percentage and yield (Muntaz *et al*., 2012).

Vala and Savaliya (2014) observed that application of 0.1% borax significantly increased the fruit yield of bitter gourd var. Pusa Vishesh over control.

Ilyas *et al.* (2015) found that spraying of B @ 0.15% along with Zn resulted in highest number of flowers cluster/ plant, number of flowers /cluster, number of fruits/ cluster, number of branches /plant and yield under the agro climatic conditions of Peshawar.

According to Begum *et al.* (2015) addition of B at 3 kg ha^{-1} along with Zn at 4 kg ha^{-1} in onion was found as the best treatment since it resulted in maximum plant height, length and diameter of bulbs and bulb yield and has a positive impact on its residual effect on mungbean in respect of crop growth, yield and nutrient uptake. It was also reported that the effect of B on the growth and yield of crop was more prominent than that of Zn.

Suganiya and Harris (2015) found that foliar application of boric acid at 150 ppm increased the number of flower buds/ plant, number of flower clusters /plant, number of flowers/ cluster, total flowers/ plant, percentage of flower set, percentage of fruit set, number of fruits/ plant and fresh weight of fruits/ plant when compared with the control in brinjal.

According to Preman *et al.* (2015), combined application of Mg, Zn and B either in soil at the rate of $MgSO_4$ (80 kg/ha) + $ZnSO_4$ (20 kg/ha) + Borax (10 kg/ha) or as foliar application at the rate of $MgSO_4$ (1%) + $ZnSO_4$ (0.5%) + Borax (0.25%) produced maximum panicles per hill, spikelets per panicle and grain yield in irrigated rice. The highest straw yield was recorded with soil application of B along with NPK applied as recommended by POP.

Jose (2015) conducted a study on Mg and B nutrition for yard long bean in southern laterites of Kerala, which revealed that use of Mg and B in soil and foliar application had a significant effect on vegetative and yield characters. Foliar application of Mg and B as 2% $MgSO_4$ and 0.25% borax at fortnightly intervals along with soil test based package of practices recommendations of NPK recorded the highest yield.

Soil application of B @1.0kg/ha in equal splits at active tillering and flowering stages give the highest grain yield and lower spikelet sterility in rice (Remesh, 2016).

2.4.6. Effect of Boron on Quality Parameters

Foliar application of borax at 10 and 13 weeks after planting resulted in improvement of shelf life in potatoes. Following storage for 6 months, discoloration of tubers harvested from B-treated plants reduced and the reduction is attributed to lower phenolic concentrations and higher ascorbate concentrations in tubers from B-treated plants (Mai and Abawi, 1987).

Bumpy disorder, due to the deficiency of B in papaya can be overcome by the application of borax (Dassanayaka and Thantirige, 1993).

Meerabai (2001) reported that the application of B @ 4kg/ha in turmeric has increased the oil content and curcumin content to a great extent.

According to Jeanine *et al.* (2003) soil application of B has the power to improve the shelf life and reduce the incidence of fruit cracking in tomato.

Tomato fruits from the plants receiving foliar or root applied B were superior in characters such as fruit shelf life and fruit firmness. Fruits were also rich in B and K indicating that B has translocated from leaves to fruits (Davis *et al.,* 2003).

According to Jyolsna and Mathew (2008), B significantly improved the quality parameters like vitamin C, reducing sugars, total sugars, and lycopene content following B application alongwith increased yield.

The quality parameters of tomato variety PKM 1 such as lycopene, ascorbic acid, crude protein and total soluble sugars were significantly increased due to the soil application of borax @ 20 kg ha^{-1} whereas crude fibre and titratable acidity were the lowest (Sathya *et al.,* 2010).

Shukla *et al.* (2011) observed in Aonla that borax concentration of 0.4% was very effective in increasing the total sugar, TSS, ascorbic acid content, and reduced titrable acidity.

Shazly and Kotb (2011) found that B application in pear trees contributed to increased TSS and total sugars and reduced acidity.

Rab and Haq (2012) observed that foliar application of borax (0.2%) along with $CaCl_2$ (0.6%) resulted in better quality aspects such as maximum fruit firmness, and total soluble solids.

Foliar spraying of B @ 100 ppm along with Zn was found to be the best treatment to improve growth, yield and fruit quality of tomato cv. Azad T-6 under Lucknow subtropical condition. B alone or in combination with Zn has contributed to improved quality parameters such as ascorbic acid, TSS, fruit length and fruit diameter (Meena *et al*., 2015).

Harris and Lavanya (2016) conducted a study on the Influence of foliar application of B, Cu and their combinations on the quality of Tomato. They found that the application of B increased the fresh weight of fruits, pulp weight and TSS and B concentration at different levels had significant positive effect on most of the quality parameters such as acidity, ascorbic acid, TSS and pH.

2.4.7. Effect of boron on Disease Resistance

Guerra and Anderson (1985) found that the application of B in beans depressed the total length of lesion caused by Fusarium solani. The association of B with lignin synthesis suggests that boron suppress infection of the stele by a lignified physical barrier at the epidermis.

B is reported to decrease the expression of club root (*Plasmodiophora brassicae*) of crucifers and potato wart disease (*Synchytrium endobioticum*) by reducing the high concentration of auxin or auxin like substances in plants (Dixon and Webster, 1988).

Xuan *et al*. (2003) observed that pre-harvest B application will improve the ability of fruit tissue to better resist impaired storage conditions by avoiding typical browning disorders.

Several physiological disorders of fruits can be controlled by the proper and timely application of micronutrients and thereby increasing their marketability to a great extent (Jeyakumar, 2005).

Dordas (2008) reported verticillium wilt in tomato can be controlled efficiently by B apaplication. Roots of B supplied plants showed no vascular discolouration. This emphasise that boron inhibits the invasion of xylem by the pathogens.

Foliar application of borax (0.2%) along with $CaCl_2$ (0.6%) resulted in lowest blossom end rot incidence in tomato (Rab and Haq, 2012).

Deficiency of B reduces the amount of the plants natural antifungal compounds at the site of infection and thereby increasing the sevearity of the disease (KSPB, 2013).

Materials and Methods

3. MATERIALS AND METHODS

An investigation entitled "Response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district" was carried out at *Onattukara* Regional Agricultural Research Station (ORARS) farm of Kayamkulam from September to December 2016 to study the effect of calcium and boron on yield and quality of tomato and to develop a recommendation for these nutrients to optimize the productivity using tomato as the test crop. The details of the whole study are presented in this chapter.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The field experiment was conducted in the farm of ORARS, Kayamkulam. The farm is located at 9° 09' 34.56" N latitude and 76° 33' 15.36" E longitude at an altitude of 20 m above MSL.

3.1.2 Soil

Soil of the experimental site comes under the taxonomic family of Loamy Skeletal Kaolinitic Isohyperthermic Ustic Quartzi *Psamments*. Soil samples (15 cm depth) were collected from the experimental site before the application of treatments. Air dried samples were sieved through 2 mm sieve and analysed for pH, EC, OC (0.5 mm sieved soil), available nutrients such as N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B through standard procedures given in Table 1. The physico-chemical characteristics of the experimental site are presented in Table 2.

3.1.3 Season

The experiment was conducted during September to December 2016.

3.1.4 Weather Conditions

The weather conditions (maximum temperature, minimum temperature, relative humidity and monthly rainfall) prevailed during the crop period is given in Fig.1.

Table 1. Standard analytical methods followed for soil analysis

Sl. No.	Parameter	Method	Reference
1	pH	pH meter	Jackson (1973)
2	Electrical conductivity	Conductivity meter	Jackson (1973)
3	Organic carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
4	Available nitrogen	Alkaline potassium permanganate method	Subbiah and Asija (1956)
5	Bray No. 1 extractable phosphorous	Bray and Kurtz extraction method. Estimation by spectrophotometry.	Jackson (1973)
6	Neutral normal ammonium acetate extractable K	Flame photometry	Jackson (1973)
7	Neutral normal ammonium acetate extraction and titration with EDTA for exchangeable Ca and Mg	Versanate titration method	Hesse (1971)
8	0.01N $CaCl_2$ extractable sulphur	Turbidimetry	Chesnin and Yien (1950)
9	0.1 N HCl extractable Fe, Mn, Zn and Cu	Atomic Absorption Spectrophotometer	Sims and Johnson (1991)
10	Boron	Hot water extraction and colorimetry using Azomethine- H	Hesse (1971)

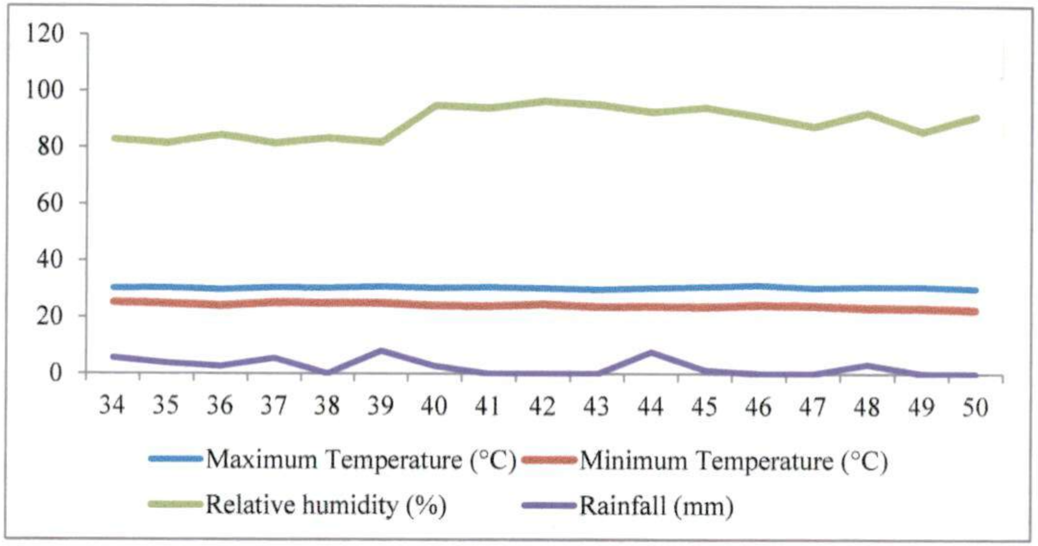


Fig.1 Weather parameters during the cropping period

Table 2. Soil physico- chemical properties of the experimental site

Sl.No.	Parameter	Mean value
	Physical properties	
1	Mechanical composition	
	Coarse sand (%)	68.24
	Fine sand (%)	17.82
	Silt (%)	5.03
	Clay (%)	9.32
2	Bulk density (Mgm^{-3})	1.70
3	Particle density (Mgm^{-3})	2.53
4	Water holding capacity (%)	15.92
5	Porosity (%)	25.38
	Chemical properties	
1	Soil reaction	5.46 (Strongly acid)
2	Electrical conductivity ($\mu S\ m^{-1}$)	212
3	Available N ($kg\ ha^{-1}$)	194.56 (low)
4	Available P_2O_5 ($kg\ ha^{-1}$)	9.37 (low)
5	Available K_2O ($kg\ ha^{-1}$)	103.67 (low)
6	Available Ca ($mg\ kg^{-1}$)	210.20(deficient)
7	Available Mg ($mg\ kg^{-1}$)	73.37 (deficient)
8	Available S ($mg\ kg^{-1}$)	4.92 (deficient)
9	Available Cu ($mg\ kg^{-1}$)	1.10 (sufficient)
10	Available Mn ($mg\ kg^{-1}$)	3.21 (sufficient)
11	Available Fe ($mg\ kg^{-1}$)	19.54(sufficient)
12	Available Zn ($mg\ kg^{-1}$)	1.12 (sufficient)
13	Available B ($mg\ kg^{-1}$)	0.424 (deficient)

3.2 EXPERIMENTAL MATERIALS

3.2.1 Crop and Variety

The experiment has been done with tomato variety Vellayani Vijay. It is a variety released from COA, Vellayani which is resistant to bacterial wilt disease. Tomato seeds were purchased from *Onattukara* Regional Agricultural Research Station, Kayamkulam.

3.2.2 Manures and Fertilizers

Farm yard manure (FYM) was given @ 20 t/ha as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2011). The source of N, P and K were Urea (46 per cent N), Rajphos (20 per cent P_2O_5) and Muriate of Potash (60 per cent K_2O) respectively. Calcium was supplied through CaO and the dose of Ca has been worked out from lime requirement by SMP method. Boron was supplied through borax at 50 per cent flowering stage.

3.3 DESIGN AND LAYOUT OF THE EXPERIMENT

3.3.1 Experimental Details

Design : RBD

Treatments : 17 (4 x 4 + 1)

Replications : 2

Spacing : 60 x 60 cm

Plot size : 3 m x 2 m

The layout of the field experiment is given in Fig. 2. An overall view of the experimental field is shown in plate 1.

3.3.2 Treatments

Treatments were the combinations of four levels each of Ca and B plus one control (4^2 *ie* 16 plus one control). Altogether there were 17 treatments and 2 replications and in each plot there were 16 plants. Ca was applied in soil at the time of land preparation. B was applied at 50 per cent flowering as foliar spray.

3.3.2.1 Levels of Nutrients

Levels of Calcium

1. No calcium (Ca-0)

2. Full dose of calcium as basal (Ca-1: 546 g CaO per plot)

3. 1/2 dose of calcium as basal (Ca-2: 273 g CaO per plot)

4. 1/4 dose of calcium as basal (Ca-3: 136 g CaO per plot)

Levels of Boron

1. No boron (B-0)

2. Foliar spray 0.1% (B-1)

3. Foliar spray 0.2% (B-2)

4. Foliar spray 0.3% (B-3)

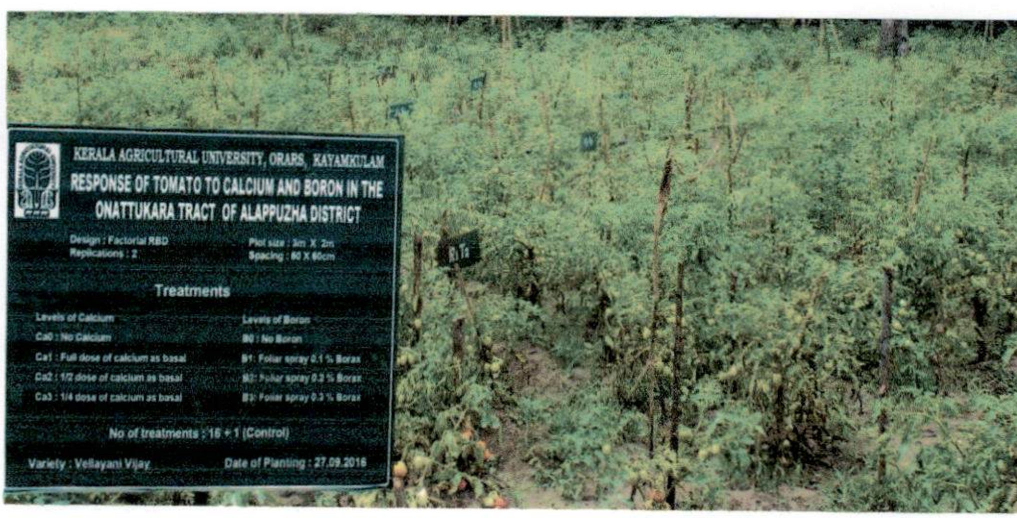
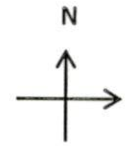


Plate 1. General view of the experimental field

3.3.2.2 Treatment Combinations

- Ca_0B_0
- Ca_0B_1
- Ca_0B_2
- Ca_0B_3
- Ca_1B_0
- Ca_1B_1
- Ca_1B_2
- Ca_1B_3
- Ca_2B_0
- Ca_2B_1
- Ca_2B_2
- Ca_2B_3
- Ca_3B_0
- Ca_3B_1
- Ca_3B_2
- Ca_3B_3
- Control: Soil test based application of N, P, K, B (foliar spray 0.5 % B) and recommended dose of lime (120 g CaO per plot).



