YIELD AND QUALITY OF ONION SEED AS INFLUENCED BY BORON AND CALCIUM

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CERTIFICATE

*This is to certify that thesis entitled, "***YIELD AND QUALITY OF ONION SEED AS INFLUENCED BY BORON AND CALCIUM***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) IN INSTITUTE OF SEED TECHNOLOGY, embodies the result of a piece of bona-fide research work carried out by MIRZA GOLAM MORSHED, Registration no. 10-03981 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.

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YIELD AND QUALITY OF ONION SEED AS INFLUENCED BY BORON AND CALCIUM

BY

Mirza Golam Morshed

ABSTRACT

A field experiment with BARI Piaz-1 was conducted in the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the winter season (October to February) to investigate the performance of boron and calcium. The experiment was carried out with four levels of boron viz. B_0 (0ppm), B_1 (500ppm), B_2 (1000ppm) and B_3 (2000ppm); and three level of calcium viz. C_0 (0ppm), C_1 (2500ppm) and C_2 (5000ppm). This experiment was laid out in RCBD (Randomized Complete Block Design) with three replications and 12 treatment combinations. The results showed that the treatments significantly influenced the plant height and number of leaves at all growth stages except harvesting time. At harvest boron and calcium significantly increased the umbel plot^{-1}, flowers umbel^{-1}, fruits umbel^{-1}, fruit set (%), yield plant^{-1}, yield per plot, 1000-seed weight, yield ha^{-1}, germination percentage and normal seedling percentage; and reduced the abnormal seedling percentage. Combined application of boron and calcium also significantly increased the all above parameters mentioned except abnormal seedling percentage of onion. The highest result of all parameters showed in above excluding abnormal seedling percentage from B_3 (2000ppm) and C_2 (5000ppm) treatment. B_3 and C_2 treatment reduced production of abnormal seedling. Among the combined treatment of boron and calcium B_3C_2 (2000ppm boron and 5000ppm calcium) gave the highest plant height, leaf number and chlorophyll content. But after reviewing the combined effects of both treatments, application of 2000 ppm of boron together with 5000 ppm of calcium (B_3C_2) treatment gave the best performance showing the yield and quality of onion seed.

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LIST OF ABBREVIATIONS

%	Percent
AEZ	Agro-Ecological Zone
B	Boron
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Ca	Calcium
cm	Centimeter
Cont'd	Continued
CV%	Percentage of Coefficient of Variance
DAP	Days after planting
DF	Degree of freedom
et al.	and others
FAO	Food and Agriculture Organization
g	Gram
ha	Hectare
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LSD	Least significant difference
m^2	Square meter
mg cm^{-2}	Milligram per square centimeter
ppm	Parts-per million
PSII	Photo-system II
q/ha	Quintal per hectare
RNA	Ribonucleic acid
SPAD	Soil Plant Analysis Development
viz.	Namely
WP	Wettable powder

Chapter 1

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the Alliaceae family and it is one of the most important commercial spice in Bangladesh as well as earliest vegetable crops worldwide. Also onion is the oldest known major bulbous crop among the cultivated spice crops. According to economic and social reviews of Bangladesh, onion outruns all other spice crops. Among the spice crops grown in Bangladesh, onion ranks the top in respect of production and area. It is used as a fresh vegetable, as a spice and as an ingredient of curry, sauce, soup, pickles, seasoning food, etc. It is also used as medicinal preparations (in the prevention of 'atherosclerosis' and 'coronary heart disease', diuretic and heart stimulant). According to Jones and Mann (1963), onion is originated between western China and the deserts lying east of the Caspian Sea. On the basis of FAO the major onion producing countries of the world are China, India, USA, Japan, Turkey, Spain, Brazil, Poland and Egypt. In Bangladesh, onion is grown in an area of 86,429 hectares and total onion production is 5,89,410 m tons. FAO (2018) reported that worldwide 60 million tons of dry onions are produced annually, with the crop grown across 3.0 million hectares in over 134 different countries.

BBS (2017) reported that the average yield of onion in Bangladesh was 10.27 tons per hectare being produced from1.85 lakh hectares of land in 2016-17 with production 19 lakh tons of onion but imported 15 lakh tons of onion in the same year. There was a shortage of 8.05 lakh tons in that particular year (BBS, 2017). To meet the shortage of onion, Bangladesh has to import onion from India and China every year as reported by Hossain and Islam (1994). FAO (2006) showed that the yield of onion in Bangladesh is very low (5.08 t/ha in 2006) compared to the world average yield (17.00 t/ ha) and it remained nearly the same for the last five years.

Onion is grown in all districts in Bangladesh, but Faridpur is the largest producer of onion. However, seeds are produced by limited number of farmers in limited areas such as Faridpur, Natore and Rajshahi districts of Bangladesh (BBS, 2016). Moreover, the availability of seeds at market is often very poor in terms of seed viz. quality germination, varietal purity and seed viability. Lower seed production in a limited areas is caused by the scarcity of quality onion seed during the growing season in Bangladesh. Bangladesh requires some 1,300 tons of onion seed per year. Of them, about 300 tons are managed through farmer-to-farmer exchange while seed firms can supply 100 tons and the remaining seed comes through importing (BBS, 2017). There are still opportunities to increase the yield of onion seed by modifying the cultivation practices including fertilization in particular with boron and calcium and also by adopting other cultural management practices.

Successful seed production of onion relies on specific environmental conditions. Moreover, onion cultivars are very sensitive to their growing environment particularly temperature and photoperiod (Rahim *et al*., 1982). The plant growth and yield of onion seed are greatly influenced by a number of factors such as optimization of fertilizer application (macro and micronutrients) and conservation of soil moisture (Anez, 1996 and Singh *et al*., 1996).

Boron is a vital micronutrient for increasing the onion seed production. Many researchers have the opinion that some secondary and trace elements like boron (B)and manganese (Mn) can play vital role in escalating the yield of onion seed (Rao and Deshpande, 1971). Relatively small amount of B is required for plant growth and development. Protch and Islam (1984) evidenced that B deficiency in Bangladesh soils is widespreading. Application of micronutrients to soil deficient in these soils has shown remarkable increase in yield of several crops, partisularly of seed production and high quality grain production. Micronutrients play a vital role in the plant metabolic process from cell wall development to respiration, photosynthesis, chlorophyll formation, enzymes activity, nitrogen fixation etc. Micronutrients also work as a co-factor for a large number of enzymes. In addition, they play an essential role in improving yield and quality (Alam *et al*., 2010, Hansch and Mendel, 2009). Manna and Maity (2016) reported that foliar applications of micronutrient such as boron was effective in improving growth, yield and quality of onion and also reported that it was important for higher seed of onion. Boron is the only nonmetal micronutrient required for new cell development in meristematic tissue of plant (Reid, 2007); proper pollination, fruit and seed weight, translocation of sugars, starch, nitrogen, and phosphorus; and the synthesis of amino acids and proteins (Tisdale et al., 1997). Boron at different doses had significant effects on the production of leaf, plant height, root numbers, seed yield and 1000 seeds weight (Bhonde *et al.*, 1999).

