GROWTH AND YIELD PERFORMANCE OF DIFFERENT CHERRY TOMATO VARIETIES GROWN IN DIFFERENT CALCIUM LEVELS

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CERTIFICATE

This is to certify that thesis entitled ***GROWTH AND YIELD PERFORMANCE OF DIFFERENT CHERRY TOMATO VARIETIES GROWN IN DIFFERENT CALCIUM LEVELS"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in HORTICULTURE,*** *embodies the result of a piece of bona fide research work carried out by* ***JANNATUL NAIMA ATKIA*** *Registration No. 14-06279 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated: June, 2021
Place: Dhaka, Bangladesh

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DEDICATED
TO
MY BELOVED
PARENTS

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ABSTRACT

A pot experiment was conducted in the semi-greenhouse at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, Bangladesh, during October 2019 to March 2020 to find out the best combination of calcium fertilizers and different varieties for successful cherry tomato production. The experiment consisted of two factors: Factor A: three types of variety viz. V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg and Factor B: Four doses of calcium fertilizer viz. C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm. There were 12 treatment combinations and experiment was setup in Completely Randomized Design (CRD) with three replications. In case of varieties, the highest plant height at 60 DAT (255.32 cm), maximum branch number per plant (4.58) at 60 DAT, maximum chlorophyll content (75.71 %) at 75 DAT, minimum days required for first flowering (27.67 DAT) and first fruiting (36.33 DAT), maximum flower cluster per plant (30.83), maximum fruit number per plant (284.56), highest single fruit weight (10.52 g), highest amount of TSS (8.90 degrees Brix) and yield per plant (2.94 kg) were obtained from V_2 treatment. Similarly, in case of calcium fertilizer, the highest plant height at 60 DAT (233.92 cm), maximum branch number per plant (4.78) at 60 DAT, maximum chlorophyll content (81.53 %) at 75 DAT, minimum days required for first flowering (25.33 DAT) and first fruiting (33.89 DAT), maximum flower cluster per plant (35.28), maximum fruit number per plant (292.77), highest single fruit weight (11.61 g), highest amount of TSS (8.96 degrees Brix) and yield per plant (3.32 kg) were obtained from C_2 treatment. In combined effect, the highest plant height at 60 DAT (273.33 cm), maximum branch number per plant (5.67) at 60 DAT, maximum chlorophyll content (86.77 %) at 75 DAT, minimum days required for first flowering (24.00 DAT) and first fruiting (32.00 DAT), maximum flower cluster per plant (36.67), maximum fruit number per plant (362.02), highest single fruit weight (13.33 g), highest amount of TSS (9.47 degrees Brix) and yield per plant (4.34 kg) were obtained from V_2C_2 treatment. Among the treatment combination, V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment seemed to be more promising for obtaining higher yield of cherry tomato.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
cm	Centi-meter
CV	Coefficient of variation
^{o}C	Degree Celsius
df	Degrees of freedom
DAT	Days After Transplanting
et al.	And others
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
CRSP	Collaborative Research Support Program
J.	Journal
kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
MoP	Muriate of Potash
CRD	Completely Randomized Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Superphosphate

CHAPTER I

INTRODUCTION

Cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*) is regarded as a botanical variety of the cultivated tomato which is round in shape, similar to a cherry juicy and meaty berry, bigger than 1.5 cm in diameter (Silva and Giordano, 2000). Various colorful cherry tomatoes were found like Red, Black, Green, Bi-Color, White, Stripped, Yellow-Orange and Pink cherry tomato. Commonly cherry tomato is called garden tomato for its size and shape. Its size and shape depend on the range in size from a thumb tip up to the size of a golf ball, and can range from being spherical to slightly oblong in shape (Prema, 2011). It is the sort of tomato, where as it belongs to the Solanaceae family. However, cherry tomato is now very popular in the whole world for its nutritive value, taste and attractive color. Furthermore, it has high content of vitamin A, C and sugar, low calories, lycopene and β- carotene (Rosales, 2011). Use of cherry tomatoes is now available for meal decoration of home, hotel and restaurant. Especially, children like to eat cherry tomato. Fruit set can easily occur in comparatively high temperature which is very significant for tropical climate. Furthermore, Cherry tomatoes are source of germplasm for providing disease resistance and adaptability to cool and hot seasons (Anon, 2009). In Bangladesh, cherry tomato is new type for tomato production and still infancy for farmer field and as well as for consumer market. Due to the awareness of food consumption and nutritive status of Bangladeshi people, cherry tomato can supply both of demand. In general, with ever increasing demand, it has become imperative to develop high yielding varieties with resistance to biotic and abiotic stresses and suitable to fresh market and processing. Hence, identification of qualitative character is another important feature for cherry tomato. Moreover, farmer should know the targeted variety for growth and production of cherry tomato.

Therefore, potential value of cherry tomatoes has to be improved by evaluating the cultivated species for its desirable characters under various agro climatic regions. Besides, cultivars and cultural practices, many biotic and abiotic factors also limit the yield of tomato crop. (Ali *et al.,* 2014). Abiotic stresses like changes in environmental conditions and nutrition results in physiological disorders ultimately decrease crop yield (Khavari-Nejad *et al.,* 2009).

Nutrient management is essential to maximize crop yield (Menzel and Simpson, 1987), enhance fruit quality and increase profitability (Ganeshamurthy *et al.,* 2011). Tomato plant requires macro and micro nutrients for growth and development as well as to complete its life cycle (Brady and Weil, 2002). Essential nutrients are needed for optimum plant growth and development (Fageria, 2005; 2007; Fageria and Baligar, 2005). Soil characterized by high pH limits micronutrients availability to the plant (Ibrahim *et al.,* 2008). Thus, application of essential nutrients enhances the uptake and utilization of nutrients (Phillips *et al.,* 2004) and decrease nutrients deficiency related disorders.

The nutrients required in large quantity are supplied through soil application (Fageria *et al.,* 2009) but nutrients needed in lower quantity can be better absorbed through foliar spray (Fageria *et al.,* 2009; Girma *et al.,* 2007). Treatments with $CaCl_2$ have been found to have better preservation quality on tomato fruits (Genanew, 2013). Calcium (Ca) is an essential macronutrient (Kadir, 2005) and tomato fruits contain calcium levels ranging from 3.08 to 16.42 mg 100/g (Anjum *et al.,* 2020), which may be deficient in plants either due to low calcium in soil, low calcium availability due to high soil pH, and low mobility in the plants especially to the fruits (Kadir, 2005; Peter, 2005) and which can be an effective treatment in reducing physiological disorder (blossom end rot), increasing the fruit firmness, delaying the ripening process, and ethylene production in tomatoes (Abbasi *et al.,* 2013). $CaCl_2$ delays the fruit color development in tomato fruits by slowing down the ethylene production and respiration rate, thereby extending the shelf life of fruits (Anjum *et al.,* 2020). The physiological weight loss of tomato fruits declined up to 19% by applying 0.25% of $CaCl_2$, which maintained the higher firmness during storage (Bhattarai and Gautam, 2006). The foliar application of Ca (0.5% $CaCl_2$) in sweet cherry increases the Ca concentration in fruits and substantial changes in the levels of numerous primary and secondary metabolites (Michailidis *et al.,* 2021).

The ability of calcium to form intermolecular linkages gives it an important role in maintaining the integrity and structure of membranes and cell walls (Hirshi, 2004). In plants, calcium also plays a role similar to a hormone in the regulation of various cell functions (Demidchik *et al.,* 2018). One such function is in the regulation of the protein pump that controls the uptake and movement of nutrients into the root and throughout cells within the plant. At the root level, calcium activates and leads to stimulation of the protein channels that take up nutrients (DiMeglio and Imel, 2019). Adequate availability of calcium at the root surface is required for this process to work effectively (Gweyi, 2015). Saline conditions predispose crops to calcium deficiency by decreasing water uptake (Oshunsanya *et al.,* 2019). This calls for the need to undertake soil tesing before any crop production venture. The movement of calcium in tomato is virtually confined to the xylem and transport of absorbed calcium to the shoots is subdued by salinity (Oshunsanya *et al.,* 2019).

Therefore, a continuous supply of calcium is required for leaf development, plant canopy, and vigorous root growth (Del-Amor and Marcelis, 2006). Foliar fertilization can supplement soil fertilization to maximize crop yield (Fageria *et al.,* 2009). Low levels of Ca in fruit tissues can also cause blossom end rot, which is a physiological disorder that reduces the yield of many vegetables such as tomato (Tonetto de Freitas *et al.,* 2011). Fruit cracking is one of the primary causes of reduced quality and market value in tomatoes and require attention to minimise losses experienced by farmers. Therefore, supplemental calcium or manipulation of calcium nutrition through pruning or water management may prevent radial cracking of tomoato fruit or reduce cuticle cracking (Dorais *et al.,* 2001).

Varieties associated with proper calcium fertilizer is an important factor for successful cherry tomato production. The combined effect of these production practices have not been defined clearly and the information in this respect is meagre in Bangladesh. Considering the above facts, the experiment has been undertaken with the following objectives:

- To identify the effect of calcium (Ca^{2+}) on the growth and yield contributing characters of cherry tomato,
- To study the morphological characters of some cherry tomato varieties under different level of calcium application; and
- To study the combined effect of variety and calcium application on the growth and yield of cherry tomato.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this chapter was to review the literatures having relevance to the present study. The review of literature of the past studies and opinions of the researchers pertinent to the present experiment were collected through reviewing of journals, thesis, reports and other form of publications. The information were compiled and presented below:

2.1. Effect of calcium (Ca)

2.2.1 Effect of Ca on growth and yield

Mazumder *et al*. (2021) carried out an experiment to determine the effect of pre-harvest treatments of $CaCl_2$ solution (0.0%, 1.0%, 1.5% and 2.0% w/v) on the growth, yield, quality, and shelf-life performance of tomato varieties. Spraying with 2% of $CaCl_2$ showed an improvement in controlling physiological disorders such as blossom end rot (BER), weight loss, declined disease incidence, and disease severity as well as performed better in growth, yield, quality and shelf-life performance compared to other $CaCl_2$ treatment.

Lavanya and Bahadur (2021) conducted an experiment to identify the effect of calcium and boron on yield and quality of cherry tomato and to find out suitable method in cherry tomato at VRF SHUATS, Naini (Prayagraj) India, during rabi season 2019-20. It was concluded from the investigation that foliar application with increasing levels of Ca and B from 0% to 0.6% exhibited significant increase in morphological characters as well as yield attributes of cherry tomato. The maximum net returns and (B:C) ratio was obtained in treatment fertilized with 0.6% of calcium + 0.6% of boron which resulted in higher yield and consequently maximum (B:C) ratio (3.45).

Sturiao *et al*. (2020) conducted a study on deficiency of calcium affects anatomical, biometry and nutritional status of cherry tomato. For this study it can be concluded that, the best responses of biometric and production variables, as well as the better nutritional plant status occur with estimated concentrations from 6.0 to 7.0 mmol L^{-1} Ca in nutrient solution.

Azad *et al.* (2019) conducted a study to investigate the influences of calcium and mulching practices on yield and fruit quality of tomato. The trials comprised three factors: 1) three tomato varieties viz, BARI F_1 Tomato-5, BARI F_1 Tomato-6 and BARI F_1 Tomato-7; 2) four levels of calcium (Ca) treatment (40 ppm, 60 ppm, 80 ppm, 120ppm) and 3 mulching practices. Results suggested that BARI F_1 Tomato-5 variety receiving 80 ppm calcium treatment with mulching condition exposed better quality, yield and yield contributing characters of tomato.

Pinero *et al.* (2018) conducted a study on sweet pepper fruit quality disorders as affected by foliar Ca applications to mitigate the supply of saline water under a climate change scenario. High CO_2 favoured generative growth instead of vegetative growth. Foliar Ca supply did not affect the marketable yield, but reduced the total yield when combined with salinity and 400 µmol mol^{-1} CO_2. Salinity affected negatively the total yield but this was overcome when CO_2 was applied. The B and K concentrations were reduced by foliar Ca application, while Ca and Mn were increased at 400 µmol mol^{-1} CO_2. The effect of Ca application differed according to the other treatments applied. This procedure should be optimized to overcome future climate impacts on fruit quality.

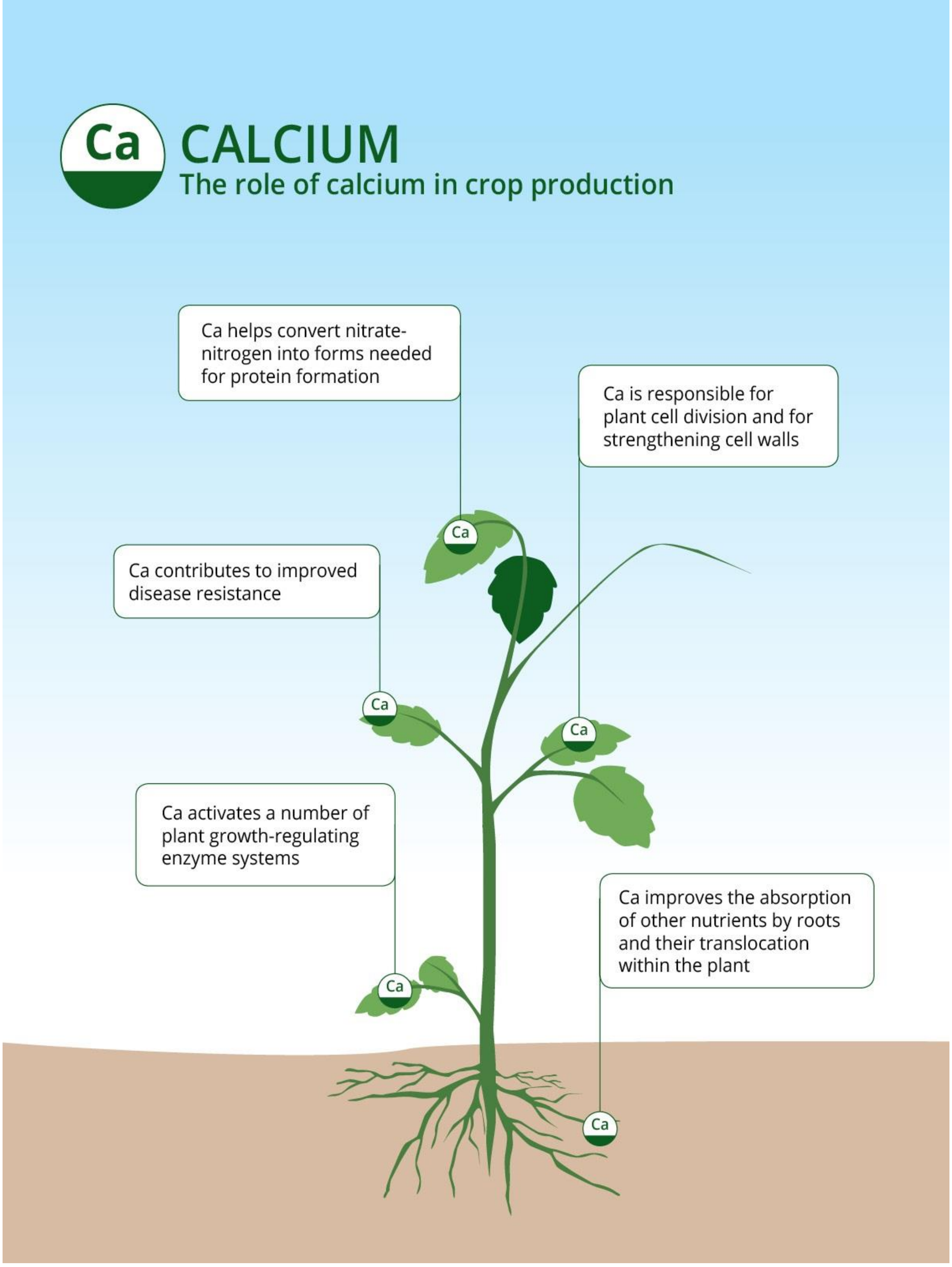
Effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato was investigated during the year 2013 at ARI Tarnab, Peshawar to optimize calcium, boron and zinc concentration for enhancing the growth and fruit related attributes of tomato. The experiment was conducted using Randomized Complete

Block (RCB) Design with 3 factors, replicated 3 times. Calcium (0, 0.3, 0.6 and 0.9%), Boron (0, 0.25, 0.5%) and Zinc (0, 0.25, 0.5%) were applied as foliar spray three times. Calcium application at 0.6% increased plant height (88.04 cm), number of primary (2.63) and secondary (7.15) branches, leaves plant-1 (182), leaf area (65.52 cm2), and fruit per plant (66.15). In case of B levels, more plant height (88.14 cm), number of primary (2.61) and secondary (7.44) branches, number of leaves plant-1 (177), number fruits plant-1 (67.78) were recorded with foliar spray of B at 0.25%, while maximum leaf area was found at 0.5% B. Comparing the means for Zn concentrations, maximum plant height (86.53 cm), number of primary (2.53) and secondary (6.42) branches, leaves plant-1 (167), leaf area (63.33 cm2), and fruit per plant (63.78) were higher with 0.5% foliar Zn application. The interaction between Ca, B and Zn also showed significant results for most of the attributes. Therefore, application of Ca (0.6%), B (0.25%), and Zn (0.5%) as a foliar spray can be used alone or in combination to improve growth and fruit production of tomato (Haleema *et al.*, 2018).

Islam *et al.* (2016) conducted an experiment to investigate the effect of foliar spraying with boron and calcium on the qualities of light red maturity-stage ‘Unicorn’ cherry tomato. These results indicate that B and Ca treatment increases cell -wall compactness, reduces the respiration rate, reduces fresh weight loss, increases shelf life, maintains flesh firmness, and increases vitamin C content in cherry tomato.

An experiment was conducted by Kabir *et al.* (2013) on the growth and yield of groundnut with phosphorus, calcium and boron and reported that the highest plant height (59.68cm), dry matter content (31.1 g), CGR (20.39 g m^{-2} d^{-1}), highest branches per plant (7.22) was obtained from Ca_2 (165 kg Ca ha^{-1}) and the lowest one (47.18 cm) was found at control (0 kg Ca ha^{-1}).

The role of calcium in tomatoes in plants is quite similar to that in people, it is essential for good growth and structure (Martínez-Andújar *et al.,* 2016). Calcium plays a fundamental role in membrane stability, cell wall stabilization and cell integrity (Hirshi, 2004). Insufficient calcium levels lead to deterioration of the cell membrane, the cells become leaky resulting in the loss of cell compounds and eventually death of cell and plant tissues (Biswas *et al.,* 2016). Reduced calcium in edible tomato fruit tissues negatively impacts total yield. Tissues low in calcium are more susceptible than with normal calcium levels to some parasitic diseases during storage. The problems associated with a low plant calcium level can be attributed to soil problems. e.g calcium deficiencies are prevalent in very low soil pH and on soils high in magnesium and potassium (Esfandiarpour-Borujeni *et al.*, 2018). Calcium also plays a role in regulating various cell and plant function as a secondary messenger (Ranty *et al.,* 2016). This function as a secondary messenger assists in various plant functions from nutrient uptake to changes in cell status to help react to the impact of environmental and disease stresses (Ho and White, 2005). Calcium is crucial regulator of growth and development in tomatoes.