Ca_3B_0	Ca_1B_1	Ca_0B_3	
Ca_0B_0	Ca_2B_3	Ca_2B_1	
Control	Ca_0B_1	Ca_3B_2	R_1
Ca_3B_1	Ca_2B_2	Ca_1B_3	
Ca_1B_2	Ca_1B_0	Ca_2B_0	
Ca_0B_2	Ca_3B_3		

Ca_2B_1	Ca_0B_3	Ca_3B_3	
Ca_1B_0	Ca_0B_0	Ca_1B_3	
Ca_1B_1	Ca_3B_1	Ca_0B_1	R_2
Ca_0B_2	Ca_2B_0	Ca_3B_0	
Ca_2B_2	Ca_1B_2	Ca_2B_3	
Ca_3B_2	Control		

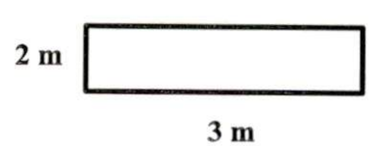


Fig. 2 Layout of the experimental field

3.4 FIELD EXPERIMENT

3.4.1 Land Preparation

The experimental area was ploughed thoroughly and then levelled. Weeds were removed completely and a light irrigation was given. The whole field was laid out into 34 plots of 3x2 m size according to the orientation of land.

3.4.2 Manure and Fertilizer Application

Doses of fertilizers and farm yard manure for tomato were N-P-K @ 75: 40: 25 kg/ha and 20 t/ha. Fertilizer dose was modified based on soil test results. Half dose of nitrogen (as urea), potassium (as muriate of potash) and full dose of phosphorus (as rajphos) was given as basal dose. One fourth dose of nitrogen and remaining potassium was applied 20 days after planting and the remaining quantity of nitrogen was applied 2 months after planting.

3.4.3 Sowing

Tomato seeds were sown in the nursery on 1st September 2016. Seeds were sown on slightly raised bed. Seedlings were transplanted to the respective plots on 27th September 2016 with FYM and required quantity of basal dose of fertilizers. Spacing adopted in the plot was 60 x 60 cm. Irrigation was carried out at regular intervals.

3.4.4 Plant Protection

Flubendiamide @ 1ml/10 l was given to prevent Spodoptera attack.

3.5 BIOMETRIC OBSERVATIONS

3.5.1 Vegetative Characters

3.5.1.1 Plant Height

Height of the plants was recorded at 3 MAP. Plant height was measured using a field scale from the ground level to the top most leaf bud. Then the mean value was computed and recorded as plant height in cm.

3.5.1.2 Node to First Inflorescence

Number of the node from which the first inflorescence was emerged at the time of first flowering was recorded.

3.5.1.3 Primary Branches per Plant

Number of primary branches in each observational plant was recorded at 3 MAP and the mean value was computed and recorded as primary branches per plant.

3.5.1.4 Internodal Length

Intermodal length was recorded at 3 MAP and the mean value was computed and expressed in cm.

3.5.1.5 Leaf Length

Length of leaves in each observational plant was recorded at 3 MAP. Then the mean values was computed and expressed in cm.

3.5.1.6 Leaf Width

Width of leaves in each observational plant was recorded at 3 MAP. Mean values was computed and expressed in cm.

3.5.2 Flowering Characters

3.5.2.1 Days to First Flowering

The number of days taken for the first flower to emerge after transplanting was recorded for each plant and the average obtained.

3.5.2.2 Days to Fruit Set

The numbers of days taken for the fruit set after flowering was recorded for each observational plant and mean value was worked out.

3.5.2.3 Flowers per Cluster

The number of flowers per cluster in observational plant was recorded from the same cluster which was tagged for taking observations and the average obtained.

3.5.2.4 Inflorescence per Plant

The total numbers of inflorescence in each observational plant was counted and mean value for each plant was determined.

3.5.2.5 Fruit Set (per cent)

Fruit set percentage in each observational plant was calculated at full fruiting stage by counting the total number of flowers and number of fruits which were set. Fruit set percentage can be calculated by the following formula

$$\text{Percentage fruit set} = \frac{\text{Number of fruits/ inflorescence}}{\text{Number of flowers/ inflorescence}} \times 100$$

3.5.3 Fruiting Characters and Yield

3.5.3.1 Fruits per Cluster

Number of fruits produced per cluster of the observational plants was recorded and the mean obtained.

3.5.3.2 Fruits per Plant

Total number of fruits produced per observational plant till the last harvest was counted.

3.5.3.3 Fruit Length (cm)

Length of fruits was measured as the distance between the pedicel attachment of the fruit and apex using twine and scale. Mean value was obtained and expressed in cm.

3.5.3.4 Fruit Girth (cm)

Girth of fruits was taken from the same fruits used for recording the fruit length using vernier caliper. The average was worked out and expressed in cm.

3.5.3.5 Fruit Weight (g)

Weight of fruits used for recording fruit length and girth was measured and expressed in g.

3.5.3.6 Yield per Plant (g)

The total weight of all fruits harvested from each observational plant was recorded at the time of harvest and expressed in g.

3.5.3.7 Yield per Plot (kg)

The total weight of all fruits harvested from every plot was recorded at the time of harvest and expressed in kg.

3.5.4 Quality Characters

3.5.4.1 TSS (%)

Total soluble solids in fruits were estimated using Abbe hand refractometer after crushing the fruits in a muslin cloth and expressed in %.

3.5.4.2 Lycopene (μg g^{-1})

The content of lycopene in full ripe fruits were estimated by colorimetric method and expressed in μg g^{-1} of fresh ripe fruits.

3.5.4.3 Ascorbic Acid (mg 100g^{-1})

Ascorbic acid content of fruits was estimated by 2, 6 dichlorophenol indophenol redox titration method and expressed as mg 100 g^{-1} of fresh ripe fruits.

3.5.5 Incidence of Pests and Diseases

All plots were monitored for the incidence of pests and diseases throughout the crop period. Attack of Spodoptera was observed during early growth stage. Timely spraying of pesticide (Flubendiamide @ 1ml/ 10 l) was done to avoid crop damage.

3.5.6 Physiological Disorders

3.5.6.1 Blossom End Rot (BER)

Per cent occurrence of BER was noted at each harvest.

3.5.6.2 Fruit Cracking

Per cent occurrence of fruit cracking was noted at each harvest.

3.5.7 Soil Analysis

Soil samples were collected after final harvest for chemical analysis. The air dried samples were sieved through 2 mm sieve and analysed for pH, EC, OC (0.5 mm sieved soil), available N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B using standard analytical procedures presented in Table 1.

3.5.8 Plant Analysis

Plant samples were collected at the time of harvest. The samples were oven dried at 70°C, powdered using a Wiley mill and used for the estimation of plant content of N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn and B for uptake studies. Standard analytical procedures followed for plant analysis is presented in Table 3.

3.5.9 Statistical Analysis

Experimental data generated from the study were subjected to statistical analysis by applying ANOVA for RBD and significance was tested by 'F' test (Snedecor and Cochran, 1967). CD was calculated in situations where the treatments were found to be significant, using standard procedures.

3.5.10 Economic Analysis

Economics of cultivation for the experiment was worked out by considering the cost of cultivation and prevailing market price of tomato.

B: C ratio was calculated as follows:

Benefit: Cost ratio = Gross income/ Total expenditure

Table 3. Standard analytical methods followed for plant analysis

Sl. No.	Parameter	Methods	Reference
1	Nitrogen	Micro Kjeldhal distillation after digestion in sulphuric acid	Jackson (1973)
2	Phosphorus	Nitric – perchloric acid (9:4) digestion and colorimetry making use of vanado-molybdo phosphoric yellow colour method	Jackson (1973)
3	Potassium	Nitric – perchloric acid (9:4) digestion and flame photometry	Jackson (1973)
4	Calcium and Magnesium	Versanate titration method	Hesse (1971)
5	Sulphur	Nitric – perchloric acid (9:4) digestion and turbidimetry	Chesnin and Yien (1950)
6	Fe, Mn, Zn, Cu	Nitric – perchloric acid (9:4) digestion and atomic absorption spectrophotometry	Jackson (1973)
7	Boron	Dry ashing, extraction in 0.36 N H_2SO_4, filtration and photoelectric colorimetry using Azomethine- H	Gupta (1967)

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Results

4. RESULTS

A field experiment was conducted to study the response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district. The data on the various observations were statistically analysed and presented in this chapter.

4.1 BIOMETRIC CHARACTERS OF TOMATO AS INFLUENCED BY THE APPLICATION OF Ca AND B

4.1.1 Vegetative Characters

4.1.1.1 Plant Height

The results on the effect of Ca and B application on the plant height of tomato are presented in Table 4. There was significant difference among the main effects of Ca and main effects of B.

Plant height was significantly influenced by the application of Ca. Full dose of Ca as basal (Ca-1) resulted in the highest plant height of 63.37 cm which was on par with Ca-2 (half dose of Ca as basal). The lowest plant height of 58.83 cm was observed in Ca-0 (No Ca).

Application of B had a significant effect on plant height. Foliar spray of 0.3% B (B-3) recorded the highest plant height of 63.35cm. The lowest value of 59.82 cm was observed at B-0 (No B)

None of the interactions significantly influenced the plant height.

Control was found to be non-significant over treatments.

4.1.1.2 Node to First Inflorescence

Data on the effects of Ca and B application on the node to first inflorescence are presented in Table 4. There was significant difference among the main effects of Ca.

Table 4. Effect of Ca and B application on plant height (cm) and node to first inflorescence of tomato variety Vellayani Vijay

Treatments	Plant height	Node to first inflorescence
Levels of Ca		
Ca-0	58.83	5.76
Ca-1	63.37	4.13
Ca-2	62.71	4.44
Ca-3	60.98	4.75
SEm	0.434	0.202
CD (0.05)	1.32	0.613
Levels of B		
B-0	59.82	5.41
B-1	60.97	5.13
B-2	61.74	5.29
B-3	63.35	5.67
SEm	0.434	0.415
CD (0.05)	1.32	NS
Interactions		
Ca_0B_0	57.75	6.13
Ca_0B_1	58.63	5.88
Ca_0B_2	59.39	5.62
Ca_0B_3	59.58	5.41
Ca_1B_0	60.73	5.02
Ca_1B_1	62.25	4.31
Ca_1B_2	64.00	4.20
Ca_1B_3	66.50	3.00
Ca_2B_0	60.69	5.12
Ca_2B_1	62.00	4.40
Ca_2B_2	62.30	4.24
Ca_2B_3	65.85	4.00
Ca_3B_0	60.12	5.38
Ca_3B_1	61.03	4.59
Ca_3B_2	61.28	4.53
Ca_3B_3	61.50	4.51
SEm	0.868	0.403
CD (0.05)	NS	NS
Control	59.58	5.16
Control vs.Treatments	NS	NS

There was significant effect of Ca on node to first inflorescence. The lowest number of nodes to first inflorescence of 4.13 was observed in Ca-1 which was found to be on par with Ca-2. The highest number of nodes to first inflorescence of 5.76 was found at Ca-0.

B had no significant effect on node to first inflorescence.

None of the interactions were found to be significantly influence the number of nodes to first inflorescence.

Control versus treatments was found to be non-significant.

4.1.1.3 Primary Branches per Plant

Data on the effects of Ca and B application on the primary branches per plant are presented in Table 5. There was significant difference among the main effects of Ca and main effects of B.

Perusal of the data indicated that Ca exerted a significant effect on the number of primary branches per plant. Ca-1 recorded the highest primary branches per plant of 5.36 which were on par with Ca-2. The lowest number of primary branches per plant was recorded under Ca-0 (4.27).

B application significantly influenced the primary branches per plant. The highest primary branches per plant of 5.38 were recorded at B-3 and the lowest in B-0 (4.39).

None of the interactions were found to be significantly influence the primary branches per plant.

Control versus treatments was found to be non-significant.

4.1.1.4 Internodal Length

Data on the effects of Ca and B application on intermodal length are presented in Table 5. There was significant difference among the main effects of Ca and main effects of B.

Table 5. Effect of Ca and B application on primary branches per plant and internodal length(cm) of tomato variety Vellayani Vijay

Treatments	**Primary branches per plant**	**Internodal length**
Levels of Ca		
Ca-0	4.27	4.63
Ca-1	5.36	8.05
Ca-2	5.29	7.42
Ca-3	4.64	6.28
SEm	0.131	0.096
CD (0.05)	0.398	0.0292
Levels of B		
B-0	4.39	6.27
B-1	4.84	6.46
B-2	4.96	6.74
B-3	5.38	6.91
SEm	0.131	0.096
CD (0.05)	0.398	0.0292
Interactions		
Ca_0B_0	4.12	4.13
Ca_0B_1	4.29	4.49
Ca_0B_2	4.33	4.85
Ca_0B_3	4.36	5.06
Ca_1B_0	4.55	7.80
Ca_1B_1	5.29	7.93
Ca_1B_2	5.31	8.19
Ca_1B_3	6.30	8.30
Ca_2B_0	4.49	7.05
Ca_2B_1	5.18	7.32
Ca_2B_2	5.50	7.61
Ca_2B_3	6.01	7.72
Ca_3B_0	4.40	6.11
Ca_3B_1	4.60	6.13
Ca_3B_2	4.73	6.31
Ca_3B_3	4.86	6.59
SEm	0.262	0.192
CD (0.05)	NS	NS
Control	4.53	5.79
Control vs.Treatments	NS	NS

Ca application had a significant effect on internodal length. The highest internodal length of 8.05 cm was observed at Ca-1 and the lowest in Ca-0 (4.63 cm).

Application of B significantly influenced the internodal length. B-3 produced the highest internodal length of 6.91cm which was on par with B-2. The lowest internodal length was recorded at B-0 (6.27 cm).

None of the interactions were significant.

Control versus treatments was found to be non-significant.

4.1.1.5 Leaf Length

The results on the effect of Ca and B application on leaf length are presented in Table 6. There was significant difference among the main effects of Ca and main effects of B.

Ca application significantly influenced the length of leaves. The highest leaf length of 6.10cm was observed in Ca-1 and the lowest value was recorded at Ca-0 (4.15 cm).

B application had a significant effect on leaf length. The highest leaf length of 5.30cm was observed in B-3 which was on par with B-2. The lowest leaf length was observed at B-0 (4.84 cm).

Interactions were found to be non-significant.

Control versus treatments was found to be non-significant.

4.1.1.6 Leaf Width

Data on the effects of Ca and B application on leaf width are presented in Table 6. There was significant difference among the main effects of Ca.

Table 6. Effect of Ca and B application on leaf length (cm) and leaf width (cm) of tomato variety Vellayani Vijay

Treatments	Leaf length	Leaf width
Levels of Ca		
Ca-0	4.15	2.24
Ca-1	6.10	3.29
Ca-2	5.36	2.91
Ca-3	4.77	2.64
SEm	0.064	0.077
CD (0.05)	0.196	0.234
Levels of B		
B-0	4.84	2.64
B-1	5.05	2.72
B-2	5.19	2.83
B-3	5.30	2.89
SEm	0.064	0.077
CD (0.05)	0.196	NS
Interactions		
Ca_0B_0	4.09	2.12
Ca_0B_1	4.12	2.25
Ca_0B_2	4.16	2.30
Ca_0B_3	4.25	2.32
Ca_1B_0	6.00	3.11
Ca_1B_1	6.04	3.16
Ca_1B_2	6.18	3.38
Ca_1B_3	6.20	3.51
Ca_2B_0	5.02	2.83
Ca_2B_1	5.20	2.87
Ca_2B_2	5.45	2.95
Ca_2B_3	5.78	3.00
Ca_3B_0	4.28	2.51
Ca_3B_1	4.84	2.63
Ca_3B_2	4.98	2.71
Ca_3B_3	5.00	2.74
SEm	0.129	0.154
CD (0.05)	NS	NS
Control	4.13	2.15
Control vs.Treatments	NS	NS

Application of Ca had a significant effect on leaf width. The highest leaf width of 3.29 cm was recorded at Ca-1 and the lowest was recorded at Ca-0 (2.24 cm).