Application of macronutrients (N, P, K,Ca and S fertilizers) is important for production of onion seed. Calcium is one of the important macronutrient for crop growth and development. Calcium is an active component of cells maintaining the structure of cell walls and stabilizing the cell membranes. It also has a direct effect on the salt balance within plant cells and activates potassium ion to regulate the opening and closing of stomata to allow water movement from the plant. Calcium increases pollen germination, regulates some enzyme systems and influences the growth and health of cells and conductive tissues. Calcium has a direct effect on root establishment and elongation as well as early crop growth rate, increasing plant height and vigor. It helps to improve tolerance to diseases. Various studies reported that improvements in fruit and vegetable firmness when supplemental Ca is supplied during growth (DeEll *et al.*, 2001; Manganaris *et al.*, 2006;). In addition to improvements in firmness, Ca applications can exaggerate disease resistance in some crops (Conway *et al.*, 1991; Volpin and Elad, 1991). Sullivan *et* *al.*, (1974) showed that calcium deficiency has also been shown to decrease seed quality by inhibiting plumule development.

BARI Piaz-1 is a modern variety of onion growing widely throughout Bangladesh. Seeds of this variety are produced by bulb to seed method in some particular areas of the country. The available information on the effects of plant nutrients particularly of B and Ca on seed production of BARI Piaz-1 under Bangladesh condition is not fully decisive.

Research work on effects of B and Ca on seed production is negligible in Bangladesh. Considering with the all above situations, the present research work has been undertaken to study the effects of B and Ca on seed production of onion with the following objectives:

1. To optimize different levels of B on growth, yield and quality seed production of onion,
2. To determine the optimum level of Ca on growth, yield and quality seed production of onion, and
3. To assess the suitable combination of B and Ca on growth , yield and quality seed production of onion

Chapter 2

REVIEW OF LITERATURE

Onion is an important spice crop in Bangladesh. Application of boron (B) and calcium (Ca) fertilizer plays an important role on growth, yield and quality seed production of Onion. The literature dealing with the effects of B and Ca on the yield and quality seed production of onion is inaccessible. However, the incidental literatures so far available are reviewed in this chapter.

2.1 Effect of boron

In 2000 Madal carried out a field experiment with 13 cultivars using three boron levels 0, 10 and 15kg boron per hectare. They found that all the cultivars showed significant response to boron. Maurya and Lal (1975) reported that1ppm rate of boron gave the best response in terms of leaf and root numbers and fresh and dry weights of plant and bulb of Poona Red onion. They also found that 2ppm of boron application gave the higher plant height.

Hossain *et al*. (2017) found that the highest seed yield (879.9 kg/ha) were recorded from 3kgB/ha with Zn and Mn. Boron application increased yield by 24-40% and also increase the storage time. Chemsiri *et al.* (1995) found that higher garlic yield was found in boron treated field than without boron. Significant increases in onion leaves, plant height, bulb diameter, bulb fresh weight, dry matter content and bulb yield were obtained with a combined application of boron and zinc to the foliage; this gave the 17.07% higher yield than the control (Baghel and Sarnaik, 1988). Sindhu and Tiwari (1993) observed in an experiment that application of boron increased the bulb yield, TSS and total sugar content of onion (27.5tha^{-1}, 15.36% and 16.74%, respectively).

Howlader *et al*. (2010) directed a field experiment at the Spices Research Sub-center Faridpur, during 2009 - 2010 to find out the best requirement of P, K & B for higher seed yield of BARI Piaz–l. Different treatments showed significant sign on onion seed yield. They found their experiment that the highest seed yield was obtained from T9 (P50, K120 and B2 kg/ha + 20% B extra). Saieed *et al*., (2010) showed that the combined treatment boron at 4 kg/ha with molybdenum at 4 kg/ha produced the highest seed yield (695.6 kg/ha) and germination of onion seed 92.3%.

A field experiment was conducted by Rashid *et al*. in 2007 at Spices Research center Bogra, during 2006 - 2007 growing season to find out the best requirement of S and B for plant height, number of leaves, number of flowers per umbel, number of fruits per umbel of BARI Piaz–1. They found the highest seed yield from combined treatment of 100 kg S + 5 kg B/ha.

Reid (2007) observed that boron is required for new cell development in meristematic tissue, also in proper pollination; fruit and seed weight; translocation of sugars, starch, nitrogen, and phosphorus. Chattopadhyay and Mukhopadhyay (2004) directed an experiment on the response of onion seed crop to boron and molybdenum as foliar feeding in West Bengal, India. They observed that foliar application of boron at 0, 0.26, 0.56 and 1.12 kg/ha land and molybdenum at 0, 0.10, 0.20 and 0.40 kg/ha land had pronounced effect on plant height and bulb production. Application of boron at the rate of 0.3% significantly increased bulb yield over plants that were not sprayed. The highest bulb production (280.1 t/ha) was recorded from the spray of 1.12 $kgBha^{-1}$.

In 2004 Chowdhury *et al*. directed an experiment at Field Laboratory of USDA *Alliums* Project, Horticulture Farm, Bangladesh Agricultural University, Mymensingh, during 2003 - 2004 to observe the effects of boron and sulphur on seed production of onion *cv.* Taherpuri. The experiment was conducted with five levels of boron treatment *viz*. 0, 1, 2, 3 and 4 kg/ha and five levels of sulphur *viz*. 0, 20, 40, 80 and 160 kg/ha. They recorded the highest seed yield from 4kgBha^{-1}. The positive effects of boron they found were in order to 4> 3> 2> 1> 0 kgBha^{-1}.

Jana and Mukhopadhaya (2002) conducted an experiment to find out the effect of boron and zinc on yield and quality of onion seed production. They reported that higher seed yield and seed quality were observed by applying boron at the rate of 5 kg borax per hectare of land as compared to no boron application field. They also showed that the combined effect of boron and zinc showed significant increase in number of primary inflorescence stalks (8.7 per plant), pods per plant (1085.7) and seed yield (489.3 kg/ha).