Source: White and Broadley (2003)

Halina *et al.* (2016) conducted an experiment to evaluate the effects of foliar Ca feeding on the yield of sweet pepper „Caryca F1" and on selected elements of its fruit quality in field ground cultivation. Ca was applied in the form of the following preparations:

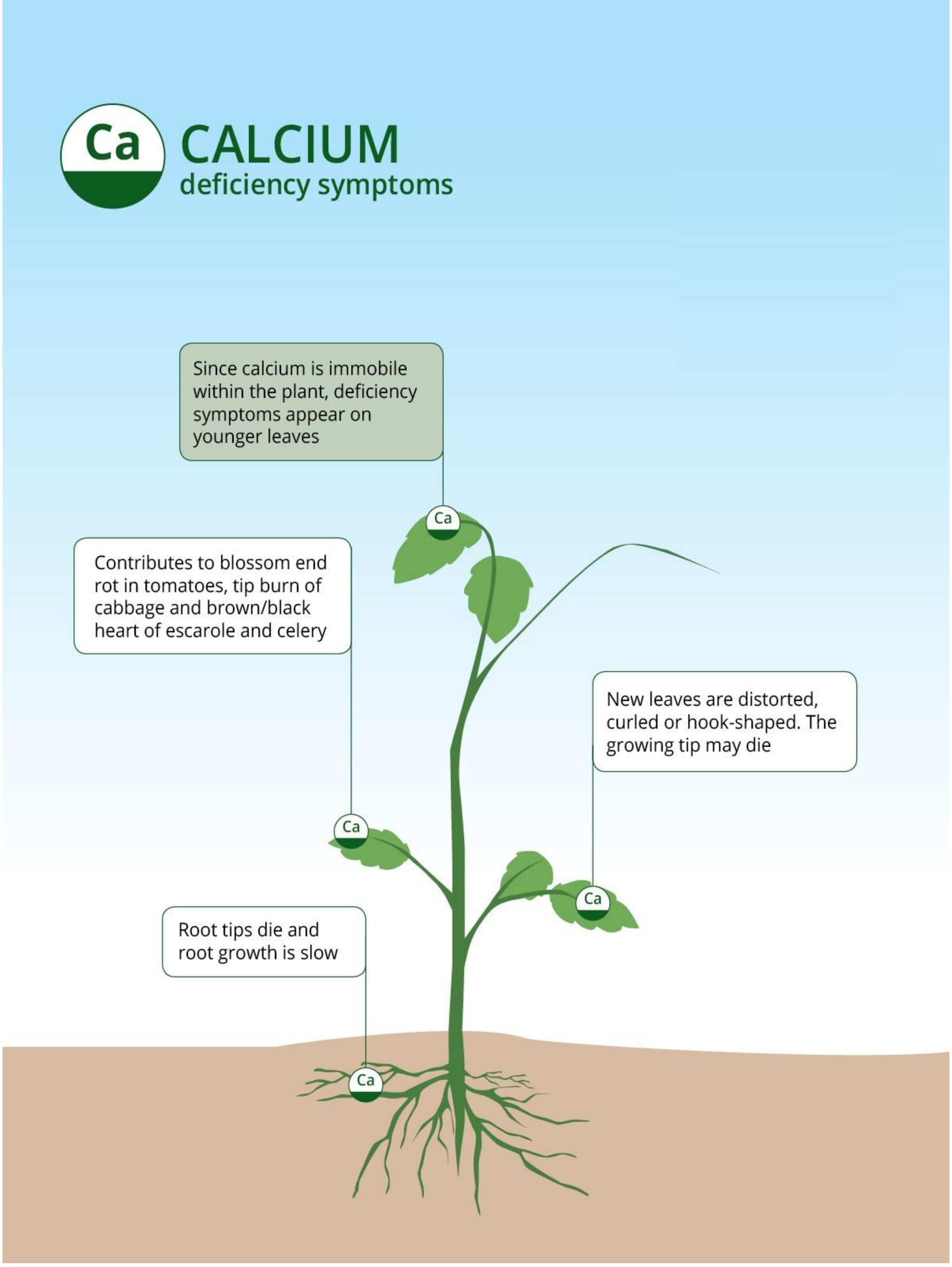
$Ca(NO_3)_2$, Insol Ca, or Librel Ca. Calcium preparations were applied on 3 or 5 dates in 1% concentration of the solution to the full wetting of the plants. A positive influence of Ca feeding on the marketable yield of the fruit was observed: 4.26–4.63 kg m^{-2} as compared with the controls at 3.80 kg m^{-2}. Calcium foliar feeding caused a limited number of fruits with BER symptoms at 4.3%–5.2% of the total number of fruits, as compared with 14.4% of those of the control fruits. The use of $Ca(NO_3)_2$ had a positive effect on the accumulation of vitamin C and carotenoids as compared with other fertilizers. Reduced Ca spraying proved to be beneficial in terms of fruit yield and concentrations of carotenoids.

Rubio *et al.* (2010) investigated a study on the influence of Ca^{2+} and K^+ levels on fruit yield and quality of sweet pepper (*Capsicum annuum* L. cv. Orlando) plants under hydroponic culture. The treatments consisted of three concentrations of Ca^{2+} (1.5, 4 and 8 mmol L^{-1}) and K^+ (2.5, 7 and 12 mmol L^{-1}) that were imposed separately. Fruit yield parameters and different fruit quality parameters, as well as dry matter production and mineral composition in individual parts of the plant, were determined. The increase of Ca^{2+} in the root medium increased the marketable yield from 1.67 to 2.38 kg $plant^{-1}$, mainly due to an increase in the number of fruits per plant, while higher K^+ levels decreased marketable yield from 2.2 to 1.66 kg $plant^{-1}$, due to decreases in the number of fruits per plant and the mean fruit weight. With respect to fruit quality, fruit shape index and, therefore, pepper fruit appearance improved with Ca^{2+} addition to the root medium. Fertilization with K^+ increased fruit acidity and decreased maturity index, which could improve fruit storability. Low Ca^{2+} or high K^+ levels reduced both root and shoot dry matter. Therefore, an adequate management of fertilization with Ca^{2+} and K^+ could improve the yield and fruit quality of pepper grown in soilless culture.

2.1.2 Role of Ca on crop protection

Manaf *et al.* (2017) reported that the amounts of Ca in soil solution are usually high enough to provide for all plant demands. Ca-deficiency in plants is a physiological disorder, and occurs only rarely as a result of low Ca levels in the soil. Ca-deficiency symptoms in plants do not generally disappear simply by raising the Ca level of the soil. Therefore, it is important to understand the mechanisms of Ca^{2+} ion uptake, transport, and distribution in plants. Any factor inhibiting root growth, such as low temperature, inadequate aeration, poor nutrient status, or high H^+ ion concentration, can thus restrict Ca uptake and hence impair Ca translocation because of the absence of young root tip cells.

For most crops which include tomatoes, net photosynthesis declines as temperatures increase to 34^{o}C, and calcium is able to mitigate heat stress effects by improving stomatal function and other cell processes (Patterson, 2008). Calcium is also believed to have an influence on the development of shock proteins that help the plant tolerate the stress of prolonged heat (Patterson, 2008). In addition, calcium plays a major role in the quality and shelf life of tomatoes. Excessive calcium restricts plant communities' growth in calcareous soils and this too affect tomato production if grown in these types of soils (Shukla *et al.,* 2018). Calcium deficiency is rare in nature, but may occur in soils with low base saturation and/or high level of acidic deposition (Havlin *et al.,* 2016).



Source: White and Broadley (2003)

Manaf *et al.* (2017) executed a greenhouse experiment to evaluate the impact with two concentrations (5 and 10 mM l^{-1}) of calcium chloride ($CaCl_2$) foliar application on growth parameters, yield and some biochemical constituents and blossom-end rot

(BER) incidence of sweet pepper (*Capsicum annuum* L.) under drought stress. The obtained results indicated that $CaCl_2$ foliar application $CaCl_2$ with under both irrigation regimes achieved an increment in most of growth parameters, yield and some biochemical constituents. On the contrary, the same applications led to decrease BER incidence in the plants under normal irrigation or water deficiency. However, no-significant effect of $CaCl_2$ was observed on chlorophyll a/b ratio, carotenoids and carotenoids/chlorophyll a+b.

Manaf *et al.* (2017) reported that Ca sprays help to prevent Ca-deficiency disorders in plants. Ca-deficiency-related disorders are usually linked to the inability of a plant to translocate adequate Ca to the affected part rather than insufficient levels of soil Ca. Ca is a relatively immobile element in plants. Foliar sprays can be used to correct these deficiencies. It is important to cover any young terminal growth with Ca, as application on the older leaves will not benefit the plant.

The increase in the number of fruit of tomato with Ca application might be due the higher uptake of phosphorus that resulted in more flower cluster and enhanced fruits plant-1 in tomato plant (Ilyas *et al*., 2014). Moreover, calcium may also inhibit flower abscission and, thus, results in increased fruits plant^{-1}.

The combination of Ca^+ and B was more effective in increasing fruits plant^{-1}. Similarly, B and Zn promote the translocation of carbohydrate from site of formation to sinks that resulted in increased fruits plant^{-1} (Singh and Tiwari, 2013).

Ayyub *et al*. (2012) who reported that tomato plant height, generally, respond positively to foliar application of Ca and increases vegetative or shoot growth of tomato plant.

Kerton *et al*. (2009) reported that Ca is not recycled when deposited in leaf tissue. Ca flows through the plant in the xylem (White and Broadley, 2003), mostly passively, with the water flow caused by transpiration.

Fedrizzi *et al.* (2008) found that a Ca signal is involved in the regulation of cell division and Ca can be found in the mitotic spindle. Ca is also critical in signal transduction path ways by binding with calmodulin, a cytosolic plant protein.

Tomato fruits that take up B and Ca have better firmness than the control because these treatments may lead to pectin bonding to stabilize cell-wall structure. Ca-treated strawberries contain fewer soluble solids and higher acidity than the control (Hemandez-Munoz *et al*., 2006, Singh *et al*., 2007).

Lecourieux *et al.* (2006) described Ca ions as a second messenger in numerous plant signaling pathways, conveying a wide range of environmental and developmental stimuli to elicit the appropriate physiological responses.

Lecourieux *et al.* (2006) found that calmodulin is a highly conserved and broadly distributed Ca-binding protein which acts as a multifunctional intermediary by connecting Ca signals to the activation of other cellular components.

Ho and White (2005) showed that Ca controls cell expansion by influencing the incorporation into the plasma membrane of vesicles containing the materials and enzymes required for cell membrane and cell wall construction.

Shoba *et al.* (2005) conducted a field experiment in Tamil Nadu, India, during the 2002 rabi season, to investigate the effects of calcium (Ca) and boron (B) fertilizer and ethrel [ethephon] applications and 45x45 and 65x45 spacings against fruit cracking in the tomato genotypes LCR 1 and LCR 1 x H 24. Between the 2 genotypes, the fruit cracking percentage was low in LCR 1 x H 24. Among the 2 spacings, closer spacing showed less fruit cracking and among the different nutrient treatments, the spraying of B with Ca was effective in controlling fruit cracking.

Ca-interacts with B, which has a stabilizing influence on Ca complexes in the middle lamella of fresh-market tomatoes (Huang and Snapp, 2004). As cell compactness increases, so does shelf life; as a result, tomatoes retain their firmness longer.

Increasing Ca levels in fruit during development leads to increased firmness (Agusti *et al.*, 2004), and Ca-treated tomatoes contain higher Ca levels than the control (Liebisch *et al*., 2009, Lee and Kim, 2010), as Ca uptake increases in these tomatoes, leading to Ca-pectate bonding. Ca treatment increases calcium pectate levels.

Tomato (*Lycopersicon esculentum* Mill.) 'Trust' was grown on rockwool with two concentrations of calcium (150 and 300 mg L^{-1}) in combination with four concentrations of magnesium (20, 50, 80 and 110 mg L^{-1}) in fall, 1999, to investigate their effects on plant growth, leaf photosynthesis, and fruit yield and quality (fruit firmness, dry matter, soluble solids and russeting). High Ca (300 mg L^{-1}) concentration increased fruit yield and reduced the incidence of blossom-end rot (BER) and fruit russeting, compared with the low Ca concentration (150 mg L^{-1}). High Ca concentration reduced fruit firmness but did not affect fruit size and leaf photosynthesis (Hao and Papadopoulos, 2003).

White and Broadley (2003) experimented that Ca is required for various structural roles in the cell wall and in membranes. Ca is essential for the synthesis of cell walls. Ca is bound as Ca-pectate in the middle lamella and it is essential for strengthening cell walls and plant tissues.

Kleemann (2000) demonstrated that spraying with Ca reduced the incidence of Ca-deficiency injury in plants.

CHAPTER III

MATERIALS AND METHODS

3.1. Experimental site and period

The pot experiment was conducted in the semi-greenhouse at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka 1207, during October 2019 to March 2020.

3.2. Experimental location

The location of the study site was situated in 23°74′N latitude and 90°35′E longitudes. The altitude of the location was 8m from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207, which have been shown in the Appendix I.

3.3. Plant and other materials

The study included three cherry tomato varieties, viz. Red Star F_1, Sweet Charlie F_1 and Thai Pink Egg. The seeds of the varieties were collected from Siddik Bazar, Gulistan, Dhaka. The styrofoam, cocopeat, earthen pot, plastic tray, plastic pipe, polythene sheet, etc. were collected from Town Hall, Mohammadpur, Dhaka. Experimental chemicals were bought from Agargaon Nursery, Dhaka. Different types of daily instruments also used from many purposes to complete the experiment.

3.4. Experimental Design and treatments

The experiment was conducted in a Completely Randomized Design (CRD) with three replications. Two factors were considered as treatments denoted as V (Different Varieties) and C (Different level of Calcium).

Factor-A: Different Cherry tomato varieties

V_1= Red Star F1

V_2= Sweet Charlie F1

V_3= Thai Pink Egg

Factor-B: Different Calcium levels

C_1= 0 ppm

C_2= 40 ppm

C_3= 80 ppm

C_4= 120 ppm

There were 12 (3 × 4) treatments combination such as V_1C_1, V_1C_2, V_1C_3, V_1C_4, V_2C_1, V_2C_2, V_2C_3, V_2C_4, V_3C_1, V_3C_2, V_3C_3 and V_3C_4.

3.5. Preparation of growing media

The mixture of coco peat and khoa were used to make the growing media. Coco peat blocks were also soaked a plastic container for overnight. The soaked coco peat was washed well in water and spread in a polythene sheet for three hours. Then three ingredients coco peat, khoa and vermicompost @ 60%, 30% and 10% were mixed according to mixer ratio.

3.6. Experimental environment

Round eight inch 36 earthen pots were prepared for culturing the plants. Polythene sheet was placed in the surface of the soil. Pots were filled with different substrates mixture according to the ratio. For seedling growing, Styrofoam box filled with media mixture of coco peat, brick broken and vermicompost at the ratio of 6:3:1 (w/v). Two-week-old seedlings were transferred into the earthen pots. The experiment was conducted in a white net house under intensive care. The room was kept clean and tidy during the time of the experiment. Daily supervision was maintained to protect plants. The plants were cultivating and it continued until March 2020.

3.7. Growing media preparation for seedling raising

The mixture of coco peat, broken bricks (khoa) and vermicompost at the ratio of 60:30:10 (w/v). Coconut block was soaked in a big bowl for 24 hours. Then they are mixed with khoa and vermicompost properly. This mixer was placed in a styrofoam sheet box for using seedbed.

3.8. Seed sowing

The seeds were soaked in water for 24 hours and then wrapped with piece of thin cloth. The socked seed were then spread over polythene sheet for 2 hours to dry out the surface water. After that seeds were sown in styrofoam sheet box and covered with newspaper under room temperature for rising seedling.

3.9. Transplanting of cherry tomato seedling

15 days old cherry tomato seedlings were transferred to earthen pot contains the mixture of coco peat, khoa and ash. After four weeks these seedlings were transplanted to the main 12-inch earthen pot. The plants were transplanted carefully so that the roots were not damaged. After transplanting of tomato plant in the plastic pot light watering was done with sprayer so that the plant was got proper moisture.

3.10. Intercultural operations

3.10.1. Pruning

Four weeks after transplanting, the lower yellow leaves were removed, allowing plants to develop an adequate vegetative frame before fruit set.

3.10.2. Irrigation

Immediately after transplanting, light irrigation to the individual pot was provided to overcome water deficit. After establishment of seedlings, each pot was watered in alternate days to keep the soil moist for normal growth and development of the plants. During pre-flowering stage, irrigation was done sincerely.

3.10.3. Weeding

No weeding was done in the experiment.

3.10.4. Stalking

Firstly, a bamboo stick was used for support cherry tomato plant. Secondly, a small plastic pipe was cut roundly different pieces. Then it used as a hook in plant base and plastic rope used for support the plant.

3.10.5. Insect management

Cherry tomato plants were grown in controlled environment. So, no insecticides were applied in the experiment.

3.10.6. Diseases management

Cherry tomato plants were grown in controlled environment in hydroponic system and all nutrients required for plant were supplied artificially to the plants. The growing environment was clean and no disease attacked to the plant.

3.11. Harvesting

The crop was harvested after 120 and 150 DAT. Harvesting of the crop was done according to treatment.

3.12. Data collection

3.12.1. Plant height (cm)

Plant height was measured in centimeter (cm) by a meter scale at 20, 40 and 60 DAT (days after transplanting) from the point of attachment of growing media up to the top of the trunk.

3.12.2. Number of branches per plant

Total number of branches per plant was counted from the plant of each of unit pot. Data recorded at 20 days interval started from the 20 days of planting up to 60 days.

3.12.3. Number of leaves per plant

Total number of leaves per plant was counted from the plant of each of unit pot. Data was recorded at 20 days interval started from the 20 days of planting up to 60 days.

3.12.4. Length of leaflet (cm)

The length of leaflet was measured with a scale from the neck of the leaf to the bottom of 10 selected leaves from each plant and their average was taken in cm.

3.12.5. Breadth of leaflet (cm)

The breadth of leaflet was measured with a scale from 10 selected leaves from each plant and their average was taken in cm.

3.12.6. Chlorophyll contents (SPAD value)

Leaf chlorophyll content as SPAD values were measured from the youngest fully expanded leaf in the third position from the tip by a portable chlorophyll meter (SPAD-502, Konica Minolta Sensing, Inc., Japan). The SPAD-502 chlorophyll meter can estimate total chlorophyll amounts in the leaves of a variety of species with a high degree of accuracy and is a nondestructive method. Data was recorded at 25 days interval started from the 25 days of planting upto 75 days.

3.12.7. Days to first flowering

The date of flower blooming was recorded from the number of days of 1st the date of flower blooming after transplanting.

3.12.8. Number of flower cluster per plant

Total number of flower cluster of individual plant was recorded.

3.12.9. Number of flowers per plant

Total number of flower cluster of individual plant was recorded.

3.12.10. Days of first fruit initiation

The date of fruiting was recorded from the number of days of 1st the date of fruiting after transplanting of cherry tomato.

3.12.11. Number of fruits per plant

Number of fruits per plant were counted at 75 (First harvesting), 120 (Second harvesting) and 180 (Third harvesting) DAT. All the fruits of each plant were counted separately. Only the smallest young fruits at the growing point of the plant were excluded from the counting and the average number was recorded.

3.12.12. Fruit length (cm)

The length of fruit was measured with a slide caliper from the neck of the fruit to the bottom of 5 individual fruits from individual plant three times and their average was taken and expressed in cm.

3.12.13. Fruit diameter (cm)

Diameter of fruit was measured at middle portion of 5 individual fruits from individual plant three times with a slide caliper. Their average was taken and expressed in cm.

3.12.14. Individual fruit weight (g)

The fresh weight of 5 individual fruits from individual plant was recorded by an electric balance three times and the mean value was calculated by the following formula:

$$\text{Individual fruit weight} = \frac{\text{Total weight of fruits per plants}}{\text{Total number of fruits per plant}}$$

3.12.15. Total soluble solids (% Brix)

Total soluble solid (TSS) content of pineapple pulp was estimated by using Abbe refractometer. A drop of pulp solution squinted from the fruit pulp was placed on the prism of refractometer. Percent TSS was obtained from direct reading of the instrument.