B application did not have any significant effect on leaf width.

None of the interactions were significant.

Control versus treatments was found to be non-significant.

4.1.2 Flowering Characters

4.1.2.1 Days to First Flowering

Data on the effects of Ca and B application on days to first flowering are presented in Table 7. The results revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.1.2.2 Days to Fruit Set

The results on the effect of Ca and B application on days to fruit set are presented in Table 7. There was significant difference among the main effects of boron.

Application of Ca did not have any significant effect on days to fruit set.

Application of B had a significant effect on days to fruit set. The minimum number of days to fruit set, 5.25 days was recorded at B-3 and the highest was at B-0 (8.08 days).

None of the interactions could significantly influence the days to fruit set.

Control versus treatments was found to be significant.

Table 7. Effect of Ca and B application on days to 1st flowering and days to fruit set of tomato variety Vellayani Vijay

Treatments	Days to 1st flowering	Days to fruit set
Levels of Ca		
Ca-0	28.48	6.76
Ca-1	28.20	6.69
Ca-2	28.36	6.77
Ca-3	28.38	6.63
SEm	0.101	0.182
CD (0.05)	NS	NS
Levels of B		
B-0	28.27	8.08
B-1	28.38	7.38
B-2	28.34	6.13
B-3	28.43	5.25
SEm	0.101	0.182
CD (0.05)	NS	0.553
Interactions		
Ca_0B_0	28.36	8.32
Ca_0B_1	28.46	7.25
Ca_0B_2	28.54	6.20
Ca_0B_3	28.55	5.28
Ca_1B_0	28.25	8.00
Ca_1B_1	28.22	7.49
Ca_1B_2	28.09	6.02
Ca_1B_3	28.25	5.27
Ca_2B_0	28.29	8.02
Ca_2B_1	28.41	7.61
Ca_2B_2	28.50	6.19
Ca_2B_3	28.24	5.27
Ca_3B_0	28.18	8.00
Ca_3B_1	28.46	7.19
Ca_3B_2	28.22	6.13
Ca_3B_3	28.69	5.20
SEm	0.203	0.363
CD (0.05)	NS	NS
Control	28.36	5.30
Control vs.Treatments	NS	15.19*

Note:
*- f calculated value

4.1.2.3 Flowers per Cluster

Data on the effects of Ca and B application on flowers per cluster are presented in Table 8. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

Ca application produced a significant effect on number of flowers per cluster. The highest flowers per cluster of 7.34 were recorded at Ca-1 which was on par with Ca-2. The lowest number of flowers per cluster was observed at Ca-0 (5.70).

B application had a significant effect on number of flowers per cluster. The highest number of flowers per cluster of 7.18 was recorded at B-3 and the lowest in B-0 (6.04).

Interaction of Ca and B produced a significant effect on flowers per cluster. Full dose of Ca as basal along with 0.3% foliar spray of B (Ca_1B_3) produced the highest number of flowers per cluster of 8.00 which was on par with the application of half dose of Ca as basal along with 0.3 % foliar spray of B (Ca_2B_3).

Control versus treatments was found to be non-significant.

4.1.2.4 Inflorescence per Plant

The results on the effect of Ca and B application on inflorescence per plant are presented in Table 8. There was significant difference among the main effects of Ca and main effects of B.

Ca application had a significant effect on inflorescence per plant. Ca-1 produced the highest inflorescence per plant of 16.19 which was on par with Ca-2. The lowest number of inflorescence per plant was recorded at Ca-0 (9.55).

Application of B produced a significant effect on inflorescence per plant. Maximum inflorescence per plant of 15.63 was observed at B-3 which was on par

Table 8. Effect of Ca and B application on flowers per cluster, inflorescence per plant and fruit set (%) of tomato variety Vellayani Vijay

Treatments	Flowers per cluster	Inflorescence per plant	Fruit set
Levels of Ca			
Ca-0	5.70	9.55	47.97
Ca-1	7.34	16.19	60.80
Ca-2	7.12	14.81	59.50
Ca-3	6.62	11.93	57.30
SEm	0.056	0.953	0.964
CD (0.05)	0.169	2.90	2.933
Levels of B			
B-0	6.04	10.56	50.88
B-1	6.64	12.65	56.63
B-2	6.93	13.64	58.05
B-3	7.18	15.63	60.01
SEm	0.056	0.953	0.964
CD (0.05)	0.169	2.90	2.933
Interactions			
Ca_0B_0	4.93	9.01	40.87
Ca_0B_1	5.75	9.3	48.26
Ca_0B_2	6.02	9.45	50.66
Ca_0B_3	6.12	10.45	52.08
Ca_1B_0	6.65	11.18	56.43
Ca_1B_1	7.12	15.65	60.26
Ca_1B_2	7.62	16.95	61.51
Ca_1B_3	8.00	21	65
Ca_2B_0	6.30	11.05	53.15
Ca_2B_1	7.02	13.45	60.01
Ca_2B_2	7.34	15.95	61.30
Ca_2B_3	7.85	18.80	63.56
Ca_3B_0	6.29	10.99	53.08
Ca_3B_1	6.70	12.20	57.98
Ca_3B_2	6.74	12.22	58.75
Ca_3B_3	6.78	12.30	59.39
SEm	0.111	1.907	1.929
CD (0.05)	0.338	NS	NS
Control	6.81	12.45	59.65
Control vs.Treatments	NS	NS	NS

with B-2. Minimum number of inflorescence per plant was recorded at B-0 (10.56).

None of the interactions were significant.

Control versus treatments was found to be non-significant.

4.1.2.5 Fruit Set (%)

Data on the effects of Ca and B application on fruit set (per cent) are presented in Table 8. There was significant difference among the main effects of Ca and main effects of B.

Ca application produced a significant effect on fruit set per cent. Ca-1 recorded the maximum fruit set per cent of 60.80 per cent which was on par with Ca-2. The lowest fruit set per cent was observed at Ca-0 (47.97).

B application had a significant effect on fruit set per cent. B-3 recorded the highest fruit set per cent of 60.01 which was found to be on par with B-2. Minimum fruit set per cent was recorded at B-0 (50.88).

None of the interactions could significantly influence the fruit set per cent.

Control versus treatments was found to be non-significant.

4.1.3 Fruit Characters

4.1.3.1 Fruits per Cluster

The results on the effect of Ca and B application on number of fruits per cluster are presented in Table 9. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

Application of Ca had a significant influence on fruits per cluster. The highest number of fruits per cluster of 4.48 was observed in Ca-1 and the lowest in Ca-0 (2.75).

Table 9. Effect of Ca and B application on fruits per cluster and fruits per plant of tomato variety Vellayani Vijay

Treatments	Fruits per cluster	Fruits per plant
Levels of Ca		
Ca-0	2.75	20.68
Ca-1	4.48	25.70
Ca-2	4.26	24.91
Ca-3	3.80	22.80
SEm	0.042	0.369
CD (0.05)	0.128	1.123
Levels of B		
B-0	3.11	21.59
B-1	3.79	22.76
B-2	4.05	24.19
B-3	4.34	25.54
SEm	0.042	0.369
CD (0.05)	0.128	1.123
Interactions		
Ca_0B_0	2.01	19.98
Ca_0B_1	2.77	20.10
Ca_0B_2	3.05	20.98
Ca_0B_3	3.18	21.66
Ca_1B_0	3.75	22.42
Ca_1B_1	4.29	24.16
Ca_1B_2	4.69	26.89
Ca_1B_3	5.20	29.34
Ca_2B_0	3.35	22.10
Ca_2B_1	4.21	23.97
Ca_2B_2	4.50	25.80
Ca_2B_3	4.99	27.79
Ca_3B_0	3.34	21.88
Ca_3B_1	3.88	22.82
Ca_3B_2	3.96	23.10
Ca_3B_3	4.02	23.39
SEm	0.084	0.738
CD (0.05)	0.255	2.246
Control	4.06	23.93
Control vs.Treatments	8.11*	NS

Note:

*- f calculated value

B application produced a significant effect on fruits per cluster. B-3 recorded the maximum fruits per cluster of 4.34 and the lowest in B-0 (3.11).

Interaction of Ca and B produced a significant effect on fruits per cluster. Full dose of Ca along with 0.3% foliar spray of B (Ca_1B_3) produced the maximum number of fruits per cluster of 5.20 which was on par with the application of half dose of Ca as basal along with 0.3 % foliar spray of B (Ca_2B_3).

Control versus treatments was found to be significant.

4.1.3.2 Fruits per Plant

Data on the effects of Ca and B application on fruits per plant are presented in Table 9. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

Ca application had a significant effect on number of fruits per plant. Ca-1 produced the maximum fruits per plant of 25.70 which was on par with Ca-2. The lowest number of fruits per plant was observed at Ca-0 (20.68).

B application produced a significant effect on fruits per plant. The highest number of fruits per plant of 25.54 was recorded at B-3. The lowest number of fruits per plant was observed at B-0 (21.59).

Interaction of Ca and B had a significant effect on fruits per plant. Full dose of Ca along with 0.3% foliar spray of B (Ca_1B_3) produced the maximum number of fruits per plant of 29.34 which was on par with the application of half dose of Ca as basal along with 0.3 % foliar spray of B (Ca_2B_3).

Control versus treatments was found to be non-significant.

4.1.3.3 Fruit Length

Data on the effects of Ca and B application on fruit length are presented in Table 10. The results concluded that there was no significant difference among

Table 10. Effect of Ca and B application on fruit length (cm) and fruit girth (cm) of tomato variety Vellayani Vijay

Treatments	Fruit length	Fruit girth
Levels of Ca		
Ca-0	3.05	10.02
Ca-1	3.44	11.02
Ca-2	3.41	10.82
Ca-3	3.28	10.52
SEm	0.103	0.223
CD (0.05)	NS	0.678
Levels of B		
B-0	3.18	10.17
B-1	3.29	10.49
B-2	3.33	10.78
B-3	3.39	10.95
SEm	0.103	0.223
CD (0.05)	NS	NS
Interactions		
Ca_0B_0	2.96	9.61
Ca_0B_1	3.05	9.94
Ca_0B_2	3.09	10.27
Ca_0B_3	3.12	10.28
Ca_1B_0	3.30	10.39
Ca_1B_1	3.41	10.85
Ca_1B_2	3.47	11.13
Ca_1B_3	3.60	11.71
Ca_2B_0	3.29	10.35
Ca_2B_1	3.40	10.72
Ca_2B_2	3.46	11.06
Ca_2B_3	3.49	11.18
Ca_3B_0	3.19	10.35
Ca_3B_1	3.30	10.46
Ca_3B_2	3.30	10.65
Ca_3B_3	3.35	10.65
SEm	0.205	0.446
CD (0.05)	NS	NS
Control	3.35	10.69
Control vs.Treatments	NS	NS

the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.1.3.4 Fruit Girth

The results on the effect of Ca and B application on fruit girth are presented in Table 10. There was significant difference among the main effects of Ca.

The results revealed that the application of Ca had a significant effect on fruit girth. Ca-1 produced the highest fruit girth of 11.02 cm which was on par with Ca-2 and Ca-3. The lowest fruit girth was recorded at Ca-0 (10.02 cm).

B did not report any significant effect on fruit girth.

None of the interactions were significant.

Control versus treatments was found to be non-significant.

4.1.3.5 Fruit Weight

The results on the effect of Ca and B application on fruit weight are presented in Table 11. Critical appraisal of the data revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.1.3.6 Yield per Plant

Data on the effects of Ca and B application on yield per plant are presented in Table 11. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

The results revealed that the application of Ca had a significant effect on yield per plant. The highest yield per plant of 697.35 g was recorded in Ca-1. The lowest yield was reported in Ca-0 (498.57 g).

Table 11. Effect of Ca and B application on fruit weight (g), yield per plant (g) and yield per plot (kg) of tomato variety Vellayani Vijay

Treatments	Fruit weight	Yield per plant	Yield per plot
Levels of Ca			
Ca-0	23.36	498.57	7.98
Ca-1	26.31	697.35	11.15
Ca-2	26.10	660.70	10.57
Ca-3	25.46	605.85	9.69
SEm	0.784	3.987	0.063
CD (0.05)	NS	12.126	0.192
Levels of B			
B-0	24.20	559.43	8.95
B-1	25.16	586.34	9.38
B-2	25.47	628.43	10.05
B-3	26.40	688.27	11.01
SEm	0.784	3.987	0.063
CD (0.05)	NS	12.126	0.192
Interactions			
Ca_0B_0	21.03	442.75	7.10
Ca_0B_1	23.28	481.25	7.70
Ca_0B_2	24.26	493.75	7.90
Ca_0B_3	24.89	576.56	9.22
Ca_1B_0	25.43	604.68	9.60
Ca_1B_1	26.03	633.49	10.14
Ca_1B_2	25.82	717.81	11.48
Ca_1B_3	27.99	833.43	13.33
Ca_2B_0	25.26	595.31	9.52
Ca_2B_1	25.84	623.43	9.97
Ca_2B_2	26.32	693.75	11.10
Ca_2B_3	27.00	730.31	11.68
Ca_3B_0	25.10	595.00	9.52
Ca_3B_1	25.48	607.18	9.71
Ca_3B_2	25.50	608.43	9.73
Ca_3B_3	25.75	612.81	9.80
SEm	1.568	7.73	0.126
CD (0.05)	NS	24.253	0.385
Control	25.78	615.62	9.85
Control vs.Treatments	NS	NS	NS

From the results, it can be concluded that the application of B produced a significant effect on yield per plant. Maximum yield per plant of 688.27 g was observed in B-3 and the lowest in B-0 (559.43 g).

The interaction of Ca and B had a significant effect on yield per plant. Full dose of Ca along with 0.3% foliar spray of B (Ca_1B_3) produced the maximum yield per plant of 833.43 g.

Control versus treatments was found to be non-significant.

4.1.3.7 Yield per Plot

The results on the effect of Ca and B application on yield per plot are presented in Table 11. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

From the results, it was found that the application of Ca had a significant effect on yield per plot. The highest value for yield per plot, 11.15 kg was recorded in Ca-1 and the lowest in Ca-0 (7.98 kg).

Application B produced a significant effect on yield per plot. Maximum yield per plot of 11.01 kg was recorded in B-3and the lowest in B-0 (8.95 kg).

The interaction of Ca and B had a significant effect on yield per plot. Full dose of Ca along with 0.3% foliar spray of B (Ca_1B_3) produced the maximum yield per plot of 13.33 kg.

Control versus treatments was found to be non-significant.

Correlation coefficients were computed 7 characters under study namely, primary branches per plant, flowers per cluster, inflorescence per plant, fruit set (%), fruits per cluster, fruits per plant and yield per plant (Table 12). The results revealed that the above mentioned characters are positively correlated with each other.

Table 12. Correlation coefficients among 7 characters under study

Character	X1	X2	X3	X4	X5	X6	X7
X1	1						
X2	0.8658**	1					
X3	0.7302**	0.7816**	1				
X4	0.6971**	0.8904**	0.7527**	1			
X5	0.8302**	0.9769**	0.8173**	0.9617**	1		
X6	0.8865**	0.9099**	0.8132**	0.8032**	0.9067**	1	
X7	0.8475**	0.9430**	0.8060**	0.8611**	0.9408**	0.9211**	1

X1 : Primary branches per plant
X2 : Flowers per cluster
X3 : Inflorescence per plant
X4 : Fruit set (%)
X5 : Fruits per cluster
X6 : Fruits per plant
X7 : Yield per plant

* Significant at 5 % level
** Significant at 1 % level

4.2 QUALITY CHARACTERS OF TOMATO AS INFLUENCED BY THE APPLICATION OF Ca AND B

4.2.1 TSS (per cent)

Data on the effects of Ca and B application on TSS are presented in Table 13. The results revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.2.2 Lycopene Content

Data on the effects of Ca and B application on lycopene content are presented in Table 13. The critical evaluation of the data revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.2.3 Ascorbic Acid

The results on the effect of Ca and B application on ascorbic acid content are presented in Table 13. The results revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.3 INCIDENCE OF PHYSIOLOGICAL DISORDERS AS INFLUENCED BY THE APPLICATION OF Ca AND B

4.3.1 BER

The results on the effect of Ca and B application on BER are presented in Table 14. There was significant difference among the main effects of Ca.