A bag pot experiment was conducted on response of onions *cv*. Texas Early Granex 502 to the application of sulphur, magnesium, boron and zinc in alkaline soil in Venezuela (Pena *et al*. 1999). Different combinations of fertilizer treatments were applied to onion. The doses of S, Zn, Mg and B were 16 kg/ha, 2.52 kg/ha, 8 kg/ha and 5.25 kg/ha, respectively, with or without NPK fertilizer (120 kg N, 60 kg P_2O_5 and 120 kg K_2O, respectively). The application of Zn at 2.52 kg/ha as zinc sulphate fertilizer significantly increased the crop yield and bulb weight. The application of Manganese and Boron alone increased the crop yield and bulb weight which was insignificant.

Haque *et al.* (2014) conducted an experiment with Three levels of Zn: 0 kgha^{-1} (control), 7 kgha^{-1}, or 12 kgha^{-1} and three levels of B: 0 kgha^{-1} (control), 6 kgha^{-1}, or 8 kgha^{-1} for assessing the number of umbels per plant, number of seeded fruit per umbel, 1000-seed weight, seed yield, and germination percentage. They found highest seed yield (3.67 g plant^{-1}), seed yield (1073 kgha^{-1}), and germination (89.82%) was from the 12 × 8 kgha^{-1} of Zn and B combination.

Manna *et al.* (2017) carried out an experiment with combination of micro and macro nutrients for observing the seed yield of onion. They found that the application of recommended dose of fertilizers along with Boron (B) @ 1 $kgha^{-1}$ produced higher seed yield (907.55$kgha^{-1}$) followed by recommended dose of fertilizers + Micronutrient Mixture @ 20 $kgha^{-1}$ (870.14 $kgha^{-1}$). Increased yield in this treatment was due to better umbel and yield attributing characteristics.

A field experiment was conducted by Tiwari *et al.* (2003) in Nadia, West Bengal, India to study the effects of boron and zinc on garlic cv. Lalgola production. They used four levels of both B and Zn with same doses (0.015, 0.020, 0.025 and 0.030%) was applied. They sprayed the micronutrients to the plants at 30 and 45 days after transplanting. Among the boron rates, 0.025% of boron resulted in the highest number of leaves (10.87), individual bulb weight (14.19 g), bulb diameter (2.62 cm), individual clove weight (0.64 g) and yield (7.07 tha^{-1}).

In 2001 Gupta and Ganeshe observed a response of Borax and zinc sulphate on growth and yield of garlic in a replicated trial conducted to evaluate the performance of zinc sulphate and Borax in sandy loam soil. Combined application of zinc sulphate and Borax (25$kgha^{-1}$ + 10$kgha^{-1}$) promoted the yield by 45.8$kgha^{-1}$ than the control.

A study was conducted by Setty *et al.* (2005) in Pantnaga, Uttaranchal, India to investigate the effect of Zn and B on the yield, quality and storability of onion. Zinc was applied as zinc sulphate at 0.0, 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2%, while Boron fertilizer was applied as boric acid at 0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0%. The fertilizers were applied at 30 and 60 days after planting of onion. Boric acid at 0.1% resulted in the maximum bulb yield and in the heaviest bulbs than other treatments.

According to the report of Alam *et al*. (2010) that the response of onion to micronutrients in terms of growth and yield in calcareous soils increased over the control treatment. They found that the combination of zinc and boron increased the maximum bulb yield by 49.66% over the control.

Boron is related in numerous important processes, including protein synthesis, transport of sugars, respiration, RNA and carbohydrate metabolism, and the metabolism of plant hormones (indole acetic acid). Moreover, functions of boron are involved to cell wall synthesis, lignification, and cell wall structure by cross-linking of cell wall polysaccharides as well as the structural integrity of bio-membranes. It increases the transport of chlorine and phosphorus as a result of plasma-lemma ATPase enzyme induction. Other investigations have shown that boron can stimulate proton pumping that causes hyper-polarization of the membrane potential (Blevins and Lukaszewski, 1998). More than 90% of the boron in plants is found in cell walls (Maschner, 1995). Since all these functions are fundamental to meristematic tissues, boron deficiency is mainly damaging actively growing organs such as shoot and root tips so that the whole plant may be stunted (rosetting). Flower bearing, pollen formation, pollen tube growth or germination, nitrogen fixation, and nitrate assimilation are also affected by boron (Camacho-Cristobal, 2008).

Smriti *et al.* (2002) showed that the plant height, number of leaves, leaf length, leaf width, bulb size, bulb weight of onion were significantly increased using 40 kg sulphur ha^{-1} and 1 kg boric acid ha^{-1}.

2.2 Effect of calcium

Calcium plays an extremely important role in producing plant tissues and enables plants to grow better. It increases the plant tissues, resistance and allows for more erect stems, contributes to normal root system development, increases resistance to outside attack and increases the feed value of forage crops. Calcium is a non-toxic mineral nutrient and plant cells can tolerate very high concentrations of extracellular Ca (Palta and Lee-Stadelmann, 1983).

Coolong and Randle (2008) carried out an experiment to observe the effects of supplemental $CaCl_2$ on the quality of field-grown onions. They found that Bulb scale firmness increased with supplemental $CaCl_2$ fertility and bulb pungency decreased with additional of $CaCl_2$. Larger applications of $CaCl_2$ may be necessary to realize improvements in firmness during storage. Rahman (2006) reported that oil and protein content of groundnut increased when calcium level was increased from 0 – 100kg/ha. Vigor and germination capacity of the seed increased with increase calcium application. Seeds produced in calcium deficient conditions will exhibit much poorer germination than those produced with adequate calcium supply.

Sullivan *et al*. (1974) conducted an experiment and observed that calcium deficiency showed to decrease seed quality by inhibiting plumule development. These scientists concluded that seed quality of groundnut was influenced by seed Ca concentration, which was known to be affected by seed size and soil Ca fertility during seed production.

Marschner (1995) reported that calcium (Ca^{2+}) plays important structural and signaling roles in plant cells. Onion is a biennial, and must usually undergo vernalization to flower in their second season of growth (Rabinowitch, 1990). Temperature is the primary factor affecting inflorescence development. Generally, bulbs must be exposed to temperatures of 5-10 ºC for a period of one to two months in order for vernalization to occur. The foliar application of calcium salts is a safe and simple method that has been shown to effectively reduce the effect of abiotic stress in various plants, foliar application of CaCl2 was found to improve the heat tolerance by reducing oxidative damage (Larkindale and Huang, 2004). Sultana *et al.* (2001) found in rice (*Oryza sativa*) that the foliar application of CaNO3 was reported to mitigate the adverse effect of salt stress on photosynthesis. Cooke *et al.* (1986) observed that Ca^{2+} ions protect cell membranes from heat injury, possibly by binding directly to the cell membrane to reduce its fluidity under high temperatures. Yang *et al.* (2013) evidenced that the application of exogenous Ca^{2+} sustained the PSII-complex, and improved the rates of photosynthesis.