3.12.16. Yield per plant

Yield of cherry tomato per plant was recorded as the whole fruit per plant harvested in different times and was expressed in kilogram.

3.13. Statistical analysis

The data in respect of yield, quality and yield components were statistically analyzed to find out the significance of the experimental results. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by "F" test. The difference among the treatment means were evaluated by Least Significant Difference (LSD) test and interpretation of the results were determined by Duncan's Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Plant height

The variation in plant height at different days after transplanting (DAT) among the studied varieties was statistically significant (Figure 1). At 20 DAT, the maximum (52.92 cm) plant height was recorded from V_2 (Sweet Charlie F_1) and the minimum plant height (46.00 cm) was obtained from V_1 (Red Star F_1) which was statistically similar with V_3 (47.92 cm) treatment. On the other hand, at 40 DAT, the maximum plant height (143.67 cm) was recorded from V_2 which was followed by V_3 (143.36 cm), while the minimum plant height (107.96 cm) was obtained from control (V_1). Similarly, at 60 DAT, the maximum plant height (255.32 cm) was recorded from V_2 which was followed by V_3 (222.67 cm) treatment, while the minimum plant height (144.17 cm) was found from V_1 treatment. Variation of plant height might be due to the genetic variation among the varieties. Mazumder *et al.* (2021) and Rina (2015) reported in their studies that plant height varied significantly due to use of different groundnut varieties. Parvin (2012) also found same type of result in tomato. She found that BARI Tomato 15 gives the tallest plant at different days after transplanting.

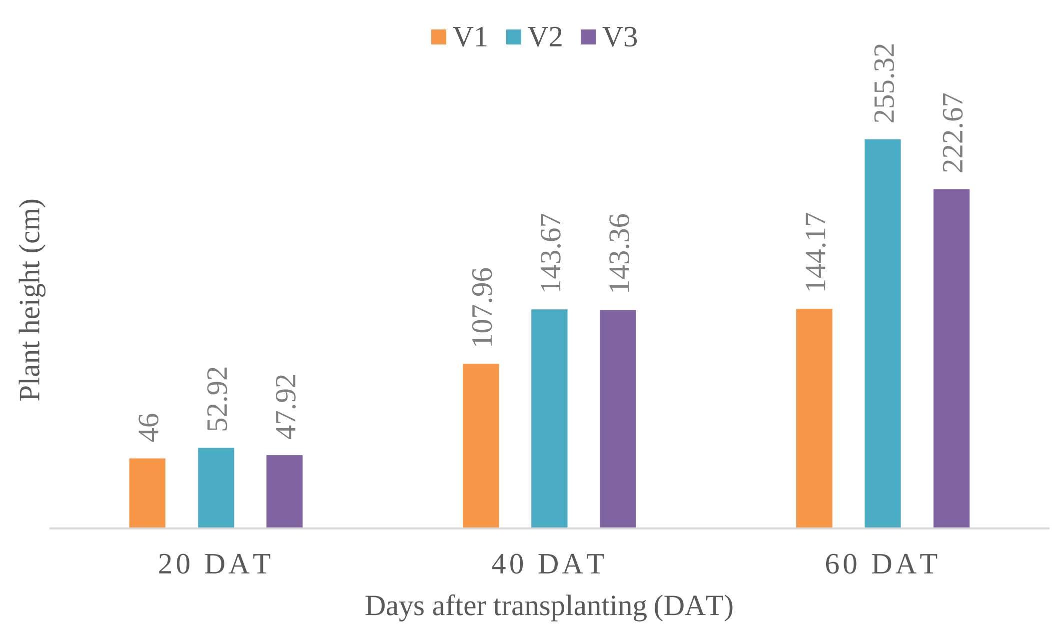


Figure 1. Effect of different varieties on plant height of cherry tomato at different days after transplanting (DAT)

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

There was significant variation among different doses of calcium in respect of plant height at different stages of growth (Appendix II and Figure 2). The maximum (57.44 cm) plant height was recorded from C_2 (40 ppm Ca) which was statistically similar with C_3 (53.89 cm) and the minimum plant height (38.00 cm) was found in control (0 ppm Ca) treatment at 20 DAT. On the other hand, at 40 DAT, the maximum plant height (147.37 cm) was recorded from C_2 which was statistically identical with C_3 (139.67 cm) treatment, while the minimum plant height (118.42 cm) was obtained from control (C_1) treatment. Similarly, at 60 DAT, the maximum plant height (233.92 cm) was recorded from C_2, while the minimum plant height (184.86 cm) was found from control treatment. It is clear that all calcium levels maintained a lead over control with regard to plant height. The result might be due to the fact that calcium enhances the vegetative growth of tomato plant (Parvin, 2012). She obtained the maximum plant height (33.71 cm, 53.77 cm and 75.33 cm) at (30, 45 and 60 DAT) from T_3 treatment (Ca @ 100.0

kg/ha). Sturiao *et al*. (2020) and Manivannan *et al.* (2007) also reported that calcium increased the plant height.

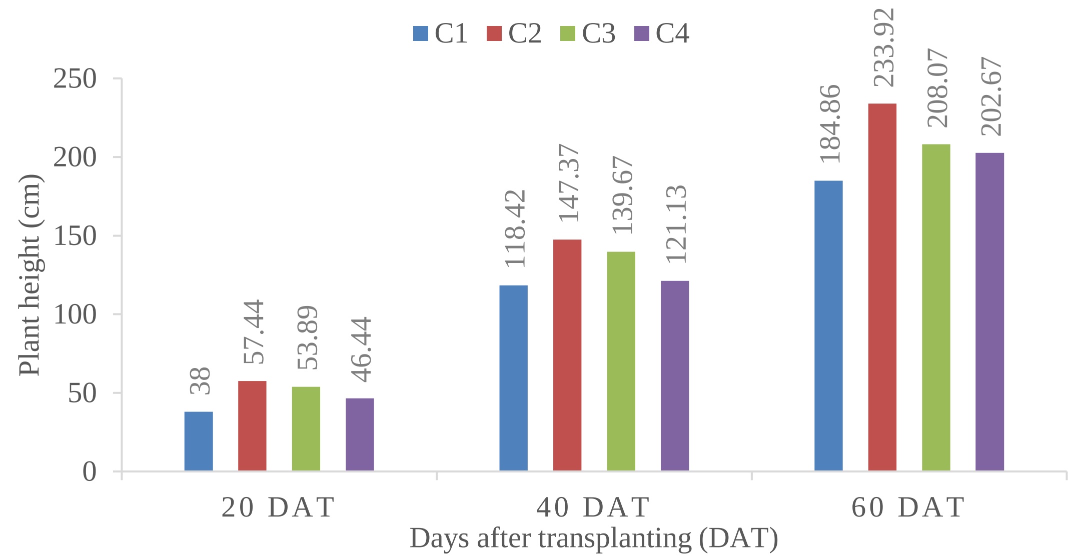


Figure 2. Effect of different levels of boron fertilizer on plant height of cherry tomato at different DAT

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Combination of variety and level of calcium showed significant variation for plant height throughout the growing season (Table 1 and Appendix II). At 20 DAT, the longest plant (58.33 cm) was recorded from the V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment and V_2C_3 (Sweet Charlie F_1 variety with 80 ppm Ca), while the shortest plant (27.33 cm) from V_1C_1 (Red Star F_1 variety with 0 ppm Ca). Similarly, at 40 DAT, the longest plant height (154.32 cm) was recorded from the V_2C_2 treatment combination which was statistically similar with the V_2C_3 (152.36 cm), V_3C_2 (151.76 cm), V_3C_3 (151.36 cm), V_1C_2 (144.32 cm) and V_2C_4 (143.75) treatment while, the shortest plant height (88.67 cm) was recorded from V_1C_1 treatment combination. At 60 DAT, the tallest plant (273.33 cm) was recorded from V_2C_2 treatment combination and the shortest plant (113.06 cm) was obtained from V_1C_1 treatment combination.

Table 1: Combined effect of different varieties and calcium on plant height of cherry tomato at different days after transplanting (DAT)

Interactions	Plant height (cm) at different days after transplanting (DAT)		
	20 DAT	**40 DAT**	**60 DAT**
V_1C_1	27.33 f	88.67 d	113.06 f
V_1C_2	52.67 b	144.32 a	240.36 abc
V_1C_3	48.33 cd	139.00 ab	219.37 c
V_1C_4	46.67 d	123.06 cb	178.07 d
V_2C_1	45.00 d	112.06 c	147.76 de
V_2C_2	58.33 a	154.32 a	273.33 a
V_2C_3	58.33 a	152.36 a	257.02 ab
V_2C_4	51.67 bc	143.76 a	236.33 bc
V_3C_1	38.33 e	92.00 d	137.72 ef
V_3C_2	57.33 a	151.76 a	254.33 ab
V_3C_3	55.67 ab	151.36 a	250.37 abc
V_3C_4	47.67 cd	127.07 bc	180.32 d
CV (%)	4.96	7.20	9.18
$LSD_{(0.05)}$	4.02	15.71	31.56

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.2 Branch number per plant

Statistically non-significant variation was recorded for branch number per plant due to use of different cherry tomato varieties at 20, 40 and 60 DAT (Appendix III and Figure 3). Numerically, at different days after transplanting (DAT) the maximum number of branches per plant (1.58, 3.33 and 4.58) was recorded from V_2 (Sweet Charlie F_1) at 20, 40 and 60 DAT, respectively. On the other hand, at the same DAT the minimum number of branches per plant (1.42, 3.00 and 4.17) was recorded from V_1 (Red Star F_1).

Mazumder *et al.* (2021) and Rina (2015) reported in their studies that number of branches varied significantly due to use of different groundnut varieties. Parvin (2012) also found same type of result in tomato. She found that BARI Tomato 15 gives the highest number of branches at different days after transplanting.

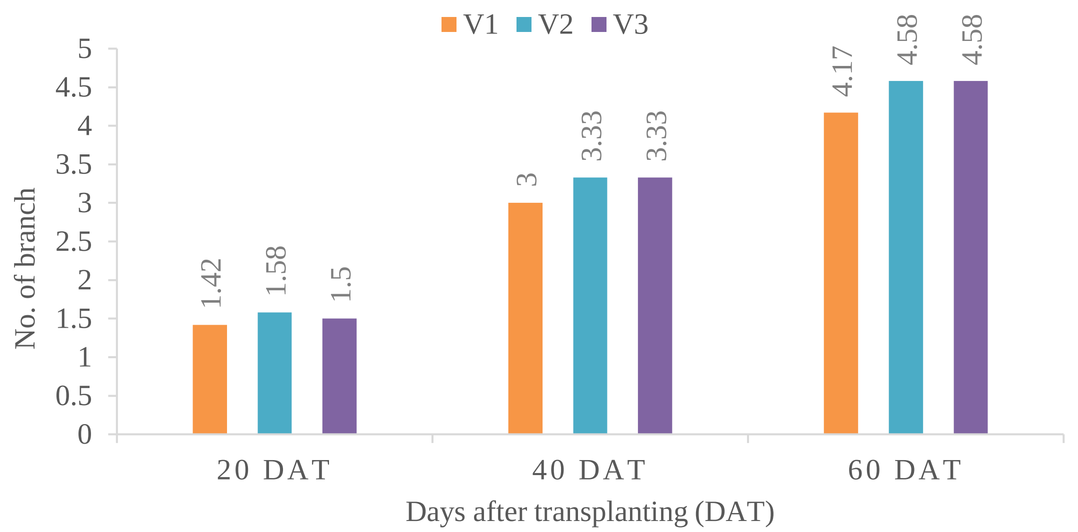


Figure 3. Effect of different mulches on branch number per plant of cherry tomato at different DAT

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Statistically non-significant variation was recorded for branch number per plant of cherry tomato due to application of different doses of calcium at 20 DAT, 40 DAT and 60 DAT (Appendix III and Figure 4). Numerically, at different days after transplanting (DAT) the maximum number of branches per plant (1.56, 3.44 and 4.78) was recorded from C_2 (40 ppm Ca) at 20, 40 and 60 DAT, respectively. On the other hand, at the same DAT the minimum number of branch per plant (1.44, 3.00 and 4.22) was recorded from control (C_1) condition. Sturiao *et al*. (2020) and Manivannan *et al.* (2007) also reported that calcium increased the number of branches.

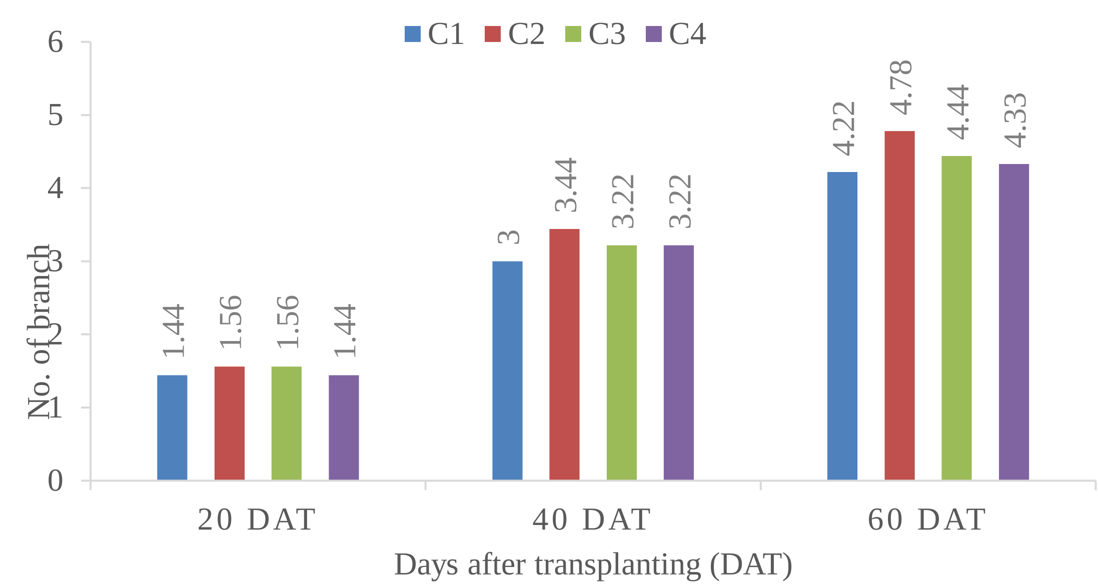


Figure 4. Effect of different level of calcium on branch number per plant of cherry tomato at different DAT

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Due to combined effect of variety and calcium also showed significant differences of the branch number per plant of cherry tomato at 40 and 60 DAT (Table 2 and appendix III). Numerically, at different days after transplanting (DAT) the maximum number of branches per plant (1.67, 3.67 and 5.67) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination at 20, 40 and 60 DAT, respectively. On the other hand, at the same DAT the minimum number of branches per plant (1.33, 2.33 and 3.33) was recorded from V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination, respectively.

Table 2: Interaction effect of different varieties and calcium on branch number per plant of cherry tomato at different days after transplanting

Interactions	Branch number per plant at different days after transplanting (DAT)		
	20 DAT	40 DAT	60 DAT
V_1C_1	1.33 a	2.33 b	3.33 d
V_1C_2	1.67 a	3.33 ab	4.33 bcd
V_1C_3	1.33 a	3.33 ab	4.33 bcd
V_1C_4	1.33 a	3.33 ab	4.33 bcd
V_2C_1	1.33 a	2.67 ab	3.67 cd
V_2C_2	1.67 a	3.67 a	5.67 a
V_2C_3	1.67 a	3.67 a	5.33 ab
V_2C_4	1.67 a	3.33 ab	4.33 bcd
V_3C_1	1.33 a	2.67 ab	3.67 cd
V_3C_2	1.67 a	3.67 a	5.33 ab
V_3C_3	1.67 a	3.33 ab	4.67 abc
V_3C_4	1.33 a	3.33 ab	4.33 bcd
CV (%)	38.49	17.92	12.99
LSD (0.05)	0.96	0.96	0.96

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.3 Number of leaves per plant

Different varieties had significant influences on number of leaves per plant (Table 3 and appendix IV). The maximum number of leaves (67.83) per plant was recorded from V_2 (Sweet Charlie F_1) treatment which was identical from all other varieties. On the other hand, the minimum number of leaves (46.67) per plant was recorded from V_1 (Red Star F_1) treatment. Similar trend of results was found by Parvin (2012). She found that BARI Tomato 15 gives the maximum number of leaves per plant at different days after transplanting. Mazumder *et al.* (2021) and Rina (2015) reported in their studies that number of leaves varied significantly due to use of different groundnut varieties.

Number of leaves per plant of cherry tomato varied significantly due to application of different level of calcium fertilizer (Table 4 and appendix IV). The maximum number of leaves (68.33) per plant was recorded from C_2 (40 ppm Ca) which was statistically similar with C_3 (53.89 cm), while the minimum number of leaves (49.89) per plant was recorded from control treatment which was statistically similar with C_4 (52.78) treatment. The results agreed with the findings of Azad *et al.* (2019) and Safarzadeh (2004) who stated that gypsum increased foliage yield by its application at rate of 150 kg ha^{-1}. This fact was supported by other authors like Tzortzakis (2010) in leafy vegetables and Lolaei *et al.* (2012) in tomato.

Combine effect of varieties and calcium showed statistically significant differences on number of leaves per plant (Table 5 and appendix IV). The maximum number of leaves per plant (82.00) of cherry tomato was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination while, the minimum number of leaves per plant (43.67) was recorded from V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination which was statistically similar with V_3C_1 (44.67) treatment combination.

4.4 Length of leaflet

Leaflet length of cherry tomato varied significantly due to use of different varieties (Table 3 and appendix IV). The longest leaflet length (32.58 cm) was recorded from V_2 (Sweet Charlie F_1) which was statistically similar with the V_3 (30.83 cm) treatment, while the shortest leaflet length (25.33 cm) was recorded from V_1 (Red Star F_1) treatment.

Leaflet length of cherry tomato varied significantly due to application of different doses of calcium fertilizer (Table 4 and appendix IV). The longest leaflet length (32.00 cm) was recorded from C_2 (40 ppm Ca) treatment which was statistically identical with C_3 (30.44 cm) treatment, while the shortest leaflet length (26.11 cm) was recorded from calcium-controlled condition.

Combine effect of varieties and calcium showed statistically significant differences on leaflet length of cherry tomato (Table 5 and appendix IV). The highest leaflet length (35.00 cm) of cherry tomato was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination while, the lowest leaflet length (21.00 cm) was recorded from V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination.

4.5 Breadth of leaflet

Different varieties had significant influences on breadth of the leaflet of cherry tomato (Table 3 and appendix IV). The longest leaflet breadth (21.42 cm) was recorded from V_2 (Sweet Charlie F_1) treatment, while the shortest leaflet breadth (16.25 cm) was recorded from V_1 (Red Star F_1) treatment which was statistically similar with V_3 (18.33 cm) treatment.

Leaflet breadth of cherry tomato varied significantly due to application of different doses of calcium fertilizer (Table 4 and appendix IV). The longest leaflet breadth (20.00 cm) was recorded from C_2 (40 ppm Ca) treatment, while the shortest leaflet breadth (17.00 cm) was recorded from calcium-controlled condition.

Combine effect of varieties and calcium showed statistically significant differences on leaflet breadth of cherry tomato (Table 5 and appendix IV). The highest leaflet breadth (23.33 cm) of cherry tomato was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination while, the lowest leaflet breadth (13.67 cm) was recorded from V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination which was statistically similar with V_3C_1 (14.00 cm) treatment combination.

