INFLUENCE OF CALCIUM ON SWEET PEPPER TO REDUCE BLOSSOM END ROT

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CERTIFICATE

This is to certify that the thesis entitled, "INFLUENCE OF CALCIUM ON SWEET PEPPER TO REDUCE BLOSSOM END ROT" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in HORTICULTURE, embodies the result of a piece of bona fide research work carried out by MST. AISHA SIDDIKA, Reg. No.: 12-04997, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: JUNE, 2018
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED MOTHERS

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ABSTRACT

A pot experiment was carried out at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to March 2018. Three sweet pepper cultivars; V_1 = Yellow Master F_1, V_2 = Green California Wonder and V_3 = Red Master F_1 and four calcium levels; C_0 = 0 ppm Ca, C_1 = 50 ppm Ca, C_2 = 100 ppm Ca and C_3 = 150 ppm Ca were considered for the present study. The experiment was laid out in Randomized Complete Block Design with three replications. Data on different growth, yield components and yield and also on BER affected fruit of sweet pepper were recorded. Different parameters of the study were significantly influence due to varietal difference, Ca application at different levels and also their combination. In the case of cultivars the highest no. of fruits (3.58 plant^{-1}) affected by BER was recorded from $V_2$and the lowest no. of fruits (2.50 plant^{-1}) affected by BER was recorded from V_1. In terms of calcium levels,the highest no. of fruits (4.89 plant^{-1}) affected by BER was recorded from C_0 and the lowest no. of fruits (1.67 plant^{-1}) affected by BER was recorded from C_3. In combination, the highest no. of fruits (5.67 plant^{-1}) affected by BER was recorded from V_2C_0 and the lowest no. of fruits (1.00 plant^{-1}) affected by BER was recorded from V_1C_3. So the use of Yellow Master F1 cultivar with 150 ppm calcium plant^{-1} showed better performance against blossom end rot.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization of United Nations
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
m^2	=	Meter squares
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
SE(±)	=	Standard Error
SS	=	Sum of Squares
MS	=	Mean Square
df	=	degrees of freedom

CHAPTER I

INTRODUCTION

Peppers are vegetable crops belonging to the family Solanaceae and the genus Capsicum. They are indigenous to Central and South America. Columbus found them growing in West Indies but were introduced into Europe in the 16th century. (Agricultural Alternative, 2000). Gibbon and Pain (1985) also reported that all Capsicums are of American origin, but they are now widely spread throughout the tropical and subtropical regions of the world. Capsicum consists of approximately twenty two wild species and five domesticated species. The five domesticated species include, *C. annum* L., *C. baccatum* L., *C. chinensis* L., *C. pubescens* L., and *C. frutescens* L., (Bosland and Votava, 2000). On the other hand, Capsicum can be divided into several groups based on fruit/pod characteristics ranging in pungency, color, shape, intended use, flavor and size. Despite their vast trait differences most cultivars of pepper commercially cultivated in the world belongs to the species C. annum L. (Smith *et al*., 1987). It is one of the most important vegetables grown in Nigeria and other parts of subhumid and semi-arid tropics (Aliyu, 2000).

Sweet Pepper is a high valued crop in Bangladesh. Sweet pepper (*Capsicum annuum* L.), also known as bell pepper is a multi-use vegetable that is eaten both fresh and cooked. Most of the peppers cultivated in temperate and tropical areas belong to the botanical species *Capsicum annuum*, thought to originate in Mexico and Central America (Andrews, 1984). High money income crops, for example, sweet pepper have involved a critical rank in Egyptian and world farming because of its high benefit and dietary qualities for human health (Rajput and Poruleker, 1998).

Sweet pepper is used either green or red and may be eaten as cooked or raw, as well as in a salad. It is also used for pickling in brine, baking, and stuffing. The leaves are also consumed as salad, soup or eaten with rice (Lovelook, 1973). It was also

discovered to be a good source of medicinal preparation for black vomit, a tonic for gout and paralysis (Knott and Deanon, 1967).

Capsicum has little energy value. But the nutritive value of sweet pepper is high as it contains 1.29 mg protein, 11 mg calcium, 870 I.U vitamins-A, 175 mg ascorbic acid. 0.06 mg thiamine, 0.03 mg riboflavin and 0.55 mg niacin per l00 g edible fruit (Joshi and Singh, 1975). The vitamin C content was found as high as 321 mg. Meanwhile, stated that green peppers, with a p-carotene equivalent to 180 mg per 100 g contain approximately as much carotene as spinach. The sweet pepper is an excellent source of vitamins A and C and is rich in health-promoting antioxidant compounds (Nadeem, *et al*., 2011).

Sweet pepper is a minor vegetable in Bangladesh and its production statistics is not available (Hasanuzzaman, 1999).Successful cultivation of any crop depends on several factors. The suitable variety and optimum plant nutrition ensure proper growth and development of plant resulting maximum yield of the crop and economic use of land. Variety of sweet pepper can play an important role for higher production. Mengel and Kirkby (1982) reported that the genotypic and phenotypic variation was significant for branches plant^{-1} and yield plant^{-1}.

Despite its economic importance growers are not in a position produce good quality capsicum with high productivity due to various biotic (pest and diseases), abiotic (rainfall, temperature, relative humidity, and light intensity), crop factors (flower and fruit drop) and nutritional disorder (Ca, Mg and Mn). Calcium (Ca) nutrition is an important factor for successful sweet pepper production. Calcium deficiency disorders pose a significant problem in the cultivation of many horticultural crops. An increase in such disorders has been seen over the past few years. There is also the commercial desire to produce the largest quantity of saleable fruit per plant, which in itself may cause certain nutritional stresses within the plant. The calcium deficiency disorder of fruit 'Blossom end rot' (BER), is one of the most important nutritional

disorders of the Sweet pepper plant. The first symptoms of BER are often the appearance of a small necrotic grey /brown area of tissue towards the distal end of the fruit. The symptom is a result of cellular degradation, the coloration due to leakage of phenolic precursors from the vacuoles of cells and their subsequent oxidation to polyphenols.

BER is related to many factors including substrate salinity, high Mg, and/or K concentration, disturbed xylem function, fast plant growth rate, unfavorable water regime, low availability of Ca, high temperature, high and low transpiration intensity, which may result in suppressed transport of Ca in the blossom end of the fruit (Ho and White, 2005). The induction of BER, considered as the symptoms of physiological disorder caused by a local Ca deficiency in young fruit, is influenced by a number of environmental factors (Ho *et al*., 1993). Relative humidity around the fruit influences the mineral composition and incidence of blossom end rot in sweet pepper fruit (Tadesse *et al*. 2001).

Considering the above fact, it was evident that varietal performance of sweet pepper with Ca nutrition are very important for a successful production. Therefore, the present study was undertaken with the following objectives:

1. To find out the suitable variety to reduce the incidence of BER;
2. To determine the optimum level of Calcium to reduce the incidence of BER; and
3. To study the combined responses of variety and Calcium to reduce the incidence of BER.

CHAPTER II

REVIEW OF LITERATURE

Sweet pepper is an important vegetable in many parts of the world. It possesses mild flavour with little pungency. It is sensitive to various environmental factors and Ca deficiency. Optimum Ca nutrition with suitable variety are the important and uncontroversial factor for maximizing the yield of a crop against blossom end rot. Many research has been conducted on various aspects of sweet pepper on related terms in abroad but scanty in Bangladesh. The available literature related to the present study is reviewed here.

2.1 Literatures on variety

Kenneth (2017) evaluated three pepper varieties in a replicated small plot trial during 2016. Two of the peppers are classified as a bell or sweet peppers, while the third is a mild pimiento variety. Total fruit weights averaged just over 100 g of marketable fruit per plant for the three sweet pepper varieties. Of the three sweet pepper varieties, „Revolution‟ had the highest marketable fruit weights per plant. This was followed closely by „Mavras‟, while the pimiento heirloom, a distinct type from the two hybrids, yielded less than one-third of the top performer.

Farooq *et al.* (2015) carried out a study at Sher-e-Bangla Agricultural University, Bangladesh to investigates the growth and yield of sweet pepper hybrids under the plastic tunnel. The experiment comprises five hybrids *viz.*, „Orobelle‟ „Figaro‟ „Green Beauty‟ „Mighty‟ „Capistrano‟ with control „Yolo wonder‟. Data were chronicled on number of fruits per plant, fruit weight per plant , length of fruits , the diameter of fruits , pericarp thickness , number of locules per plant and yield. Orobella rank first regarding number of flowers/plant (55.4), fruit/plant (43.47), fruit weight/plant (1.96 kg) and yield (51 t ha^{-1}) followed by Figaro (32.84, 1.72 kg, 48.57

t ha^{-1}) and Capistrano (41.48, 1.76 kg, 45.90 t ha^{-1}), respectively. The mighty hybrid produced highest (5.98, 6.27 cm) value for fruit length and fruit diameter.

Jamaluddin *et al.* (2015) carried out an experiment at Sher-e-Bangla Agricultural University, Dhaka, from March 2015 to June 2015, to evaluate the growth, yield and quality performance of chili varieties. This experiment was consisted of two chili varieties namely V_1, SAU-Agni and V_2, SAU- Cayenne, and was done in randomized completely block design (RCBD) with three replications. A significant difference was observed with the cultivars on plant height, leaf number, number of branches, number of flowers, number of fruits, fruit length and diameter, fresh single fruit weight, dry matter content, and yield.

Hasan *et al.* (2014) conducted an experiment at Sher-e-Bangla Agricultural University, Bangladesh to study the morpho-physiological and yield performance of four chili lines (coded from L1 to L4) during November 2013 to May 2014. Maximum number of flowers (49.8/plant), number of fruits (33.0/plant), length of individual fruits (7.5 cm) and number of seeds (69.0/fruit) was found from L2, whereas maximum fresh weight of 50-fruits (65.4 g), dry weight of 50-fruits (17.7 g), fruit diameter (0.7 cm) and total yield (149.2 g/plant and 947.3 g/plot) was found from L3. Maximum chlorophyll content (57.7%), C02 references (383.5 vpm), H20 references as partial pressure (30.7 pmol- 2s-1) and Vitamin-C (80.5 mg/100 g fruit) was found from L1, while maximum photosynthetic rate (5.3 pmolm-2s-1), and P.A.R incident on leaf surface (252.3 pmolm-2s-1) was recorded from L3.

Vijaya *et al.* (2014) conducted the present experiment to evaluate 24 chili genotypes for different growth and yield parameters. The genotype Chikballapur Local‟ was found to have maximum plant height (118.6 cm), leaf number (122.6), branch number (8.7) and plant spread (0.481 m^2) while, genotype „Sankeshwar‟ recorded a higher number of primary branches $plant^{-1}$ (7.47) and maximum fruit length (14.61 cm). Genotype Byadgi Dabbi‟ registered maximum fruit diameter (1.60 cm),

pericarp weight (0.80 g), stalk weight (0.14 g) and a number of seeds fruit^{-1} (98.42). The higher number of fruits plant^{-1} (186.30), single fruit weight (36.2 g) and dry fruit yield (97.33 g plant^{-1}) were recorded in the genotype „Sankeshwar" followed by genotype LCA-206.

Lemma *et al*. (2008) reported that each variety of pepper has its own significant effect on yield and yield components, and each variety has its own traits that are part and parcel as a quality parameter of the crop (shape, size, and color, taste, and pungency). The most important trait among others includes number of branches per plant, plant height, number of fruit per plant, days to maturity, fruit yield per plant and fruit length.

2.2 Susceptibility of a different variety to Blossom end rot regarding calcium deficiency

Olle and Bender (2009) conducted a study to provide an overview of the causes and control of calcium (Ca)-deficiency disorders in vegetables. Ca-deficiency is usually related to the inability of the plant to translocate adequate Ca to the affected part. Many vegetables develop unique symptoms: for example blackheart in celery, tipburn in lettuce, chervil, onion, fennel, Chinese cabbage, and other cabbages, blossom end rot (BER) in tomato and pepper. Ca-deficiency disorders in vegetables can be controlled by various means. The growing medium influences the development of Ca-deficiency symptoms in plants. Restriction of the root volume is one factor that favours the development of Ca-deficiency symptoms in leafy vegetables but reduces the incidence of BER in pepper. Ca-deficiency can also be avoided by using reasonable levels of nitrogen in the nutrient solution. Cations depress Ca-uptake and distribution, while anions depress the development of tipburn in plants. Watering helps to prevent Ca-deficiency injury, as when growing vegetables outdoors. Maintaining an optimum soil moisture level helps to promote adequate movement of Ca to the roots and into the plant. Low relative humidity

during the day-time increases the Ca-contents of leaves in leafy vegetables with an open growing point, but reduces the Ca contents of fruit and the inner leaves of leafy vegetables with a closed growing point. Shading may influence the incidence of BER, by reducing the appearance of symptoms of BER. Growing plants under a far-red wavelength filter help to prevent Ca-deficiency disorders. Avoiding high or low temperatures also prevents Ca-deficiency injury. Ca sprays also help to prevent Ca-deficiency disorders in plants? Mulches can be used to protect plants against Ca-deficiency. Planting a little later than the optimum date can avoid Ca-deficiency symptoms in leafy vegetables. Harvesting a little earlier than the optimum date can also avoid Ca deficiency- symptoms in leafy vegetables.