Mild-flavored, sweet onions are often soft and highly susceptible to disease during storage and for this reason improvements in firmness is required. Ca applications can enhance disease resistance in some crops (Conway *et al*., 1991; Volpin and Elad, 1991).

Somers (1973) reported that onion cell walls had a high affinity for Ca^{2+} ions. Earlier studies on the effects of Ca^{2+} fertility on onion were focused on nutrient balancing or yield (Boyhan *et al.*, 2002; Coolong *et al.*, 2004).

Hirschi (2004) observed that calcium was bound to the outer surface of the plasma membrane and maintained membrane stability and cell integrity. In addition, calcium acts as a second messenger, coupling stimuli such as stress, light and plant hormones to a response (Sanders *et al*., 1999).

Stark and Westermann (2003) recommended that when the exchangeable soil Ca concentration was less than 300 mg $kgha^{-1}$ a pre-plant application of 224 kg ha^{-1} of Ca was essential for plant growth.

Onion nutrient contents and bulb mineral uptakes were examined by Fink *et al.*, (1999) to determine the nutritional status for optimum yield.. Bosch Serra (1999) reported that the equilibrium N:P:K:Ca:Mg for onion bulb nutrient uptakes was 8:1:9:2:0.3 in bulb dry-matter yields of around 11–13 t ha^{-1}. Soil bulk density at the initial bulbing was positively correlated with DM, C, Ca, Mg, etc., in the bulb at harvest. Soil available P content at the initial bulbing showed strongly negative correlation with dry matter (DM), car-bon (C), calcium (Ca), magnesium (Mg) and iron (Fe) at harvest (Lee and Lee, 2014).

Ruamrungsri and Inkham (2017) conducted a field experiment with five calcium nitrate solutions i.e., 0, 50, 100, 150 and 200mgL^{-1}. The experimental design was completely randomized design (CRD) with three replications per treatment (10 plants replication^{-1}). The results showed that at bulbs harvest stage, applying additional calcium nitrate significantly affected the number of leaves per plant and leaf length of *Hippeastrum*. Plant supplied with calcium nitrate at 150 and 200 mg L^{-1} treatments gave higher results in the number of leaves per plant than plant supplied with calcium nitrate at 0 and 50mgL^{-1} treatments. Bulb quality in terms of bulb fresh weight and root length was affected by treatments.

According to onion fertilization guideline during the early stages, Calcium (Ca), Boron (B), Zinc (Zn), and Iron (Fe) are key elements for the formation and development of plant tissue, and they also increase the production of storage substances and boost bulb formation. Calcium (Ca) also promotes healthy bulb formation, improves their qualitative characteristics, and increases their storability after the harvest.

DeEll *et al.* (2001) reported that calcium fertility has often been considered important in determining cell wall strength and firmness of fruits and vegetables.

Manganaris *et al*. (2006) found that improvement in firmness of fruits and vegetables when supplemental calcium is applied during growth stage.

Marschner (1995) observed that calcium with leaf values typically ranging from 0.1 to 0.5 % dry weight. Rubatzky and Yamaguchi (1997) reported that Ca^{2+}disorders include blossom end rot in Solanaceous crops, tip burn in lettuce and bitter pit in pome fruits. Calcium is taken up by the roots as part of the soil solution. Calcium is thought to move both apoplastically and symplastically through the root until it is delivered to the xylem according to Cholewa and Peterson (2004). After traveling in the xylem, Ca^{2+} is unloaded into cells where it can be sequestered in the vacuole, bound to proteins in the cytosol, or incorporated into the cell wall.

According to Elad (1997) experiment calcium influences the activity of pathogenic organisms through two documented mechanisms. First, is the indirect effect of Ca^{2+} on strengthening the cell wall, thereby creating a mechanical barrier to pathogenic attack. The second involves excess unbound Ca^{2+} inhibition of endo and exo-polygalacturonase activity. Calcium applications were shown to be effective in preventing or reducing *B. cinerea* infection in a number of plant systems.

Van Alphen and de los Rios Romero (1971) conclude that up to 2 percent of gypsum in the soil favors plant growth, between 2 and 25 percent has little or no adverse effect if in powdery form, but more than 25 percent can cause substantial reduction in yields. They also suggest that reductions are due in part to imbalanced ion ratios, particularly K:Ca and Mg:Ca ratios. Walker *et al.* (1976) found that application of gypsum to soils low in calcium increased the percentage of oil in all peanut cultivars, while the nitrogen content of the seed was reduced.

Ghoname *et al.* (2007) found that the combined soil application of potassium nitrate (KNO_3) and calcium nitrate ($Ca(NO_3)_2$)plus potassium chloride (KCl) as a foliar spray resulted in the highest values in vegetative growth characters (plant length, leaves number, neck diameter, leaves fresh and dry weight as well as bulb fresh and dry weight) and also gave the highest total yield and quality of onion bulb (bulb weight, diameter, length and TSS). They also showed that application of calcium in soil significantly increased vegetative growth, bulb yield and quality however calcium chloride ($CaCl_2$) foliar spray had no significant impact on all measured parameters. Calcium nitrate was very beneficial in reducing flaking and increasing exportable portion of the yield.

Also physiologically, calcium is important in many fruits and vines since it is associated with reduced senescence and retardation of softening in fruits (Gerasopoulos and Drogoudi, 2005). It is well documented that use of calcium is very helpful in controlling physiological disorders like as tip burn on lettuce, blossom end rot of tomatoes, rain cracking in sweet cherries, and incidence of greening and cork spot in pears (Raese and Drake, 2000). It was found that high calcium levels in the soil reduced potassium uptake in several crops such as grape and cantaloupe (Lester and Jifon, 2007).

Fenn *et al.* (1986) also found that application of calcium in soil significantly increase plant length, leaves number, leaves fresh and dry weight as well as bulb fresh. Shukla (2011) reported that foliar-applied calcium can have a positive effect on seed set and quality on some ornamental plant species.

As for the use of calcium in postharvest, there are several studies showed that calcium could be used as a pre- or post-harvest treatment to increase postharvest quality or control postharvest diseases (Babalar et al., 1999; Abd El-Gawad, 2012). Warncke (2006) concluded that using $CaCl_2$ on onion had no effect on onion bulbs yield and quality and it will be an extra cost on the farmers.