Table 3: Leaves number/plant, length of leaflet and breadth of leaflet of three cherry tomato varieties

Varieties	Leaves/plant	Length of leaflet	Breadth of leaflet
V_1	46.67 c	25.33 b	16.25 b
V_2	67.83 a	32.58 a	21.42 a
V_3	60.92 b	30.83 a	18.33 b
CV (%)	6.87	6.04	9.19
LSD $_{(0.05)}$	6.66	2.96	2.84

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Table 4: Effect of different level of calcium on leaves number/plant, length of leaflet and breadth of leaflet of cherry tomato

Calcium	Leaves/plant	Length of leaflet	Breadth of leaflet
C_1	49.89 b	26.11 b	17.00 b
C_2	68.33 a	32.00 a	20.00 a
C_3	62.89 a	30.44 a	18.89 ab
C_4	52.78 b	29.78 a	18.78 ab
CV (%)	6.87	6.04	9.19
LSD $_{(0.05)}$	6.66	2.96	2.84

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Table 5: Interaction effect of different varieties and calcium on leaves number/plant, length of leaflet and breadth of leaflet of cherry tomato

Interactions	Leaves/plant	Length of leaflet	Breadth of leaflet
V_1C_1	43.67 f	21.00 g	13.67 e
V_1C_2	61.00 c	32.00 ab	19.33 bcd
V_1C_3	53.67 de	30.00 bcd	18.67 cd
V_1C_4	48.33 ef	27.33 def	18.00 cd
V_2C_1	47.33 ef	26.33 ef	17.33 d
V_2C_2	82.00 a	35.00 a	23.33 a
V_2C_3	73.00 b	33.33 ab	22.00 ab
V_2C_4	57.67 cd	31.00 bc	19.33 bcd
V_3C_1	44.67 f	25.33 f	14.00 e
V_3C_2	70.67 b	32.67 ab	21.00 abc
V_3C_3	69.67 b	32.33 ab	19.33 bcd
V_3C_4	50.00 ef	28.67 cde	18.00 cd
CV (%)	6.87	6.04	9.19
LSD (0.05)	6.66	2.96	2.84

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.6 Chlorophyll percentage

There was non-significant variation was observed in case of chlorophyll content (%) at different days after transplanting (DAT) due to use of different varieties of cherry tomato (Appendix V and Figure 5). Numerically, the maximum (66.78 %) chlorophyll content was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum chlorophyll content (53.38 %) was obtained from V_1 (Red Star F_1) at 25 DAT. Similarly, at 50 DAT, the maximum chlorophyll content (59.17 %) was recorded from V_2 treatment and the minimum chlorophyll content (55.98 %) was obtained from V_1 treatment. Similarly, at 75 DAT, the maximum chlorophyll content (75.71 %) was recorded from V_2 treatment while, the minimum chlorophyll content (69.12 %) was found from V_1.

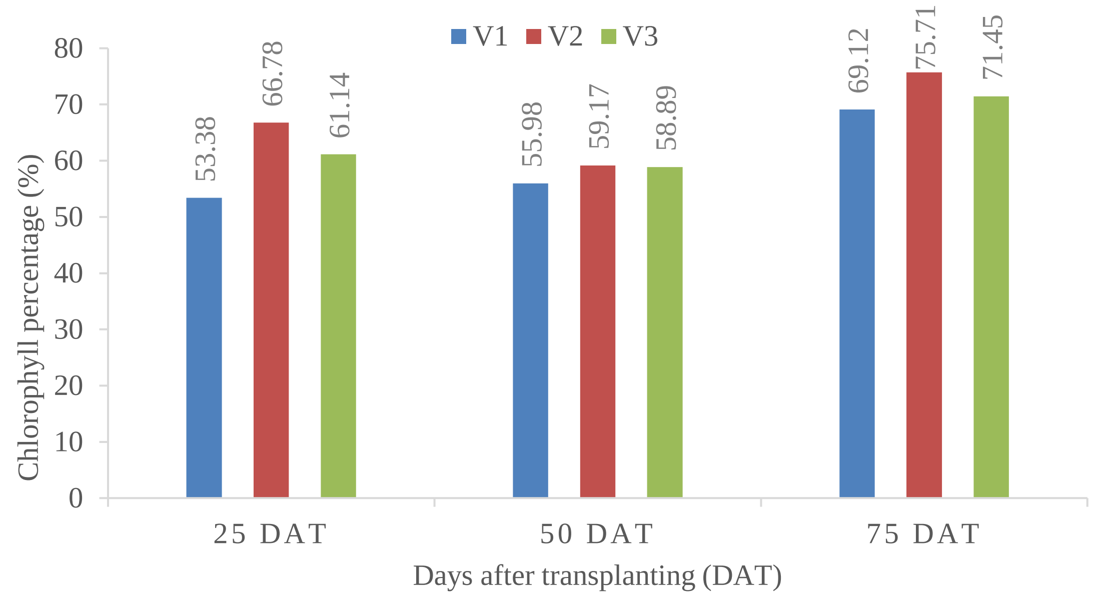


Figure 5. Effect of different varieties on chlorophyll content (%) at different DAT

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

There was significant variation among different doses of calcium in respect of chlorophyll content (%) at different stages of growth (Appendix V and Figure 6). The maximum (72.59 %) chlorophyll content was recorded from C_2 (40 ppm Ca) and the minimum amount of chlorophyll content (47.56 %) was found in control (C_1) condition at 25 DAT. On the other hand, at 50 DAT, the maximum chlorophyll content (65.99 %) was recorded from C_2, while the minimum chlorophyll content (52.23 %) was obtained from control (C_1). The maximum chlorophyll content (81.53 %) was recorded from C_2, while the minimum chlorophyll content (61.73 %) was found from control at 75 DAT. This study suggests that, exogenous Ca^{2+} supply improves the total chlorophyll content in plant which was strongly related to the fruits weight plant^{-1} as well as to yield of tomato.

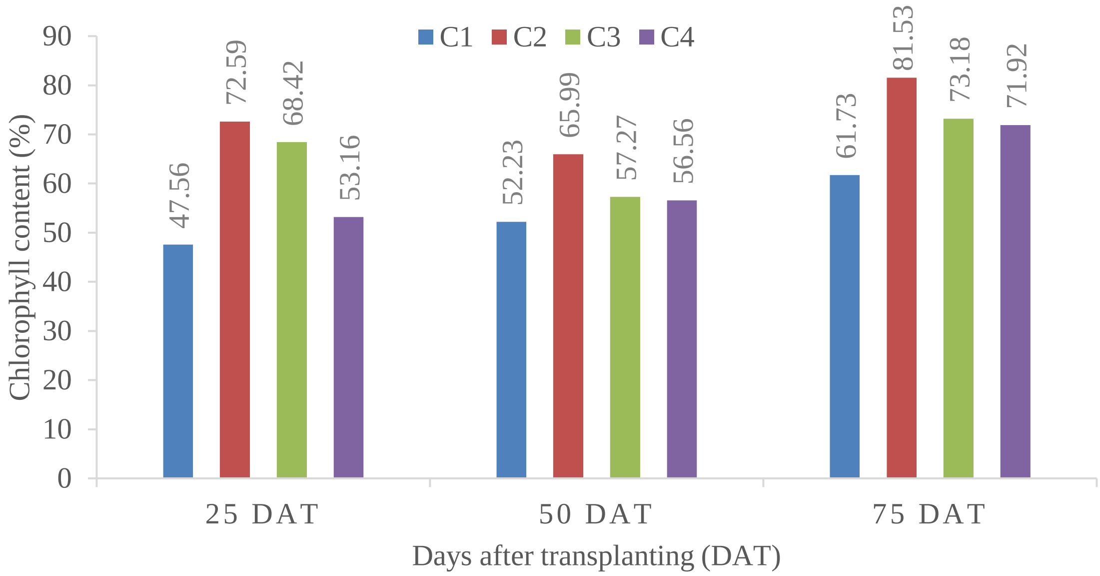


Figure 6. Effect of different level of boron on chlorophyll content (%) at different DAT

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Combine effect of varieties and calcium also showed significant differences of the chlorophyll content (%) of cherry tomato at 25, 50, 75 DAT and average (Table 6). At 25 DAT, the highest chlorophyll content (86.60 %) was recorded from the V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination while, the lowest chlorophyll content (43.80 %) from V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination. Similarly, at 50 DAT, the highest chlorophyll content (68.37 %) was recorded from the V_2C_2 treatment combination which was statistically similar with V_2C_3 (68.20 %) and V_3C_2 (67.67 %) treatment combination while, the lowest chlorophyll content (42.03 %) was recorded from V_1C_1 treatment combination. Similarly, at 75 DAT, the highest chlorophyll content (86.77%) was recorded from V_2C_2 treatment combination which was statistically similar with V_2C_3 (86.30 %) treatment combination and the lowest chlorophyll content (59.57 %) was obtained from V_1C_1 treatment combination which was statistically similar with V_3C_1 (60.73 %) and

V_2C_1 (62.47 %) treatment combination. In this study Sweet Charlie F_1 variety with 40 ppm Ca possibly maintained higher chlorophyll content (%).

Table 6: Interaction effect of different varieties and calcium on chlorophyll percentage of cherry tomato at different days after transplanting

Interactions	Chlorophyll percentage at different days after transplanting		
	25 DAT	50 DAT	75 DAT
V_1C_1	43.80 d	42.03 c	59.57 b
V_1C_2	65.10 bc	61.40 abc	76.90 ab
V_1C_3	49.53 cd	56.70 abc	70.73 ab
V_1C_4	48.77 cd	55.03 abc	64.90 ab
V_2C_1	45.77 d	54.33 abc	62.47 b
V_2C_2	86.60 a	68.37 a	86.77 a
V_2C_3	77.77 ab	68.20 a	86.30 a
V_2C_4	64.93 bc	58.63 abc	71.53 ab
V_3C_1	44.10 d	46.30 bc	60.73 b
V_3C_2	74.90 ab	67.67 a	78.63 ab
V_3C_3	74.87 ab	62.10 ab	78.43 ab
V_3C_4	49.03 cd	55.37 abc	68.13 ab
CV (%)	15.85	17.65	16.67
LSD $_{(0.05)}$	15.88	16.98	19.92

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.7. Days to first flowering from transplanting

Days from transplanting to 1st flowering of cherry tomato varied significantly due to use of different varieties under the present trial (Appendix VI and Figure 7). It varied from 39.67 to 27.67 days after transplanting. The minimum days from transplanting to 1st flowering (27.67 DAT) was found from V_2 (Sweet Charlie F_1) treatment and the maximum days (39.67 DAT) required to first flowering in V_1 (Red Star F_1) treatment, which was statistically similar with V_3 (36.08 DAT) treatment.

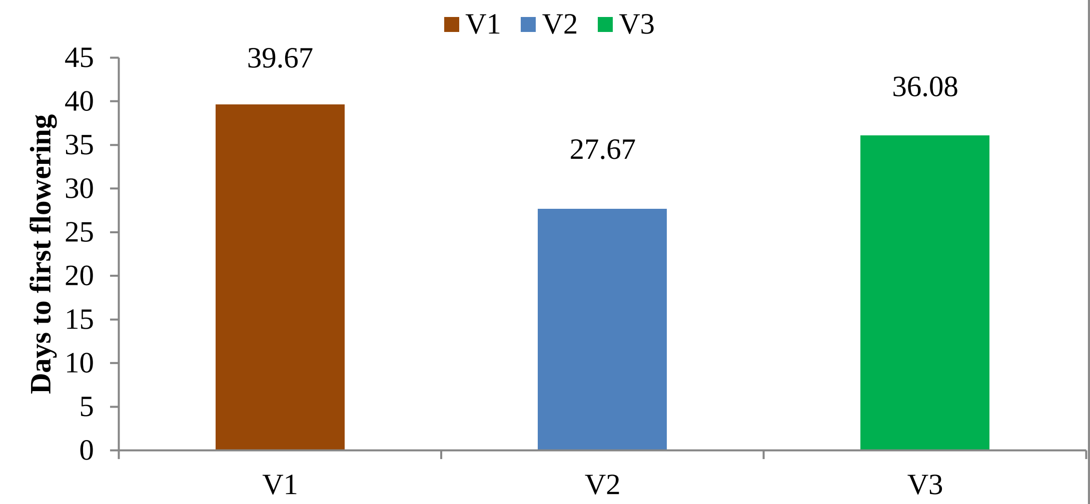


Figure 7. Days to first flowering of three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Significant differences were recorded due to different levels of calcium showed on days from transplanting to 1st flowering of cherry tomato (Appendix VI and Figure 8). It varied from 25.33 to 46.78 days after transplanting. The minimum days from transplanting to 1st flowering (25.33 DAT) was recorded from C_2 (40 ppm Ca) treatment which was statistically similar with C_3 (28.78 DAT) and followed by C_4 (37.00 DAT). On the other hand, the maximum days (46.78 DAT) required to first flowering in C_1 (0 ppm Ca). Similar findings also reported by Hao and Papadopoulos (2004) earlier from their experiment. Wu *et al.*, 2002 reported that calcium is associated with the middle lamella of cell walls playing a role in support and growth of cell that lead to produced earliest flowering.

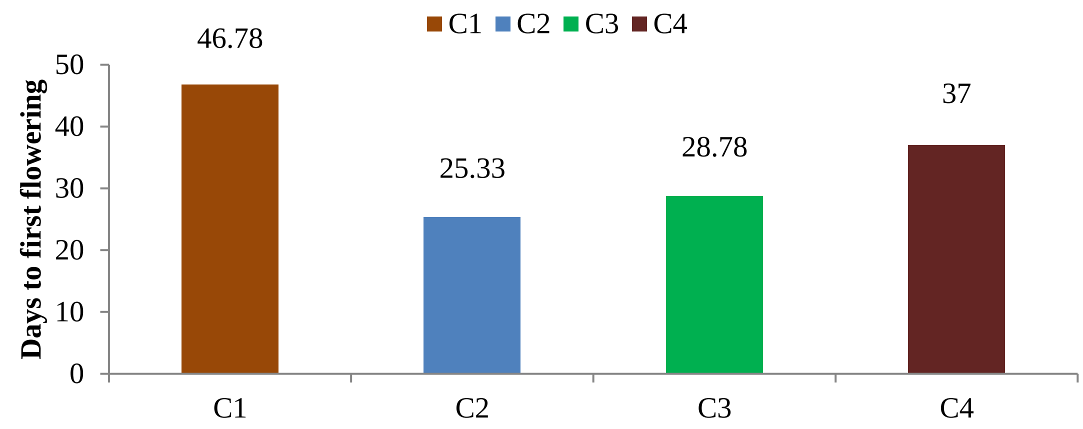


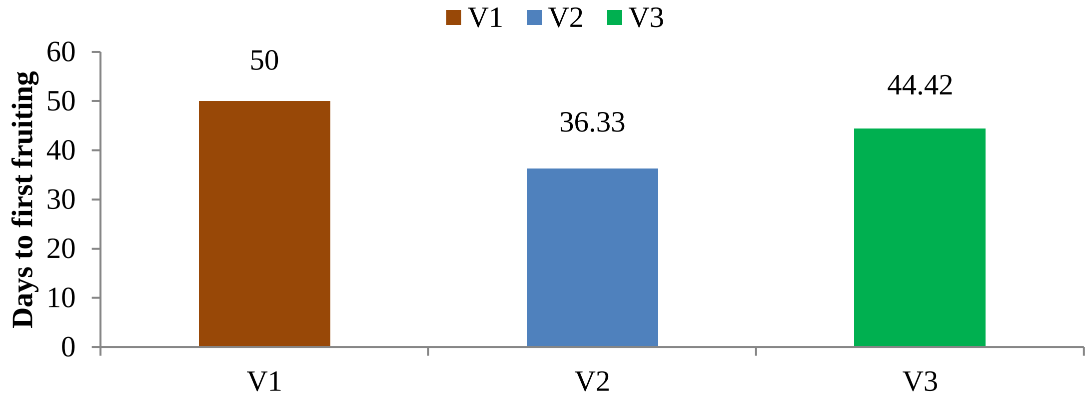
Figure 8. Effect of different calcium levels on days to first flowering in cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Statistically significant differences recorded on days to first flowering from transplanting due to the combined effect of varieties and different levels of calcium application (Table 7 and Appendix VI). The minimum days (24.00 DAT) required to first flowering in V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination which was statistically similar with V_1C_3, V_1C_4, V_2C_3, V_3C_2, and V_3C_4 treatment. On the other hand, the maximum days (54.00 DAT) required to first flowering in V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination which was statistically similar with V_2C_1 and V_3C_1 treatment combination.

4.8. Days to fist fruiting from transplanting

Days from transplanting to first fruiting of cherry tomato varied significantly due to use of different varieties under the present trial (Appendix VI and Figure 9). It varied from 36.33 to 50.00 days after transplanting. The minimum days (36.33 DAT) required to first fruiting in V_2 (Sweet Charlie F_1) treatment and the maximum days (50.00 DAT) required to first flowering in V_1 (Red Star F_1) treatment.



Fingure 9. Days to first fruiting in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Significant differences were recorded due to different levels of calcium showed on days from transplanting to 1st fruiting of cherry tomato (Appendix VI and Figure 10). It varied from 33.89 to 52.89 days after transplanting. The minimum days (33.89 DAT) required to first fruiting in C_2 (40 ppm Ca) treatment which was statistically similar with C_3 (40.22 DAT). On the other hand, the maximum days (52.89 DAT) required to first fruiting in C_1 (0 ppm Ca).

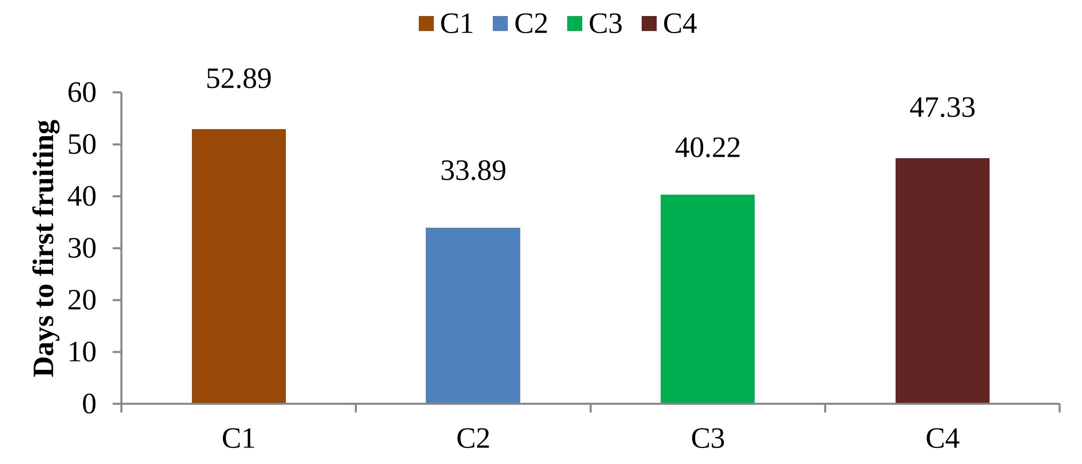


Figure 10. Effect of different levels of calcium on days to first fruiting in cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Statistically significant differences recorded on days to first fruiting from transplanting due to the combined effect of varieties and different levels of calcium application (Table 7 and Appendix VI). The minimum days (32.00 DAT) required to first flowering in V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination which was statistically similar with V_1C_2, V_2C_3, V_3C_2, and V_3C_4 treatment and the maximum days (64.67 DAT) required to first flowering in V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination.