Morley *et al*. (1993) conducted an experiment with fifteen cultivars of sweet pepper (*Capsicum annuum* L.) which were grown hydroponically on Rockwool under standard glasshouse conditions from January to November. Significant differences in varietal susceptibility to Blossom end rot (BER) were found. This was related to fruit load over the growing season. Analysis of tissue showed no significant differences in fruit calcium concentration between cultivars. Calcium concentration was seen to vary in different areas of the fruit. Data are presented in relation to differences in susceptibility of sweet pepper cultivars to BER, particularly with respect to the distribution of calcium.

2.3 Role of Ca on Ca deficiency disorder

Manaf *et al*. (2017) reported that the amounts of Ca in the 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. It was 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 the growth parameters, yield, and some biochemical constituents. On the contrary, the same applications led to decrease in 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.

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 (Clarkson, 2006; Kerton *et al.*, 2009).

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

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. He 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.

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 (Burns and Pressey, 1987).

Marschner (1995) reported that Ca is an essential plant mineral which plays many roles in normal plant functions. It readily enters the apoplasm and is bound, in an exchangeable form, to cell walls and to the exterior surface of the plasma membrane. Marschner (1995) also reported that a high proportion of cellular Ca can be found in the vacuoles, whereas its concentration in the cytosol is extremely low. Most of its activity is related to its capacity for coordination, by which it provides stable, but reversible, intermolecular linkages, predominantly in the cell walls and in the plasma membrane.

Bush *et al.* (1993) reported that Ca also plays a significant role in the processes of seed germination with gibberellic acid (GA) and abscisic acid (ABA) which regulate a-amylase production in aleurone tissues during germination of the barley grain. They found that GA increased and ABA decreased both the Ca ion flux into the endoplasmatic reticulum and the amount of Ca that accumulated in the endoplasmic reticulum of barley aleurone cells *in vivo*.

Bush *et al.* (1986) concluded that Ca directly affects the processes of enzyme synthesis and transport. Ca is required by many enzymes as a cofactor, although, at high concentrations, it may inhibit enzyme activity.

Poovaiah (1985) reported that Ca and calmodulin, together, are involved in regulating many metabolic processes including plant responses to the environment, and metabolic responses to plant growth regulators.

Konno *et al.* (1984) postulated that polygalacturonase activity is increased in Ca-deficient cells and tissues. The degradation of pectates is mediated by polygalacturonase, which is inhibited by high Ca concentrations. Typical symptoms of Ca-deficiency are the disintegration of cell walls and the collapse of affected tissues such as petioles and the upper parts of the stem.

Collier and Tibbits (1984) found that diurnal fluctuations in the water potential of lettuce increased the Ca^{2+} ion concentration in inner leaves and delayed the incidence of tipburn.

Egmond (1979) found that Ca and other cations precipitate as oxalate crystals in shoot cells. Oxalate results from a carboxylation reaction in which the excess OH^- ions generated in shoot cells by nitrate assimilation are neutralized. Any Ca in these cells be precipitated as oxalate crystals, and thus cause Ca-deficiency in the plant.

Kirkby (1979) reported that Ca is absorbed only by young root tips in which the cell walls of the epidermis are not yet suberised. Once a suberin layer develops in these cells, water and Ca can no longer be absorbed. Suberin is a waxy substance through which water and nutrients cannot move. Ca is absorbed as divalent Ca^{2+} ions. Ca uptake by roots is associated with water uptake. The uptake of Ca is stimulated by high levels of NO_3^- ions and depressed by high levels of NH_4+, K+, Mg^{2+}, or Al^{3+} ions.

Palzkill and Tibbits (1977) found that a root pressure flow is required to move adequate amounts of Ca to prevent tipburn in cabbage plants that are not undergoing transpirational water loss (e.g., the innermost leaves of the head). Ca movement in plants is influenced by transpiration and by fluctuations in transpiration. s.

2.4 Ca deficiency disorder in plants

Physiological Ca-deficiency has been an economic problem for commercial vegetable growers for many years. While this disorder has probably always been present, it has become more severe in recent years, possibly because more intensive production practices have been used. Ca-deficiency is usually related to the inability of a plant to translocate adequate Ca to the affected part, rather than being due to insufficient levels of soil Ca. Physiological Ca-deficiency is not generally prevented by Ca fertilization, therefore it is quite difficult to protect plants against this disorder. Ca-deficiency is a common problem for vegetable growers and unpredictability of the occurrence of Ca-deficiency and the absence of any effective control procedures make this a serious problem (Manaf *et al*., (2017). Many vegetables develop unique symptoms: for example blossom end rot (BER) in tomato and sweet pepper (Adams and Ho, 1995; Adams and Holder, 1992), black-heart in celery (Geraldson, 1952; Bible and Stiehl, 1986), tipburn in lettuce (Cox *et al*., 1976; Collier and Tibbits, 1982), tipburn in chervil (Kleemann, 1999), tipburn in Chinese cabbage (Aloni, 1986; Aloni *et al.,* 1986), and Ca-deficiency in glasshouse cucumber (Bakker and Sonneveld, 1988).

Adams and Holder (1992) reported that blossom end rot (BER) is a Ca-deficiency disorder which appears as brown-to-black leathery spots around the pistil scar (blossom-end) of tomato and pepper fruit. The affected areas are sunken and grey-to-black in colour. One-half or more of the fruit may be affected. The fruits ripen earlier and are usually commercially worthless.

Collier and Tibbits (1982) reported that tipburn is a Ca-deficiency disorder of cabbage, Chinese cabbage, brussels sprouts, lettuce, chervil, chicory, escarole, onion, fennel and potatoes and is usually characterized by necrosis at the edges of young, rapidly-expanding leaves. Injury may develop on more than half of the area of these

leaves. This necrosis is often visible in leaf lettuce and chervil; but, in heading crops, the affected leaves are in the head and not observed until the head is used.

Bible and Stiehl (1986) reported that Blackheart of celery is a Ca-deficiency disorder which has many symptoms in common with those of tipburn in other vegetable crops. The young, affected leaves become necrotic, first at the tip, then throughout the rest of the leaf. In severe cases, all the interior leaves may rot.

Several factors affect the development of Ca-deficiency injury in plants. First, several conditions influence Ca-uptake by plants such as the soil moisture content, the salt content of the soil solution, the oxygen content of the soil, soil temperature, the Ca-content of the soil, the cation/anion balance, and an inadequate rate of root production. Other factors affecting the development of Ca-injury in plants are air temperature, CO_2 concentration, photoperiod, radiation level, relative humidity (RH), and/or diurnal fluctuations in water potential (Manaf *et al*., 2017).

2.5 Control of calcium deficiency disorders in vegetables

Manishi *et al*. (1996) conducted an experiment on tomatoes under three regimes, using three different amounts of bark compost (0, 5, or 10 kg) applied under conditions of root zone restriction, by placing root-proof sheets 25 cm below the soil surface. They found that the incidence of BER decreased as the amount of compost applied increased.

Terraza *et al*. (2008) carried out an experiment to study the effect of calcium and osmotic potential of the nutritive solution on the tomato blossom-end rot, mineral composition and yield of tomato and found that increasing the levels of Ca in the nutrient solution significantly reduced the number of tomato fruit with BER.

Ho and White (2005) carried out a study aimed at a cellular hypothesis for the induction of blossom-end rot in tomato fruit and showed that high N in the feed could promote BER in tomato.

Taylor and Locascio (2004) reported that higher incidences of BER in tomato were associated with high Mg^{2+}, high NH_4^+, high $K^{+,}$ and low soluble Ca concentrations in the nutrient solution.

Karni *et al*. (2000) reported that the removal of 50% or 75% of the roots from fruit-bearing pepper plants significantly reduced the incidence of BER compared to plants with intact roots. Restriction of root volume is one factor that favours the development of Ca deficiency in leafy vegetables but reduces the incidence of BER in pepper.

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 an application on the older leaves will not benefit the plant.

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

Grasselly *et al.* (2001) showed that spraying young tomato fruit with CaCl2 limited the development of BER. Similar results were found by Schmitz-Eiberger *et al.* (2002).

Tuzel *et al.* (2003) reported that spraying tomato leaves at 2-week intervals with Ca sprays reduced the incidence of BER.

Schmitz-Eiberger *et al.* (2002) found that the spray application of a formulated $CaCl_2$ solution, on a weekly basis, reduced BER symptoms.

2.6 Varietal performance against BER

Adams and Ho (1992) found that tomato varieties differed in their susceptibility to BER. They found that the incidence of BER in „Calypso" and „Spectra" was substantially higher than in „Counter".

Cardoso *et al.* (1995) demonstrated that the tomato variety, „Petomech II", had a higher percentage of BER than the variety „IPA-L".

According to Sperry *et al.* (1996), the tomato variety „Celebrity" had a significantly greater percentage of BER than the varieties „Rutgers", „Mountain Pride", and „Mountain Spring".

Grasselly *et al.* (2008) showed that Marmande-type tomato varieties had a higher incidence of BER on their fruit than cherry, cocktail, or round tomato types.

Magan *et al.* (2008) found that the tomato variety „Boludo" had a higher percentage of BER than the variety „Daniela".

Rhim and Jebari (2008) showed that the pepper varieties „Marconi" and „J27" were more sensitive to BER. These have a larger final fruit size, faster fruit growth, and a higher rate of transpiration compared to „Jerid", a variety characterized by its small fruit.

Ki-Young and Yong-Beom (2008) reported that the Ca content of the lettuce variety „Omega" was lower compared to the variety „Grand Rapid". Results indicated that the different patterns of internal uptake of Ca in the morphologically different cultivars may be associated with cultivar differences in the incidence of Ca-

deficiency symptoms. Some crop varieties are less susceptible to Ca-deficiency and should be grown where possible.

2.7 Effect of Ca on growth and yield

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 was 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.

Halina *et al*. (2016) conducted an experiment to evaluate the effects of foliar Ca feeding on the yield of sweet pepper „Caryca F_1" and on selected elements of its fruit quality infield ground cultivation. Ca was applied in the form of the following preparations: $Ca(NO_3)_2$, Insol Ca, or Liberal 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, adequate management of fertilization with Ca^{2+} and K^{+} could improve the yield and fruit quality of pepper grown in soilless culture.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to March 2018 to study the influence of calcium on different verities of sweet pepper (*Capsicum annum*) to reduce the incidence of blossom end rot (BER). The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´ E longitude and 23°77´ N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28. Topsoil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.1 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix II.

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three (3) distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period

from May to October. Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.2 Test crop

Three chili varieties; California wonder, Red master F_1, Yellow master F_1 were used as test crop for the present study.

3.3 Experimental details

3.3.1 Treatments

The experiment comprised two factors.

Factor A: Cultivar– Three cultivars

1. V_1 = Yellow Master F_1
2. V_2 = Green California Wonder
3. V_3 = Red master F_1

Factor B: Calcium (Ca) – Four doses

1. C_0 = 0 ppm Ca
2. C_1 = 50 ppm Ca
3. C_2 = 100 ppm Ca
4. C_3 = 150 ppm Ca

Treatment combination: Twelve treatment combinations

V_1C_0, V_1C_1, V_1C_2, V_1C_3, V_2C_0, V_2C_1, V_2C_2, V_2C_3, V_3C_0, V_3C_1, V_3C_2 and V_3C_3

3.3.2 Experimental design and layout

The factorial experiment was laid out in a Completely Randomized Design (CRD) with three replications. The 36 plants were planted in the 36 earthen pots (one plant in each pot). The earthen pot size was 40 cm in diameter and 30 cm in height with the depth of 25 cm.

3.4.1 Seed collection

The seeds of the test crop i.e., Yellow master F_1, Green California wonder and Red master F_1 were collected from Siddik Bazar, Dhaka, Bangladesh.