Chapter 3

MATERIALS AND METHODS

This chapter shows a short description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, planting of bulbs, intercultural operations, data collection and statistical analysis.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted at the Experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2017-February 2018. The location of the experimental site has been shown in Appendix I.

3.1.2 Soil

The soil of the experimental area belonged to the Modhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.7. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.1.3 Climate

The experimental area was present under the subtropical climate and characterized by high temperature, high humidity and heavy precipitation with occasional a blast of winds during the period from October 2017-February 2018. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.2 Plant materials

BARI Piaz-1 was used in the experiment. Features of this variety are given below:

BARI Piaz-1: It is grown in Rabi season. It was released by Bangladesh Agricultural Research Institute (BARI) in 1996. It is comparatively less infestation of pest and diseases. It completes its life cycle within 130-140 DAS. It attains a plant height 50-55 cm. Its yield is 12-16 ton bulb ha^{-1} and 800-1000 kg seed ha^{-1}.

3.3 Land preparation

The experimental plot was thoroughly prepared by ploughing for several times with a power tiller followed by laddering. All the weeds and stubbles were collected and removed from the land. The clods were broken into friable soil and the surface was leveled until the desired tilth was obtained. Finally, irrigation and drainage channels were prepared around the plots. The land was prepared a month before planting the bulbs.

3.4 Manure and fertilizer application

The following doses of manure and fertilizers were applied to the plots for seed production (BARI, 2008)

Manure/ Fertilizer	Dose/ hectare	Doses/plot
Well decomposed cowdung	10 tons	1.5kg
Urea	200 kg	30 g
Triple superphosphate (TSP)	200 kg	30 g
Muriate of potash (MoP)	150 kg	23 g

The whole amount of cow-dung, TSP and MoP were applied during final land preparation but the entire amount of boron and calcium were applied in each of the treatment plots before bulb planting. The first half of urea was applied as top dressing at 30 DAP bulb followed by light irrigation. The second half of urea was applied at 60 DAP.

3.5 Treatment

There were two factors in the experiment. These were

Factor A: Four levels of boron.

1. 0 ppm (B_0)
2. 500 ppm (B_1)
3. 1000 ppm (B_2)
4. 2000 ppm (B_3)

The source of boron was borax (Na2B407.10 H2O).

Factor B: Three levels of calcium.

1. 0 ppm (C_0)
2. 2500 ppm (C_1)
3. 5000 ppm (C_2)

The source of calcium was gypsum.

In total there were 12 treatment combinations. These were-

$T_1 = B_0C_0$
$T_2 = B_0C_1$
$T_3 = B_0C_2$
$T_4 = B_1C_0$
$T_5 = B_1C_1$
$T_6 = B_1C_2$
$T_7 = B_2C_0$
$T_8 = B_2C_1$
$T_9 = B_2C_2$
$T_{10} = B_3C_0$
$T_{11} = B_3C_1$
$T_{12} = B_3C_2$

3.6 Design and layout

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. There were all together 36 plots in the experiment. The layout is given below:

R1	**R2**	**R3**
B_3C_2	B_0C_1	B_0C_2
B_0C_1	B_3C_1	B_1C_2
B_1C_1	B_1C_0	B_2C_1
B_1C_0	B_0C_2	B_0C_0
B_2C_1	B_1C_1	B_3C_0
B_3C_0	B_3C_2	B_1C_0
B_1C_2	B_2C_1	B_3C_1
B_0C_0	B_2C_0	B_0C_1
B_2C_0	B_3C_0	B_2C_2
B_3C_1	B_0C_0	B_3C_2
B_2C_2	B_2C_2	B_1C_1
B_0C_2	B_1C_2	B_2C_0

3.7 Planting of bulbs

Medium bulbs of uniform size (about 3.5 cm in diameter) were planted in the unit plots in 6 rows and there were 7 bulbs in each row. Twenty five bulbs were planted in each unit plot. The planting was done on 16 October, 2016. The distances between the rows and between the bulbs in a row were maintained at 25 cm and 20 cm, respectively. Border plants were also grown by planting bulbs around the experimental plots in the same date.

3.8 Intercultural operations

3.8.1 Gap filling

The un-sprouted bulbs were replaced by healthy plants taken from the border after 20 DAP the main crop. The damaged plants were also replaced by border plants through gap filling.

3.8.2 Weeding and mulching

Weeding and mulching were done whenever necessary to keep the crop free from weeds for better soil aeration and to conserve soil moisture before flowering.

3.8.3 Irrigation

The crop was irrigated by watering can whenever required. Eight times of can watering were requiredfor having successful crop performance.

3.8.4 Control of pests and diseases

At the emergence stage, some plants were attacked by cutworm *(Agrotis ipsilon*) and field cricket *(Brachytrypes portentosus L.).* These insects were controlled mechanically and chemically. Purple blotch disease caused by *Alternaria porii* was found in many plants at later stages of crop growth. The disease was controlled by spraying Rovral 50 WP at 7-10 days interval at the rate of 2g per liter of water.

3.9 Germination test

Germination test for harvested seeds of different treatments was conducted in laboratory. For laboratory test, petridishes were used. Filter paper was placed inside petridishes. Firstly, seeds were soaked in 10ml of 70% alcohol for 10 minutes. Then the filter paper soaked with 10 ml water for 12 treatment of each replication. Seeds were randomly placed in petridishes. 10 days after germination data were collected. The normal seedlings and abnormal seedlings were classified according to the formal rules given by ISTA (1999).

Germination percentage was measured by the following formula-

$$\text{Germination percentage} = \frac{\text{Number of normal seedlings obtained}}{\text{Number of seeds placed for germination}} \times 100$$

3.10 Collection of data

Data were recorded on the following parameters from the sample taken at random except border rows and plants of extreme ends of the inner rows.

3.10.1 Plant height

Plant height was measured from 10 sample plants in centimeter, from the ground level to the tip of the longest leaf at 30, 45, 60, 75 and 90 days after planting of bulbs. Mean height was then calculated.

3.10.2 Number of leaves

The total numbers of leaves was counted from the 10 sample plants at 30, 45, 60, 75 and 90 days after planting of bulbs. Mean of total number of leaves was then calculated.

3.10.3 Chlorophyll content

Five leaves were randomly selected per pot. The top, middle and base of each leaf were measured with atLEAF as atLEAF value. Then it was averaged and total chlorophyll content was measured by the conversion of atLEAF value into SPAD units and then totals chlorophyll content.

3.10.4 Number of umbels per plot

The umbels that were emerged in each plot were counted before blooming of flowers to determine the average number of umbels per plot.

3.10.5 Number of flowers per umbel

At the time of flowering, the total number of flowers per umbels from the five sample plants was counted and the average number of flowers per umbel per plant was then calculated.