Table 7: Combined effects of different varieties and calcium on days to first flowering and days to first fruiting from transplanting

Interactions	Days to first flowering	Days to first fruiting
V_1C_1	54.00 a	64.67 a
V_1C_2	34.00 b	33.33 d
V_1C_3	26.67 c	44.33 c
V_1C_4	24.67 c	44.33 c
V_2C_1	51.67 a	57.67 b
V_2C_2	24.00 c	32.00 d
V_2C_3	26.33 c	33.00 d
V_2C_4	33.00 b	44.33 c
V_3C_1	52.33 a	56.33 b
V_3C_2	25.67 c	32.67 d
V_3C_3	35.00 b	44.67 c
V_3C_4	26.33 c	35.67 d
CV (%)	8.22	6.26
LSD $_{(0.05)}$	4.70	4.52

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.9. Number of flower cluster per plant

A significant variation was recorded due to effect of different varieties on number of flower clusters per plant under the present investigation (Appendix VI and Figure 11). The maximum number of flower cluster per plant (30.83) was recorded in V_2 (Sweet Charlie F_1) treatment and the minimum number of flower cluster per plant (27.71) was recorded from V_1 (Red Star F_1) treatment. Parvin (2012) found BARI Tomato 15 variety gave the highest number of flower cluster per plant (10.61) which was similar to the present study.

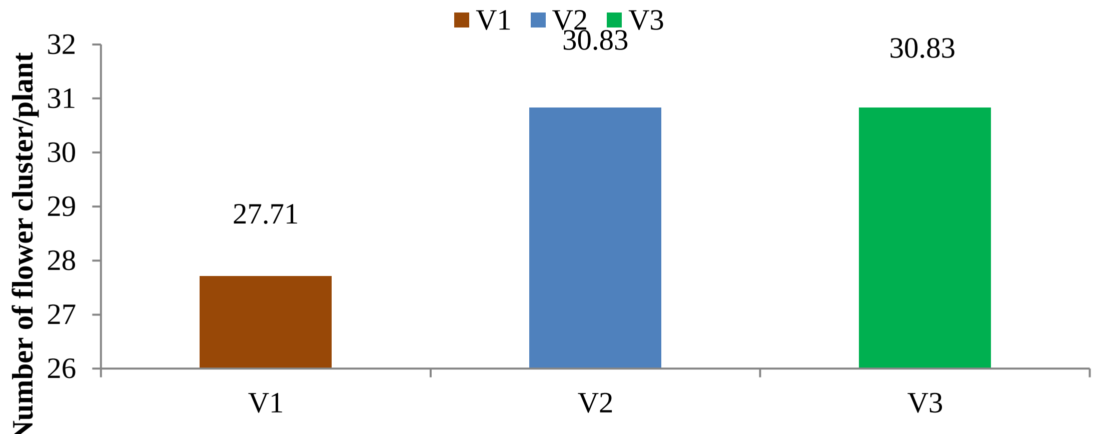


Figure 11. Number of flower cluster per plant in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Different levels of calcium showed significant differences on number of flower clusters per plant (Appendix VI and Figure 12). The Maximum number of flower clusters per plant (35.28) was found in C_2 (40 ppm Ca) which was statistically similar with C_3 (33.06) and the minimum (25.00) was found from the control C_1 (0 ppm Ca). The results clearly showed that the number of flower clusters per plant was gradually increased with increasing levels of calcium except the highest dose (120 ppm Ca). Nizam (2013) found 10 mM Ca^{2+} gave the highest number of flower cluster per plant (8.14) which was similar to the present study.

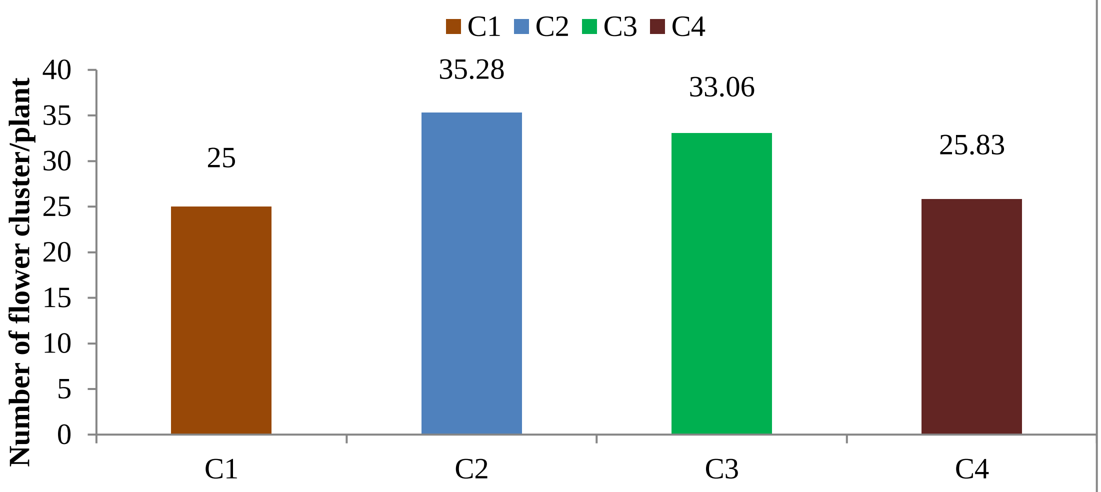


Figure 12. Effect of different levels of calcium on the number of flower cluster per plant

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

A significant variation was found due to combined effect of varieties and different level of calcium in terms of number of flower cluster per plant (Table 8 and Appendix VI). The maximum number of flower cluster per plant (36.67) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination, which was statistically identical (35.83) with V_2C_3 (Sweet Charlie F_1 variety with 80 ppm Ca). While V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination gave the minimum number of cluster (19.17) per plant.

4.10. Number of flowers per plant

Different varieties showed significant variation on number of flowers per plant under the present trial (Appendix VI and Figure 13). The maximum (359.56) number of flowers per plant was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum (292.07) was found from V_1 (Red Star F_1) treatment. Parvin (2012) found BARI Tomato 15 variety gave the highest number of flowers per plant (324.61) which was similar to the present study.

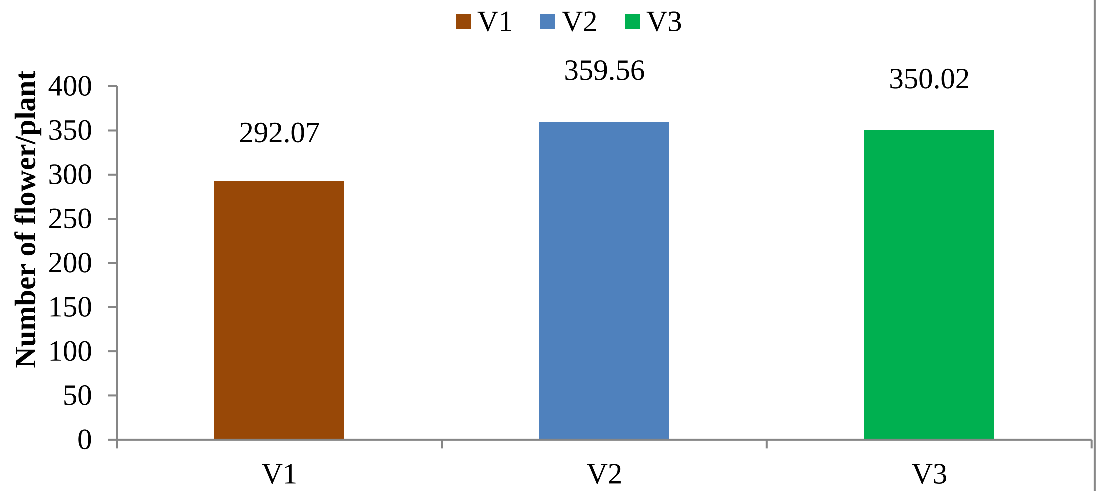


Figure 13. Number of flower per plant in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Statistically significant variation was recorded for different levels of calcium on number of flowers per plant of cherry tomato under the present trial (Appendix VI and Figure 14). The maximum (411.39) number of flowers per plant was recorded from C_2 (40 ppm Ca) which was statistically similar with C_3 (397.33) treatment and the minimum (249.36) was found from control condition i.e. no calcium which was statistically similar with C_4 (277.37) treatment. The results clearly showed that the number of flower per plant was gradually increased with increasing levels of calcium except the highest dose (120 ppm Ca). Nizam (2013) found 10 mM Ca^{2+} gave the highest number of flower per cluster (127.4) which was similar to the present study.

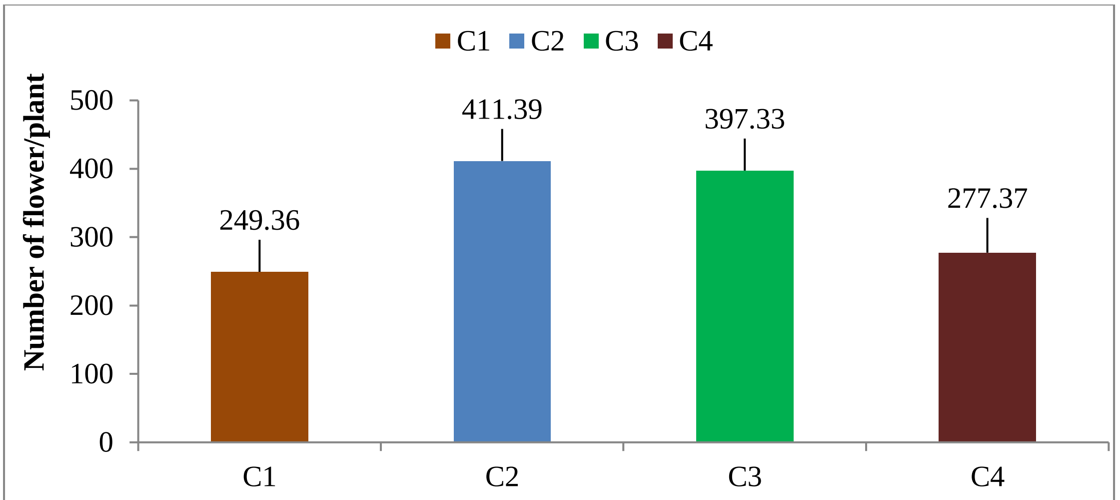


Figure 14. Effect of different levels of calcium on the number of flower per plant in cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

A significant variation was found due to combined effect of varieties and different level of calcium on number of flowers per plant under the present trial (Table 8 and Appendix VI). The maximum number of flowers per plant (423.00) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination, which was statistically identical with V_2C_3 (421.07), V_3C_2 (410.09) and $V_3C_{3,}$ (410.06). While V_1C_1 (Red Star F_1 variety with 0 ppm Ca) gave the minimum number of flower (179.03) per plant.

4.11. Number of fruits per plant

Different varieties showed significant variation on number of fruits per plant under the present investigation (Appendix VI and Figure 15). The maximum (284.56) number of fruits per plant was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum (183.53) was observed in V_1 (Red Star F_1) treatment. Parvin (2012) found BARI Tomato 15 variety gave the highest number of flower per plant (148.05) which was similar to the present study.

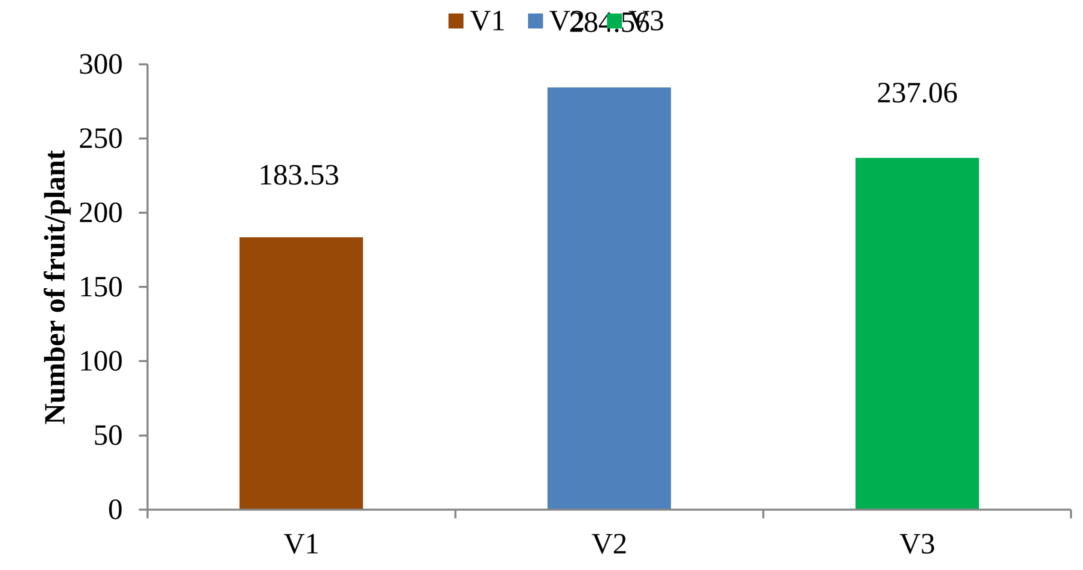


Figure 15. Number of fruit per plant in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Number of fruit per plant of cherry tomato showed statistically significant differences due to different level of calcium (Appendix VI and Figure 16). The highest number of fruits per plant (292.77) was obtained with the application of 40 ppm of Ca, which was statistically similar with 80 ppm of Ca application. The lowest number of fruits per plant (178.77) was found in control treatment which was statistically identical with C_4 (192.76) treatment. Further it was observed that number of fruits per plant was increased with increasing level of calcium but at a certain level of calcium application the fruit number per plant was decreased. Nizam (2013) found 10 mM Ca^{2+} gave the highest number of fruits per plant (41.4) which was similar to the present study.

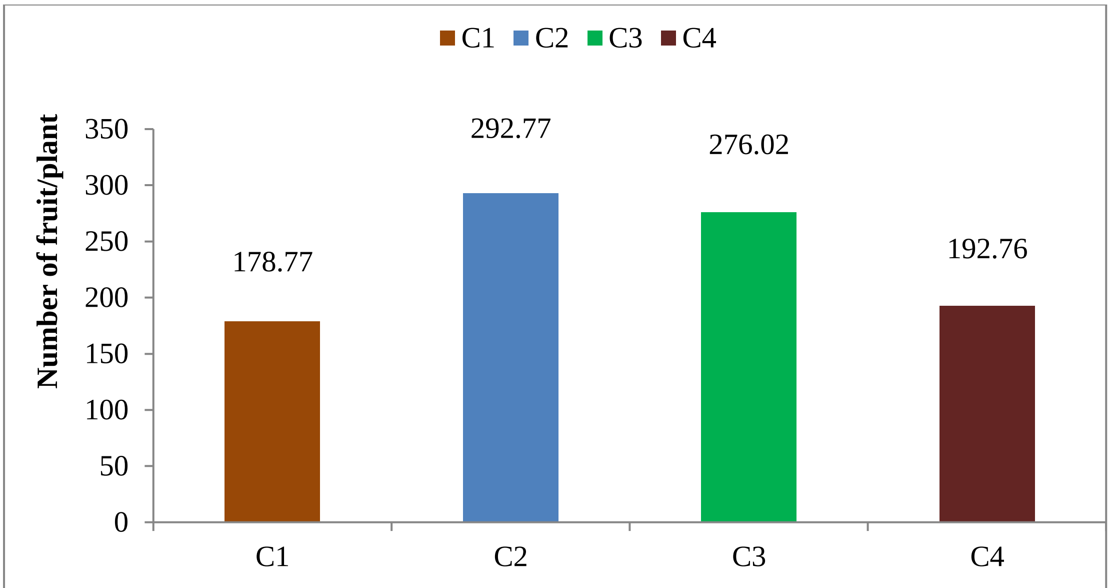


Figure 16. Effect of different level of calcium on the number of fruit per plant in cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

A significant variation was found due to combined effect of varieties and different level calcium on number of fruits per plant in cherry tomato (Table 8 and Appendix VI). The maximum number of fruits per plant (362.02) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination, while V_1C_1 (Red Star F_1 variety with 0 ppm Ca) gave the minimum number of fruit (100.02) per plant.

Table 8: Interaction effects of different varieties and calcium on number of flower cluster per plant, number of flower/plant and number of fruit/plant

Interactions	No. of Flower cluster per plant	No. of Flower/plant	No. of Fruit/plant
V_1C_1	19.17 d	179.03 e	100.02 e
V_1C_2	33.33 ab	401.06 ab	256.06 bc
V_1C_3	30.00 abc	345.00 abc	248.00 bc
V_1C_4	25.83 cd	297.02 cd	228.02 c
V_2C_1	25.00 cd	233.04 de	172.00 d
V_2C_2	36.67 a	423.00 a	362.02 a
V_2C_3	35.83 a	421.07 a	292.07 b
V_2C_4	30.83 abc	361.07 abc	250.02 bc
V_3C_1	24.17 cd	218.00 de	130.06 de
V_3C_2	35.00 ab	410.09 a	288.00 bc
V_3C_3	34.17 ab	410.06 a	260.01 bc
V_3C_4	27.50 bc	308.02 bcd	234.07 bc
CV (%)	13.63	15.91	14.08
LSD $_{(0.05)}$	6.73	88.02	54.85

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.12. Length of individual fruit (cm)

Different varieties showed significant variation on length of individual fruit under the present trial (Appendix VII and Figure 17). The maximum (2.34 cm) length of individual fruit was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum (2.26 cm) was obtained from V_1 (Red Star F_1) treatment.

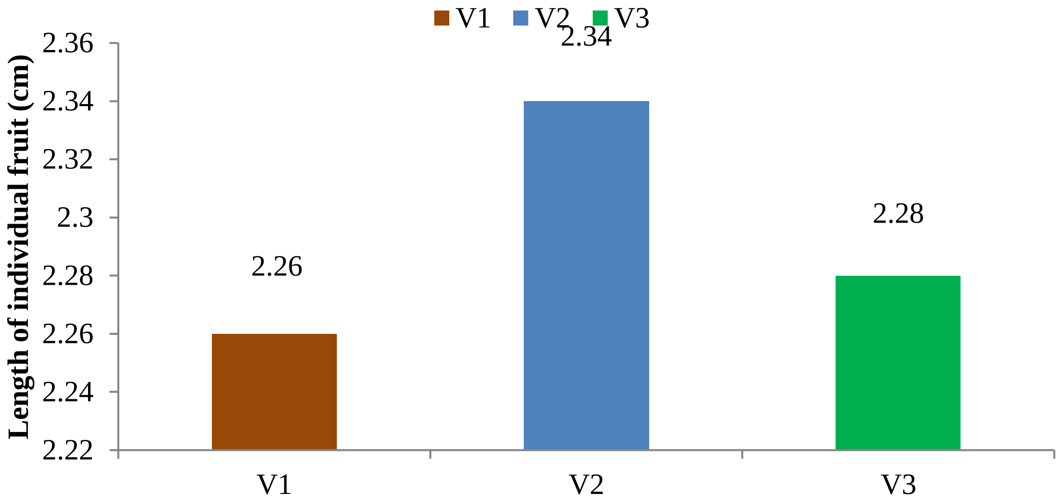


Figure 17. Length of individual fruit of three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

Calcium had significant effect on fruit length at harvest (Appendix VII and Figure 18). Fruit length varied from 2.50 cm to 2.04 cm. The longest fruit (2.50 cm) was produced from 40 ppm Ca which was statistically similar with C_3 (2.31 cm) and the shortest fruit (2.04 cm) was produced from C_1 (0 ppm Ca). This result showed that fruit length was increased gradually with the increasing levels of calcium expect the highest level (120 ppm Ca). Zahan (2018) found 50 ppm Ca gave the longest fruit (6.15 cm) in hot pepper which was similar to the present study.