3.4.2 Raising of seedlings

The land selected for the nursery bed was well drained and were sandy loam type soil. The area was well prepared and converted into loose friable and dried mass to obtain fine tilth. All weeds and dead roots were removed and the soil was mixed with well rotten cowdung at the rate of 5 kg/bed. Seedbed size was 3m × 1m raised above the ground level. One bed was prepared for raising the seedlings. Five (5) grams of seeds were sown in the seedbed on 10 October 2017. After sowing, the seeds were covered with light soil. Complete germination of the seeds took place with 5 days after seed sowing. Necessary shading was made by bamboo mat (chatai) from scorching sunshine or rain. No chemical fertilizer was used in the seedbed.

3.5 Pot preparation

Before transplanting the growing structures were prepared with silt loam soils. Well, rotten cow dung and soil were mixed using the ratio of 1:3. Earthen pots were filled 10 days before transplanting. Soils were made completely stubbles and weed free.

3.6 Fertilizers and manure application

The N, P, K, S, B and Ca fertilizer were applied through urea, Triple superphosphate (TSP), MoP, Gypsum, Borax, and $CaCl_2$ respectively. Cowdung also used as organic manure. Calcium (Ca) was applied through $CaCl_2$ as per treatment. Nutrient doses used through fertilizers under the present study are presented as follows:

Nutrients	Manures/fertilizers	Doses ha^{-1}
-	Cowdung	10 ton
N	Urea	210 kg
P	TSP	330 kg
K	MoP	200 kg
B	Borax	5 kg
Ca	$CaCl_2$	As per treatment

One third (1/3) of the whole amount of Urea and the full amount of TSP, MoP, Gypsum, and Borax were applied at the time of final pot preparation. The remaining Urea was top dressed in two equal installments- at 25 days after transplanting (DAT) and 50 DAT respectively. Ca was applied as a foliar spray.

3.7 Uprooting and transplanting of seedlings

Healthy and uniform sized 25 days old seedlings were taken separately from the seedbed and were transplanted in the experimental pot on 5 November 2017. The seedbed was watered before uprooting the seedlings so as to minimize the damage of the roots. This operation was carried out during late hours in the evening. The seedlings were watered after transplanting.

3.8 Intercultural operations

Intercultural operations were done whenever needed for better growth and development. Intercultural operations followed in the experiment were irrigation, weeding, staking, and topdressing etc.

3.8.1 Irrigation

Irrigation was provided once in a day either in morning or at evening at the early stage of seedling with a hand sprayer. After that irrigation was provided to the plants twice a day except for the rainy days.

3.8.2 Stalking

Staking was given to each plant by bamboo sticks for support when the plants were well established.

3.8.3 Weeding

Weeding was done whenever it was necessary, mostly in the vegetative stage for better growth and development.

3.8.4 Topdressing

After basal dose, the remaining doses of urea were used as top-dressed in 3 equal installments at 15, 30 and 45 DAT. The fertilizers were applied on both sides of plant pots and mixed well with the soil. Earthing up operation was done immediately after top-dressing with nitrogen fertilizer.

3.8.5 Plant Protection Measures

Malathion 57 EC was applied @ 2 ml L^{-1} of water against the insect pests like cutworm, leafhopper, fruit borer, and others. The insecticide application was made fortnightly after transplanting and was stopped before the second week of the first harvest. Furadan 10G was also applied during pot preparation as soil insecticide. Emitaf 20 SL @ 0.25 ml L^{-1} of water at 7 days interval for three weeks was also applied.

3.9 Harvesting and cleaning

Fruits were harvested at 30 days intervals during maturity to ripening stage. Harvesting was started from 2 January 2018 and completed by 28 March 2018.

3.10 Data collection

The following parameters were recorded during the study:

1. Plant height
2. Number of leaves $plant^{-1}$
3. Stem length
4. Stem breadth
5. Number of branches $plant^{-1}$
6. Days to 50% flowering
7. Number of flowers $plant^{-1}$
8. Number of fruits $plant^{-1}$
9. Fruit length
10. Fruit diameter
11. Individual fruit weight
12. Yield per plant
13. Fruits affected by blossom end rot (BER)

3.11 Procedure for recording data

3.11.1 Plant height

The height of the plant was recorded in centimeter (cm) at different days after transplanting of crop duration. Data were recorded as the average of each replication (each pot). The height was measured from the ground level to the tip of the leaves. Data were taken at 30, 60, 90 days after transplanting (DAT) and at harvest.

3.11.2 Number of leaves plant^{-1}

A number of leaves plant^{-1} was counted at different days after transplanting of crop duration. Leaves number plant^{-1} was recorded from each plant of each pot at replication wise by counting all leaves from each pot. Data were taken at 30, 60, 90 days after transplanting (DAT) and at harvest.

3.11.3 Stem length

Stem length was recorded in centimeter (cm) at different days after transplanting of crop duration. Data were recorded from each plant of each pot. The length was measured from the ground level of the stem to the tip of the stem. Data were taken at 30, 60, 90 days after transplanting (DAT) and at harvest.

3.11.4 Stem breadth

The breadth of the stem in centimeter (cm) was recorded from each plant of each pot at different days after transplanting (at 30, 60, 90 DAT and at harvest) at the base portion of the plant with slide calipers.

3.11.5 Number of branches per plant

At different days after transplanting (DAT) i.e. at 30, 60, 90 DAT and at harvest, all the primary branches were counted from each plant of each pot and their average value was taken as a number of branches per plant.

3.11.6 Days to 50% flowering

Days to 50% flowering was recorded from the date of transplanting to when 50% of the flower appears in the plant.

3.11.7 Number of flowers plant^{-1}

A total number of flowers was counted from each plant of each pot and the average value was taken.

3.11.8 Number of fruits plant^{-1}

Total fruit number was counted from each plant of each pot from 1st to last harvest and the average number was calculated as a number of fruits per plant.

3.11.9 Fruit length

The length of the fruit was measured with digital slide calipers in centimeter from the neck of the fruit to the bottom of the fruit. It was measured from each pot and their average was calculated in centimeter.

3.11.10 Fruit diameter

The breadth of the fruits was measured from each pot with the digital slide calipers in centimeter and their average was taken as the breadth of the fruits.

3.11.11 Individual fruit weight

From the first harvest to last harvest total fruit number and weight were counted from each plant to determine single fruit weight. Single fruit weight was calculated from the total weight of fruit divided by a total number of fruits and expressed in gram (g).

3.11.12 Fruit weight plant^{-1}

Total fruit weight was counted from each plant of each pot from 1st to last harvest and the average weight was calculated as fruit weight per plant and was expressed in gram (g).

3.11.13 Fruits affected by blossom end rot (BER)

Number of fruits was collected affected by blossom end rot from each plant of each pot and average was measured and expressed in per plant basis

3.12 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the SPSS computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was carried out to investigate the Influence of calcium on different varieties of sweet pepper (*Capsicum annum*) to reduce the incidence of blossom end rot (BER). The results obtained in the study have been presented and discussed in this section through tables, figures, appendices, and other information as and when necessary.

4.1 Growth parameters

4.1.1 Plant height

Different variety had a significant influence on plant height of sweet pepper at different growth stages (Fig. 1 and Appendix IV-VII). Results revealed that the highest plant height (16.03, 29.63, 38.95 and 52.72 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the variety, V_2 (Green California wonder) where the lowest plant height (13.15, 24.91, 34.96 and 45.59 cm at 30, 60, 90 DAT and at harvest, respectively) was observed from the variety, V_1 (Yellow master F_1) which was statistically similar with the variety V_3 (Red master F_1). A similar result was also observed by Jamaluddin *et al.* (2015) and Vijaya *et al.* (2014) which supported the present study.

There was a significant variation on plant height of sweet pepper at different growth stages influenced by different levels of Ca application (Fig. 2 and Appendix IV-VII). It was observed that the highest plant height (15.61, 28.61, 37.90 and 50.66 cm at 30, 60, 90 DAT and at harvest, respectively) was obtained from the treatment, C_3 (150 ppm Ca) which was closely followed by C_2 (100 ppm Ca) and C_1 (50 ppm Ca) at all growth stages. The lowest plant height (12.88, 23.50, 33.94 and 46.49 cm at 30, 60,

90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca).

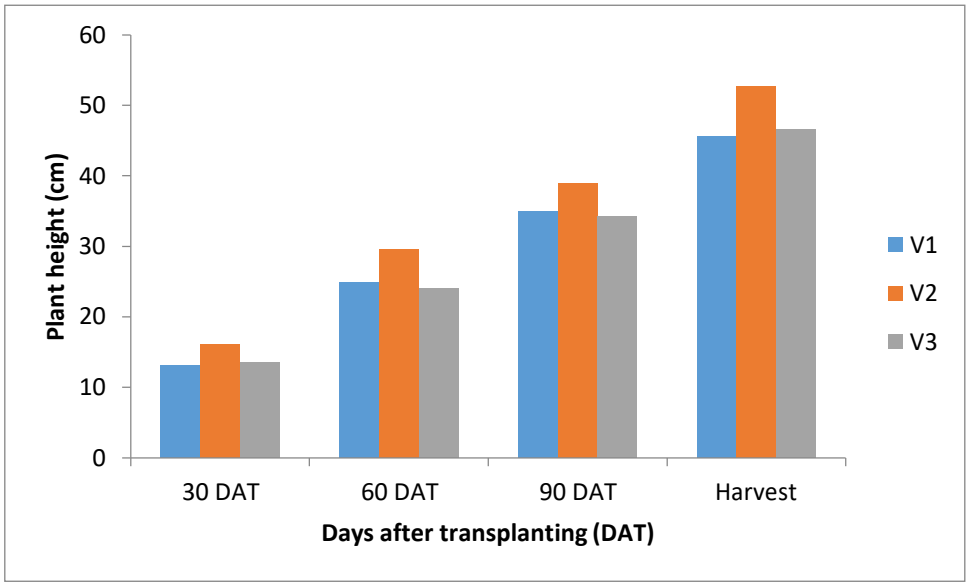
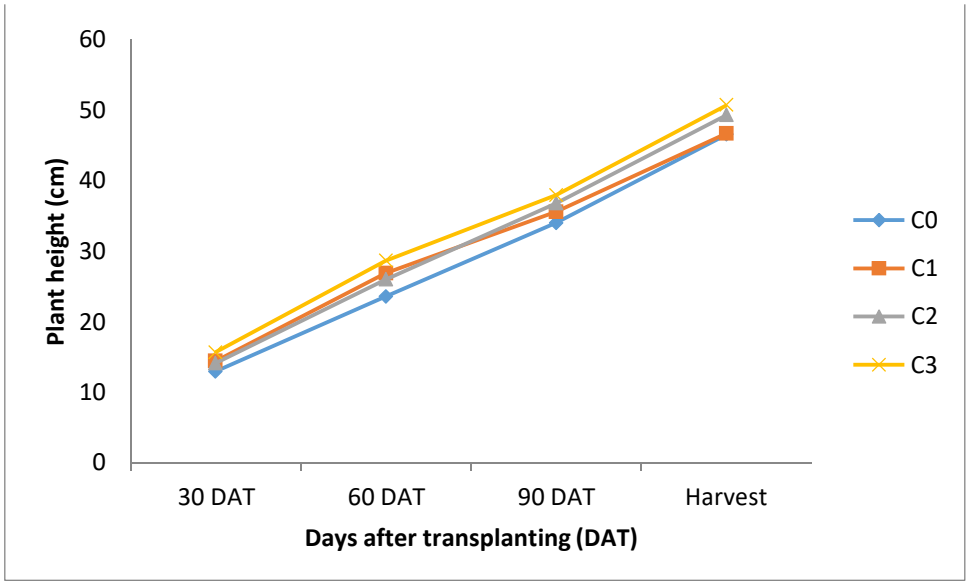


Fig. 1. Plant height of sweet pepper influenced by varieties

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1



C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Fig. 2. Plant height of sweet pepper influenced by Ca

Plant height was significantly influenced by the combined effect of variety and calcium at different growth stages of sweet pepper (Table 1 and Appendix IV-VII). The highest plant height (17.47, 32.33, 40.77 and 54.47 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the treatment combination of V_2C_3 which was statistically similar with V_2C_2 at the time of harvest except at 60 DAT. The lowest plant height (12.13, 19.77, 32.07 and 41.90 cm at 30, 60, 90 DAT and at harvest, respectively) was achieved from the treatment combination of V_1C_0 which was not statistically similar with other treatment combination.