3.10.6 Number of fruits per umbel

The umbels of the five sample plants were harvested together and the fruits obtained from them were calculated and the average number of fruits per umbel was counted.

3.10.7 Percentage of fruit set

The percent fruit set was calculated by using following formula

Percentage of fruit set= $\frac{\text{Total number of fruits}}{\text{Total number of flowers}} \times 100$

3.10.8 Yield of seed per plant

The seeds obtained from the randomly selected 15 sample plants were weighed by an electric balance and then the average weight of seed for each plant was determined.

3.10.9 Yield of seed per plot

Seeds from all plots were harvested individually and then sun dried and weighed.

3.10.10 Weight of 1000-seed

For each treatment, five thousand seeds were counted and weighed by an electric balance. Then the average weight of 1000-seed was determined.

3.10.11 Yield of seed

Yield of seeds per hectare was determined by converting the value of seed yield per plot.

3.11 Statistical analysis

The data obtained for different parameters were statistically analyzed following computer based software Statstix 10.0 and mean separation was done by LSD at 5% level of significance.

Chapter 4

RESULTS AND DISCUSSION

The research work on yield and quality of onion seed as influenced by Boron and Calcium was undertaken at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. Data on different yield and quality contributing characters were recorded to find out the better seed yield of onion through application of Boron and Calcium. The analysis of variance (ANOVA) of the data on different yield and quality components has been presented in Appendices II-VIII. The experimental results on growth, yield and quality parameters are presented as follows :

4.1 Crop growth parameters

4.1.1 Plant height (cm)

There was a significant variation noticed in plant height among boron and calcium treatments (Table 1). In case of Boron treatments, plant height at 30DAP ranged from 8.03 to 10.77cm. The maximum plant height (10.77cm) was recorded from B_3 (2000ppm) treatment whereas the minimum plant height (8.03cm) was observed in B_0 (control) treatment. After application of Boron, plant height increased by 34.12% over the control treatment.

At 45DAP, plant height ranged from 12.43 to 14.87cm. The maximum plant height (14.87cm) was recorded from B_3 (2000ppm) treatment whereas the minimum plant height (12.43cm) was observed in B_0 (control) treatment. After application of Boron, plant height increased 19.63% over control treatment.

At 60DAP, plant height ranged from 20.47 to 22.83cm. The highest plant height (22.83cm) was recorded from B_3 (2000ppm) treatment whereas the lowest plant height (20.47cm) was observed in B_0 (control) treatment. Boron increased the plant height by 11.53% over the control treatment.

At 75DAP, plant height ranged from 29.57 to 35.57cm. Higher plant height (35.57cm) was recorded from B_3 (2000ppm) treatment whereas the lowest plant height (29.57cm) was found in B_0 (control) treatment. Boron increased the plant height by 20.29% over the control treatment.

At 90DAP, plant height ranged from 42.07 to 45.17cm. The maximum plant height (45.17cm) was recorded from B_3 (2000ppm) treatment whereas the minimum plant height (42.07cm) was observed in B_0 (control) treatment. After application of Boron, plant height increased 7.37% over control treatment.

At harvest, plant height ranged from 41.97 to 45.43cm. The maximum plant height (45.43cm) was recorded from B_3 (2000ppm) treatment which was statistically identical to B_1 and B_2 treatment, whereas the minimum plant height (41.97cm) was found in B_0 (control) treatment. After application of Boron, the trial plant height increased by 8.24% over the control treatment.

In case of calcium treatments, plant height at 30DAP ranged from 8.03 to 9.03cm. The maximum plant height (9.03cm) was recorded from C_2 (5000ppm) treatment whereas the minimum plant height (8.03cm) was observed in C_0 (control) treatment. After application of Calcium, plant height increased by 12.45% over control treatment.

At 45DAP, plant height ranged from 12.43 to 13.17cm. The maximum plant height (13.17cm) was recorded from C_2 (5000ppm) treatment whereas the minimum plant height (12.43cm) was found in C_0 (control) treatment. After application of Calcium, plant height increased by 5.95% over control treatment.

At 60DAP, plant height ranged from 20.47 to 21.63cm. The maximum plant height (21.63cm) was recorded from C_2 (5000ppm) treatment whereas the minimum plant height (20.47cm) was observed in C_0 (control) treatment. After application of Calcium, plant height increased by 5.67% over control treatment.

At 75DAP, plant height ranged from 29.57 to 30.57cm. The highest plant height (30.57cm) was recorded from C_2 (5000ppm) treatment whereas the lowest plant height (29.57cm) was obtained in C_0 (control) treatment. After application of Calcium, plant height increased by 3.38% over control treatment.
At 90DAP, plant height ranged from 42.07 to 43.67cm. The highest plant height (43.67cm) was recorded from C_2 (5000ppm) treatment whereas the lowest plant height (42.07cm) was observed in C_0 (control) treatment. After application of Calcium, plant height increased by 3.81% over control treatment.

At harvest, plant height ranged from 41.97 to 43.60cm. The maximum plant height (43.60cm) was recorded from C_2 (5000ppm) treatment whereas the minimum plant height (41.97cm) was observed in C_0 (control) treatment. After application of Calcium, the final plant height increased by 3.88% over control treatment.

Table 1. Effect of boron and calcium treatments on plant height of onion at different days after planting

Effect of Boron on plant height (cm)						
Treatment	**30 DAP**	**45 DAP**	**60 DAP**	**75DAP**	**90DAP**	**At Harvest**
B_0	8.03c	12.43c	20.47c	29.57b	42.07b	41.97b
B_1	9.43b	13.50b	21.80b	31.03ab	44.27a	44.43a
B_2	9.80b	13.77b	22.10ab	31.33a	44.80a	45.13a
B_3	10.77a	14.87a	22.83a	32.57a	45.17a	45.43a
$LSD_{(0.05)}$	**0.4225**	**0.7378**	**0.8854**	**1.6049**	**1.2248**	**1.0988**
CV (%)	**2.2**	**2.71**	**2.03**	**2.58**	**1.93**	**1.24**
Effect of Calcium on plant height (cm)						
Treatment	**30 DAP**	**45 DAP**	**60 DAP**	**75DAP**	**90DAP**	**At Harvest**
C_0	8.03b	12.43b	20.47a	29.57a	42.07a	41.97a
C_1	8.70a	12.83ab	20.80a	29.97a	43.33a	43.13a
C_2	9.03a	13.17a	21.63a	30.57a	43.67a	43.60a
$LSD_{(0.05)}$	**0.5125**	**0.6185**	**1.2347**	**1.2173**	**2.0333**	**1.9391**
CV (%)	**2.63**	**2.13**	**2.60**	**1.79**	**2.08**	**1.99**

A significant variation was noticed in plant height from combined application of boron and calcium (Table 2). In case of combined application of boron and calcium, plant height at 30DAP ranged from 8.03 to 13.10cm. The maximum plant height (13.10cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment, whereas the minimum plant height (8.03cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 63.14% over B_0C_0 (control) treatment.