The results concluded that the application of Ca produced a significant effect on the incidence of BER. The lowest percent (6.18) of BER was recorded in Ca-1 and the highest in Ca-0 (8.95).

Table 13. Effect of Ca and B application on TSS (%), lycopene (μg g^{-1}) and ascorbic acid (mg $100g^{-1}$) of tomato variety Vellayani Vijay

Treatments	TSS	Lycopene	Ascorbic acid
Levels of Ca			
Ca-0	4.30	22.82	17.33
Ca-1	4.38	22.83	17.70
Ca-2	4.39	22.84	17.66
Ca-3	4.35	22.81	17.55
SEm	0.084	0.08	0.095
CD (0.05)	NS	NS	NS
Levels of B			
B-0	4.32	22.82	17.46
B-1	4.37	22.82	17.55
B-2	4.36	22.83	17.60
B-3	4.38	22.83	17.62
SEm	0.084	0.08	0.095
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	4.30	22.80	17.28
Ca_0B_1	4.31	22.81	17.33
Ca_0B_2	4.32	22.85	17.35
Ca_0B_3	4.30	22.85	17.36
Ca_1B_0	4.32	22.81	17.59
Ca_1B_1	4.41	22.83	17.68
Ca_1B_2	4.39	22.84	17.74
Ca_1B_3	4.43	22.85	17.80
Ca_2B_0	4.37	22.86	17.51
Ca_2B_1	4.38	22.81	17.63
Ca_2B_2	4.40	22.84	17.71
Ca_2B_3	4.42	22.85	17.81
Ca_3B_0	4.30	22.82	17.48
Ca_3B_1	4.40	22.83	17.57
Ca_3B_2	4.35	22.81	17.61
Ca_3B_3	4.38	22.80	17.54
SEm	0.169	0.16	0.19
CD (0.05)	NS	NS	NS
Control	4.46	22.83	17.60
Control vs.Treatments	NS	NS	NS

Table 14. Effect of Ca and B application on BER and fruit cracking (per cent) of tomato variety Vellayani Vijay

Treatments	Blossom End Rot	Fruit cracking
Levels of Ca		
Ca-0	8.95	13.09
Ca-1	6.18	13.02
Ca-2	7.45	13.05
Ca-3	8.18	13.07
SEm	0.002	0.004
CD (0.05)	0.007	0.012
Levels of B		
B-0	7.69	15.40
B-1	7.68	14.25
B-2	7.69	12.11
B-3	7.69	10.48
SEm	0.002	0.004
CD (0.05)	NS	0.012
Interactions		
Ca_0B_0	8.96	15.46
Ca_0B_1	8.94	14.28
Ca_0B_2	8.95	12.14
Ca_0B_3	8.95	10.51
Ca_1B_0	6.18	15.34
Ca_1B_1	6.18	14.22
Ca_1B_2	6.18	12.08
Ca_1B_3	6.19	10.45
Ca_2B_0	7.46	15.39
Ca_2B_1	7.45	14.24
Ca_2B_2	7.45	12.10
Ca_2B_3	7.46	10.48
Ca_3B_0	8.18	15.42
Ca_3B_1	8.18	14.26
Ca_3B_2	8.19	12.13
Ca_3B_3	8.19	10.49
SEm	0.005	0.008
CD (0.05)	NS	0.024
Control	8.46	10.45
Control vs.Treatments	NS	179.50*

Note:
*- f calculated value

B application did not produce any significant effect on the incidence of Blossom End Rot.

None of the interactions were found to be significant.

Control versus treatments was found to be non-significant.

4.3.2 Fruit Cracking

The results on the effect of Ca and B application on fruit cracking are presented in Table 14. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

Application of Ca produced a significant effect on the incidence of fruit cracking. The lowest percent (13.02) of fruit cracking was recorded in Ca-1 and the highest in Ca-0.

Application of B produced a significant effect on the incidence of fruit cracking. The lowest percent (10.48) of fruit cracking was recorded in B-3 and the highest in B-0.

The interaction of Ca and B had a significant effect on the incidence of fruit cracking. Full dose of Ca along with 0.3% foliar spray of B (Ca_1B_3) produced the minimum fruit cracking incidence of 10.45 per cent.

Control versus treatments was found to be significant.

4.4 PLANT CONTENT OF NUTRIENTS AS INFLUENCED BY THE APPLICATION OF Ca AND B

4.4.1 Effect of Ca and B application on plant content of primary nutrients

Data on the effects of Ca and B application on plant content of primary nutrients are presented in Table 15.

Results suggested that the application of Ca and B did not have any significant effect on the plant content of primary nutrients. Interaction effects

Table 15. Effect of Ca and B application on plant content of N, P and K (per cent)

Treatments	N	P	K
Levels of Ca			
Ca-0	3.13	1.26	1.57
Ca-1	3.13	1.26	1.57
Ca-2	3.13	1.25	1.57
Ca-3	3.12	1.26	1.57
SEm	0.002	0.002	0.003
CD (0.05)	NS	NS	NS
Levels of B			
B-0	3.13	1.26	1.57
B-1	3.13	1.26	1.57
B-2	3.12	1.25	1.57
B-3	3.12	1.26	1.57
SEm	0.002	0.002	0.003
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	3.13	1.26	1.58
Ca_0B_1	3.14	1.26	1.57
Ca_0B_2	3.13	1.26	1.57
Ca_0B_3	3.12	1.26	1.57
Ca_1B_0	3.13	1.26	1.58
Ca_1B_1	3.13	1.26	1.58
Ca_1B_2	3.13	1.25	1.58
Ca_1B_3	3.12	1.27	1.57
Ca_2B_0	3.13	1.26	1.57
Ca_2B_1	3.13	1.26	1.57
Ca_2B_2	3.12	1.26	1.57
Ca_2B_3	3.13	1.26	1.57
Ca_3B_0	3.13	1.27	1.58
Ca_3B_1	3.13	1.26	1.57
Ca_3B_2	3.12	1.27	1.58
Ca_3B_3	3.12	1.26	1.57
SEm	0.005	0.003	0.006
CD (0.05)	NS	NS	NS
Control	3.12	1.26	1.57
Control vs.Treatments	NS	NS	NS

were also found to be non-significant. Control versus treatments also was found to be non-significant for plant content of primary nutrients.

4.4.2 Effect of Ca and B application on plant content of secondary nutrients

Data on the effects of Ca and B application on plant content of secondary nutrients are presented in Table 16.

From the results it can be concluded that the application of Ca had significant effect on the plant content of Ca. The highest value was recorded in Ca-1 (4.15 %) and Ca-0 recorded the lowest value (2.06 %). Application of B did not have any significant effect on the plant content of Ca and none of the interactions were significant.

Application of Ca and B did not produce any significant effect on the plant content of Mg and S. Interaction effects were also non-significant.

Control versus treatments was found to be non-significant for plant content of secondary nutrients.

4.4.3 Effect of Ca and B application on plant content of micronutrients

Data on the effects of Ca and B application on plant content of micro nutrients are presented in Table 17 and 18.

Application of Ca and B did not have any significant effect on the plant content of Fe, Mn, Cu and Zn. Interaction effects were found to be non-significant.

Application of Ca did not report any significant effect on the plant content of B. But the application of B produced significant effect. The highest value was observed in B-3 (400.32 mg/kg) and the lowest in B-0 (210.54 mg/kg). But none of the interactions were found to be significant.

Control versus treatments was found to be non-significant for plant content of all micronutrients except B.

Table 16. Effect of Ca and B application on plant content of Ca, Mg and S (%)

Treatments	Ca	Mg	S
Levels of Ca			
Ca-0	2.06	1.17	1.27
Ca-1	4.15	1.17	1.27
Ca-2	3.62	1.18	1.27
Ca-3	2.16	1.17	1.27
SEm	0.002	0.003	0.002
CD (0.05)	0.005	NS	NS
Levels of B			
B-0	3.00	1.17	1.27
B-1	2.99	1.18	1.27
B-2	2.99	1.18	1.27
B-3	2.99	1.17	1.27
SEm	0.002	0.003	0.002
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	2.07	1.17	1.28
Ca_0B_1	2.06	1.18	1.27
Ca_0B_2	2.06	1.18	1.27
Ca_0B_3	2.06	1.18	1.27
Ca_1B_0	5.16	1.18	1.27
Ca_1B_1	4.15	1.19	1.27
Ca_1B_2	4.15	1.17	1.27
Ca_1B_3	4.15	1.17	1.27
Ca_2B_0	3.63	1.18	1.27
Ca_2B_1	3.62	1.18	1.28
Ca_2B_2	3.62	1.19	1.27
Ca_2B_3	3.62	1.18	1.27
Ca_3B_0	2.16	1.18	1.27
Ca_3B_1	2.16	1.18	1.27
Ca_3B_2	2.16	1.17	1.27
Ca_3B_3	2.16	1.17	1.27
SEm	0.004	0.006	0.003
CD (0.05)	NS	NS	NS
Control	2.13	1.17	1.27
Control vs.Treatments	NS	NS	NS

Table 17. Effect of Ca and B application on plant content of B and Fe (mg kg^{-1})

Treatments	B	Fe
Levels of Ca		
Ca-0	310.09	21.06
Ca-1	310.67	21.07
Ca-2	310.43	21.08
Ca-3	310.55	21.07
SEm	0.001	0.013
CD (0.05)	NS	NS
Levels of B		
B-0	210.54	21.06
B-1	300.60	21.07
B-2	330.12	21.08
B-3	400.32	21.07
SEm	0.001	0.013
CD (0.05)	0.001	NS
Interactions		
Ca_0B_0	210	21.03
Ca_0B_1	300	21.08
Ca_0B_2	330	21.08
Ca_0B_3	400	21.04
Ca_1B_0	210	21.09
Ca_1B_1	300	21.04
Ca_1B_2	330	21.08
Ca_1B_3	400	21.08
Ca_2B_0	210	21.08
Ca_2B_1	300	21.08
Ca_2B_2	330	21.09
Ca_2B_3	410	21.08
Ca_3B_0	200	21.04
Ca_3B_1	300	21.08
Ca_3B_2	330	21.08
Ca_3B_3	410	21.08
SEm	0.001	0.025
CD (0.05)	NS	NS
Control	420	21.04
Control vs.Treatments	427.25*	NS

Note:
*- f calculated value

Table 18. Effect of Ca and B application on plant content of Cu, Mn and Zn (mg kg^{-1})

Treatments	Cu	Mn	Zn
Levels of Ca			
Ca-0	1.60	9.06	2.21
Ca-1	1.60	9.05	2.16
Ca-2	1.61	9.05	2.20
Ca-3	1.60	9.05	2.17
SEm	0.002	0.002	0.032
CD (0.05)	NS	NS	NS
Levels of B			
B-0	1.60	9.05	2.18
B-1	1.60	9.05	2.20
B-2	1.60	9.05	2.22
B-3	1.60	9.04	2.15
SEm	0.002	0.002	0.032
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	1.60	9.06	2.22
Ca_0B_1	1.61	9.05	2.21
Ca_0B_2	1.60	9.05	2.23
Ca_0B_3	1.60	9.05	2.20
Ca_1B_0	1.60	9.05	2.20
Ca_1B_1	1.60	9.05	2.20
Ca_1B_2	1.60	9.05	2.15
Ca_1B_3	1.60	9.05	2.10
Ca_2B_0	1.61	9.05	2.10
Ca_2B_1	1.60	9.05	2.30
Ca_2B_2	1.60	9.05	2.20
Ca_2B_3	1.60	9.04	2.20
Ca_3B_0	1.60	9.05	2.20
Ca_3B_1	1.61	9.05	2.10
Ca_3B_2	1.60	9.06	2.30
Ca_3B_3	1.60	9.04	2.10
SEm	0.003	0.004	0.064
CD (0.05)	NS	NS	NS
Control	1.60	9.05	2.20
Control vs.Treatments	NS	NS	NS

4.5 EFFECT OF Ca and B APPLICATION ON UPTAKE OF NUTRIENTS BY TOMATO

4.5.1 Effect of Ca and B application on uptake of primary nutrients by tomato

Data on the effects of Ca and B application on uptake of micro nutrients are presented in Table 19.

Application of Ca and B had significant effect on the uptake of N. Among different Ca levels, Ca-1 recorded the highest uptake of N (69.63 kg ha^{-1}) and the lowest in Ca-0 (58.72 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of N (68.46 kg ha^{-1}) and the lowest in B-0 (62.88 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of N (72.27 kg ha^{-1}).

Application of Ca and B produced significant effect on the uptake of P. Among different Ca levels, Ca-1 recorded the highest uptake of P (28.14 kg ha^{-1}) and the lowest in Ca-0 (23.67 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of P (27.65 kg ha^{-1}) and the lowest in B-0 (25.39 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of P (29.42 kg ha^{-1}).

Ca and B produced significant effect on the uptake of K. Among various Ca levels, Ca-1 recorded the highest uptake of K (35.12 kg ha^{-1}) and the lowest in Ca-0 (29.51 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of K (34.42 kg ha^{-1}) and the lowest in B-0 (31.66 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of K (36.36 kg ha^{-1}).

Control versus treatments was found to be significant for the uptake of all primary nutrients.

4.5.2 Effect of Ca and B application on uptake of secondary nutrients by tomato

Data on the effects of Ca and B application on uptake of secondary nutrients are presented in Table 20.

Table 19. Effect of Ca and B application on the uptake of N, P and K (kg ha^{-1})

Treatments	N	P	K
Levels of Ca			
Ca-0	58.72	23.67	29.51
Ca-1	69.63	28.14	35.12
Ca-2	68.72	27.74	34.47
Ca-3	66.73	27.02	33.64
SEm	0.044	0.036	0.059
CD (0.05)	0.135	0.109	0.180
Levels of B			
B-0	62.88	25.39	31.66
B-1	65.38	26.38	32.82
B-2	67.08	27.15	33.83
B-3	68.46	27.65	34.42
SEm	0.044	0.036	0.059
CD (0.05)	0.135	0.109	0.180
Interactions			
Ca_0B_0	51.98	21.00	26.24
Ca_0B_1	57.91	23.23	28.95
Ca_0B_2	61.55	24.87	30.97
Ca_0B_3	63.45	25.58	31.87
Ca_1B_0	66.96	26.91	33.75
Ca_1B_1	68.86	27.83	34.76
Ca_1B_2	70.44	28.42	35.61
Ca_1B_3	72.27	29.42	36.36
Ca_2B_0	66.52	26.84	33.31
Ca_2B_1	67.81	27.40	34.01
Ca_2B_2	69.34	28.11	34.89
Ca_2B_3	71.23	28.62	35.67
Ca_3B_0	66.07	26.81	33.35
Ca_3B_1	66.97	27.06	33.59
Ca_3B_2	66.99	27.22	33.87
Ca_3B_3	66.90	27.01	33.77
SEm	0.089	0.072	0.118
CD (0.05)	0.270	0.219	0.359
Control	67.18	27.09	33.75
Control vs.Treatments	147.58*	13.76*	80.65*

Note:
*- f calculated value

Table 20. Effect of Ca and B application on the uptake of Ca, Mg and S (kg ha^{-1})

Treatments	Ca	Mg	S
Levels of Ca			
Ca-0	19.94	22.11	23.88
Ca-1	114.63	26.22	28.33
Ca-2	79.54	25.98	27.92
Ca-3	46.13	25.10	27.16
SEm	0.022	0.060	0.046
CD (0.05)	0.066	0.183	0.139
Levels of B			
B-0	62.68	23.64	25.57
B-1	64.39	24.68	26.61
B-2	65.83	25.30	27.26
B-3	67.34	25.79	27.84
SEm	0.022	0.06	0.046
CD (0.05)	0.066	0.183	0.139
Interactions			
Ca_0B_0	17.77	19.43	21.26
Ca_0B_1	19.64	21.75	23.51
Ca_0B_2	20.84	23.30	24.97
Ca_0B_3	21.52	23.95	25.78
Ca_1B_0	110.22	25.20	27.23
Ca_1B_1	113.30	26.18	28.05
Ca_1B_2	115.73	26.40	28.53
Ca_1B_3	119.30	27.10	29.53
Ca_2B_0	77.03	25.03	26.90
Ca_2B_1	78.43	25.56	27.73
Ca_2B_2	80.45	26.44	28.22
Ca_2B_3	82.25	26.92	28.85
Ca_3B_0	45.70	24.91	26.91
Ca_3B_1	46.21	25.24	27.17
Ca_3B_2	46.30	25.08	27.33
Ca_3B_3	46.31	25.19	27.84
SEm	0.043	0.120	0.091
CD (0.05)	0.132	0.366	0.278
Control	47.34	25.15	27.30
Control vs.Treatments	11.68*	6.09*	25.62*

Note:
*- f calculated value

Application of Ca and B had significant effect on the uptake of Ca. Among different Ca levels, Ca-1 recorded the highest uptake of Ca (114.63 kg ha^{-1}) and the lowest in Ca-0 (19.94 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of Ca (67.34 kg ha^{-1}) and the lowest in B-0 (62.68 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of Ca (119.30 kg ha^{-1}).