Table 1. Plant height of sweet pepper influenced by the combined effect of variety and Ca

Treatments	Plant height (cm) at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1C_0	12.13f	19.77g	32.07f	41.90h
V_1C_1	12.93ef	25.87cde	35.67cd	45.90ef
V_1C_2	12.37ef	22.50f	34.17e	46.07ef
V_1C_3	15.17bcd	27.10c	37.93b	47.17ef
V_2C_0	14.33cde	26.57c	37.67b	51.40bc
V_2C_1	16.57ab	29.97b	36.93bc	51.67bc
V_2C_2	15.73abc	29.67b	40.43a	53.37ab
V_2C_3	17.47a	32.33a	40.77a	54.47a
V_3C_0	12.17f	24.17ef	32.10f	45.33fg
V_3C_1	13.57def	24.60de	34.00e	43.23gh
V_3C_2	14.07cdef	25.63cde	35.30de	48.33de
V_3C_3	14.20cdef	26.40cd	35.33de	50.33cd
SE(±)	0.321	0.567	0.473	0.675
Sgn. Level (P)	0.000	0.000	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.1.2 Number of leaves plant^{-1}

Significant variation was observed on a number of leaves plant^{-1} at different growth stages influenced by different variety (Fig. 3 and Appendix VIII-XI). It was observed that the highest number of leaves plant^{-1} (25.00, 47.17, 66.50 and 77.08 at 30, 60, 90 DAT and at harvest, respectively) was found from the variety, V_2 (Green California wonder). The lowest number of leaves plant^{-1} (18.08, 34.33, 51.75 and 62.25 at 30, 60, 90 DAT and at harvest, respectively) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_2 (Green California wonder) at all growth stages. Jamaluddin *et al.* (2015) and Vijaya *et al.* (2014) also found a similar result with the present study.

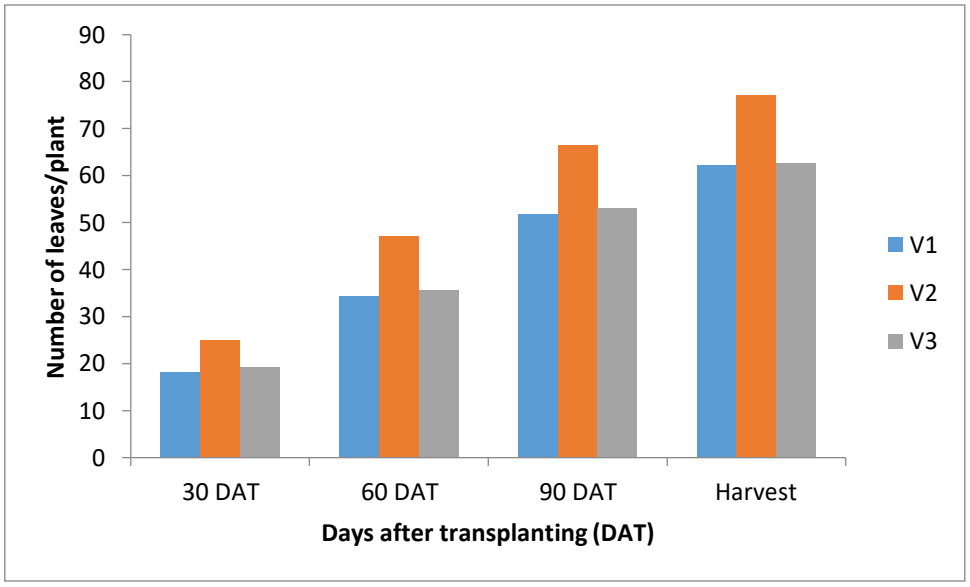


Fig. 3. Number of leaves plant^{-1} influenced by varieties

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

Number of leaves plant^{-1} was significantly varied due to different levels of Ca application at different growth stages (Fig. 4 and Appendix VIII-XI). The highest number of leaves plant^{-1} (24.22, 43.89, 61.11 and 70.78 at 30, 60, 90 DAT and at harvest, respectively) was obtained from the treatment, C_3 (150 ppm Ca) which was statistically similar with C_2 (100 ppm Ca) at all growth stages. The lowest number of leaves plant^{-1} (17.22, 34.67, 53.11 and 61.78 at 30, 60, 90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca).

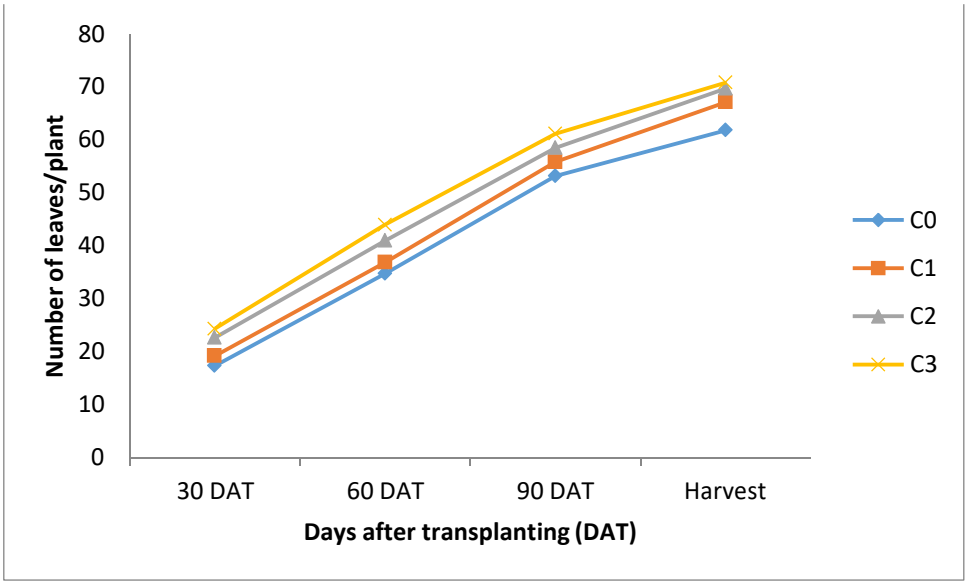


Fig 4. Number of leaves plant^{-1} influenced by Ca

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Remarkable variation was observed on a number of leaves plant^{-1} influenced by the combined effect of variety and calcium at different growth stages (Table 2 and Appendix VIII-XI). The highest number of leaves plant^{-1} (29.67, 54.33, 70.00 and 80.67 at 30, 60, 90 DAT and at harvest, respectively) was found from the treatment combination of V_2C_3 which was statistically identical with V_2C_2 at the time of harvest. The lowest number of leaves plant^{-1} (15.33, 29.33, 48.00 and 57.00 at 30, 60, 90 DAT and at harvest, respectively) was achieved from the treatment combination of V_1C_0 which was statistically identical with V_3C_1 at 90 DAT and at harvest.

Table 2. Number of leaves plant^{-1} of sweet pepper influenced the combined effect of variety and Ca

Treatments	Number of leaves plant^{-1}			
	30 DAT	60 DAT	90 DAT	Harvest
V_1C_0	15.33d	29.33g	48.00g	57.00e
V_1C_1	19.67c	32.00f	51.00fg	62.67cd
V_1C_2	19.67c	37.00e	52.67ef	66.67bc
V_1C_3	21.67bc	39.00de	55.33de	62.33cd
V_2C_0	20.33bc	41.33d	62.33c	70.67b
V_2C_1	22.67b	44.33c	65.33bc	77.33a
V_2C_2	27.33a	48.67b	68.33ab	79.67a
V_2C_3	29.67a	54.33a	70.00a	80.67a
V_3C_0	16.00d	33.33f	49.00g	57.33e
V_3C_1	15.00d	34.00f	51.00fg	61.33de
V_3C_2	20.67bc	37.00e	54.33e	62.67cd
V_3C_3	21.33bc	38.33e	58.00d	69.33b
SE(±)	0.747	1.183	1.261	1.389
Sgn. Level (P)	0.000	0.000	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.1.3 Number of branches plant^{-1}

The considerable influence was observed on a number of branches plant^{-1} at different growth stages persuaded by a different variety of sweet pepper (Fig. 5. and Appendix XX-XXIII). The highest number of branches plant^{-1} (1.58, 3.33, 5.25 and 6.17 at 30, 60, 90 DAT and at harvest, respectively) was found from the variety, V_2 (Green California wonder). The lowest number of branches plant^{-1} (1.00, 1.67, 2.67 and 3.50 at 30, 60, 90 DAT and at harvest, respectively) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_3 (Red master F_1). The result obtained from the present study was similar to the findings of Jamaluddin *et al.* (2015) and Vijaya *et al*. (2014).

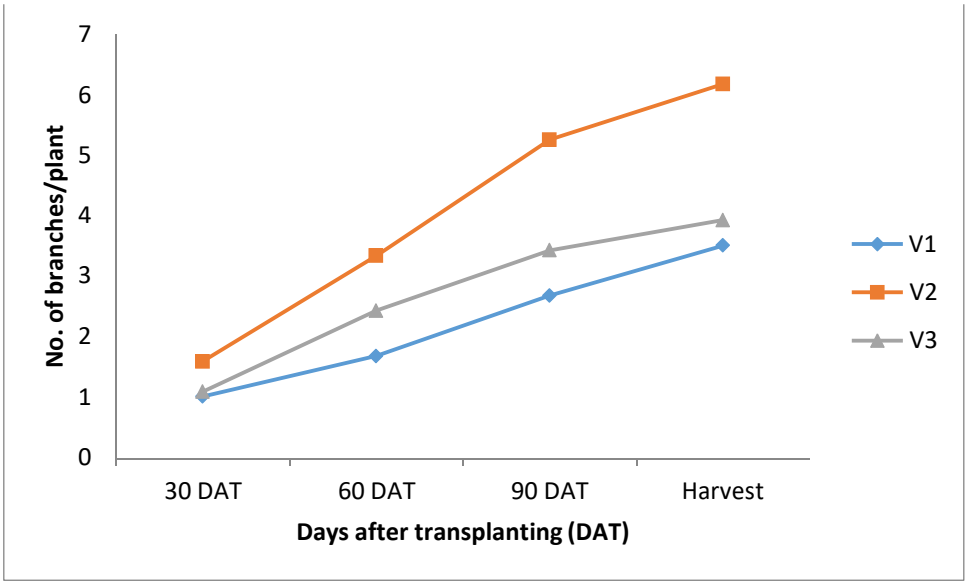


Fig. 5. Number of branches plant^{-1} influenced by variety

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

Remarkable variation was not found on a number of branches plant^{-1} at different growth stages due to the different levels of Ca application (Fig. 6. and Appendix XX-XXIII). However, the highest number of branches plant^{-1} (1.33, 2.67, 3.93 and 5.00 at 30, 60, 90 DAT and at harvest, respectively) was obtained from the treatment, C_3 (150 ppm Ca) and the lowest number of branches plant^{-1} (1.10, 2.23, 3.44 and 3.89 at 30, 60, 90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca).