At 45DAP, plant height ranged from 12.43 to 16.23cm. The maximum plant height (16.23cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum plant height (12.43cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 30.57% over B_0C_0 (control) treatment.

At 60DAP, plant height ranged from 20.47 to 25.03cm. The highest plant height (25.03cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the lowest plant height (20.47cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 22.28% over B_0C_0 (control) treatment.

At 75DAP, plant height ranged from 29.57 to 38.43cm. The highest plant height (38.43cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the lowest plant height (29.57cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 29.96% over B_0C_0 (control) treatment.

At 90DAP, plant height ranged from 42.07 to 53.67cm. The maximum plant height (53.67cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum plant height (42.07cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 27.57% over B_0C_0 (control) treatment.

At harvest, plant height ranged from 41.97 to 53.97cm. The maximum plant height (53.97cm) was recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum plant height (41.97cm) was observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment, plant height increased 29.27% over B_0C_0 (control) treatment.

Table 2. Combined effect of boron and calcium treatments on plant height of onion at different days after planting

Treatment	Plant height (cm) at					
	30 DAP	45 DAP	60 DAP	75DAP	90DAP	At Harvest
B_0C_0	8.03g	12.43h	20.47h	29.57i	42.07g	41.97h
B_0C_1	8.70f	12.83gh	20.80gh	29.97hi	43.33fg	43.13gh
B_0C_2	9.03f	13.17fg	21.63fg	30.57ghi	43.67efg	43.60fg
B_1C_0	9.43e	13.50ef	21.80f	31.03fgh	44.27def	44.43efg
B_1C_1	10.47d	14.53d	22.83de	32.03ef	44.93def	45.17def
B_1C_2	11.27c	15.27bc	23.13cd	33.13de	45.43d	46.40cd
B_2C_0	9.80e	13.77e	22.10ef	31.33fg	44.80def	45.13def
B_2C_1	11.37c	15.70ab	23.93bc	33.67cd	45.90cd	46.17cd
B_2C_2	11.97b	15.90a	24.17ab	34.87bc	47.30bc	47.37bc
B_3C_0	10.77d	14.87cd	22.83de	32.57de	45.17de	45.43de
B_3C_1	11.93b	15.80ab	24.15ab	35.70b	48.10b	48.47b
B_3C_2	13.10a	16.23a	25.03a	38.43a	53.67a	53.97a
$LSD_{(0.05)}$	**0.3762**	**0.5789**	**0.8952**	**1.2188**	**1.6955**	**1.5748**
CV (%)	**2.12**	**2.36**	**2.32**	**2.20**	**2.19**	**2.02**

4.1.2 Number of leaves

There was a significant variation noticed in leaf numbers among boron treatment and calcium treatment (Table 3).

In case of Boron treatments, at 30DAP, leaf numbers ranged from 2.37 to 2.69. The maximum leaves (2.69) were recorded from B_3 (2000ppm) treatment whereas the minimum leaves (2.37) were observed in B_0 (control) treatment. After application of Boron, leaf numbers increased 13.5% over control treatment.

At 45DAP, leaf numbers ranged from 4.20 to 5.43. The maximum leaves (5.43) were recorded from B_3 (2000ppm) treatment whereas the minimum leaves (4.20) were observed in B_0 (control) treatment. After application of Boron, leaf numbers increased 29.28% over control treatment.

At 60DAP, leaf numbers ranged from 5.23 to 6.33. The highest leaves (6.33) were recorded from B_3 (2000ppm) treatment whereas the lowest leaves (5.23) were observed in B_0 (control) treatment. Boron increased leaf numbers 21.03% over control treatment.

At 75DAP, leaf numbers ranged from 6.33 to 7.10. Higher leaves (7.10) were recorded from B_3 (2000ppm) treatment whereas the lowest leaves (6.33) were found in B_0 (control) treatment. Boron increased the leaf numbers 12.16% over control treatment.

At 90DAP, leaf numbers ranged from 7.20 to 7.67. The maximum leaves (7.67) were recorded from B_3 (2000ppm) treatment whereas the minimum leaves (7.20) were observed in B_0 (control) treatment. After application of Boron, leaf numbers increased 6.80% over control treatment.

At harvest, leaf numbers ranged from 5.20 to 6.47. The maximum leaves (6.47) were recorded from B_3 (2000ppm) treatment whereas the minimum leaves (5.20) were found in B_0 (control) treatment. After application of Boron, leaf numbers increased 24.42% over control treatment.

In case of calcium treatments, at 30DAP, leaf numbers ranged from 2.37 to 2.47. The maximum leaves (2.47) were recorded from C_2 (5000ppm) treatment whereas the minimum leaves (2.37) were observed in C_0 (control) treatment. After application of Calcium, leaf numbers increased 4.22% over control treatment.

At 45DAP, leaf numbers ranged from 4.20 to 4.87. The maximum leaves (4.87) were recorded from C_2 (5000ppm) treatment whereas the minimum leaves (4.20) were found in C_0 (control) treatment. After application of Calcium, leaf numbers increased 15.95% over control treatment.

At 60DAP, leaf numbers ranged from 5.23 to 5.67. The maximum leaves (5.67) were recorded from C_2 (5000ppm) treatment whereas the minimum leaves (5.23) were observed in C_0 (control) treatment. After application of Calcium leaf numbers increased 8.41% over control treatment.

At 75DAP, leaf numbers ranged from 6.33 to 6.76. The highest leaves (6.76) were recorded from C_2 (5000ppm) treatment whereas the lowest leaves (6.33) were obtained in C_0 (control) treatment. Calcium increased leaf numbers 6.79% over control treatment.

At 90DAP, leaf numbers ranged from 7.20 to 7.90. The highest leaves (7.90) were recorded from C_2 (5000ppm) treatment whereas the lowest leaves (7.20) were observed in C_0 (control) treatment. Calcium increased leaf numbers 9.72% over control treatment.

At harvest, leaf numbers ranged from 5.20 to 6.60. The maximum leaves (6.60) were recorded from C_2 (5000ppm) treatment whereas the minimum leaves (5.20) were observed in C_0 (control) treatment. After application of Calcium, leaf numbers increased 26.92% over control treatment.