Ca and B produced significant effect on the uptake of Mg. Among various Ca levels, Ca-1 recorded the highest uptake of Mg (26.22 kg ha^{-1}) and the lowest in Ca-0 (22.11 kg ha^{-1}). Among various B levels B-3 recorded the highest uptake of Mg (25.79 kg ha^{-1}) and the lowest in B-0 (23.64 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of Mg (27.10 kg ha^{-1}).

Ca and B produced significant effect on the uptake of S. Among various Ca levels, Ca-1 recorded the highest uptake of S (28.33 kg ha^{-1}) and the lowest in Ca-0 (23.88 kg ha^{-1}). Among various B levels B-3 recorded the highest uptake of S (27.84 kg ha^{-1}) and the lowest in B-0 (25.57 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of S (29.53 kg ha^{-1}).

Control versus treatments was found to be significant for the uptake of all secondary nutrients.

4.5.3 Effect of Ca and B application on uptake of micronutrients by tomato

Data on the effects of Ca and B application on uptake of micro nutrients are presented in Table 21 and 22.

Application of Ca and B reported to have a significant effect on the uptake of Fe. Among different Ca levels, Ca-1 recorded the highest uptake of Fe (4.68 kg ha^{-1}) and the lowest in Ca-0 (3.94 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of Fe (4.61 kg ha^{-1}) and the lowest in B-0 (4.22 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of Fe (4.88 kg ha^{-1}).

Ca and B application had a significant effect on the uptake of Mn. Among different Ca levels, Ca-1 recorded the highest uptake of Mn (2.10 kg ha^{-1}) and the lowest in Ca-0 (1.69 kg ha^{-1}). Among various B levels B-3 has recorded the

Table 21. Effect of Ca and B application on the uptake of B and Fe (kg ha^{-1})

Treatments	B	Fe
Levels of Ca		
Ca-0	0.585	3.94
Ca-1	0.695	4.68
Ca-2	0.688	4.62
Ca-3	0.655	4.49
SEm	0.006	0.002
CD (0.05)	0.018	0.007
Levels of B		
B-0	0.408	4.22
B-1	0.624	4.39
B-2	0.703	4.51
B-3	0.889	4.61
SEm	0.006	0.002
CD (0.05)	0.018	0.007
Interactions		
Ca_0B_0	0.340	3.48
Ca_0B_1	0.550	3.88
Ca_0B_2	0.640	4.14
Ca_0B_3	0.810	4.27
Ca_1B_0	0.430	4.50
Ca_1B_1	0.660	4.62
Ca_1B_2	0.740	4.73
Ca_1B_3	0.950	4.88
Ca_2B_0	0.440	4.47
Ca_2B_1	0.645	4.56
Ca_2B_2	0.730	4.68
Ca_2B_3	0.935	4.78
Ca_3B_0	0.420	4.44
Ca_3B_1	0.640	4.51
Ca_3B_2	0.700	4.51
Ca_3B_3	0.860	4.51
SEm	0.012	0.004
CD (0.05)	NS	0.013
Control	0.90	4.52
Control vs.Treatments	20.48*	247.53*

Note:
*- f calculated value

Table 22. Effect of Ca and B application on the uptake of Cu, Mn and Zn (kg ha^{-1})

Treatments	Cu	Mn	Zn
Levels of Ca			
Ca-0	0.29	1.69	0.40
Ca-1	0.35	2.10	0.47
Ca-2	0.34	1.98	0.46
Ca-3	0.33	1.92	0.46
SEm	0.001	0.001	0.007
CD (0.05)	0.003	0.002	0.022
Levels of B			
B-0	0.31	1.81	0.43
B-1	0.33	1.88	0.45
B-2	0.33	1.93	0.46
B-3	0.34	1.97	0.47
SEm	0.001	0.001	0.007
CD (0.05)	0.003	0.002	0.022
Interactions			
Ca_0B_0	0.26	1.50	0.36
Ca_0B_1	0.29	1.66	0.40
Ca_0B_2	0.31	1.77	0.43
Ca_0B_3	0.32	1.83	0.44
Ca_1B_0	0.34	1.93	0.46
Ca_1B_1	0.35	1.99	0.48
Ca_1B_2	0.35	2.03	0.47
Ca_1B_3	0.37	2.09	0.48
Ca_2B_0	0.33	1.92	0.44
Ca_2B_1	0.34	1.96	0.49
Ca_2B_2	0.35	2.01	0.48
Ca_2B_3	0.36	2.05	0.49
Ca_3B_0	0.33	1.91	0.46
Ca_3B_1	0.34	1.93	0.44
Ca_3B_2	0.34	1.94	0.49
Ca_3B_3	0.34	1.93	0.45
SEm	0.002	0.001	0.014
CD (0.05)	0.006	0.004	NS
Control	0.34	1.94	0.47
Control vs.Treatments	14.23*	395.76*	NS

Note:
*- f calculated value

highest uptake of Mn (1.97 kg ha^{-1}) and the lowest in B-0 (1.81 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of Mn (2.09 kg ha^{-1}).

Application of Ca and B had a significant effect on the uptake of Cu. Among different Ca levels, Ca-1 recorded the highest uptake of Cu (0.35 kg ha^{-1}) and the lowest in Ca-0 (0.29 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of Cu (0.34 kg ha^{-1}) and the lowest in B-0 (0.31 kg ha^{-1}). Among interactions, Ca_1B_3 reported the highest uptake of Cu (0.37 kg ha^{-1}).

Application of Ca and B had a significant effect on the uptake of Zn. Among different Ca levels, Ca-1 recorded the highest uptake of Zn (0.47 kg ha^{-1}) which was found to be on par with Ca-2 and Ca-3 (0.46 kg ha^{-1}) and the lowest in Ca-0 (0.40 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of Zn (0.47 kg ha^{-1}) which was found to be on par with B-2 (0.46 kg ha^{-1}) and B-1(0.45 kg ha^{-1}) and the lowest in B-0 (0.43 kg ha^{-1}). Interaction effects were found to be non-significant.

Ca and B application had a significant effect on the uptake of B. Among different Ca levels, Ca-1 recorded the highest uptake of B (0.695 kg ha^{-1}) which was found to be on par with Ca-2 (0.688 kg ha^{-1}) and the lowest in Ca-0 (0.585 kg ha^{-1}). Among various B levels B-3 has recorded the highest uptake of B (0.889 kg ha^{-1}) and the lowest in B-0 (0.408 kg ha^{-1}). None of the interactions were significant.

Control versus treatments was found to be significant for the uptake of micronutrients except Zn.

4.6 SOIL FERTILITY PARAMETERS AFTER HARVEST AS INFLUENCED BY THE APPLICATION OF Ca AND B

4.6.1 Organic Carbon

The results on the effect of Ca and B application on organic carbon content are presented in Table 23. The results revealed that there was no significant difference among the main effects of Ca, main effects of B and interaction effects. Control versus treatments also was non-significant.

4.6.2 Soil pH

The results on the effect of Ca and B application on soil pH are presented in Table 23. There was significant difference among the main effects of Ca.

Application of Ca produced significant effect on soil pH. The pH of the experimental site before the experiment was 5.46 and after the experiment it was significantly influenced by the application of Ca. Ca-1 contributed to the maximum increase in pH to 5.60.

B application did not produce any significant effect on soil pH.

None of the interactions were found to be significant.

Control versus treatments was found to be non-significant.

4.6.3 Available Primary Nutrients

The results on the effect of Ca and B application on available primary nutrients are presented in Table 24.

Application of Ca and B did not have any significant effect on soil available primary nutrients.

Interaction effects could not profoundly influence the available primary nutrients.

Table 23. Effect of Ca and B application on organic carbon content (per cent) and pH of soil

Treatments	Organic carbon	pH
Levels of Ca		
Ca-0	0.435	5.46
Ca-1	0.435	5.60
Ca-2	0.426	5.52
Ca-3	0.431	5.48
SEm	0.004	0.005
CD (0.05)	NS	0.015
Levels of B		
B-0	0.430	5.51
B-1	0.430	5.52
B-2	0.430	5.51
B-3	0.438	5.51
SEm	0.004	0.005
CD (0.05)	NS	NS
Interactions		
Ca_0B_0	0.440	5.46
Ca_0B_1	0.430	5.46
Ca_0B_2	0.430	5.46
Ca_0B_3	0.440	5.46
Ca_1B_0	0.435	5.60
Ca_1B_1	0.435	5.60
Ca_1B_2	0.440	5.59
Ca_1B_3	0.430	5.60
Ca_2B_0	0.420	5.52
Ca_2B_1	0.425	5.52
Ca_2B_2	0.420	5.52
Ca_2B_3	0.440	5.52
Ca_3B_0	0.425	5.47
Ca_3B_1	0.430	5.52
Ca_3B_2	0.430	5.47
Ca_3B_3	0.440	5.48
SEm	0.009	0.010
CD (0.05)	NS	NS
Control	0.42	5.48
Control vs.Treatments	NS	NS
Initial value	0.43	5.46

Table 24. Effect of Ca and B application on available N, P and K content (kg ha^{-1}) of soil

Treatments	N	P	K
Levels of Ca			
Ca-0	191.87	10.50	104.23
Ca-1	191.12	10.49	104.17
Ca-2	193.37	10.42	104.65
Ca-3	192.75	10.38	103.94
SEm	0.774	0.081	0.302
CD (0.05)	NS	NS	NS
Levels of B			
B-0	192.37	10.53	103.71
B-1	192.37	10.52	104.70
B-2	191.87	10.34	104.11
B-3	192.50	10.39	104.47
SEm	0.774	0.081	0.302
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	191.50	10.30	103.91
Ca_0B_1	191.00	10.36	104.06
Ca_0B_2	193.00	10.70	104.65
Ca_0B_3	192.00	10.67	104.33
Ca_1B_0	191.00	10.68	103.88
Ca_1B_1	192.50	10.57	104.68
Ca_1B_2	190.50	10.34	103.81
Ca_1B_3	190.50	10.37	104.32
Ca_2B_0	195.00	10.77	103.40
Ca_2B_1	193.50	10.52	105.14
Ca_2B_2	192.00	10.12	104.40
Ca_2B_3	193.00	10.26	105.68
Ca_3B_0	192.00	10.37	103.67
Ca_3B_1	192.50	10.66	104.94
Ca_3B_2	192.00	10.21	103.59
Ca_3B_3	194.50	10.28	103.55
SEm	1.549	0.162	0.604
CD (0.05)	NS	NS	NS
Control	190.5	10.95	105.22
Control vs.Treatments	NS	9.60*	NS
Initial value	194.56	9.37	103.67

Note:

*- f calculated value

Control versus treatments was found to be non-significant except soil phosphorus.

4.6.4 Available Secondary Nutrients

The results on the effect of Ca and B application on available secondary nutrients are presented in Table 25.

The amount of available Ca in soil before the experiment was 210.22 mg/kg. Application of Ca had a significant effect on the content of available Ca in soil. Ca-1 recorded the maximum soil available Ca of 223.20 mg/kg of soil and Ca-0 recorded the lowest value (210.22 mg/kg). B application did not produce any significant effect on soil available Ca. None of the interactions were found to be significant. Control versus treatments was also found to be non-significant.

Application of Ca and B recorded no significant effect on soil available Mg and S. Interaction effect and control versus treatments was found to be non-significant.

4.6.5 Available Micronutrients

The results on the effect of Ca and B application on available iron are presented in Table 26 and 27.

Results indicated that the available micronutrient content in the soil was not significantly influenced by the experiment. Application of Ca and B did not have any significant effect on available micronutrient content in the soil. None of the interactions produced significant effect on available iron content in the soil. Control versus treatments was found to be non-significant.

Table 25. Effect of Ca and B application on available Ca, Mg and S content (mg kg^{-1}) of soil

Treatments	Ca	Mg	S
Levels of Ca			
Ca-0	210.22	73.37	4.93
Ca-1	223.20	73.66	4.92
Ca-2	216.22	73.63	4.91
Ca-3	212.97	73.34	4.92
SEm	0.121	0.116	0.014
CD (0.05)	0.369	NS	NS
Levels of B			
B-0	215.53	73.48	4.93
B-1	215.74	73.46	4.93
B-2	215.72	73.49	4.90
B-3	215.63	73.57	4.93
SEm	0.121	0.116	0.014
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	210.00	73.55	4.93
Ca_0B_1	210.40	73.11	4.97
Ca_0B_2	210.50	73.34	4.93
Ca_0B_3	210.00	73.50	4.92
Ca_1B_0	223.22	73.68	4.96
Ca_1B_1	223.00	73.60	4.91
Ca_1B_2	223.28	73.46	4.91
Ca_1B_3	223.30	73.91	4.92
Ca_2B_0	216.40	73.53	4.93
Ca_2B_1	216.17	73.77	4.92
Ca_2B_2	216.10	73.63	4.86
Ca_2B_3	216.23	73.59	4.95
Ca_3B_0	212.50	73.17	4.92
Ca_3B_1	213.40	73.37	4.94
Ca_3B_2	213.00	73.54	4.91
Ca_3B_3	213.00	73.30	4.93
SEm	0.243	0.233	0.027
CD (0.05)	NS	NS	NS
Control	212.70	73.16	4.92
Control vs.Treatments	NS	NS	NS
Initial value	210.20	73.37	4.92

Table 26. Effect of Ca and B application on available B (kg ha^{-1}) and Fe (mg kg^{-1}) content of soil

Treatments	B	Fe
Levels of Ca		
Ca-0	0.443	19.14
Ca-1	0.436	18.07
Ca-2	0.436	19.24
Ca-3	0.430	19.28
SEm	0.005	0.559
CD (0.05)	NS	NS
Levels of B		
B-0	0.435	19.21
B-1	0.444	19.36
B-2	0.439	19.15
B-3	0.428	18.01
SEm	0.005	0.559
CD (0.05)	NS	NS
Interactions		
Ca_0B_0	0.440	19.04
Ca_0B_1	0.450	19.12
Ca_0B_2	0.460	19.30
Ca_0B_3	0.420	19.12
Ca_1B_0	0.430	19.20
Ca_1B_1	0.435	19.43
Ca_1B_2	0.430	19.11
Ca_1B_3	0.450	19.45
Ca_2B_0	0.440	19.10
Ca_2B_1	0.450	19.47
Ca_2B_2	0.435	19.12
Ca_2B_3	0.420	19.30
Ca_3B_0	0.430	19.51
Ca_3B_1	0.440	19.44
Ca_3B_2	0.430	19.07
Ca_3B_3	0.420	19.10
SEm	0.011	1.118
CD (0.05)	NS	NS
Control	0.43	19.32
Control vs.Treatments	NS	NS
Initial value	0.424	19.54

Table 27. Effect of Ca and B application on available Cu, Mn and Zn content (mg kg^{-1}) of soil

Treatments	Cu	Mn	Zn
Levels of Ca			
Ca-0	1.08	3.22	1.12
Ca-1	1.11	3.21	1.12
Ca-2	1.08	3.21	1.13
Ca-3	1.11	3.20	1.12
SEm	0.029	0.005	0.004
CD (0.05)	NS	NS	NS
Levels of B			
B-0	1.13	3.21	1.12
B-1	1.11	3.22	1.13
B-2	1.07	3.21	1.12
B-3	1.07	3.21	1.12
SEm	0.029	0.005	0.004
CD (0.05)	NS	NS	NS
Interactions			
Ca_0B_0	1.10	3.21	1.11
Ca_0B_1	1.05	3.22	1.13
Ca_0B_2	1.10	3.22	1.13
Ca_0B_3	1.10	3.22	1.13
Ca_1B_0	1.15	3.21	1.14
Ca_1B_1	1.20	3.21	1.13
Ca_1B_2	1.10	3.21	1.12
Ca_1B_3	1.00	3.21	1.11
Ca_2B_0	1.15	3.21	1.11
Ca_2B_1	1.10	3.23	1.13
Ca_2B_2	1.00	3.21	1.12
Ca_2B_3	1.10	3.22	1.11
Ca_3B_0	1.15	3.20	1.13
Ca_3B_1	1.10	3.21	1.14
Ca_3B_2	1.10	3.21	1.12
Ca_3B_3	1.10	3.21	1.12
SEm	0.057	0.011	0.008
CD (0.05)	NS	NS	NS
Control	1.05	3.21	1.11
Control vs.Treatments	NS	NS	NS
Initial value	1.10	3.21	1.12

4.7 BENEFIT COST RATIO AS INFLUENCED BY THE APPLICATION OF Ca and B

Data on the effects of Ca and B application on benefit cost ratio are presented in Table 28. There was significant difference among the main effects of Ca, main effects of B and interaction effects.