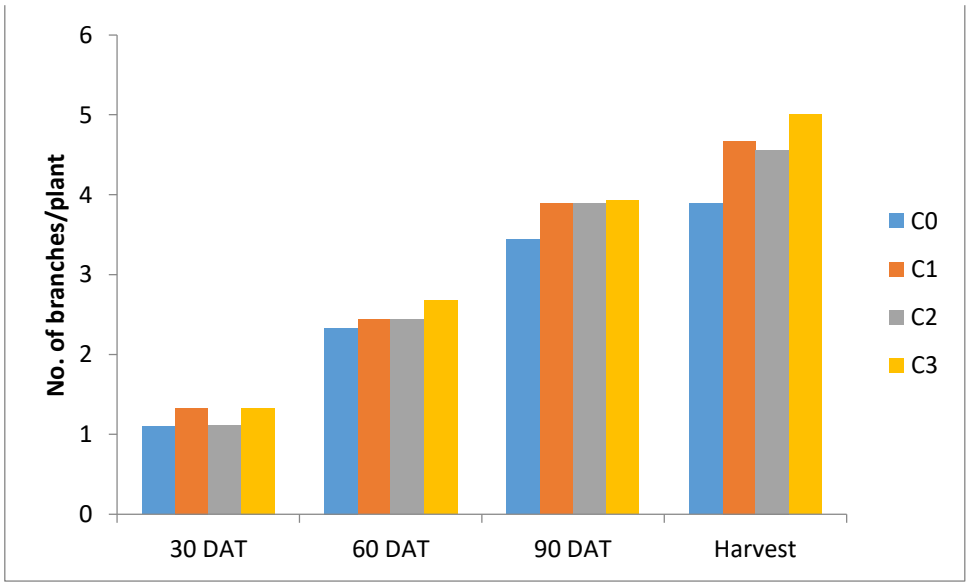


Fig. 6. Number of branches plant^{-1} influenced by Ca

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

The recorded data on a number of branches plant^{-1} at different growth stages was significant with the combined effect of variety and calcium (Table 3 and Appendix XX-XXIII). The highest number of branches plant^{-1} (2.00, 3.67, 5.67 and 6.67 at 30, 60, 90 DAT and at harvest, respectively) was found from the treatment combination of V_2C_3 which was statistically similar with and V_2C_1 and V_2C_2 at the time of harvest. The lowest number of branches plant^{-1} (1.00, 1.00, 2.00 and 3.00 at 30, 60, 90 DAT and at harvest, respectively) was achieved from the treatment combination of V_1C_0

Table 3. Number of branches plant^{-1} of sweet pepper influenced by the combined effect of variety and Ca

Treatments	Number of branches at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1C_0	1.00c	1.00d	2.00d	3.00d
V_1C_1	1.00c	2.00bd	2.33cd	3.33d
V_1C_2	1.00c	2.00bcd	3.33bc	3.33d
V_1C_3	1.00c	1.67cd	3.00bcd	4.33cd
V_2C_0	1.33bc	3.00ab	5.00a	5.33bc
V_2C_1	1.67ab	3.66a	5.00a	6.33ab
V_2C_2	1.33bc	3.00ab	5.33a	6.33ab
V_2C_3	2.00a	3.67a	5.67a	6.67a
V_3C_0	1.00c	2.33bc	3.33bc	3.33d
V_3C_1	1.00c	2.33bc	3.67b	4.00d
V_3C_2	1.00c	2.33bc	3.00bcd	4.00d
V_3C_3	1.33b	2.67abc	3.67b	4.33cd
SE(±)	0.070	0.152	0.215	0.234
Sgn. Level (P)	0.014	0.000	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1(=50 ppm Ca, C_2 =100 ppm Ca, C_3(=150 ppm Ca

4.1.4 Stem length

Significant influence was noted on stem length at different growth stages affected by different varieties of sweet pepper (Fig. 7 and Appendix XII-XV). The highest stem length (7.75, 15.08, 20.33 and 24.33 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the variety, V_2 (Green California wonder). The lowest stem length (6.58, 12.42, 16.67 and 20.33 cm at 30, 60, 90 DAT and at harvest, respectively) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_3 (Red master F_1) at different growth stages.

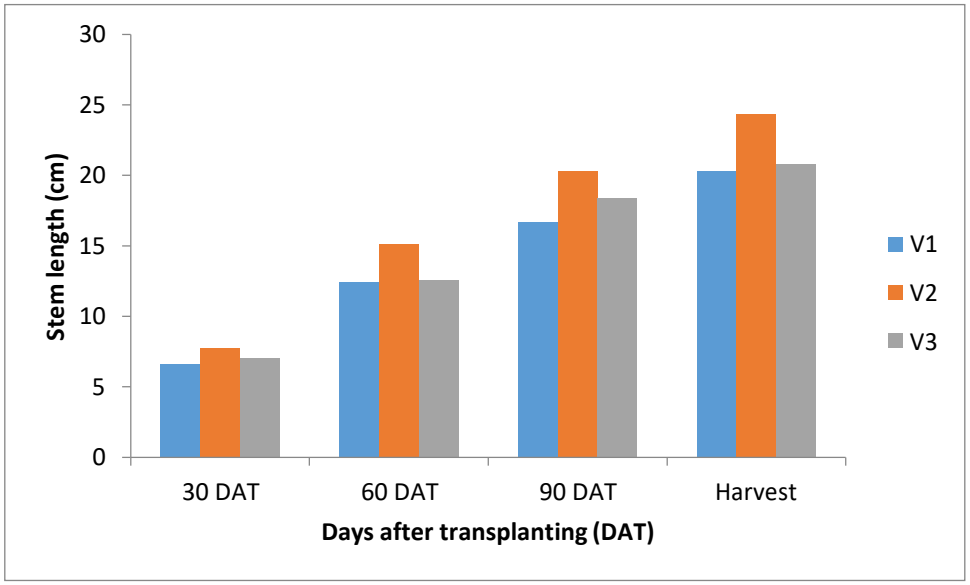


Fig. 7. Stem length of sweet pepper influenced by varieties

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

Stem length at different growth stages was not significant due to different levels of Ca application (Fig. 8 and Appendix XII-XV). However, the highest stem length (7.78, 14.00, 19.67 and 22.33 cm at 30, 60, 90 DAT and at harvest, respectively) was obtained from the treatment, C_3 (150 ppm Ca) and the lowest stem length (6.67, 12.67, 17.44 and 21.11 cm at 30, 60, 90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca).

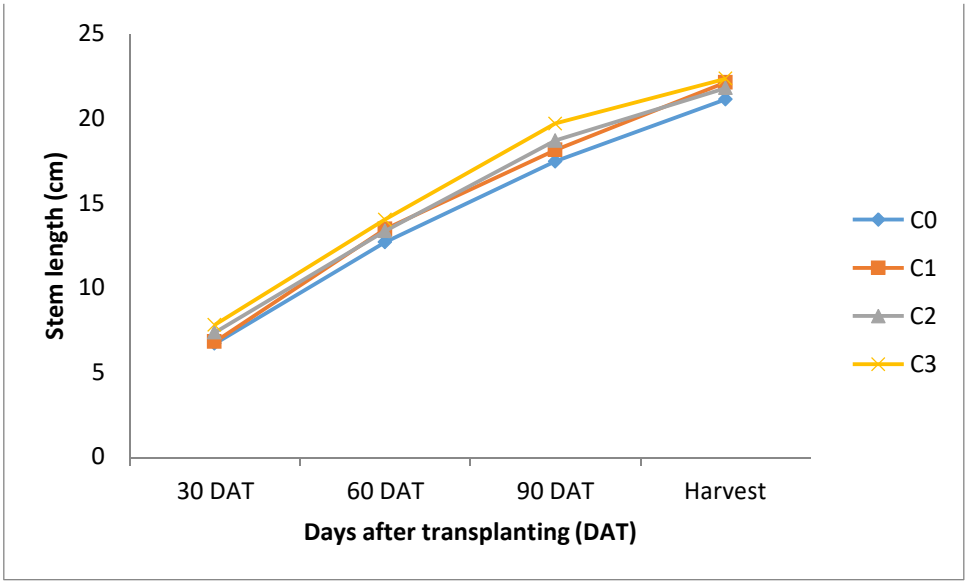


Fig. 8. Stem length of sweet pepper influenced by Ca

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Significant variation was remarked on stem length at different growth stages as influenced by the combined effect of variety and calcium (Table 4 and Appendix XII-XV). The highest stem length (8.33, 16.00, 21.67 and 26.00 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the treatment combination of V_2C_3 which was statistically similar with V_2C_0 at 90 DAT and at harvest. The lowest plant (6.00, 11.33, 15.33 and 18.33 cm at 30, 60, 90 DAT and at harvest, respectively) was achieved from the treatment combination of V_1C_0.

Table 4. Stem length of sweet pepper influenced by the combined effect of variety and Ca

Treatments	Stem length (cm) at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1C_0	6.00 d	11.33e	15.33f	18.33e
V_1C_1	6.33 cd	12.33de	16.00ef	21.00c-e
V_1C_2	7.00 bc	11.67e	15.67f	20.67de
V_1C_3	8.00 a	13.67 b-e	19.33a-d	21.00c-e
V_2C_0	7.00 bc	14.33 a-d	21.33ab	25.00ab
V_2C_1	7.67ab	14.67 a-c	17.67d-f	23.67a-c
V_2C_2	8.00a	15.33 ab	20.67a-c	22.67bcd
V_2C_3	8.33a	16.00a	21.67a	26.00a
V_3C_0	7.00bc	12.00e	17.33d-f	18.67e
V_3C_1	6.33cd	13.33b-e	18.67b-e	21.67cd
V_3C_2	7.00bc	13.00cde	19.67a-d	22.00cd
V_3C_3	7.00bc	12.33de	18.00c-f	21.00cde
SE(±)	0.133	0.288	0.401	0.417
Sgn. Level (P)	0.000	0.001	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.1.5 Stem breadth

Stem breadth was not found significant at different growth stages with different varieties of sweet pepper (Fig. 9 and Appendix XVI-XIX). However, the highest stem breadth (0.24, 0.52, 0.66 and 0.92 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the variety, V_2 (Green California wonder) and the lowest stem breadth (0.14, 0.28, 0.39 and 0.52 cm at 30, 60, 90 DAT and at harvest, respectively) was observed from the variety, V_1 (Yellow master F_1)

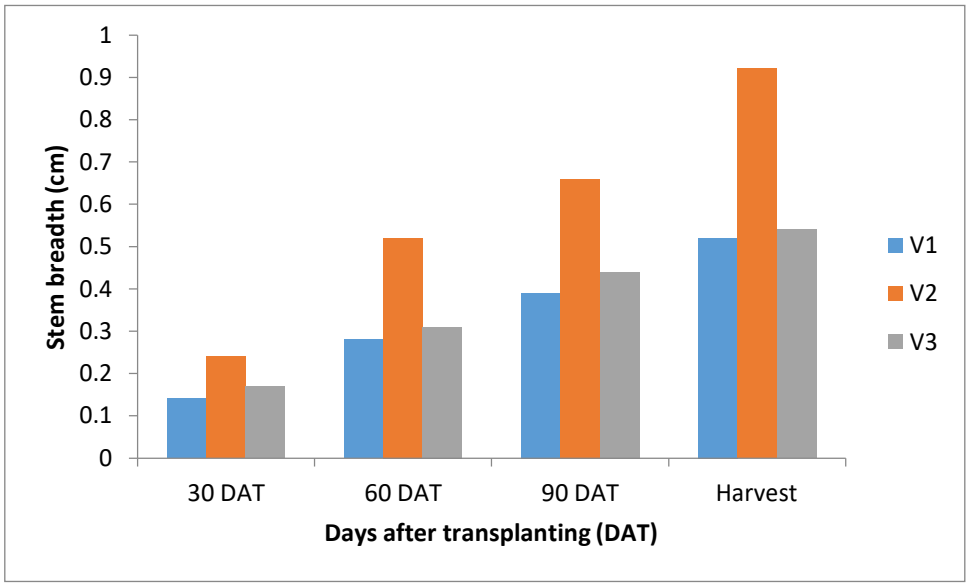


Fig. 9. Stem breadth of sweet pepper influenced by varieties

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

A non-significant variation on stem breadth was noted at different growth stages influenced by different levels of Ca application (Fig. 10 and Appendix XVI-XIX). However, the highest stem breadth (0.20, 0.40, 0.52 and 0.69 cm at 30, 60, 90 DAT and at harvest, respectively) was obtained from the treatment, C_3 (150 ppm Ca) and the lowest stem breadth (0.17, 0.34, 0.49 and 0.62 cm at 30, 60, 90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca).

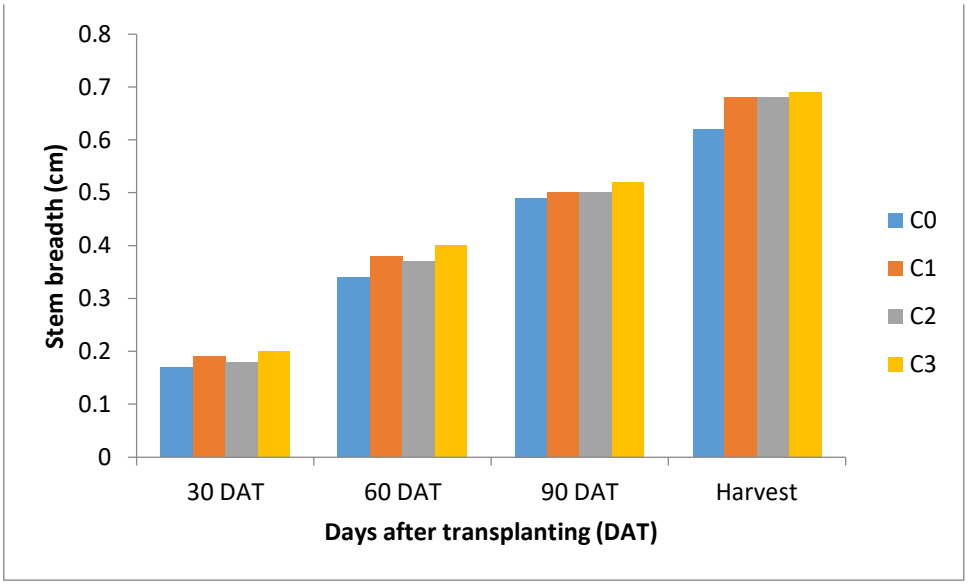


Fig. 10. Stem breadth of sweet pepper influenced by Ca

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

The recorded data on stem breadth was significant at different growth stages combined effect of variety and calcium (Table 5 and Appendix XVI-XIX). The highest stem breadth (0.27, 0.57, 0.73 and 0.93 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the treatment combination of V_2C_3 which was statistically identical with $V_2C_1$and V_2C_2 at the time of harvest where the lowest stem breadth (0.10, 0.23, 0.36 and 0.47 cm at 30, 60, 90 DAT and at harvest, respectively) was achieved from the treatment combination of V_1C_0.