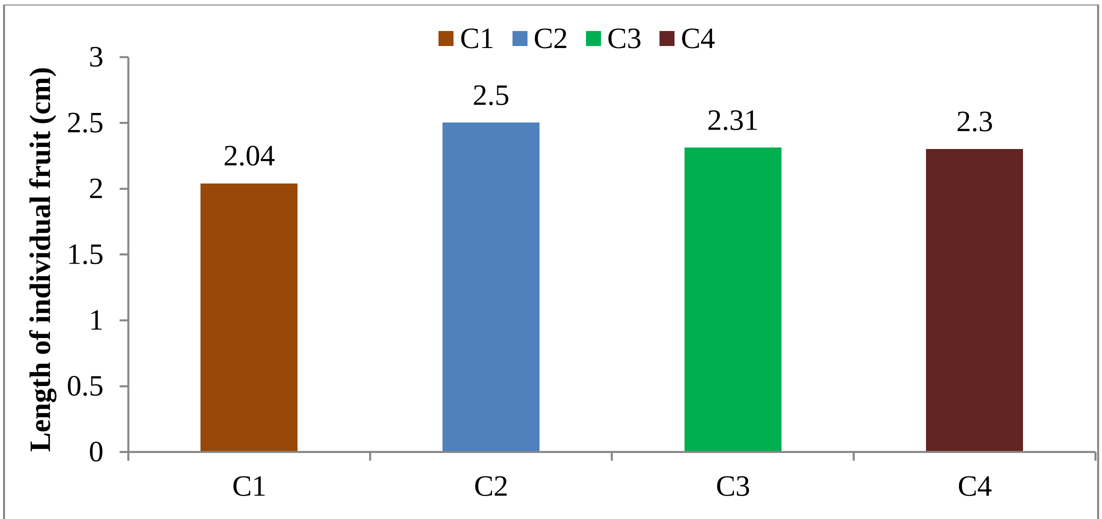


Figure 18. Effect of different level of calcium on the length of individula fruit

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

The variation was found due to interaction effect of varieties and calcium for length of individual fruit under the trial (Table 9 and Appendix VII). The maximum (2.57 cm) length of individual fruit was recorded from treatment combination V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca), while the V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination had minimum (1.37 cm) length of individual fruit.

4.13. Diameter of individual fruit (cm)

Different varieties showed significant variation on diameter of individual fruit under the present trial (Appendix VII and Figure 19). The maximum (2.10 cm) diameter of individual fruit was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum (1.91 cm) was obtained from V_1 (Red Star F_1) treatment.

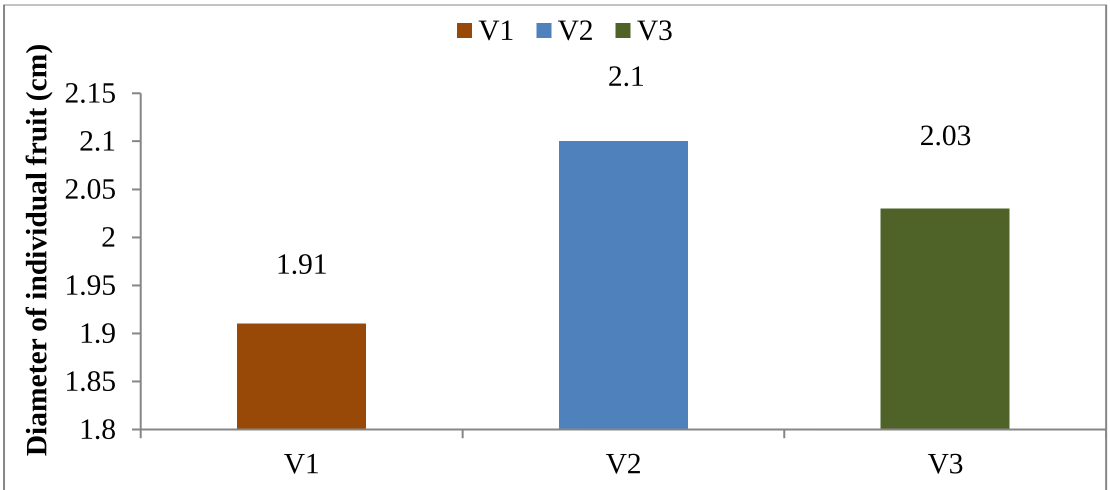


Figure 19. Diameter of individual fruit in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

The variation in diameter of fruit among the different doses of calcium was found to be statistically significant (Appendix VII and Figure 20). The maximum diameter of fruit (2.23 cm) was found from the plants grown with 40 ppm Ca which was statistically similar with C_3 (2.04) while the minimum (1.76 cm) was produced from control (0 ppm Ca). Zahan (2018) found 50 ppm Ca gave the highest diameter of fruit (0.55 cm) in hot pepper which was similar to the present study.

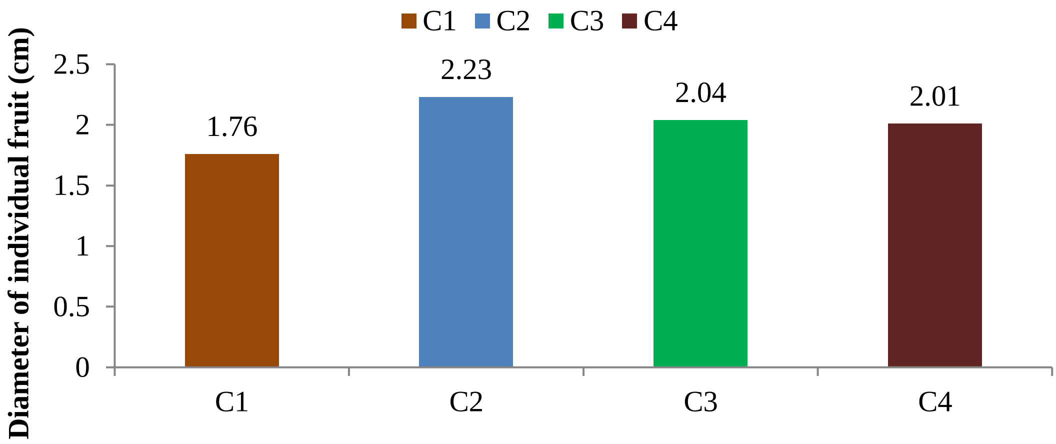


Figure 20. Effect of different doses of calcium on the diameter of individual fruit

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Interaction effect varied significantly due to different varieties and calcium for diameter of individual fruit of cherry tomato (Table 9 and Appendix VII). The maximum (2.33 cm) diameter of individual fruit was recorded from treatment combination of V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination, while the treatment combination V_1C_1 (Red Star F_1 variety with 0 ppm Ca) had minimum (1.73 cm) diameter of individual fruit which statistically similar with V_3C_1 (1.73 cm) and V_2C_1 (1.77 cm).

4.14. Weight of individual fruit (g)

A significant variation was recorded for varieties on weight of individual fruit of cherry tomato under the present trial (Appendix VII and Figure 21). The maximum weight (10.52 g) weight of individual fruit was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum (8.23 g) was recorded from V_1 (Red Star F_1) treatment

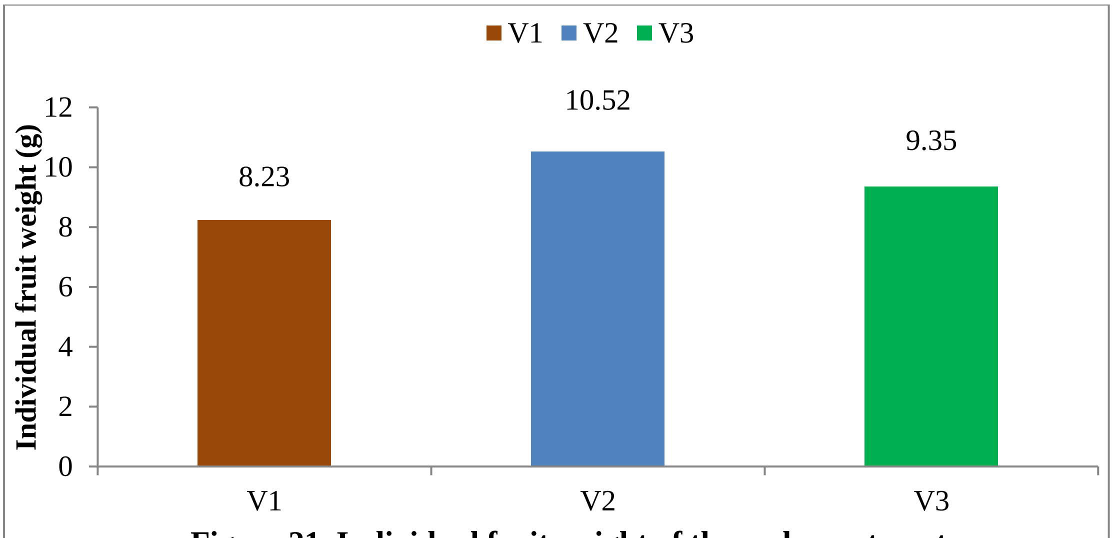


Figure 21. Individual fruit weight of three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

It was noticed that different levels of calcium exhibited significant effects on fresh weight of individual fruit (Appendix VII and Figure 22). The weight of individual fruit ranged from 6.56 g to 11.61 g. The maximum weight of individual fruit (11.61 g) was obtained from 40 ppm Ca while the control treatment gave the lowest value (6.56 g). Individual fruit weight was increased gradually with the increasing levels of calcium except the highest level (120 ppm Ca). Mazumder *et al.* (2021) found 1.5 w/v% of Ca gave the highest individual fruit weight of cherry tomato (28.30 g) which was similar to the present study.

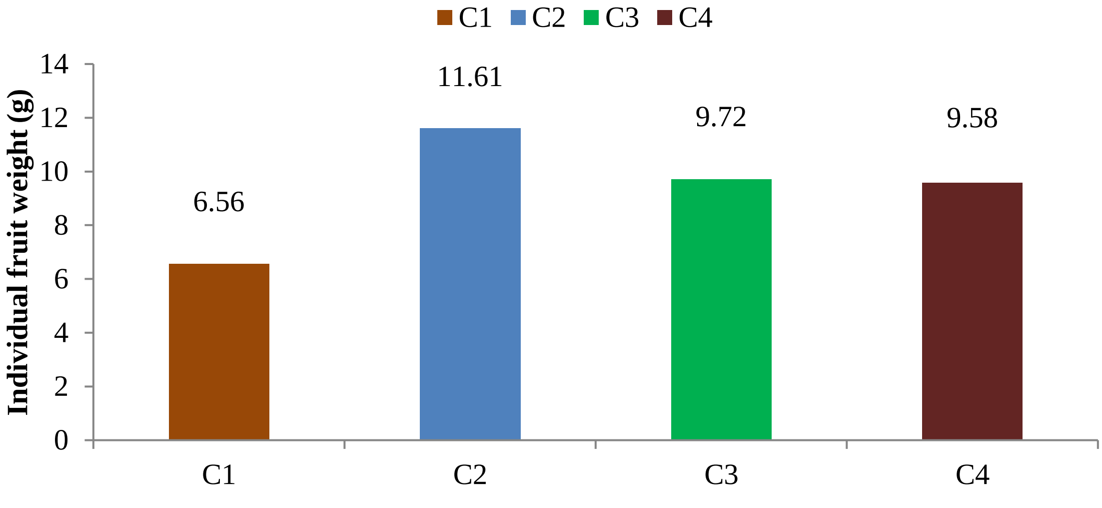


Figure 22. Effect of calcium on individual fruit weight of cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

The variation was found due to interaction effect of varieties and calcium for weight of individual fruit of cherry tomato under the trial (Table 9 and Appendix VII). The maximum (13.33 g) weight of individual fruit was recorded from treatment combination of V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca), while the treatment combination V_1C_1 (Red Star F_1 variety with 0 ppm Ca) had minimum (5.83 g) weight of individual fruit.

Table 9: Interaction effect of different varieties and calcium on yield attributing characteristics of cherry tomato

Interactions	Individual fruit length (cm)	Fruit diameter (cm)	Individual fruit weight (g)
V_1C_1	1.97 e	1.73 e	5.83 e
V_1C_2	2.40 abc	2.10 bc	10.42 b
V_1C_3	2.33 abcd	2.03 bc	9.58 bc
V_1C_4	2.13 cde	1.80 de	7.17 cde
V_2C_1	2.13 cde	1.77 e	7.08 cde
V_2C_2	2.57 a	2.33 a	13.33 a
V_2C_3	2.50 ab	2.23 ab	11.67 ab
V_2C_4	2.33 abcd	2.07 bc	10.00 b
V_3C_1	2.03 de	1.73 e	6.67 de
V_3C_2	2.43 abc	2.20 ab	10.83 ab
V_3C_3	2.43 abc	2.17 abc	10.67 b
V_3C_4	2.23 bcde	1.97 cd	9.17 bcd
CV (%)	7.05	5.74	15.73
LSD $_{(0.05)}$	0.09	0.19	0.85

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.15. Total soluble solids (degrees Brix) content

TSS is one of the most important quality factors for most of the fruits and for TSS, a TSS of 8.0 to 17.0% indicates the highest quality of fruits to attain the optimum harvesting stage (Morton, 1987). A significant variation was recorded for varieties on total soluble solids of cherry tomato under the present trial (Appendix VII and Figure 23). In the study, highest Total soluble solids (8.90 degrees Brix) was recorded from V_2 (Sweet Charlie F_1) treatment. Lowest TSS (7.14 degrees Brix) was recorded from V_1 (Red Star F_1) treatment.

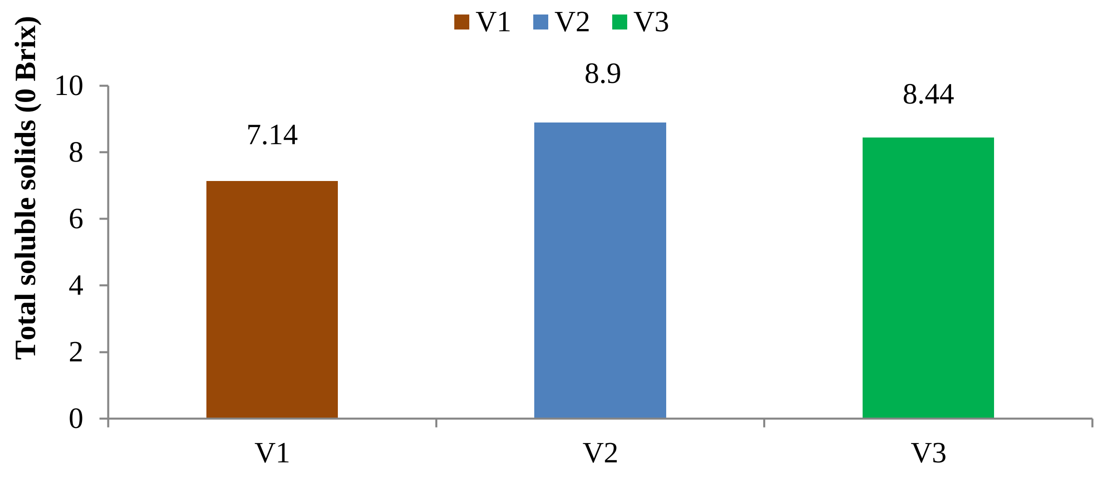


Figure 23. Total soluble solids content of three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

A significant variation was recorded for different doses of calcium on total soluble solids of cherry tomato under the present trial (Appendix VII and Figure 24). In the study, highest Total soluble solids (8.96 degrees Brix) was recorded in the fruits treated with 40 ppm Ca (C_2) which was statistically similar with C_3 (8.29 degrees Brix). Lowest TSS (7.32 degrees Brix) was recorded in control at harvest.

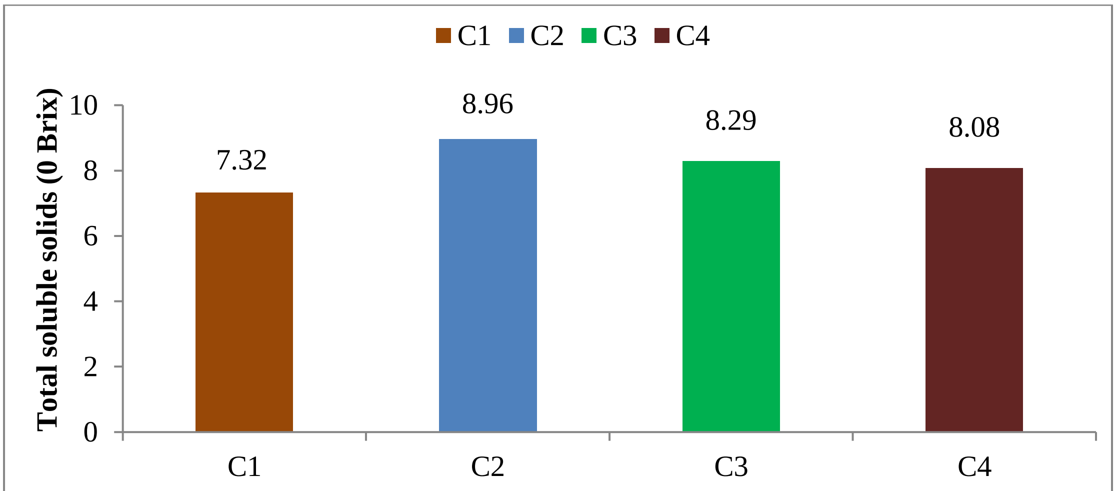


Figure 24. Effect of different doses of calcium on total soluble solids content of cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

The variation was found due to interaction effect of varieties and calcium for the total soluble solids (TSS) of cherry tomato under the trial (Figure 25 and Appendix VII). The maximum (9.47 degrees Brix) total soluble solid of individual fruit was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination which was statistically similar with V_2C_3 (9.40 degrees Brix) and V_3C_2 (9.27 degrees Brix), while the treatment combination V_1C_1 (Red Star F_1 variety with 0 ppm Ca) had minimum (6.30 degrees Brix) weight of individual fruit which was statistically similar with V_2C_1 (6.70 degrees Brix), V_3C_1 (6.53 degrees Brix) and V_1C_4 (7.03 degrees Brix).

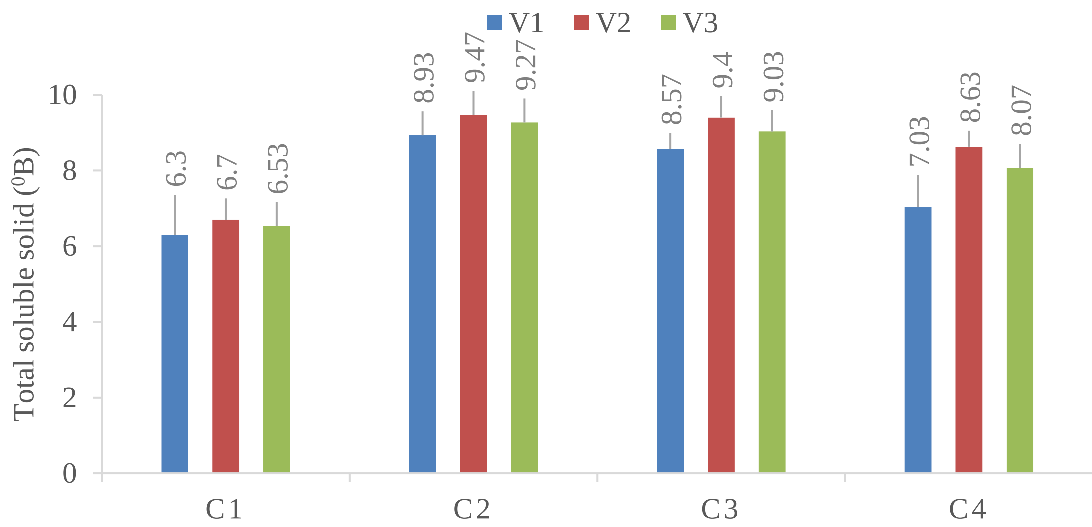


Figure 25. Combined effect of varieties and calcium on total soluble solides content of cherry tomato

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

4.16. Yield per plant (Kg)

Yield per plant varied significantly due to the use of different varieties of cherry tomato (Figure 26 and Appendix VII). The maximum yield per plant (2.94 kg) was recorded from V_2 (Sweet Charlie F_1) treatment and the minimum yield per plant (1.64 kg) was obtained from V_1 (Red Star F_1) treatment.