Application of Ca and B had significant effect on B: C ratio. Among various Ca levels, Ca-1 reported to have the highest B: C ratio (2.11) and the lowest in Ca-0 (1.46).

Among different B levels, B-3 recorded the highest B: C ratio (2.00) and the lowest in B-0 (1.61).

Among interactions, Ca_1B_3 reported the highest value (2.30).

Control versus treatments was found to be significant for B: C ratio.

Table 28. Effect of Ca and B application on B: C ratio

Treatments	B : C ratio
Levels of Ca	
Ca-0	1.46
Ca-1	2.11
Ca-2	2.05
Ca-3	1.83
SEm	0.001
CD (0.05)	0.004
Levels of B	
B-0	1.61
B-1	1.89
B-2	1.96
B-3	2.00
SEm	0.001
CD (0.05)	0.003
Interactions	
Ca_0B_0	1.18
Ca_0B_1	1.47
Ca_0B_2	1.59
Ca_0B_3	1.62
Ca_1B_0	1.84
Ca_1B_1	2.13
Ca_1B_2	2.20
Ca_1B_3	2.30
Ca_2B_0	1.73
Ca_2B_1	2.10
Ca_2B_2	2.17
Ca_2B_3	2.22
Ca_3B_0	1.70
Ca_3B_1	1.86
Ca_3B_2	1.88
Ca_3B_3	1.89
SEm	0.001
CD (0.05)	0.002
Control	1.90
Control vs.Treatments	198.36

Discussion

5. DISCUSSION

An experiment entitled "Response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district" was conducted during September to December 2016 to assess the effect of calcium and boron on yield and quality of tomato variety Vellayani Vijay and to develop a recommendation for these nutrients to optimize the productivity. The results obtained in the study are briefly discussed in this chapter.

5.1 BIOMETRIC CHARACTERS

5.1.1 Vegetative Characters

The results of the study revealed that the plant height, node to first inflorescence, number of primary branches per plant, internodal length, leaf length and leaf width were significantly influenced by the application of Ca (Tables 4, 5, 6). Full dose of Ca applied as basal as per lime requirement resulted in maximum plant height, the lowest number of nodes to first inflorescence and maximum number of primary branches per plant and the treatment was on par with application of half dose of Ca as basal. The highest internodal length was recorded where full dose of Ca as per lime requirement was given as basal. This may be due to the involvement of Ca in activation of enzymes for cell mitosis, division and elongation. Ca is associated with rapid growth, cell wall formation, cell division and carbohydrate metabolism. Therefore Ca application might have resulted in significant increase in number of primary branches production, probably through the increased photosynthetic rate. Similar results were reported by Bennett (1993), Jha (2006) and Ilyas *et al*. (2014).

Ca application significantly influenced the length and width of leaves. The highest leaf length and width were associated with full dose of Ca as per lime requirement was given as basal. This may be due to the involvement of calcium as a key nutrient in the maintenance of membrane permeability and has a major role

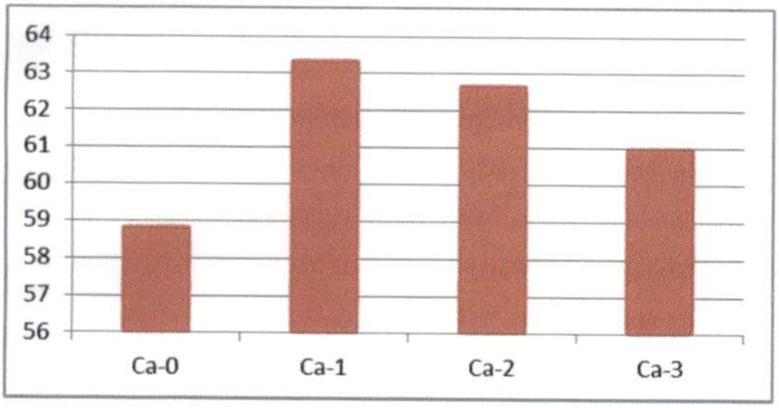

Fig. 3. Effect of Ca levels on plant height (cm) of tomato

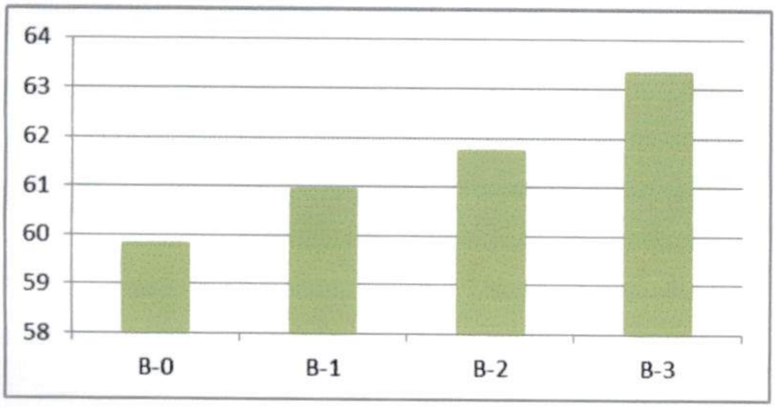

Fig. 4. Effect of B levels on plant height (cm) of tomato

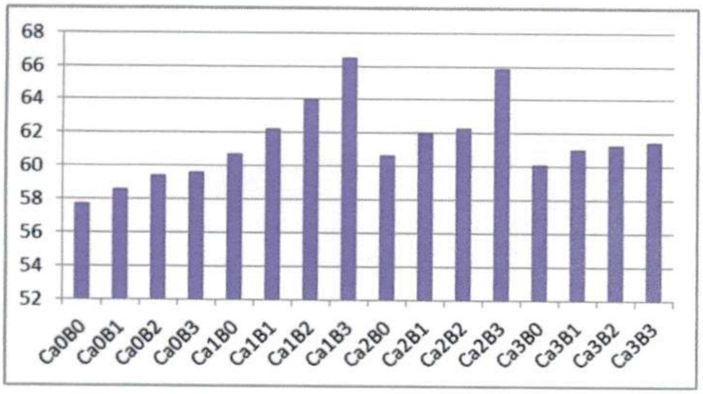

Fig. 5. Interaction effect of Ca and B levels on plant height (cm) of tomato

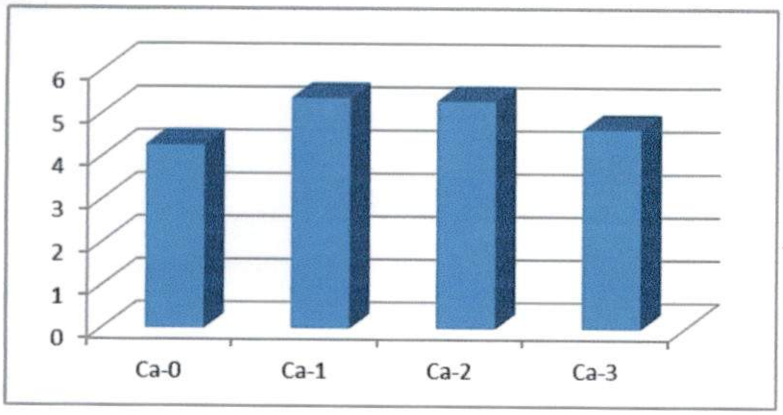

Fig. 6. Effect of Ca levels on no. of primary branches per plant of tomato

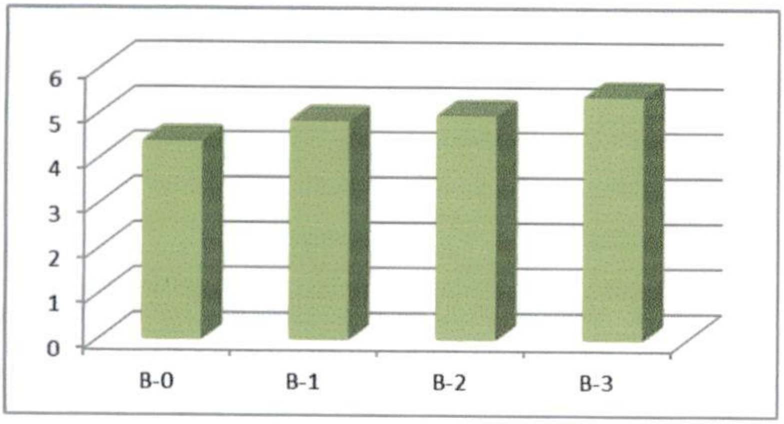

Fig. 7. Effect of B levels on no. of primary branches per plant of tomato

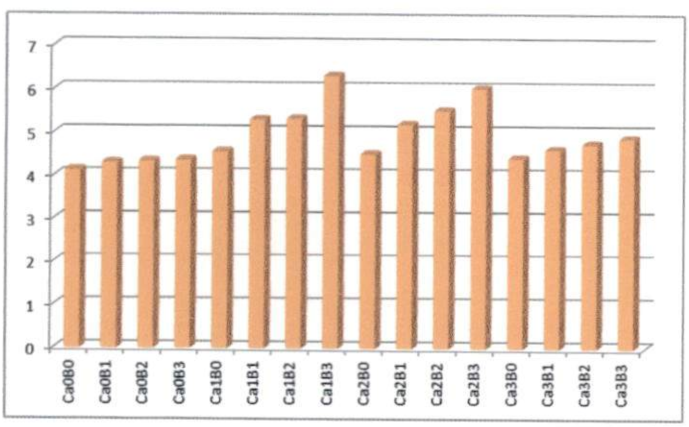

Fig. 8. Interaction effect of Ca and B levels on no. of primary branches per plant of tomato

in cell division and cell elongation. Similar reports were put forwarded by Fageria *et al*. (1997).

Plant height was significantly influenced by the application of B. (Fig 3-5). Application of higher dose of B (foliar spray of 0.3%) resulted in maximum plant height. This can be due to the effect of B in improving the mitotic activity in terminal meristem and thereby contributing to increase in plant height. A similar increase in plant height under high B status was observed by Ilyas *et al*. (2014).

Application of higher dose ie, foliar spray of 0.3% B resulted in the highest number of primary branches per plant (Fig 6-8). The improvement in number of primary branches per plant as a result of B application is due to the enhanced photosynthetic and metabolic activity which leads to an increase in various plant metabolic pathways responsible for cell division, elongation and enlargement (Barman *et al*., 1987).

Application of higher dose of (foliar spray of 0.3%) B produced the highest internodal length and leaf length which was on par with the application of 0.2 % B. This can be attributed to the influence of B on mitotic activity in terminal meristem and thereby contributing to increase in cell division and elongation. A similar increase in internodal length and leaf length under high B status was reported by Ilyas *et al*. (2014).

5.1.2 Flowering Characters

Ca applied at higher doses remarkably influenced the number of flowers per cluster, inflorescence per plant and fruit set. Maximum number of flowers per cluster was recorded with Ca-1 where full dose of Ca was given as basal as per lime requirement which was found to be on par with application of half dose of Ca as basal (Fig 9-11). This can be due to the influence of Ca as a vital nutrient for enhancing the rate of photosynthesis, secretion and activation of enzymes and carbohydrate metabolism. Full dose of Ca applied as basal enhanced inflorescence per plant and fruit set. This might be due to the effect of Ca in improving

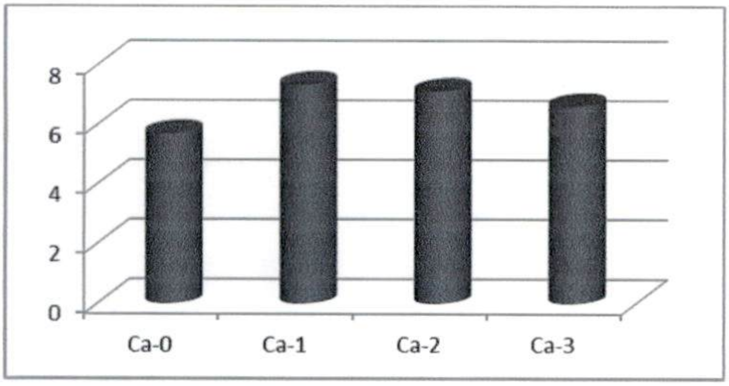

Fig. 9. Effect of Ca levels on no. of flowers per cluster of tomato

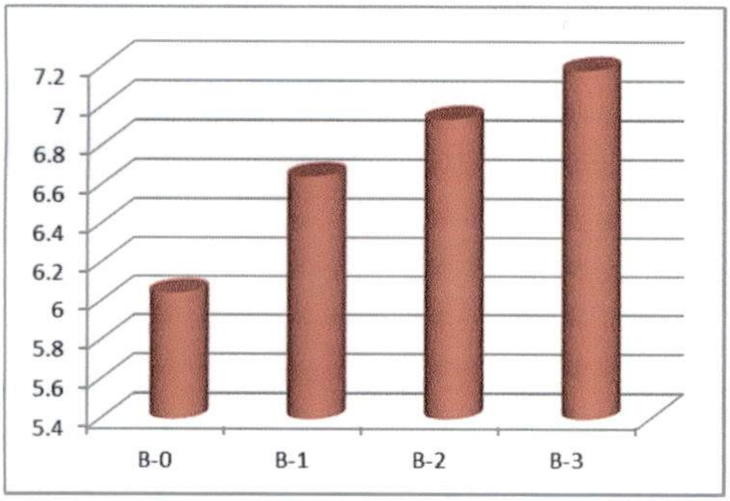

Fig. 10. Effect of B levels on no. of flowers per cluster of tomato

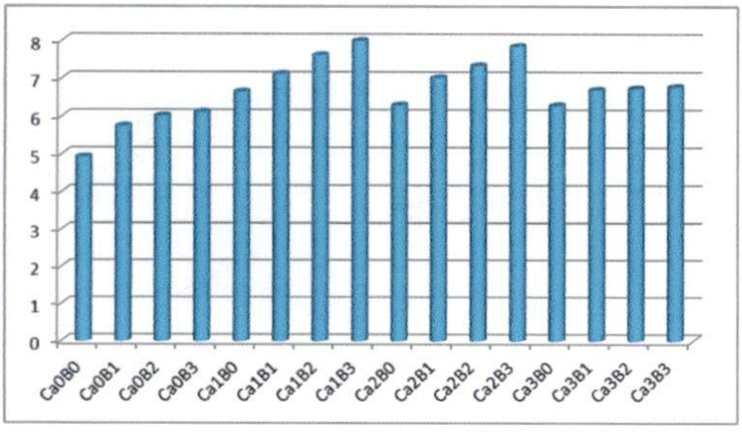

Fig. 11. Interaction effect of Ca and B levels on no. of flowers per cluster of tomato

germination of pollen tube and carbohydrate metabolism as confirmed by Fageria and Gheyi (1999). Similar results were observed by Ilyas *et al.* (2014).