Table 5. Stem breadth of sweet pepper influenced by the combined effect of variety and Ca

Treatments	Stem breadth (mm) at			
	30 DAT	60 DAT	90 DAT	Harvest
V_1C_0	0.10d	0.23d	0.36c	0.47b
V_1C_1	0.17b-d	0.33cd	0.40c	0.57b
V_1C_2	0.17b-d	0.30cd	0.47bc	0.60b
V_1C_3	0.13cd	0.27cd	0.47bc	0.53b
V_2C_0	0.20a-c	0.53a	0.63a	0.87a
V_2C_1	0.26a	0.53a	0.60ab	0.90a
V_2C_2	0.23ab	0.47ab	0.67a	0.90a
V_2C_3	0.27a	0.57a	0.73a	0.93a
V_3C_0	0.13cd	0.27cd	0.40c	0.53b
V_3C_1	0.20a-c	0.33cd	0.37c	0.53b
V_3C_2	0.17b-d	0.27cd	0.43c	0.53b
V_3C_3	0.17b-d	0.37bc	0.43c	0.57b
SE(±)	0.011	0.021	0.023	0.036
Sgn. Level (P)	0.007	0.000	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1(=50 ppm Ca, C_2 =100 ppm Ca, C_3(=150 ppm Ca

4.2 Yield contributing parameters

4.2.1 Days to 50% flowering

Significant influence was noted on days to 50% flowering affected by different varieties of sweet pepper (Table 6 and Appendix XXIV). The highest days to 50% flowering (90.42 days) was found from the variety, V_3 (Red master F_1) which was statistically identical with V_1 (Yellow master F_1). The lowest days to 50% flowering (84.75 days) was observed from the variety, V_2 (Green California wonder).

Non-significant variation was observed on days to 50% flowering influenced by different levels of Ca application (Table 6 and Appendix X). However, The highest days to 50% flowering (89.00 days) was obtained from the treatment C_1 (50 ppm Ca) and the lowest days to 50% flowering (88.11 days) was observed from the treatment C_2 (100 ppm Ca).

There was a significant variation on days to 50% flowering influenced by the combined effect of variety and calcium at different growth stages (Table 7 and Appendix X). The highest days to 50% flowering (91.00 days) was found from the treatment combination of V_3C_1 which was statistically identical with V_1C_0, V_1C_1, V_1C_2, V_1C_3, V_3C_0, V_3C_2, and V_3C_3. The lowest days to 50% flowering (84.00 days) was achieved from the treatment combination of V_2C_2 which was statistically identical with V_2C_0, V_2C_1, and V_2C_3.

4.2.2 Number of flowers plant^{-1}

Significant influence was noted on a number of flowers plant^{-1} affected by different varieties of sweet pepper (Table 6 and Appendix XXV). The highest number of flowers plant^{-1} (34.58) was found from the variety, V_2 (Green California wonder) followed by V_2 (Green California wonder). The lowest number of flowers plant^{-1} (23.42) was observed from the variety, V_3 (Red master F_1). A similar result was also observed by Farooq *et al.* (2015) which supported the present study.

A number of flowers plant^{-1} was not varied significantly due to different levels of Ca application (Table 6 and Appendix XXV). However, the highest number of flowers plant^{-1} (30.22) was obtained from the treatment, C_3 (150 ppm Ca) and the lowest number of flowers plant^{-1} (26.33) was observed from the treatment, Ca_0 (0 ppm Ca).

Significant variation was remarked on a number of flowers plant^{-1} as influenced by the combined effect of variety and calcium (Table 7 and Appendix XXV). The highest number of flowers plant^{-1} (38.33) was found from the treatment combination of V_2C_3 which was significantly different from all other treatment combinations followed by V_2C_1 and V_2C_2. The lowest number of flowers plant^{-1} (21.00) was achieved from the treatment combination of V_3C_0 which was also significantly different from all other treatment combinations.

4.2.3 Number of fruits plant^{-1}

A number of fruits plant^{-1} was found significant due to different varieties of sweet pepper (Table 6 and Appendix XXVI). The highest number of fruits plant^{-1} (11.42) was found from the variety, V_2 (Green California wonder). The lowest number of fruits plant^{-1} (9.00) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_3 (Red master F_1). Farooq *et al.* (2015) also found a similar result with the present finding.

A variation on a number of fruits plant^{-1} was noted influenced by different levels of Ca application (Table 6 and Appendix XXVI). It was found that the highest number of fruits plant^{-1} (13.44) was obtained from the treatment, C_3 (150 ppm Ca) followed by C_2 (100 ppm Ca). The lowest number of fruits plant^{-1} (6.33) was observed from the treatment, Ca_0 (0 ppm Ca).

The recorded data on a number of fruits plant^{-1} was significant with affected by the combined effect of variety and calcium (Table 7 and Appendix XXVI). The highest number of fruits plant^{-1} (15.00) was found from the treatment combination of V_2C_3 which was significantly different from all other treatment combinations followed by V_2C_2. The lowest number of fruits plant^{-1} (5.00) was achieved from the treatment combination of V_1C_0 followed by V_3C_1.

Table 6. Days to 50% flowering, number of flowers per plant and number of fruits per plant as influenced by variety and Ca

Treatment	Days to 50% flowering	No. of flowers per plant	No. of fruits per plant
Variety			
V_1	90.00a	27.00b	9.00 b
V_2	84.75b	34.58a	11.42a
V_3	90.42a	23.42c	9.67b
Sgn. Level (P)	0.000	0.000	0.000
SE(±)	0.487	0.864	0.505
Calcium			
C_0	88.33	26.33	6.33d
C_1	89.00	28.11	8.89c
C_2	88.11	28.67	11.44b
C_3	88.67	30.22	13.44a
Sgn. Level (P)	0.930	0.476	0.000
SE(±)	0.487	0.864	0.505

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Table 7. Days to 50% flowering, number of flowers per plant and number of fruits per plant as influenced by the combined effect of variety and Ca

Treatment	Days to 50% flowering	No. of flowers per plant	No. of fruits per plant
V_1C_0	90.33a	27.33d	5.00h
V_1C_1	90.33a	25.67de	8.67ef
V_1C_2	90.33a	27.33d	10.33cde
V_1C_3	90.67a	27.67d	12.00bc
V_2C_0	84.33b	30.67c	7.67fg
V_2C_1	84.67b	34.67b	10.00de
V_2C_2	84.00b	34.67b	13.00b
V_2C_3	85.67b	38.33a	15.00a
V_3C_0	90.33a	21.00f	6.33gh
V_3C_1	91.00a	24.00e	8.00fg
V_3C_2	89.67a	24.00e	11.00cd
V_3C_3	90.67a	24.67e	13.33b
SE(±)	0.487	0.864	0.505
Sgn. Level (P)	0.000	0.000	0.130

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.2.4 Length of fruits

Significant variation was observed on length of fruits influenced by different varieties of sweet pepper (Table 8 and Appendix XXVII). The highest length of fruits (7.22 cm) was found from the variety, V_2 (Green California wonder). The lowest length of fruits (5.34 cm) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_3 (Red master F_1). Farooq *et al.* (2015) and Vijaya *et al.* (2014) also found a similar result which supported the present study.

Length of fruits was not significantly influenced by different levels of Ca application at different growth stages (Table 8 and Appendix XXVII). However, the highest length of fruits (6.54 cm) was obtained from the treatment, C_3 (150 ppm Ca) and the lowest length of fruits (5.53 cm) was observed from the treatment, Ca_0 (0 ppm Ca).

The considerable influence was observed on length of fruits persuaded by the combined effect of variety and calcium (Table 9 and Appendix XXVII). The highest length of fruits (7.53 cm) was found from the treatment combination of V_2C_3 which was statistically identical with V_2C_0, V_2C_1, and V_2C_2. The lowest length of fruits (4.63 cm) was achieved from the treatment combination of V_1C_0 which was statistically similar to V_3C_0.

4.2.5 Diameter of fruits

Significant variation was observed on the diameter of fruits influenced by different varieties of sweet pepper (Table 8 and Appendix XXVIII). The highest diameter of fruits (5.44 cm) was found from the variety, V_2 (Green California wonder) whereas the lowest diameter of fruits (3.82 cm) was observed from the variety, V_3 (Red master F_1) which was statistically identical with V_1 (Yellow master F_1).

The diameter of fruits was not significantly influenced by different levels of Ca application (Table 8 and Appendix XXVIII). However, The highest diameter of fruits (4.86 cm) was obtained from the treatment, C_3 (150 ppm Ca) and The lowest diameter of fruits (4.11 cm) was observed from the treatment, Ca_0 (0 ppm Ca).

The considerable influence was observed on the diameter of fruits affected by the combined effect of variety and calcium (Table 9 and Appendix XXVII). The highest diameter of fruits 5.60 (cm) was found from the treatment combination of V_2C_3 which was statistically similar to V_2C_2. The lowest diameter of fruits (3.33 cm) was achieved from the treatment combination of V_3C_0 which was also statistically similar to V_1C_0 and V_3C_1.

Table 8. Length of fruits and diameter of fruits as influenced by variety and Ca

Treatment	Length of fruits (cm)	Diameter of fruits (mm)
Variety		
V_1	5.34b	4.23b
V_2	7.22a	5.44a
V_3	5.68b	3.82b
Sgn. Level (P)	0.000	0.000
SE(±)	0.163	0.148
Calcium		
C_0	5.53	4.11
C_1	6.11	4.43
C_2	6.13	4.59
C_3	6.54	4.86
Sgn. Level (P)	NS	NS
SE(±)	0.163	0.148

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Table 9. Length of fruits and diameter of fruits as influenced by combined effect of variety and Ca

Treatment	Length of fruits (mm)	Diameter of fruits (mm)
V_1C_0	4.63e	3.70ef
V_1C_1	5.83bc	4.33de
V_1C_2	5.90bc	4.43c-e
V_1C_3	6.37b	4.47c-e
V_2C_0	7.07a	5.30a-d
V_2C_1	7.20a	5.40a-c
V_2C_2	7.07a	5.47ab
V_2C_3	7.53a	5.60a
V_3C_0	4.93de	3.33f
V_3C_1	5.30cd	3.57d-f
V_3C_2	5.43cd	3.87ef
V_3C_3	5.70c	4.50b-e
SE(±)	0.163	0.148
Sgn. Level (P)	0.000	0.000

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.3 Yield parameters

4.3.1 Individual fruit weight

Considerable variation was observed on individual fruit weight affected by different varieties of sweet pepper (Table 10 and Appendix XXIX). The highest individual fruit weight (35.17 g) was found from the variety, V_2 (Green California wonder) which was statistically similar to V_3 (Red master F_1). The lowest individual fruit weight (27.08 g) was observed from the variety, V_1 (Yellow master F_1). Vijaya *et al.* (2014) also found a similar result which supported the present study.

Individual fruit weight was significantly influenced by different levels of Ca application (Table 10 and Appendix XXIX). The highest individual fruit weight (38.00 g) was obtained from the treatment, C_3 (150 ppm Ca) followed by C_2 (100 ppm Ca). The lowest individual fruit weight (24.33 g) was observed from the treatment, Ca_0 (0 ppm Ca).

Significant variation was observed on individual fruit weight influenced by the combined effect of variety and calcium (Table 11 and Appendix XXIX). The highest individual fruit weight (43.00 g) was found from the treatment combination of V_2C_3 which was significantly different from all other treatment combinations followed by V_2C_2. The lowest individual fruit weight (21.00 g) was achieved from the treatment combination of V_1C_0 followed by V_3C_0.

4.3.2 Yield per plant

The recorded data on yield per plant was significant due to different varieties of sweet pepper (Table 10 and Appendix XXX). The highest yield per plant (418.42 g) was found from the variety, V_2 (Green California wonder) where the lowest yield per plant (255.33 g) was observed from the variety, V_1 (Yellow master F_1) which was statistically identical with V_3 (Red master F_1). The result obtained from the present study was conformity with the findings of Farooq *et al.* (2015) and Vijaya *et al.* (2014).