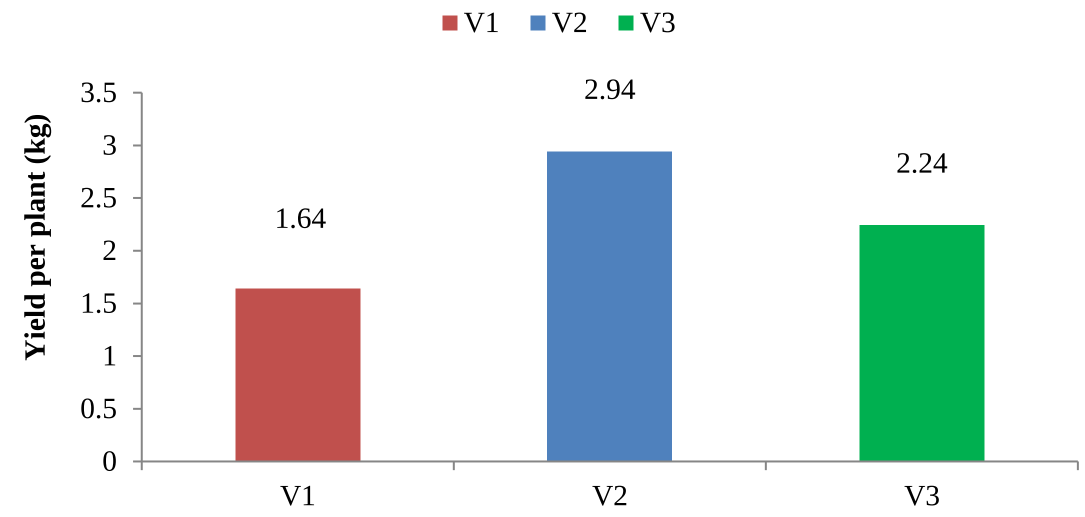


Figure 26. Yield per plant (kg) in three cherry tomato varieties

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg]

It was observed that different levels of calcium exhibited significant effect on the weight of fruits per plant (Figure 26 and Appendix VII). The weight of fruits per plant ranged from 3.32 kg to 1.30 kg. The plant fertilized with 40 ppm Ca produced the highest weight of fruits (3.32 kg) followed by 2.66 kg from 80 ppm Ca, respectively. The minimum weight of fruits per plant was obtained from the control (0 ppm Ca) which was statistically similar with C_4 (1.80 kg). The result clearly showed that weight of fruits per plant was increased with the increasing levels of calcium except the highest level (120 ppm Ca). Mazumder *et al.* (2021) found 1.0 w/v% of Ca gave the highest fruit weight per ha (21.73 t) which was similar to the present study. Nizam (2013) found 5 mM Ca^{2+} gave the highest fruit yield per plant which was decreased gradually by increasing Ca^{2+} doses (10 mM), which was similar to the present study.

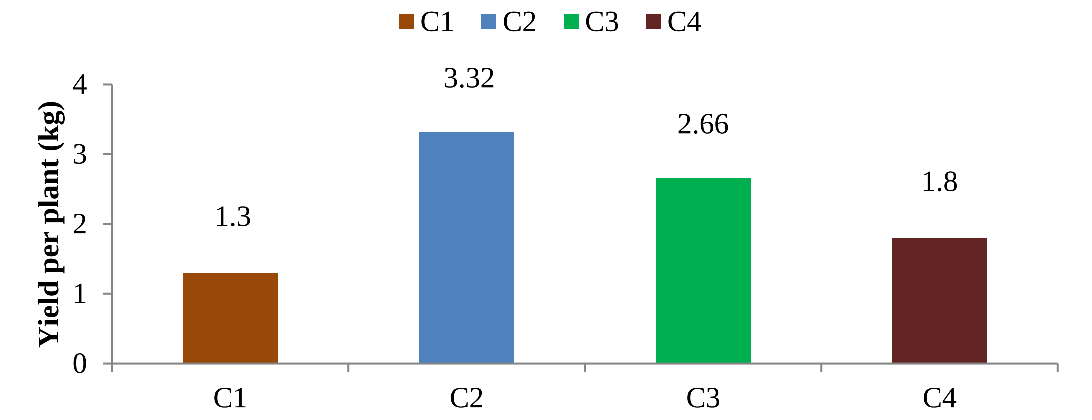


Figure 27. Effect of different level of calcium on yield per plant (kg) in cherry tomato

[C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

Combine effect of varieties and calcium had a significant variation in terms of yield of fruit (Figure 27 and Appendix VII). The maximum yield per plant (4.34 kg) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 40 ppm Ca) treatment combination, which was statistically identical (3.99 kg) with V_2C_3 (Sweet Charlie F_1 variety with 80 ppm Ca)., while the V_1C_1 (Red Star F_1 variety with 0 ppm Ca) treatment combination gave the minimum (0.59 kg) which was statistically similar with V_3C_1 (1.73 kg/ha).

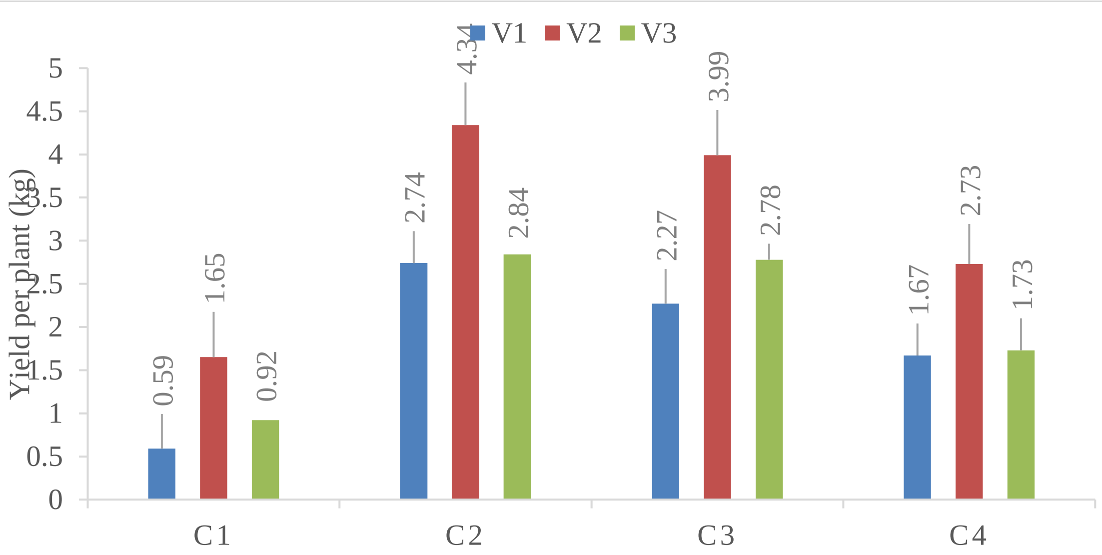


Figure 28. Combine effect of varieties and clacium on yield per plant in cherry tomato

[V_1= Red Star F_1; V_2= Sweet Charlie F_1; V_3= Thai Pink Egg; C_1= 0 ppm; C_2= 40 ppm; C_3= 80 ppm; C_4= 120 ppm]

CHAPTER V

SUMMARY AND CONCLUSION

Summary

Different growth and yield parameters of cherry tomato were significantly influenced by the using different varieties. At 20, 40 and 60 DAT the tallest plant (52.92 cm, 143.67 cm and 255.32 cm) was recorded from V_2 (Sweet Charlie F_1) and the shortest plant (46.00 cm, 107.96 cm and 144.17 cm) was found in V_1 (Red Star F_1). Similarly, at different days after transplanting (DAT) the maximum number of branch per plant (1.58, 3.33 and 4.58) was recorded from V_2 at 20, 40 and 60 DAT, respectively and the minimum number of branch per plant (1.42, 3.00 and 4.17) was recorded from V_1 treatment. The maximum and minimum number of leaves per plant (67.83 and 46.67), highest and lowest leaflet length (32.58 and 25.33 cm), highest and lowest leaflet breadth (21.42 cm and 16.25 cm) was recorded in V_2 and V_1 treatment, respectively. At 25, 50 and 75 DAT the maximum chlorophyll content (66.78 %, 59.17 % and 75.71 %) was recorded from V_2 (Sweet Charlie F_1) and the minimum chlorophyll content (47.56 %, 5223 % and 61.73%) was found in V_1 treatment. The minimum and maximum days required to first flowering (27.67 DAT and 39.67 DAT) and minimum and maximum days required to first fruiting (36.33 DAT and 50.00 DAT) was recorded in V_2 and V_1 treatment, respectively. The maximum and minimum number of flower cluster per plant (30.83 and 27.71); maximum and minimum number of fruit per plant (284.56 and 183.53); maximum and minimum weight of individual fruit (10.52 g and 8.23 g); highest and lowest amount of TSS (8.90 ^{0}B and 7.14 ^{0}B) and maximum and minimum yield of cherry tomato per plant (2.94 kg and 1.64 kg) was found in V_2 and V_1 treatment, respectively.

Different growth and yield parameters of cherry tomato were significantly influenced by the application of different doses of calcium fertilizer. At 20, 40 and 60 DAT e the tallest plant (57.44 cm, 147.37 cm and 233.92 cm) was recorded from C_2 (50 kg/ha Ca) and the shortest plant (38.00 cm, 118.42 cm and 184.86 cm) was found in C_1 (Calcium controlled condition). Numerically, at different days after transplanting (DAT) the maximum number of branch per plant (1.56, 3.44 and 4.78) was recorded from C_2 at 20, 40 and 60 DAT, respectively and the minimum number of branch per plant (1.44, 3.00 and 4.22) was recorded from control (C_1) condition. The maximum and minimum number of leaves per plant (67.83 and 46.67), highest and lowest leaflet length (32.58 cm and 25.33 cm), highest and lowest leaflet breadth (21.42 cm and 16.25 cm) was recorded in C_2 and C_1 treatment, respectively. At 25, 50 and 75 DAT the maximum chlorophyll content (72.59 %, 65.99 % and 81.53 %) was recorded from C_2 and the minimum chlorophyll content (47.56 %, 52.23 % and 61.73 %) was found in C_1. The minimum and maximum days required to first flowering (25.33 DAT and 46.78 DAT) and minimum and maximum days required to first fruiting (35.28 DAT and 25.00 DAT) was recorded in C_2 and C_1 treatment, respectively. The maximum and minimum number of flower cluster per plant (35.28 and 25.00); maximum and minimum number of fruit per plant (292.77 and 178.77); maximum and minimum weight of individual fruit (11.61 g and 6.56 g); highest and lowest amount of TSS (8.96 ^{0}B and 7.32 ^{0}B) and maximum and minimum yield of cherry tomato per plant (3.32 kg and 1.30 kg) was found in C_2 and C_1 treatment, respectively.

Different growth and yield parameters of cherry tomato were significantly influenced by combined effect of varieties and calcium fertilizer. At 20, 40 and 60 DAT the tallest plant (58.33 cm, 154.32 cm and 273.33 cm) was recorded from V_2C_2 (Sweet Charlie F_1 variety with 50 kg/ha Ca) treatment combination and the shortest plant (27.33 cm, 88.67

cm and 113.06 cm) was found in V_1C_1 (Red Star F_1 variety with Ca controlled condition) treatment. At different days after transplanting (DAT) the maximum number of branches per plant (1.67, 3.67 and 5.67) was recorded from V_2C_2 treatment combination at 20, 40 and 60 DAT, respectively and the minimum number of branch per plant (1.33, 2.33 and 3.33) was recorded from V_1C_1 treatment combination, respectively. The maximum and minimum number of leaves per plant (82.00 and 43.67), highest and lowest leaflet length (35.00 cm and 21.00 cm), highest and lowest leaflet breadth (23.33 cm and 13.67 cm) was recorded in V_2C_2 and V_1C_1 treatment combination, respectively. At 25, 50, 75 DAT the maximum chlorophyll content (86.60 %, 68.37 % and 86.77 %) was recorded from V_2C_2 treatment combination and the minimum chlorophyll content (43.80 %, 42.03 % and 59.57 %) was found in V_1C_1. The minimum and maximum days required to first flowering (24.00 DAT and 54.00 DAT) and minimum and maximum days required to first fruiting (32.00 DAT and 64.67 DAT) was recorded in V_2C_2 and V_1C_1 treatment, respectively. The maximum and minimum number of flower cluster per plant (36.67 and 19.17); maximum and minimum number of fruit per plant (362.02 and 100.02); maximum and minimum weight of individual fruit (13.33 g and 5.83 g); highest and lowest amount of TSS (9.47 ^{0}B and 6.30 ^{0}B) and maximum and minimum yield of cherry tomato per plant (4.34 kg and 0.59 kg) was found in V_2C_2 and V_1C_1 treatment, respectively.

Conclusion

Based on the experimental results, it may be concluded that-

i. Morphological characters, yield contributing characters and yield of cherry tomato varied significantly in different varieties. Among the varieties, Sweet Charlie F_1 seemed to be more promising for getting higher yield.

ii. Calcium fertilizer had a positive effect on morphological characters, yield contributing characters and yield of cherry tomato. Application of 40 ppm Ca seemed to be suitable for higher yield, and

iii. The combined effect of varieties and different doses of calcium application had a positive effect on morphological characters, yield contributing characters and yield of cherry tomato. Application of 40 ppm calcium in Sweet Charlie F_1 cherry tomato seemed to be more suitable for getting higher yield.

CHAPTER VI

REFERENCES

Abbasi, N.A., Zafar, L., Khan, H.A. and Qureshi, A.A. (2013). Effects of naphthalene acetic acid and calcium chloride application on nutrient uptake, growth, yield, and postharvest performance of tomato fruit. *Pak. J. Bot.*, **45:** 1581–1587.

Agusti, M., Juan, M., Martinez-Fuertes, A., Mesejo, C. and Almela, V. (2004). Calcium nitrate delays climacteric of persimmon fruit. *Ann. App. Bio.*, **144**: 65-69.

Ali, S., Riaz, K.A., Mairaj, G., Arif, M., Fida, M. and Bibi, S. (2014). Assessment of different crop nutrient management practices for yield improvement. *Aust. J. Crop Sci.*, **2**(3): 150- 157.

Anjum, S., Hamid, A., Ghafoor, A., Tahira, R., Shah, S.Z.A., Awan, S.I. and Ahmad, K.S. (2020). Evaluation of biochemical potential in tomato (*Solanum lycopersicum*) germplasms. *Pak. J. Agric. Sci.*, **57**: 177–187.

Anonymous. (2009). Botanical classification of cherry tomato.

Ayyub, C.M., Pervez, M.A., Shaheen, M.R., Ashraf, M.I., Haider, M.W., Hussain, S. and Mahmood, N. (2012). Assessment of various growth and yield attributes of tomato in response to pre-harvest applications of calcium chloride. *Pak. J. Life Soc. Sci*., **10**(2): 102-105.

Azad, A.K., Islam, M.S., Hossen, I. and Eaton, T.E. (2019). Yield and Fruit Quality of Tomato as Influenced by Calcium and Mulching in Rooftop Cultivation. *Agri. Sci.*, **10**(7): 123-125.

Bhattarai, D.R. and Gautam, D.M. (2006) Effect of harvesting method and calcium on postharvest physiology of tomato. *Nepal Agric. Res. J.*, **7**: 37–41.

Biswas, P., East, A.R., Hewett, E.W., and Heyes, J.A. (2016). Chilling injury in tomato fruit. *Hort. Reviews.*, **44**: 229-278.

Brady, N.C. and Weil, R.R. (2002). The Nature and Properties of Soils. 13^{th} Ed. Upper Saddle River, NJ: Prentice Hall.

Del-Amor, F.M. and Marcelis, L.F.M. (2006). Differential effect of transpiration and Ca supply on growth and Ca concentration of tomato plants. *Sci. Hort.,* **111**: 17-23. https://doi.org/10.1016/j.scienta.2006.07.032

Demidchik, V., Shabala, S., Isayenkov, S., Cuin, T.A., and Pottosin, I. (2018). Calcium transport across plant membranes: mechanisms and functions. *New Phytolo.,* **220**(1): 49-69.

DiMeglio, L.A., and Imel, E.A. (2019). Calcium and phosphate: hormonal regulation and metabolism. **In:** Basic and Applied Bone Biology. *Academic Press.,* pp.: 257-282.

Dorais, M., Papadopoulos, A.P. and Gosselin, A. (2001). Greenhouse tomato fruit quality. *Ann. Bot.,* **93:** 275-280.

Esfandiarpour-Borujeni, I., Javad Hosseinifard, S., Shirani, H., Zeinadini, M., and Asghar Besalatpour, A. (2018). Identifying Soil and Plant Nutrition Factors Affecting Yield in Irrigated Mature Pistachio Orchards. *Comm. Soil Sci. Plant Analysis.,* **49**(12): 1474-1490.

Fageria, N.K. (2005). Soil fertility and plant nutrition research under controlled conditions: Basic principles and methodology. *J. Plant Nutr.,* **28**: 1–25. https://doi.org/10.1080/01904160500311037

Fageria, N.K. (2007). Soil fertility and plant nutrition research under field conditions: Basic principles and methodology. *J. Plant Nutr.,* **30**: 203–223. https://doi.org/10.1080/01904160601117887

Fageria, N.K. and Baligar, V.C. (2005). Enhancing nitrogen use efficiency in crop plants. *Adv. Agron.,* **88**: 97–185. https://doi.org/10.1016/S0065-2113(05)88004-6

Fageria, N.K., Filho, M.P.B., Moreira, A. and Guimaraes, C.M. (2009). Foliar fertilization of crop plants. *J. Plant Nutr.,* **32**: 1044–1064. https://doi.org/10.1080/01904160902872826

Fedrizzi, L., Dimitry, L. and Ernesto, C. (2008). Calcium and signal transduction. *Bioc. Mole. Biol. Edu.,* **36**(3): 175–180.

Ganeshamurthy, A.N., Satisha, G.C. and Prakash, P. (2011). Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. *Karnataka J. Agric. Sci.,* **24**: 29-38.

Genanew, T. (2013). Effect of postharvest treatments on storage behavior and quality of tomato fruits. *World J. Agric. Sci.,* **9:** 29–37.

Girma, K., Martin, K.L., Freeman, K.W., Mosali, J., Teal, R.K., Raun, W.R. Moges, S. M. and Arnall, D.B. (2007). Determination of optimum rate and growth for foliar applied phosphorus in corn. *Comm. Soil Sci. Plant Anal.,* **38**: 1137–1154. https://doi.org/10.1080/00103620701328016

Gweyi, J.O. (2015). Advanced plant nutrition (KST 846), *Training notes,* pp.: 45-52.

Haleema, B., Rab, A. and Hussain, S.A. (2018). Effect of Calcium, Boron and Zinc Foliar Application on Growth and Fruit Production of Tomato. *Sarhad J. Agi.,* **34**(1): 19-30.

Halina, B., Michałojć Z. and Nurzyńska-Wierdak, R. (2016). Yield and fruit quality of sweet pepper depending on foliar application of calcium. *Turk. J. Agri. For.,* **40**: 222-228.