Application of B had a significant effect on days to fruit set, number of flowers per cluster, inflorescence per plant and fruit set. Minimum number of days to fruit set was recorded at higher dose ie, foliar spray of 0.3% B. Role of B in pollen production and germination might have contributed to the reduction in number of days to flowering in plants. These results are in accordance with the reports by Sood and Sharma (2004).

The highest number of flowers per cluster, inflorescence per plant and fruit set and was associated with foliar spray of 0.3% B. Role of B in production and germination of pollen, pollen tube growth and carbohydrate metabolism might have contributed to the increased number of flowers per cluster, inflorescence per plant and fruit set. These results are in accordance with the reports by Wojcik *et al.* (2008).

Interaction of Ca and B produced a significant effect on flowers per cluster. Full dose of Ca as basal along with 0.3% foliar spray of B produced the highest number of flowers per cluster which was on par with the application of half dose of Ca as basal along with 0.3 % foliar spray of B. The individual effect of Ca and B level has reflected in their interactions.

5.1.3 Fruiting characters and yield

5.1.3.1 Fruiting characters

Application of Ca had a significant influence on fruits per cluster, fruits per plant and fruit girth (Table 9 and 10). Higher dose of applied Ca markedly influenced number of fruits per cluster and fruits per plant. It may be due to, the number of fruits per plant depends on number of fruits per cluster and number of flowers per cluster. The influence of Ca on girth of fruit was also conspicuous. Ca play important role in cell wall and membrane integrity, chlorophyll components,

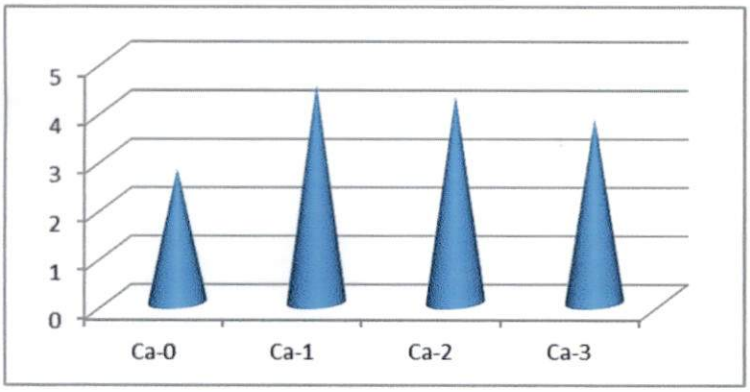

Fig. 12. Effect of Ca levels on no. of fruits per cluster of tomato

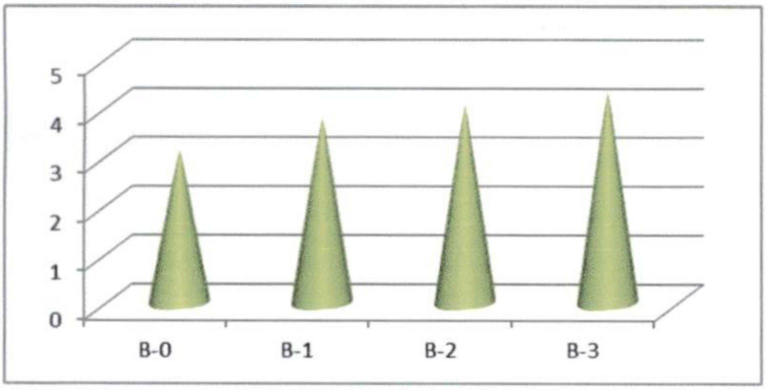

Fig. 13. Effect of B levels on no. of fruits per cluster of tomato

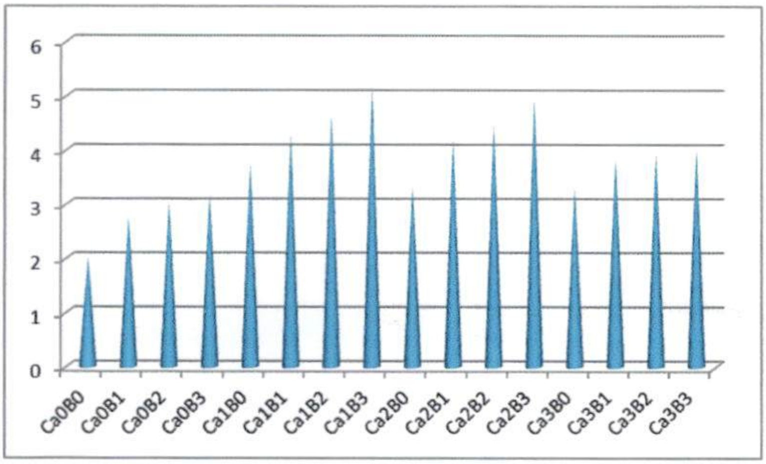

Fig. 14. Interaction effect of Ca and B levels on no. of fruits per cluster of tomato

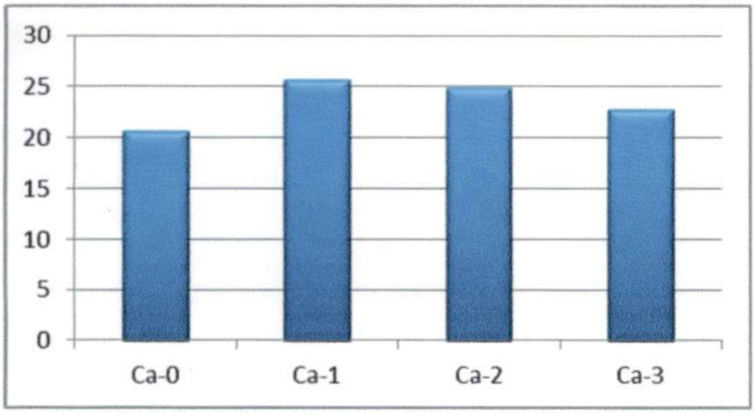

Fig. 15. Effect of Ca levels on no. of fruits per plant of tomato

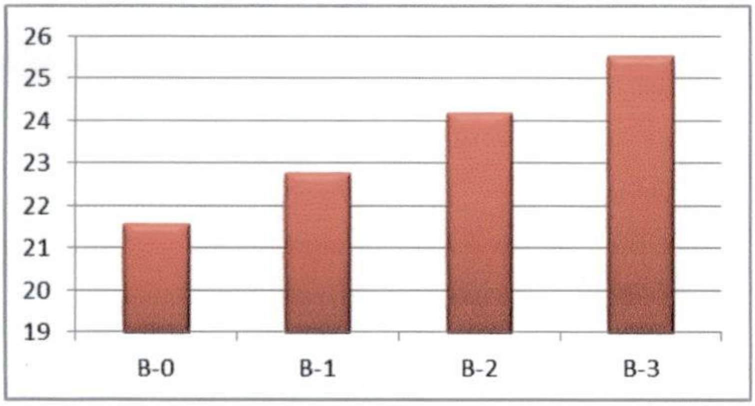

Fig. 16. Effect of B levels on no. of fruits per plant of tomato

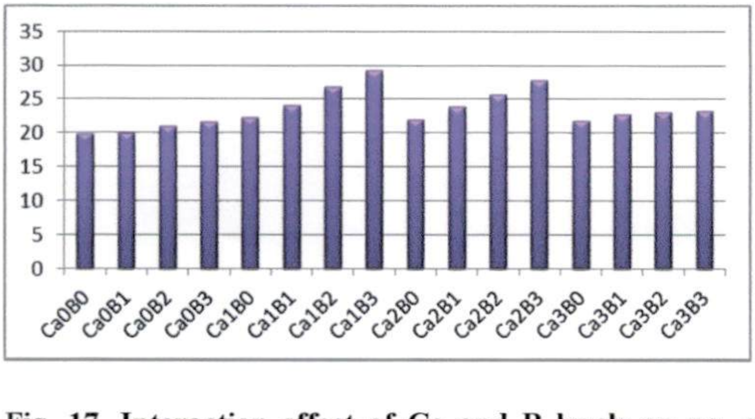

Fig. 17. Interaction effect of Ca and B levels on no. of fruits per plant of tomato

enhancing pollen germination and growth and activators of enzymes (Epstein and Bloom, 2005).

B application produced a significant effect on fruits per cluster and fruits per plant (Fig 12-14 and 15-17). Foliar spray of 0.3% B recorded the maximum number of fruits per cluster and fruits per plant. This may be due to the influence of B on production and germination of pollen, pollen tube growth and carbohydrate metabolism.

Interaction of Ca and B produced a significant effect on fruits per cluster and fruits per plant. Full dose of Ca along with 0.3% foliar spray of B produced the maximum number of fruits per cluster and fruits per plant. The individual effect of Ca and B level has reflected in their interactions.

5.1.3.2 Yield

The results revealed that the application of Ca had a significant effect on yield (Table 11). The highest yield per plant (697.35 g) and yield per plot (11.15 kg) were associated with higher dose of Ca. It may be due to the involvement of Ca in enzyme activation, photosynthesis, pollen growth and germination which results in higher yield per plant and yield per plot. Similar results were observed by Rab *et al*. (2012).

From the results, it can be concluded that the application of B produced a significant effect on yield (Fig 18-20). Maximum yield per plant (688.27 g) and yield per plot (11.01 kg) was associated with 0.3% foliar spray of B. It can be attributed to the effect of B on production and germination of pollen, pollen tube growth, synthesis and translocation of hormones and carbohydrate metabolism. B takes part in active photosynthesis, which ultimately helps to increase the number of fruits (Satpute *et al*., 2013). Brar *et al*. (2008) reported that the foliar application of nutrients always increased the yield of seed cotton irrespective of the soil nutrient status and addition of fertilizer through soil application. Similar results were reported by Jose (2015).

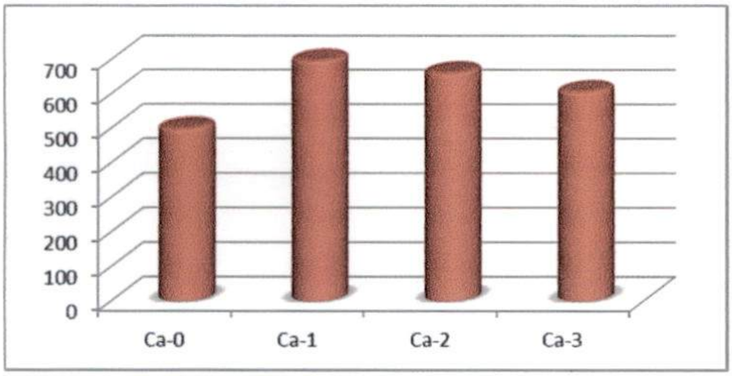

Fig. 18. Effect of Ca levels on yield per plant (g) of tomato

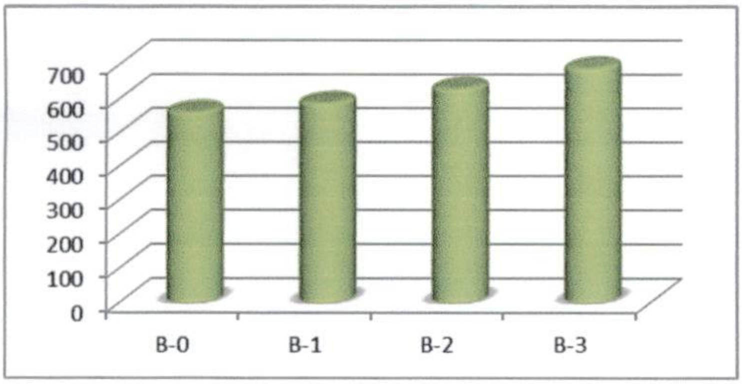

Fig. 19. Effect of B levels on yield per plant (g) of tomato

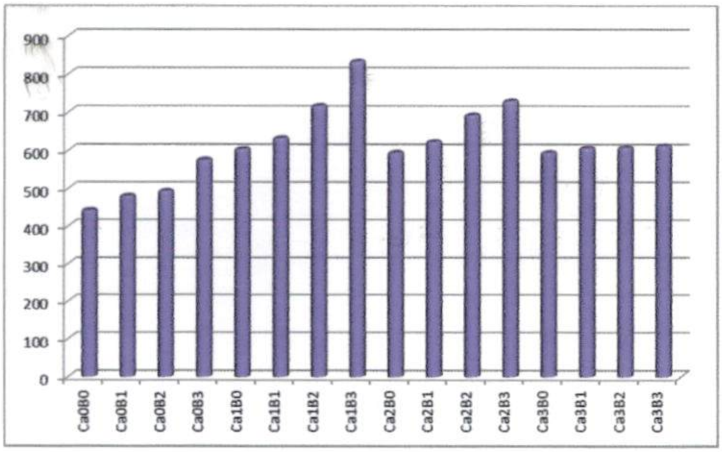

Fig. 20. Interaction effect of Ca and B levels on yield per plant (g) of tomato

The interaction of Ca and B had a significant effect on yield. Full dose of Ca along with 0.3% foliar spray of B produced the maximum yield per plant (833.43 g) and yield per plot (13.33 kg). The individual effect of Ca and B level has reflected in their interactions. Increased uptake of nutrients at higher levels of Ca and B might have led to the better expression of growth characters and yield attributes which ultimately resulted in higher yield.

5.2 PHYSIOLOGICAL DISORDERS

5.2.1 Blossom End Rot (BER)

The results concluded that the application of Ca produced a significant effect on the incidence of blossom end rot (Table 13). The lowest per cent of BER was recorded where higher dose of Ca was given ie, full dose of Ca was given as basal as per lime requirement. BER occurs when cell wall Ca concrete is deficient during early fruit development and results in cell wall membrane disintegration and appearance of dark, sunken pits at the blossom end of fruit. Similar results were given by Taylor *et al*. (2004).

5.2.2 Fruit Cracking

Application of Ca produced a significant effect on the incidence of fruit cracking (Table 12). The lowest per cent of fruit cracking was recorded where full dose of Ca was given as basal as per lime requirement. This may be due impact of Ca on cell wall, middle lamella and cell membrane.

Effect of B on incidence of fruit cracking was significant (Fig 21-23). The lowest per cent of fruit cracking was associated with higher dose of B. This may be due to the effect of B on maintaining the elasticity of the plant cell wall of the fruit skin and have the capability to improve the integrity of membrane (Xuan *et al*., 2003).