Remarkable variation was observed on yield per plant influenced by different levels of Ca application (Table 10 and Appendix XXX). The highest yield per plant (483.44 g) was obtained from the treatment, C_3 (150 ppm Ca) followed by C_2 (100 ppm Ca). The lowest yield per plant (157.00 g) was observed from the treatment, Ca_0 (0 ppm Ca) followed by C_1 (50 ppm Ca).

Significant influence was noted on yield per plant affected by the combined effect of variety and calcium (Table 11 and Appendix XXX). The highest yield per plant (645.67 g) was found from the treatment combination of V_2C_3 which was significantly different from all other treatment combinations followed by V_2C_2. The lowest yield per plant (105.67 g) was achieved from the treatment combination of V_1C_0 which was statistically similar to V_2C_0.

Table 10. Individual fruit weight and yield per plant as influenced by variety and Ca

Treatment	Individual fruit weight (g)	Yield per plant (g)
Variety		
V_1	27.08b	255.33b
V_2	35.17a	418.42a
V_3	30.75ab	285.83b
Sgn. Level (P)	0.000	0.000
SE(±)	1.037	26.132
Calcium		
C_0	24.33d	157.00d
C_1	28.78c	258.11c
C_2	32.89b	380.89b
C_3	38.00a	483.44a
Sgn. Level (P)	0.000	0.000
SE(±)	1.037	26.132

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1
C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Table 11. Individual fruit weight and yield per plant as influenced by combined effect of variety and Ca

Treatment	Individual fruit weight (g)	Yield per plant (g)
V_1C_0	21.00h	105.67f
V_1C_1	25.33fg	220.00def
V_1C_2	29.00d	300.00cde
V_1C_3	33.00c	395.67bc
V_2C_0	27.00ef	207.00ef
V_2C_1	33.00c	330.67cd
V_2C_2	37.67b	490.33b
V_2C_3	43.00a	645.67a
V_3C_0	25.00g	158.33f
V_3C_1	28.00de	223.67def
V_3C_2	32.00c	352.33c
V_3C_3	38.00b	409.00bc
SE(±)	1.037	26.132
Sgn. Level (P)	0.004	0.021

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

4.4 Blossom end rot (BER) affected parameter

4.4.1 Number of fruits plant^{-1} affected by BER

Remarkable variation was observed on a number of fruits plant^{-1} affected by BER influenced by yield per plant (Table 12 and Appendix XXXI). The highest number of fruits plant^{-1} affected by BER (3.58) was found from the variety, V_2 (Green California wonder) which was statistically identical with V_3 (Red master F_1). The lowest number of fruits plant^{-1} affected by BER (2.50) was observed from the variety, V_1 (Yellow master F_1). Olle and Bender (2009) and Rhim and Jebari (2008) also found a similar result which supported the finding.

Different levels of Ca application showed significant influence on a number of fruits plant^{-1} affected by BER (Table 12 and Appendix XXXI). The highest number of fruits plant^{-1} affected by BER (4.89) was obtained from the treatment, Ca_0 (0 ppm Ca) followed by C_1 (50 ppm Ca). The lowest number of fruits plant^{-1} affected by BER (1.67) was observed from the treatment, C_3 (150 ppm Ca) followed by C_2 (100 ppm Ca). Terraza *et al*. (2008) and Manishi *et al*. (1996) also found a similar result which supported the present study.

The combined effect of variety and calcium showed significant influence on a number of fruits plant^{-1} affected by BER (Table 13 and Appendix XXXI). The highest number of fruits plant^{-1} affected by BER (5.67) was found from the treatment combination of V_2C_0 which was significantly different from all other treatment combinations followed by V_3C_0. The lowest number of fruits plant^{-1} affected by BER (1.00) was achieved from the treatment combination of V_1C_3 which was statistically similar to the treatment combination of V_1C_2.

Table 12. Number of fruits affected by BER influenced by variety and Ca

Treatment	No. of fruits plant^{-1} affected by BER
Variety	
V_1	2.50
V_2	3.58
V_3	3.00
Sgn. Level (P)	0.000
SE(±)	0.227
Calcium	
C_0	4.89a
C_1	3.11b
C_2	2.44c
C_3	1.67d
Sgn. Level (P)	0.000
SE(±)	0.227

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1
C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

Table 13. Number of fruits affected by BER influenced by the combined effect of variety and Ca

Treatment	Fruits affected by BER
V_1C_0	4.33bc
V_1C_1	3.00de
V_1C_2	1.67gh
V_1C_3	1.00h
V_2C_0	5.67a
V_2C_1	3.67cd
V_2C_2	3.00de
V_2C_3	2.00fg
V_3C_0	4.67b
V_3C_1	2.67ef
V_3C_2	2.67ef
V_3C_3	2.00fg
SE(±)	0.227
Sgn. Level (P)	0.150

V_1 =Yellow master F_1, V_2 =Green California wonder, V_3 =Red master F_1

C_0 =0 ppm Ca, C_1=50 ppm Ca, C_2 =100 ppm Ca, C_3=150 ppm Ca

CHAPTER V SUMMARY AND

CONCLUSION

The pot experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to March 2018 to study the influence of calcium on different varieties of sweet pepper (*Capsicum annum*) to reduce the incidence of blossom end rot (BER). The two-factor experiment was conducted *viz*. Factor A: three sweet pepper varieties; V_1 = Yellow master F_1, V_2 = Green California wonder and V_3 = Red master F_1 and Factor B: four calcium levels; Ca_0 = 0 ppm Ca, Ca_1 = 50 ppm Ca, Ca_2 = 100 ppm Ca and Ca_3 = 150 ppm Ca. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. Data on different growth, yield components and yield and also on BER affected fruit of sweet pepper were recorded. Variety and calcium (Ca) individually and also their combination showed significant variation for most of the parameters.

In terms of varietal performance, considering growth characters, the highest plant height (16.03, 29.63, 38.95 and 52.72 cm at 30, 60, 90 DAT and at harvest, respectively), highest number of leaves plant^{-1} (25.00, 47.17, 66.50 and 77.08 at 30, 60, 90 DAT and at harvest, respectively), highest number of branches plant^{-1} (1.58, 3.33, 5.25 and 6.17 at 30, 60, 90 DAT and at harvest, respectively), highest stem length (7.75, 15.08, 20.33 and 24.33 cm at 30, 60, 90 DAT and at harvest, respectively) and highest stem breadth (0.24, 0.52, 0.66 and 0.92 cm at 30, 60, 90 DAT and at harvest, respectively) were found from the variety, V_2 (Green California wonder). The lowest plant height (13.15, 24.91, 34.96 and 45.59 cm at 30, 60, 90 DAT and at harvest, respectively), number of leaves plant^{-1} (18.08, 34.33, 51.75 and 62.25 at 30, 60, 90 DAT and at harvest, respectively), number of branches plant^{-1} (1.00, 1.67, 2.67 and 3.50 at 30, 60, 90 DAT and at harvest, respectively), stem

length (6.58, 12.42, 16.67 and 20.33 cm at 30, 60, 90 DAT and at harvest, respectively) and stem breadth (0.14, 0.28, 0.39 and 0.52 cm at 30, 60, 90 DAT and at harvest, respectively) were observed from the variety, V_1 (Yellow master F_1). Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (34.58), number of fruits plant^{-1} (11.42), length of fruits (7.22 cm), diameter of fruits (5.44 cm), individual fruit weight (35.17 g) and yield per plant (418.42 g) were also found from the variety, V_2 (Green California wonder). The lowest days to 50% flowering (84.75 days) was also observed from the variety, V_2 (Green California wonder). Again, the lowest number of fruits plant^{-1} (9.00) was observed from the variety, V_1 (Yellow master F_1), length of fruits (5.34 cm) was observed from the variety, V_1 (Yellow master F_1), individual fruit weight (27.08 g) was observed from the variety, V_1 (Yellow master F_1) and yield per plant (255.33 g) were observed from the variety, V_1 (Yellow master F_1) but the lowest number of flowers plant^{-1} (23.42) and diameter of fruits (3.82 cm) and highest days to 50% flowering (90.42 days) were observed from the variety, V_3 (Red master F_1) In case of blossom end rot affected fruit, V_2 (Green California wonder) showed more susceptibility than the variety V_1 (Yellow master F_1) and V_3 (Red master F_1). The highest number of fruits plant^{-1} affected by BER (3.58) was found from the variety, V_2 (Green California wonder) where the lowest number of fruits plant^{-1} affected by BER (2.50) was observed from the variety, V_1 (Yellow master F_1)

Different calcium (Ca) levels of application showed significant variation for most of the studied parameters. Considering, growth parameters, the highest plant height (15.61, 28.61, 37.90 and 50.66 cm at 30, 60, 90 DAT and at harvest, respectively), number of leaves plant^{-1} (24.22, 43.89, 61.11 and 70.78 at 30, 60, 90 DAT and at harvest, respectively), number of branches plant^{-1} (1.33, 2.67, 3.93 and 5.00 at 30, 60, 90 DAT and at harvest, respectively), stem length (7.78, 14.00, 19.67 and 22.33 cm at 30, 60, 90 DAT and at harvest, respectively) and stem breadth (0.20, 0.40, 0.52 and 0.69 cm at 30, 60, 90 DAT and at harvest, respectively) were obtained from the

treatment, Ca_3 (150 ppm Ca). The lowest days to 50% flowering (88.11 days) was observed from the treatment, Ca_2 (100 ppm Ca). Similarly, the lowest plant height (12.88, 23.50, 33.94 and 46.49 cm at 30, 60, 90 DAT and at harvest, respectively), number of leaves plant^{-1} (17.22, 34.67, 53.11 and 61.78 at 30, 60, 90 DAT and at harvest, respectively), number of branches plant^{-1} (1.10, 2.23, 3.44 and 3.89 at 30, 60, 90 DAT and at harvest, respectively) was observed from the treatment, Ca_0 (0 ppm Ca), stem length (6.67, 12.67, 17.44 and 21.11 cm at 30, 60, 90 DAT and at harvest, respectively) and stem breadth (0.17, 0.34, 0.49 and 0.62 cm at 30, 60, 90 DAT and at harvest, respectively) were observed from the treatment, Ca_0 (0 ppm Ca). The highest days to 50% flowering (89.00 days) was obtained from the treatment, Ca_1 (50 ppm Ca). Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (30.22), number of fruits plant^{-1} (13.44), length of fruits (6.54 cm), diameter of fruits (4.86 cm), individual fruit weight (38.00 g) and yield per plant (483.44 g) were also obtained from the treatment, Ca_3 (150 ppm Ca) where the lowest number of flowers plant^{-1} (26.33), number of fruits plant^{-1} (6.33), length of fruits (5.53 cm), diameter of fruits (4.11 cm), individual fruit weight (24.33 g) and yield per plant (157.00 g) were observed from the treatment, Ca_0 (0 ppm Ca). In case of blossom end rot, Ca_3 (150 ppm Ca) showed better performance to control blossom end rot effect in fruit compared to Ca_1 (50 ppm Ca) and control treatment. The lowest number of fruits plant^{-1} affected by BER (1.67) was observed from the treatment, Ca_3 (150 ppm Ca) where the highest number of fruits plant^{-1} affected by BER (4.89) was obtained from the treatment, Ca_0 (0 ppm Ca).