Hao, X.M. and Papadopoulos, A.P. (2003). Effects of calcium and magnesium on growth, fruit yield and quality in a fall greenhouse tomato crop grown on rockwool. *Canadian J. Plant Sci.,* **83**: 903-912.

Hao, X.M. and Papadopoulos, A.P. (2004). Effects of Calcium and Magnesium on Plant Growth, Biomass Partitioning, and Fruit Yield of Winter Greenhouse Tomato. *Hort. Sci.,* **39**(3): 512-515.

Havlin, J.L., Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (2016). Soil fertility and fertilizers. *Hort. Sci.,* **39**: 512-514.

Hemandez-Munoz, P., Almenar, E., Ocio, M.J. and Gavara, R. (2006). Effect of calcium dips and chitosan coating on postharvest life of strawberries (*Fragaria ananassa*). *Posthar. Biol. Tech.,* **39**: 247-253.

Hirshi, K.D. (2004). The calcium conundrum. Both versatile nutrient and specific signal. *Plant Physiol.,* **136**: 2438-2441.

Ho, L.C. and White, P.J. (2005). A cellular hypothesis for the induction of blossomend rot in tomato fruit. *Annals Bot*., **95**: 571–581.

Huang, J.S. and Snapp, S.S. (2004). The effect of boron, calcium, and surface moisture on shoulder check, a quality defect in fresh-market tomato. *J. Am. Soc. Hort. Sci.,* **129**: 599-607.

Ibrahim, M., Hassan, A., Iqbal, M. and Valeem, E.E. (2008). Response of wheat growth and yield to various levels of compost and organic manure. *Pak. J. Bot.,* **40**: 2135–2141.

Ilyas, M., Ayub, G., Hussain, Z., Ahmad, M., Bibi, B., Rashid, A. and Luqman. (2014). Response of tomato to different levels of calcium and magnesium concentration. *World Appl. Sci. J.,* **31**(9): 1560-1564.

Islam, M.Z., Mele, M.A., Back, J.P. and Kang, H. (2016). Cherry Tomato Qualities Affected by Foliar Spraying with Boron and Calcium. *Hortic. Environ. Biotechnol.,* **57**(1): 46-52.

Kabir, R., Yeasmin, S., Islam, A.K.M.M. and Sarkar, M.A.R. (2013). Effect of phosphorus, calcium and boron on the growth and yield of groundnut (*Arachis hypogea* L.). *Intl. J. Bio-Sci. Bio-Technol.,* **5**(3): 51-59.

Kadir, S.A. (2005). Influence of pre harvest calcium application on storage quality of Jonathan apple in Kansas. *Kansas Acad. Sci.,* **118**: 129-36.

Kerton, M., Newbury, H.J.H and Prichard, J. (2009). Accumulation of calcium in the centre of leaves of coriander (*Coriandrum sativum* L.) is due to uncoupling of water and ion transport. *J. Experi. Bot.,* **60**: 227–235.

Khavari-Nejad, R.A., Najafi, F. and Tofigi, C. (2009). Diverse responses of tomato to N and P deficiency. *Int. J. Agric. Biol.*, **11**: 209–213.

Kleemann, M. (2000a). Effects of salinity, nutrients, and spraying with $CaCl_2$ solution on the development of calcium deficiency in chervil (*Anthriscuscere folium* (L.) Hoffm.) and curled parsley (*Petroselinum crispum* (Mill.) Nym. Convar. Crispum). Integrated view of fruit and vegetable quality. International Multidisciplinary Conference. Lancaster, PA, USA, pp.: 41–53.

Lavanya, G. and Bahadur, V. (2021). Economics of effect of calcium and boron on growth, yield and quality of Cherry tomato under shade net condition. *Ind. J. Pure App. Biosci*., **9**(2): 232-239.

Lecourieux, D., Ranjeva, R. and Pugin, A. (2006). Calcium in plant defence signalling pathways. *New Phyto.*, **171**: 249-269.

Lee, G.J. and Kim, T.J. (2010). Effects of the use of additional calcium sources on growth and fruit character istics in tomato hydroponies. *Hort. Environ. Biotech.*, **51**: 360-366.

Liebisch, F., Max, J.F.J., Heine, G. and Horst, W.J. (2009). Blossom-end root and fruit cracking of tomato grown in net-covered greenhouses in central Thailand can partly be corrected by calcium and boron sprays. *J. Plant Nutr. Soil Sci.*, **172**: 140-150.

Lolaei, A., Rezaei, M.A., Raad, M.K. and Kaviani, B. (2012). Effect of Calcium Chloride on Growth and Yield of Tomato under Sodium Chloride Stress. *J. Orna. Hort. Plants.*, **2**(3): 155-160.

Manaf, H.H., Ashour, H.M. and El-Hamady, M.M. (2017). Impact of Calcium Chloride on Resistance Drought and Blossom-end Rot in Sweet Pepper Plants (*Capsicum annuum* L.). *Middle East J. App. Sci.*, **7**(2): 335-348.

Manivannan, P., Jaleel, C.A., Sankar, B., Somasundaram, R., Murali, P.V., Sridharan, R. and Panneerselvam, R. (2007). Salt stress mitigation by calcium chloride in *Vigna radiata* L. Wilczek. *Acta. Biol. Cracov.*, **49**: 105-109.

Martínez-Andújar, C., Albacete, A., Martínez-Pérez, A., Pérez-Pérez, J.M., Asins, M. J. and Pérez-Alfocea, F. (2016). Root-to-shoot hormonal communication in contrasting rootstocks suggests an important role for the ethylene precursor aminocyclopropane-1-carboxylic acid in mediating plant growth under low potassium nutrition in tomato. *Front. Plant Sci.,* **7**: 1782-1783.

Mazumder, M.N.N., Misran, A., Ding, P., Wahab, P.E.M. and Mohamad, A. (2021). Preharvest Foliar Spray of Calcium Chloride on Growth, Yield, Quality, and Shelf Life Extension of Different Lowland Tomato Varieties in Malaysia. *Hort.,* **7**: 466. https://doi.org/10.3390/horticulturae7110466.

Menzel, C.M. and Simpson, D.R. (1987). Lychee nutrition: *A review. Sci. Hort.,* **31**: 195-224. https://doi.org/10.1016/0304-4238(87)90046-X

Michailidis, M., Polychroniadou, C., Kosmidou, M.A., Petraki-Katsoulaki, D., Karagiannis, E., Molassiotis, A. and Tanou, G. (2021). An Early Calcium Loading during Cherry Tree Dormancy Improves Fruit Quality Features at Harvest. *Hort.,* **7**: 135-139.

Nizam, R. (2013). Mitigation of salt stress in tomato with calcium nitrate. M.S. Thesis. Dept. of Horticulture. SAU. Dhaka. pp.: 57-61.

Oshunsanya, S.O., Nwosu, N.J. and Li, Y. (2019). Abiotic Stress in Agricultural Crops Under Climatic Conditions. *Sustain. Agri. For. Environ. Manag.,* **121**: 71-100.

Parvin, S. (2012) Effect of calcium on growth and yield of tomato varieties and assessment of shelf life. M.S. Thesis. Dept. of Horticulture. SAU. Dhaka. pp.: 61-69.

Patterson, G. (2008). Calcium Nutrition in Plants article, Certified Crops Adviser, Ontario Crop Production.

Peter, K.H. (2005). Calcium: A central regulator of plant growth and development. *The Plant Cell,* **17**: 2142-2155. https://doi.org/10.1105/tpc.105.032508

Phillips, A.L., Barry, C. and Giovannoni, J. (2004). Signal transduction systems regulating fruit ripening. *Trends Plant Sci.,* **9**: 331–338. https://doi.org/10.1016/j.tplants.2004.05.004

Pinero, M.C., Perez-Jimenez, M., Lopez-Marin, J. and Del Amor, F.M. (2018). Fruit quality of sweet pepper as affected by foliar Ca applications to mitigate the supply of saline water under a climate change scenario. *J. Sci. Food Agric.,* **98**(3): 1071-1078. doi: 10.1002/jsfa.8557. Epub 2017 Aug 28.

Prema G., Indiresh, K.K. and Santosha, H.M. (2011). Evaluation of cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) genotypes for growth, yield and quality traits. *Asian J. Hort.,* **6**(1): 181-184.

Ranty, B., Aldon, D., Cotelle, V., Galaud, J.P., Thuleau, P., and Mazars, C. (2016). Calcium sensors as key hubs in plant responses to biotic and abiotic stresses. *Front. Plant Sci.,* **7**: 327-328.

Rina, T.A. (2015). Growth and yield of groundnut varieties as affected by different levels of calcium and application time. M.S. Thesis. Dept. of Agronomy. SAU. Dhaka. pp.: 47-52.

Rosales M.A., Cervilla, L., Sanchez-Rodriguez, E., Rubio-Wilhelmi, M. and Blasco, B. (2011). The effect of environmental conditions on nutritional quality under semi-arid Medierranean climte of two experimental Mediterranean greenhouse. *J. Sci. Food Agri*., **91**: 152-162.

Rubio, J.S., García-Sánchez, F., Flores, P., Navarro, J.M. and Martínez, V. (2010). Yield and fruit quality of sweet pepper in response to fertilization with Ca^{2+} and K^{+}. *Spanish J. Agric. Res.,* **8**(1): 170-177.

Safarzadeh Vishkaee, M.N. (2004). Effect of gypsum application time and rate on growth and yield of peanut in Guilan province. Rasht press, Iran. p.: 100.

Shoba, N., Natarajan, D., Veeraragavathatham and Amarnath, V. (2005). Effect of calcium, boron and ethrel on fruit cracking in tomato. *Res. Crops.,* **6**(2): 369-370.

Shukla, A.K., Behera, S.K., Pakhre, A., and Chaudhari, S.K. (2018). Micronutrients in soils, plants, animals and humans. *Indian J. Ferti.,* **14**(3): 30-54.

Silva, J.D. and Giordano, L.D.B. (2000). Tomate para processa mento industrial. Brasília: Embrapa Comunicaçãopara Transferência de Tecnologia–Embrapa Hortaliças, p.: 168.

Singh, R., Sharma, R.R. and Tyagi, S.K. (2007). Pre-harvest foliar application of calcium and boron influences physiological disorders fruit yield and quality of strawberry (*Fragaria x ananassa* Duch.). *Sci. Hortic.* **112**: 215-220.

Singh, H.M. and Tiwari, J.K. (2013). Impact of micronutrient spray on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill). *Hort. Flora. Res. Spectrum*., **2**(1): 87-89.

Sturiao, W.P., Martinez, H.E.P., Oliveira, L.A., Jezler, C.N., Pereira, L.J., Ventrella, M.C. and Milagres, C.C. (2020). Deficiency of calcium affects anatomical, biometry and nutritional status of cherry tomato. *South African J. Bot.,* **132**: 346-354.

Tonetto de Freitas, S., Padda, M., Qingyux, W., Sunghun, P. and Elizabeth, J.M. (2011). Dynamic Alternations in Cellular and Molecular Components during Blossom-End Rot Development in Tomatoes Expressing sCAX1, a Constitutively Active Ca^{2+}/H^{+} Antiporter from Arabidopsis. *Plant Physio.*, **156**: 844–855.

Tzortzakis, N.G. (2010). Potassium and calcium enrichment alleviate salinityinduced stress in hydroponically grown endives. *Hort. Sci.*, **37**: 155–162.

White, P.J. and Broadley, M.R. (2003). Calcium in plants. *Ann. Bot.,* **92**: 487-511.

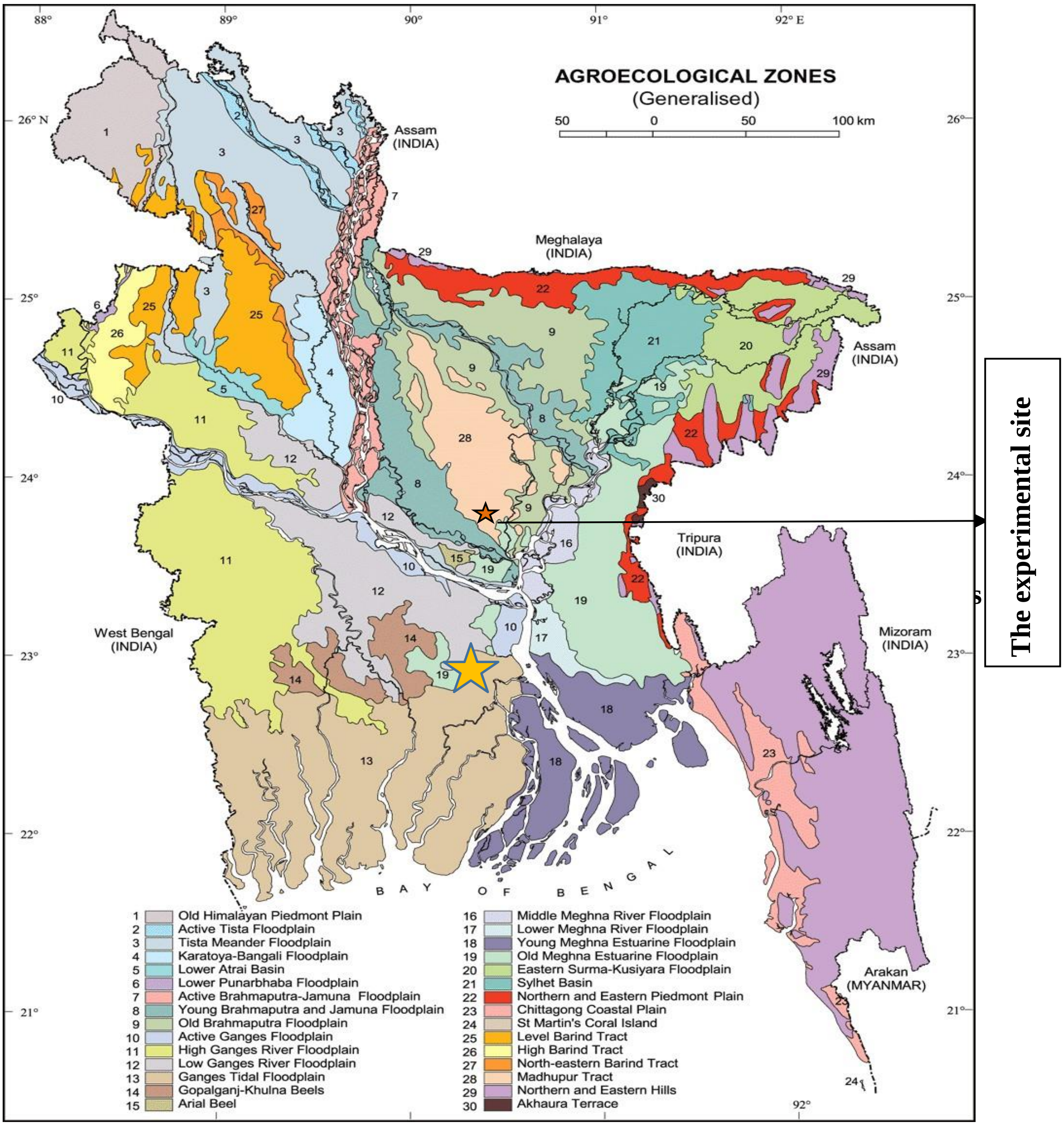
Wu Z., Liang F., Hong B., Young J.C., Sussman M.R., Harper J.F., Sze, H. (2002). An endoplasmic reticulumbond Ca^{2+}/Mn^{2+} pump, ECA1, supports plant growth and confers tolerance to Mn^{2+} stress. *Plant Physio.,* **130**: 128-137.

Zahan, M. (2018). Influence of calcium and NAA on the growth, yield and quality of hot pepper. M.S. Thesis. Dept. of Horticulture. SAU. Dhaka. pp.: 37-51.

CHAPTER VII

APPENDICES

Appendix I: Map showing the experimental site



Appendix-II. Analysis of variance of data on plant height of cherry tomato at different days after transplanting

Source of variation	Degrees of freedom (df)	Mean Square of plant height (cm)		
		20 DAT	40 DAT	60 DAT
Factor A	2	153.028	5053.028	39174.778
Factor B	3	668.185	1781.741	3711.657
AB	6	72.657	420.769	1014.185
Error	24	5.889	89.778	362.417

Appendix-III. Analysis of variance of data on branch per plant of cherry tomato at different days after transplanting

Source of variation	Degrees of freedom (df)	Mean Square of branch per plant		
		20 DAT	40 DAT	60 DAT
Factor A	2	0.083	0.444	0.694
Factor B	3	0.037	0.296	0.519
AB	6	0.12	0.741	2.324
Error	24	0.333	0.333	0.333

Appendix-IV. Analysis of variance of data on Leaves/Plant, Length of Leaflet and Breadth of Leaflet of cherry tomato

Source of variation	Degrees of freedom (df)	Mean Square		
		Leaves/Plant	Length of Leaflet	Breadth of Leaflet
Factor A	2	1397.861	171.75	81.083
Factor B	3	668.546	56.028	13.852
AB	6	88.38	3.083	10.602
Error	24	16.139	3.194	2.944

Appendix-V. Analysis of variance of data on chlorophyll percentage of cherry tomato at different days after transplanting

Source of variation	Degrees of freedom (df)	Mean Square of chlorophyll percentage (%)		
		25 DAT	50 DAT	75 DAT
Factor A	2	543.231	37.539	134.056
Factor B	3	1291.149	299.101	592.945
AB	6	467.453	216.145	144.56
Error	24	91.764	104.89	144.407

Appendix-VI. Analysis of variance of data on days of first flowering, days of first fruiting, flower cluster per plant, flower/plant and fruit/plant of cherry tomato

Source of variation	Degrees of freedom (df)	Mean Square				
		Days of first flowering	Days of first fruiting	Flower cluster per plant	Flower/plant	Fruit/plant
Factor A	2	455.361	566.583	39.063	16021.00	30639.00
Factor B	3	821.287	617.806	238.137	61113.00	29916.00
AB	6	175.287	172.917	33.97	5157.00	3287.00
Error	24	8.028	7.444	16.493	2820.00	1095.00

Appendix-VII. Analysis of variance of data on yield attributing characteristics of cherry tomato

Source of variation	Degrees of freedom (df)	Mean Square				
		Fruit length (cm)	Fruit diameter (cm)	Fruit weight (gm)	BRIX (%)	Yield/plant (kg)
Factor A	2	0.023	0.112	15.757	9.984	5.048
Factor B	3	0.317	0.347	39.34	4.074	7.244
AB	6	0.034	0.032	3.22	2.503	0.445
Error	24	0.026	0.013	2.17	0.325	0.122

Plate


Plate 1. Growing media and growing plant after transplanting

Plate 2. Immature and mature fruit cluster

Plate 3. Data collection

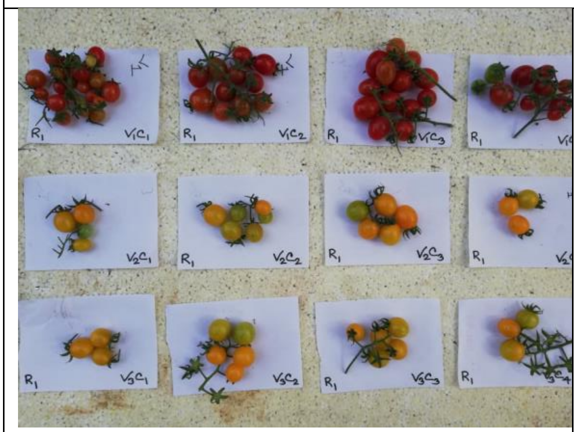


Plate 4. Ist harvested cluster of cherry tomato