The interaction of Ca and B had a significant effect on the incidence of fruit cracking. Full dose of Ca along with 0.3% foliar spray of B produced the

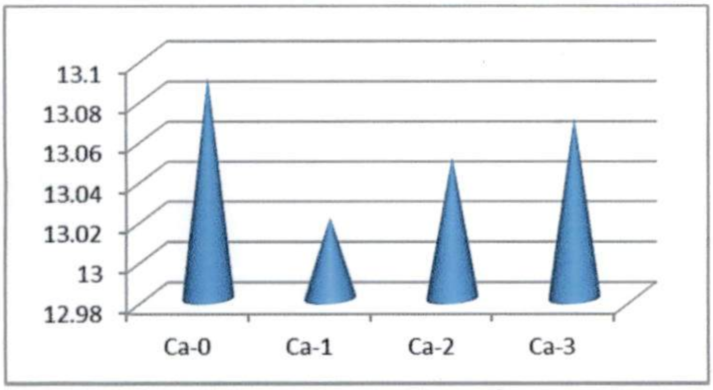

Fig. 21. Effect of Ca levels on per cent fruit cracking of tomato

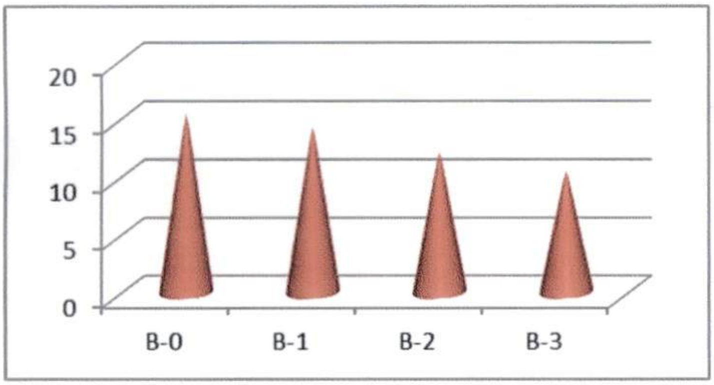

Fig. 22. Effect of B levels on per cent fruit cracking of tomato

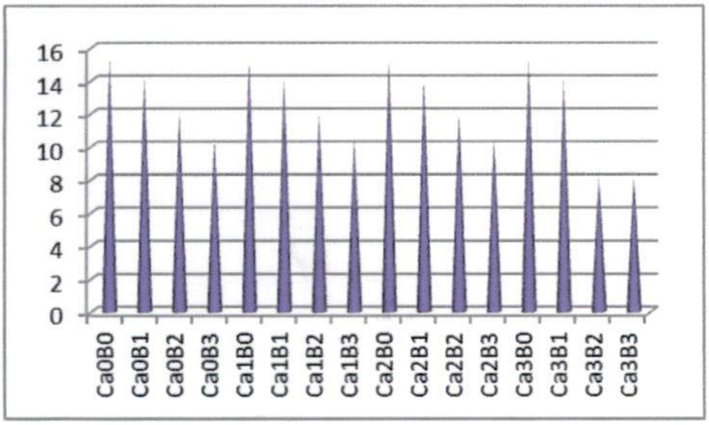

Fig. 23. Interaction effect of Ca and B levels on per cent fruit cracking of tomato

minimum fruit cracking incidence. The individual effect of Ca and B level has reflected in their interactions. The same effect was reported by Huang and Snapp (2004).

5.3 PLANT NUTRIENT CONTENT

From the results it can be concluded that the application of Ca had significant effect on the plant content of Ca (Table 15). The highest content of plant Ca was recorded where higher dose of Ca where full dose of Ca as basal as per lime requirement was given. Kamara (2010) reported an increase in Ca content with its application.

Application of B produced significant effect on plant content of B. Highest B content was observed where 0.3 % foliar spray was given. Lopez-Lefebre *et al.* (2002) found that the concentration of B increased with the application of B as compared to the control in tobacco plants.

5.4 UPTAKE OF NUTRIENTS

5.4.1 Primary Nutrients

Application of Ca and B significantly influenced the uptake of N by tomato (Table 18). The highest N uptake was associated with higher dose of Ca where full dose of Ca as basal as per lime requirement was given. Increase in N uptake with increased Ca level may be due to increased dry matter production. According to Prochnow (2014), liming has significant effect on the microbial population in the soils and thereby enhancing the fixation of N. Among various levels of B, higher dose ie, 0.3 % foliar spray resulted in maximum uptake of N. B is an important micronutrient required for biological nitrogen fixation (Giller, 2001). Interaction of Ca and B also found to be significant which was due to the production of high dry matter.

Impact of Ca and B application on P uptake by tomato was significant. The highest P uptake was associated with higher dose of Ca where full dose of Ca as basal as per lime requirement was given. Increase in P uptake with increased

Ca level may be due to increased dry matter production. Among various levels of B, higher dose ie, 0.3 % foliar spray resulted in maximum uptake of P. Interaction of Ca and B also found to be significant which was due to the production of high dry matter.

Application of Ca and B significantly influenced the uptake of K by tomato. The highest K uptake was associated with higher dose of Ca where full dose of Ca as basal as per lime requirement was given. Increase in K uptake with increased Ca level may be due to increased dry matter production. Application of higher dose of B significantly influenced the uptake of K. Interaction of Ca and B also found to be significant which was due to the production of high dry matter.

The positive interaction of B with the uptake of primary nutrients was reported by Rajkumar and Veeraraghavaiah (2002).

5.4.2 Secondary Nutrients

Application of Ca and B significantly influenced the uptake of Ca by tomato (Table 19). The highest Ca uptake was associated with higher dose of Ca where full dose of Ca as basal as per lime requirement was given. Increase in Ca uptake with increased Ca level may be due to increased dry matter production and increased levels of available Ca in soils. Application of 0.3 % foliar spray of B significantly influenced the uptake of Ca. According to Yu and Bell (2002), application of B increased the uptake of Ca in rice. Interaction of Ca and B also found to be significant which was due to the production of high dry matter.

Impact of Ca and B on the uptake of Mg and S were significant. The highest Mg and S uptake was associated with higher dose of Ca where full dose of Ca as basal was given. Application of 0.3 % foliar spray of B significantly influenced the uptake of Mg and S. Interaction of Ca and B also found to be significant which was due to the production of high dry matter.

The positive interaction of B and lime with the uptake of secondary nutrients was reported by Barman *et al*. (2014).

5.4.3 Micronutrients

Application of Ca and B significantly influenced the uptake of Fe, Cu, Mn and Zn (Table 20, 21). Higher dose of Ca contributed to maximum uptake of Fe, Cu, Mn and Zn. Higher dose of B resulted in maximum uptake of micronutrients such as Fe, Cu, Mn and Zn. According to Rajaie *et al.* (2009) reported that the application of B resulted in better plant growth and was associated with the highest uptake of Fe, Cu, Mn and Zn in lemon seedlings. Interaction effects was found to be significant for Fe, Cu and Mn.

Ca and B significantly influenced the uptake of B. Among various levels of Ca, full dose of Ca as basal as per lime requirement and among different levels of B, 0.3 % foliar spray contributed to maximum uptake of B. The results are in concurrent with the findings reported by Kumar *et al.* (1996) who reported the uptake of B increased due to B application.

5.5 NUTRIENT STATUS OF SOIL

5.5.1 Soil pH

Application of Ca produced significant effect on soil pH (Table 22). Higher dose of Ca contributed to the maximum increase in pH. Application of Ca increased the pH of soil from strongly acid to moderately acid.

5.5.2 Available Nutrients

Ca had a significant effect on the content of available Ca in soil (Table 24). Increasing levels of Ca resulted in significant increase in the available Ca status of the soil. Maximum soil available Ca was associated with higher dose of Ca where full dose of Ca as basal as per lime requirement.

5.6 ECONOMIC ANALYSIS

The economics of the treatments clearly indicates that the application of Ca and B showed significant effect on the B: C ratio (Table 27). Among different levels of Ca, full dose of Ca as basal as per lime requirement contributed to maximum B: C ratio (2.11). Among various levels of B, 0.3 % foliar spray contributed to maximum B: C ratio (2.00). Among interactions, full dose of Ca along with 0.3% foliar spray of B produced the maximum B: C ratio (2.30). Treatment combination Ca $_0$B $_0$ recorded the lowest B: C ratio (1.18).

The substantial increase in yield due to treatment effects might have resulted in maximum returns thereby enhancing B: C ratio. From the present study it was evident that the application of full dose of Ca as basal along with 0.3 % foliar spray of B had produced favourable effects on growth and yield of tomato. Use of Ca as per lime requirement and foliar spray of B (0.3 %) was found to be effective for profitable production of tomato in the *Onattukara* tract of Alappuzha district.

Summary

6. SUMMARY

An experiment was undertaken in the *Onattukara* Regional Agricultural Research Station (ORARS) farm of Kayamkulam to study the effect of Ca and B on yield and quality of tomato and to develop a recommendation for these nutrients to optimize the productivity. The experiment was laid out in factorial RBD with two replications. The treatments included two factors namely calcium levels and boron levels. Levels of calcium were - no calcium (Ca-0), full dose of calcium as basal (Ca-1), 1/2 dose of calcium as basal (Ca-2) and 1/4 dose of calcium as basal (Ca-3). Levels of boron were - no boron (B-0), foliar spray 0.1% (B-1), foliar spray 0.2% (B-2) and foliar spray 0.3% (B-3).

The salient findings of the experiment are briefed below:

Application of Ca and B significantly influenced plant height, primary branches per plant, internodal length, leaf length, flowers per cluster, inflorescence per plant, fruit set (%), fruits per cluster, fruits per plant, yield per plant (g) and yield per plot (kg). Among four Ca levels, application of full dose of Ca as per lime requirement and among different B levels, 0.3 % foliar spray of B produced significantly higher values for all the above characters.

Node to first inflorescence, leaf width and fruit girth was significantly influenced by the application of Ca. Application of full dose of Ca as per lime requirement resulted in maximum leaf width (3.29 cm) and fruit girth (11.02 cm). B application had no significant effect on leaf width and fruit girth.

B application significantly influenced the number of days to fruit set. Application of 0.3 % foliar spray of B produced significantly lower values for days to fruit set (5.25 days). Ca application had no significant effect on number of days to fruit set.

Interaction effect of Ca and B on flowers per cluster, fruits per cluster, fruits per plant, yield per plant and yield per plot was also significant. Among the interactions, Ca_1B_3 (application of full dose of Ca as basal along with 0.3 % foliar spray of B) produced the highest flowers per cluster, fruits per cluster, fruits per plant, yield per plant (833.43 g) and yield per plot (13.33 kg).

Application of Ca had a significant effect on the per cent incidence of blossom end rot. The treatment Ca–1 (application of full dose of Ca as basal) recorded the lowest incidence of BER (6.18 %). Application of B produced no significant effect on per cent incidence of BER.

Application of Ca and B had a significant effect on the per cent incidence of fruit cracking. Among Ca levels, Ca–1 (application of full dose of Ca as basal) and among B levels, B-3 (0.3 % foliar spray of B) recorded the lowest incidence of fruit cracking (13.02 % and 10.48 % respectively). Among interactions, Ca_1B_3 (application of full dose of Ca as basal along with 0.3 % foliar spray of B) produced the lowest incidence of fruit cracking (10.45 %).

Application of Ca had significant effect on the plant content of Ca. The treatment Ca–1 (application of full dose of Ca as basal) recorded the maximum plant content of Ca (4.15 %). Application of B produced significant effect on plant content of B. The highest value was observed in B-3 (400.32 mg/kg).

Application of Ca and B produced significant effect on uptake of nutrients. Maximum uptake of N, P, K, Ca, Mg, S, Cu, Mn, Fe, Zn and B was associated with Ca–1 (application of full dose of Ca as basal) and B-3 (0.3 % foliar spray of B). Interaction effects were significant for the uptake of N, P, K, Ca, Mg, S, Cu, Mn and Fe. Ca_1B_3 recorded maximum uptake of these nutrients.

Application of Ca produced significant effect on soil pH. Ca-1 contributed to the maximum increase in pH to 5.60 from 5.46.

Application of Ca had a significant effect on the content of available Ca in soil. Increasing levels of Ca significantly increased the available Ca status of the soil. Ca-1 recorded the maximum soil available Ca of 223.20 mg/kg of soil.

Application of Ca and B produced significant effect on B : C ratio. Comparing the levels of Ca, Ca–1 (application of full dose of Ca as basal) registered the highest B : C ratio (2.11). Application of 0.3 % foliar spray of B recorded the maximum B : C ratio (2.00). Among interactions, Ca_1B_3 produced the highest B: C ratio (2.30).

Based on the study, it can be concluded that the soil application of full dose of Ca as per lime requirement as basal along with 0.3 % foliar spray of B in addition to the blanket recommendations of KAU (20 t ha^{-1} FYM and 75:40:25 kg ha^{-1} NPK) will improve the yield of tomato under *Onattukara* AEU.

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RESPONSE OF TOMATO TO CALCIUM AND BORON IN THE *ONATTUKARA* TRACT OF ALAPPUZHA DISTRICT

By

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Abstract of the thesis

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8. ABSTRACT

The experiment entitled "Response of tomato to calcium and boron in the *Onattukara* tract of Alappuzha district" was conducted at the ORARS, Kayamkulam during the period from September to December 2016. The objective of the study was to find out the effect of calcium and boron on yield and quality of tomato and to develop a recommendation for these nutrients to optimize the productivity.

The experiment was laid out as factorial RBD (4^2 + 1) with two replications. The treatments included two factors viz. calcium levels and boron levels. The calcium levels were- no calcium (Ca-0), full dose of calcium as basal (Ca-1), half dose of calcium as basal (Ca-2) and one fourth dose of calcium as basal (Ca-3). Calcium was supplied through CaO and the dose of calcium was worked out from lime requirement by SMP (Buffer method by Shoemaker *et al.*) method. Levels of boron were – no boron (B-0), foliar spray 0.1% (B-1), foliar spray 0.2% (B-2) and foliar spray 0.3% (B-3). Boron was supplied through borax at 50% flowering stage. The Package of Practices Recommendations of KAU (20 t ha^{-1} FYM and 75:40:25 kg ha^{-1} NPK) was uniformly followed in all treatments. The control treatment was soil test based application of N, P, K, recommended dose of lime and B.

Results of the study revealed that the application of calcium had a significant effect on biometric characters, per cent incidence of physiological disorders, soil pH and plant uptake of nutrients. Application of full dose of calcium as basal (Ca-1) recorded the highest yield. The lowest incidence of blossom end rot and fruit cracking was observed in Ca-1. The highest B : C ratio was also observed in Ca-1. Calcium application did not have any significant effect on available nutrients except calcium. Ca-1 recorded a significant effect on the plant content of calcium. It also contributed to a significant effect on the uptake of nutrients such as N, P, K, Ca, Mg, S, B, Fe, Cu, Mn and Zn.

Boron application produced significant effect on biometric characters, per cent incidence of physiological disorders and plant uptake of nutrients. Among various levels, foliar spray of 0.3% boron (B-3) was found to be the best treatment. B-3 has recorded the highest yield and B: C ratio. It also produced the lowest incidence of fruit cracking. Boron application did not have any significant effect on soil available nutrients, soil pH and plant content of nutrients except plant boron. B-3 has also contributed to a significant effect on the uptake of nutrients such as N, P, K, Ca, Mg, S, B, Fe, Cu, Mn and Zn.

Among various interactions, application of full dose of calcium as basal along with foliar spray of 0.3% boron (Ca_1B_3) has contributed to the maximum yield, B: C ratio and the lowest incidence of fruit cracking. Ca_1B_3 recorded the highest uptake of nutrients such as N, P, K, Ca, Mg, S, Fe, Cu and Mn. None of the interactions were observed to be significant for soil pH, soil available nutrients and plant nutrient content. But the application of Ca and B produced no significant effect on the quality characters such as TSS, lycopene content and ascorbic acid contents.

From the results of the study, it can be concluded that higher yield of tomato in *Onattukara* tract of Alappuzha district can be obtained by the combined application of full dose of calcium as per lime requirement of the soil along with 0.3% foliar spray of boron (Ca_1B_3) in addition to the blanket recommendations of KAU (20 t ha^{-1} FYM and 75:40:25 kg ha^{-1} NPK).

Appendix

APPENDIX 1

Weather parameters during the cropping period, September 2016- December 2016

Standard week	Temperature (°C)		Relative humidity(%)	Rainfall (mm)
	Maximum	Minimum		
34	30.29	25.14	82.79	5.50
35	30.36	24.71	81.57	3.80
36	29.79	24.07	84.36	2.65
37	30.50	25.07	81.57	5.40
38	30.43	25.00	83.36	0.00
39	30.79	25.00	81.93	8.04
40	30.36	24.12	94.88	2.80
41	30.68	23.94	94.12	0.00
42	30.33	24.62	96.56	0.00
43	29.91	23.80	95.29	0.00
44	30.40	23.84	92.68	7.80
45	30.83	23.70	94.19	1.27
46	31.32	24.34	91.04	0.00
47	30.54	24.13	87.43	0.00
48	30.83	23.36	92.43	3.30
49	30.85	23.20	85.70	0.00
50	30.14	22.69	91.04	0.00