The combined effect of variety and Ca application, most of the studied parameters showed significant variation among the treatments. In terms of growth parameters, the highest plant height (17.47, 32.33, 40.77 and 54.47 cm at 30, 60, 90 DAT and at harvest, respectively), number of leaves plant^{-1} (29.67, 54.33, 70.00 and 80.67 at 30, 60, 90 DAT and at harvest, respectively), number of branches plant^{-1} (2.00, 3.67, 5.67 and 6.67 at 30, 60, 90 DAT and at harvest, respectively), stem length (8.33,

16.00, 21.67 and 25.00 cm at 30, 60, 90 DAT and at harvest, respectively) and stem breadth (0.27, 0.57, 0.73 and 0.93 cm at 30, 60, 90 DAT and at harvest, respectively) were found from the treatment combination of V_2C_3. Regarding yield and yield contributing parameters, the highest number of flowers plant^{-1} (38.33), number of fruits plant^{-1} (15.00), length of fruits (7.53 cm), diameter of fruits 5.60 (cm), individual fruit weight (43.00 g) and yield per plant (645.67 g) were also found from the treatment combination of V_2C_3. But the lowest days to 50% flowering (84.00 days) was achieved from the treatment combination of V_2C_2. The lowest plant height (12.13, 19.77, 32.07 and 41.90 cm at 30, 60, 90 DAT and at harvest, respectively), number of leaves plant^{-1} (15.33, 29.33, 48.00 and 57.00 at 30, 60, 90 DAT and at harvest, respectively), number of branches plant^{-1} (1.00, 1.00, 2.00 and 3.00 at 30, 60, 90 DAT and at harvest, respectively), plant (6.00, 11.33, 15.33 and 18.33 cm at 30, 60, 90 DAT and at harvest, respectively) and stem breadth (0.10, 0.23, 0.36 and 0.47 cm at 30, 60, 90 DAT and at harvest, respectively) were achieved from the treatment combination of V_1C_0 but the number of fruits plant^{-1} (5.00), length of fruits (4.63 cm), individual fruit weight (21.00 g) and yield per plant (105.67 g) were achieved from the treatment combination of V_1C_0 where the lowest diameter of fruits (3.33 cm) and number of flowers plant^{-1} (21.00) were achieved from the treatment combination of V_3C_0. Again, the highest days to 50% flowering (91.00 days) was found from the treatment combination of V_3C_1. In case of blossom end rot, the lowest number of fruits plant^{-1} affected by BER (1.00) was achieved from the treatment combination of V_1C_3 where the highest number of fruits plant^{-1} affected by BER (3.67) was found from the treatment combination of V_2C_0.

From the above result, it can be concluded that the variety, V_2 performed best regarding yield and yield attributes compared to V_1 and V_3 but V_1 performed best against BER. Considering Ca treatment, C_3 gave the best performance regarding yield performance and also against BER. In terms of combined effect, V_2C_3 showed a

better result on yield and yield attributes but V_1C_3 showed better performance against BER.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

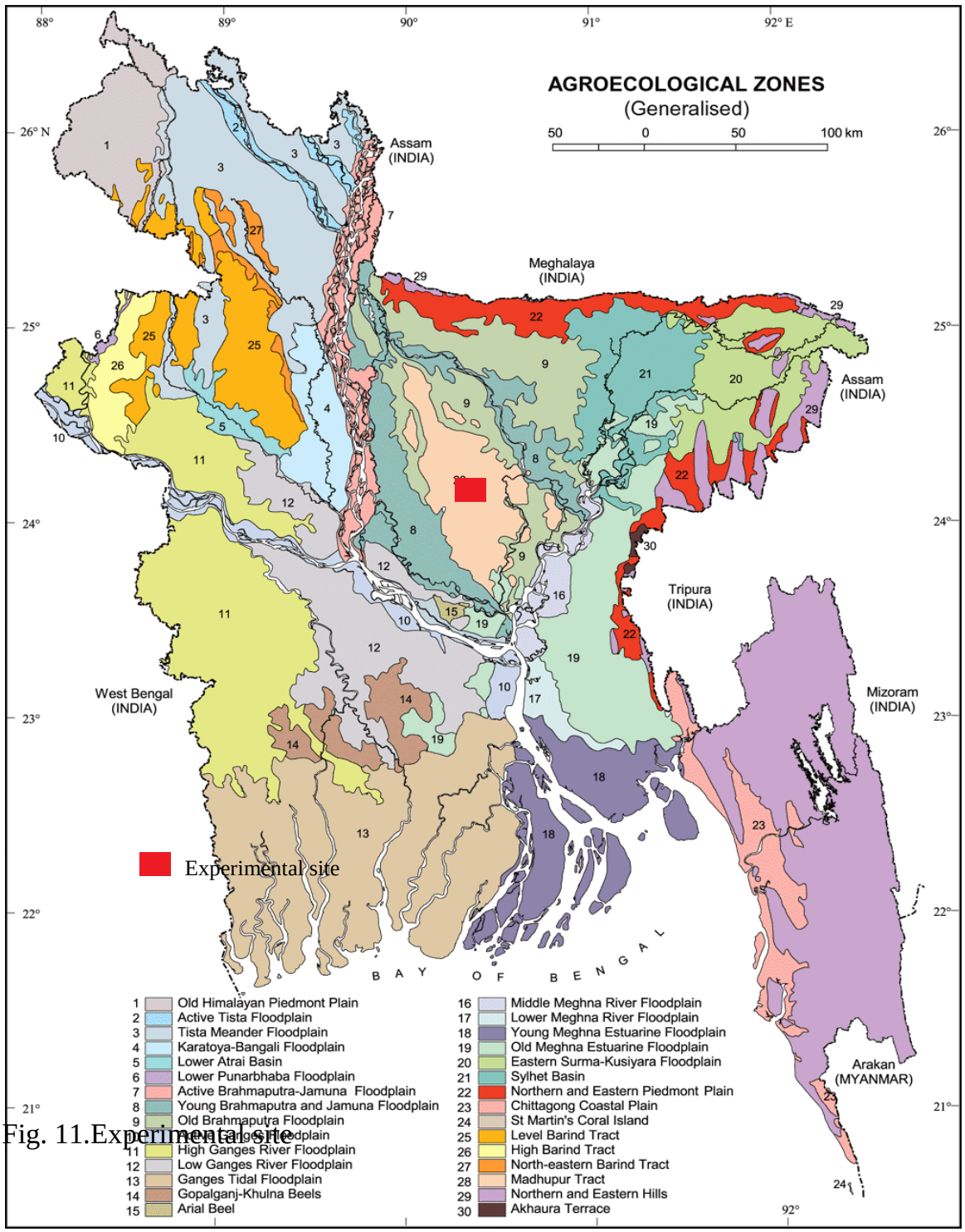

Fig. 11.Experimental site

. **Appendix II. Monthly record of air temperature, rainfall, relative humidity, rainfall and Sunshine of the experimental site during the period from October 2017 to April 2018**

Month	*Air temperature (°c)		*Relative humidity (%)	*Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
October, 2017	24.32	17.22	75	13	7.2
November, 2017	25.82	16.04	78	00	6.8
December, 2017	22.40	13.50	74	00	6.3
January, 2018	24.50	12.40	68	00	5.7
February, 2018	27.10	16.70	67	30	6.7
March, 2018	31.40	19.60	54	11	8.2
April, 2018	34.20	23.40	61	112	8.1

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Horticulture Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV.Analysis of variance on plant height at 30 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	59.055	29.527	13.799	0.000
Calcium	3	34.039	11.346	3.797	0.020
Variety × Calcium	11	100.074	9.098	7.378	0.000

Appendix V. Analysis of variance on plant height at 60 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	214.387	107.194	18.527	0.00
Calcium	3	121.925	40.642	4.589	0.009
Variety × Calcium	11	381.030	34.639	34.221	0.000

Appendix VI.Analysis of variance on plant height at 90 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	157.021	78.510	20.811	0.000
Calcium	3	77.432	25. 811	4.047	0.015
Variety × Calcium	11	266.516	24.229	38.766	0.000

Appendix VII. Analysis of variance on plant height at harvest

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	362.909	181.454	28 437	0.000
Calcium	3	111.968	37.323	2.588	0.070
Variety × Calcium	11	528.683	48.062	25.748	0.000

Appendix VIII. Analysis of variance on no.of leaves at 30 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	329.056	164.528	14.550	0.000
Calcium	3	274.000	91.333	6.825	0.001
Variety × Calcium	11	645.556	58.687	24.856	0.000

Appendix IX.Analysis of variance on no. of leaves at 60 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	1194.889	597.444	34.772	0.000
Calcium	3	460.556	153.519	3.775	0.020
Variety × Calcium	11	1711.222	155.566	73.689	0.000

Appendix X. Analysis of variance on no. of leaves at 90 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	1597.389	798.694	64.892	0.000
Calcium	3	320.000	106.667	2.027	0.130
Variety × Calcium	11	1925.556	175.051	53.862	0.000

Appendix XI. Analysis of variance on no.of leaves at harvest

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	1712.167	856.083	39.356	0.000
Calcium	3	434.000	144.667	2.319	0.094
Variety × Calcium	11	2250.000	204.545	27.273	0.000

Appendix XII.Analysis of variance on stem length at 30 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	8.222	4.111	9.633	0.001
Calcium	3	7.194	2.398	5.078	0.005
Variety × Calcium	11	17.639	1.604	8.247	0.000

Appendix XIII.Analysis of variance on stem length at 60 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	53.556	26.778	17.412	0.000
Calcium	3	8.083	2.694	0.896	0.454
Variety × Calcium	11	70.306	6.391	4.512	0.000

Appendix XIV.Analysis of variance on stem length at 90 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	80.722	40.361	10.895	0.000
Calcium	3	23.861	7.954	1.421	0.255
Variety × Calcium	11	148.306	13.482	5.919	0.000

Appendix XV. Analysis of variance on stem length at harvest

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	114.000	57.000	17.914	0.000
Calcium	3	7.667	2.556	0.387	0.763
Variety × Calcium	11	165.000	15.000	6.667	0.000

Appendix XVI.Analysis of variance on stem breadth at 30 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	0.065	0.033	12.618	0.000
Calcium	3	0.006	0.002	0.410	0.747
Variety × Calcium	11	0.090	0.008	3.273	0.007

Appendix XVII.Analysis of variance on stem breadth at 60 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	0.424	0.212	47.152	0.000
Calcium	3	0.014	0.005	0.276	0.842
Variety × Calcium	11	0.479	0.044	11.195	0.000

Appendix XVIII.Analysis of variance on stem breadth at 90 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	0.482	0.241	38.345	0.000
Calcium	3	0.001	0.000	0.013	0.998
Variety × Calcium	11	0.530	0.048	7.223	0.000

Appendix XIX. Analysis of variance on stem breadth at harvest

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	1.125	0.563	36.044	0.000
Calcium	3	0.024	0.008	0.161	0.922
Variety × Calcium	11	1.167	0.106	5.378	0.000

Appendix XX.Analysis of variance on no. of branch per plant at 30 DAT.

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	2.389	1.194	10.283	0.000
Calcium	3	0.444	0.148	0.821	0.492
Variety × Calcium	11	3.556	0.323	2.909	0.014

Appendix XXI. Analysis of variance on no. of branch per plant at 60 DAT

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	16.722	8.361	22.524	0.000
Calcium	3	0.528	0.176	0.198	0.897
Variety × Calcium	11	20.306	1.846	5.112	0.000

Appendix XXII. Analysis of variance on no. of branch per plant at 90 DAT

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	42.389	21.194	44.174	0.000
Calcium	3	1.333	0.444	0.250	0.861
Variety × Calcium	11	47.556	4.323	9.727	0.000

Appendix XXIII. Analysis of variance on no. of branch per plant at harvest

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	49.389	24.694	41.613	0.000
Calcium	3	5.861	1.954	0.991	0.410
Variety × Calcium	11	56.972	5.179	10.359	0.000

Appendix XXIV. Analysis of variance on days to 50% flowering

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	256.889	128.444	100.721	0.000
Calcium	3	4.083	1.361	0.148	0.930
Variety × Calcium	11	263.639	23.967	16.280	0.000

Appendix XXV. Analysis of variance on no. of flowers per plant

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	780.167	390.083	80.539	0.000
Calcium	3	69.556	23.185	0.852	0.476
Variety × Calcium	11	900.000	81.818	49.091	0.000

Appendix XXVI. Analysis of variance on no. of fruits per plant

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	37.389	18.694	2.175	0.130
Calcium	3	257.639	85.880	43.392	0.000
Variety × Calcium	11	299.639	27.240	30.645	0.000

Appendix XXVII. Analysis of variance on length of fruits

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	23.934	11.967	41.911	0.000
Calcium	3	4.465	1.488	1.649	0.198
Variety × Calcium	11	30.203	2.746	20.898	0.000

XXVIII. Analysis of variance on diameter of fruits

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	17.097	8.549	27.197	0.000
Calcium	3	2.610	0.870	1.120	0.356
Variety × Calcium	11	20.703	1.882	6.675	0.000

Appendix XXIX. Analysis of variance on individual fruit weight

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	393.167	196.583	6.738	0.004
Calcium	3	917.556	305.852	22.323	0.000
Variety × Calcium	11	1330.667	120.970	114.603	0.000

Appendix XXX. Analysis of variance on yield per plant

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	180419.056	90209.528	4.378	0.021
Calcium	3	547386.306	182462.102	18.650	0.000
Variety × Calcium	11	763204.972	69382.270	17.123	0.000

Appendix XXXI. Analysis of variance on fruits affected by BER

Source of variation	Df	SS	MS	F - Value	Significance
Variety	2	7.056	3.528	2.010	0.150
Calcium	3	50.972	16.991	38.836	0.000
Variety × Calcium	11	60.306	5.482	28.195	0.000