Table 3. Effect of boron and calcium treatments on leaf number of onion at different days after planting

Effect of Boron on leaf number at						
Treatment	**30 DAP**	**45 DAP**	**60 DAP**	**75DAP**	**90DAP**	**At Harvest**
B_0	2.37c	4.20c	5.23c	6.33c	7.20b	5.20d
B_1	2.58b	5.00b	5.81b	6.49bc	7.37ab	5.90c
B_2	2.58b	5.15b	6.10ab	6.80ab	7.50ab	6.13b
B_3	2.69a	5.43a	6.33a	7.10a	7.67a	6.47a
$LSD_{(0.05)}$	**0.0595**	**0.2039**	**0.3320**	**0.4014**	**0.4251**	**0.2132**
CV (%)	**1.17**	**2.06**	**2.83**	**3.01**	**2.86**	**1.80**
Effect of Calcium on leaf number at						
Treatment	**30 DAP**	**45 DAP**	**60 DAP**	**75DAP**	**90DAP**	**At Harvest**
C_0	2.37b	4.20b	5.23b	6.33a	7.20b	5.20b
C_1	2.44ab	4.60a	5.53ab	6.66a	7.53b	6.30a
C_2	2.47a	4.87a	5.67a	6.76a	7.90a	6.60a
$LSD_{(0.05)}$	**0.0807**	**0.2725**	**0.3778**	**0.4967**	**0.3663**	**0.4438**
CV (%)	**1.47**	**2.64**	**3.04**	**3.33**	**2.14**	**3.25**

4.1.2.2 Combined effect of treatments

A significant variation in the total number of leaves per plant was found among the combined treatments of boron and calcium at all growth stages (Table 4). In case of combined application of boron and calcium, at 30DAP, leaf numbers ranged from 2.37 to 2.95. The maximum leaves (2.95) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum leaves (2.37) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 24.47% over B_0C_0 (control) treatment.

At 45DAP, leaf numbers ranged from 4.20 to 6.73. The maximum leaves (6.73) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum leaves (4.20) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 60.23% over B_0C_0 (control) treatment.

At 60DAP, leaf numbers ranged from 5.23 to 7.47. The highest leaves (7.47) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the lowest leaves (5.23) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 42.82% over B_0C_0 (control) treatment.

At 75DAP, leaf numbers ranged from 6.33 to 8.63. The highest leaves (8.63) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the lowest leaves (6.33) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 36.33% over B_0C_0 (control) treatment.

At 90DAP, leaf numbers ranged from 7.20 to 9.03. The maximum leaves (9.03) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum leaves (7.20) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 25.42% over B_0C_0 (control) treatment.

At harvest, leaf numbers ranged from 5.20 to 8.17. The maximum leaves (8.17) were recorded from B_3C_2 (2000ppm boron and 5000ppm calcium) treatment whereas the minimum leaves (5.20) were observed in B_0C_0 (0ppm Boron and Calcium) treatment. After application of B_3C_2 treatment leaf numbers increased 57.11% over B_0C_0 (control) treatment.

Table 4. Combined effect of boron and calcium treatments on leaf number of onion at different days after planting

Treatment	Leaf number at					
	30 DAP	45 DAP	60 DAP	75DAP	90DAP	At Harvest
B_0C_0	2.37h	4.20j	5.23h	6.33i	7.20g	5.20i
B_0C_1	2.44g	4.60i	5.53g	6.66gh	7.53efg	6.30fg
B_0C_2	2.47g	4.87h	5.67g	6.76gh	7.90cd	6.60de
B_1C_0	2.58f	5.00gh	5.81fg	6.49hi	7.37fg	5.90h
B_1C_1	2.64e	5.27ef	6.00ef	7.13de	7.73cde	6.80d
B_1C_2	2.72d	5.73d	6.33d	7.43d	7.97cd	7.23c
B_2C_0	2.58f	5.15fg	6.10de	6.80fg	7.50efg	6.13gh
B_2C_1	2.72d	5.90cd	6.73c	7.77c	8.03c	7.47bc
B_2C_2	2.79c	6.00c	6.97bc	8.00bc	8.43b	7.63b
B_3C_0	2.69de	5.43e	6.33d	7.10ef	7.67def	6.47ef
B_3C_1	2.85b	6.27b	7.03b	8.10b	8.70ab	7.73b
B_3C_2	2.95a	6.73a	7.47a	8.63a	9.03a	8.17a
$LSD_{(0.05)}$	**0.0579**	**0.2140**	**0.2825**	**0.3122**	**0.3536**	**0.2834**
CV (%)	**1.29**	**2.33**	**2.66**	**2.54**	**2.64**	**2.46**

4.2 Physiological parameters

4.2.1 Chlorophyll content (mg cm^{-2})

4.2.1.1 Effect of treatments

Chlorophyll content on leaves was significantly influenced by boron (Table 5 and Appendix VI). The highest chlorophyll content (45.50 mg cm^{-2}) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest chlorophyll content (43 mg cm^{-2}) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on chlorophyll content of leaves (Table 5 and Appendix VI). The maximum chlorophyll content (43.63 mg cm^{-2}) was observed from C_2 (5000ppm) treatment which was statically similar to C_1 treatment and the minimum chlorophyll content (40.20 mg cm^{-2}) was found in C_0 (No Calcium) treatment.

Table 5. Effect of boron and calcium treatments on chlorophyll content (mg cm^{-2}) of onion leaves

Effect of boron	
Treatment	**Chlorophyll content (mg cm^{-2})**
B_0	40.20 c
B_1	43.00 b
B_2	44.40 ab
B_3	45.40 a
$LSD_{(0.05)}$	**2.0594**
CV (%)	**2.38**
Effect of calcium	
Treatment	**Chlorophyll content (mg cm^{-2})**
C_0	40.20 b
C_1	42.33 ab
C_2	43.63 a
$LSD_{(0.05)}$	**2.8804**
CV (%)	**3.02**

4.2.1.2 Combined effect of treatments

Combined treatment of boron and calcium showed the significant variation on chlorophyll content on leaves (Figure 1 and Appendix VI). Chlorophyll content on leaves ranged from 40.20 to 50.80 mg cm^{-2}. Among the treatments the maximum chlorophyll content (50.80 mg cm^{-2}) on leaves was observed in B_3C_2 (2000ppm boron and 5000ppm calcium) treatment and the minimum chlorophyll content (40.20 mg cm^{-2}) was found in B_0C_0 (0ppm Boron and Calcium). B_1C_2 and B_2C_1 treatment showed the statically similar result. B_3C_2 treatment increased 26.37% chlorophyll content on leaves over B_0C_0.

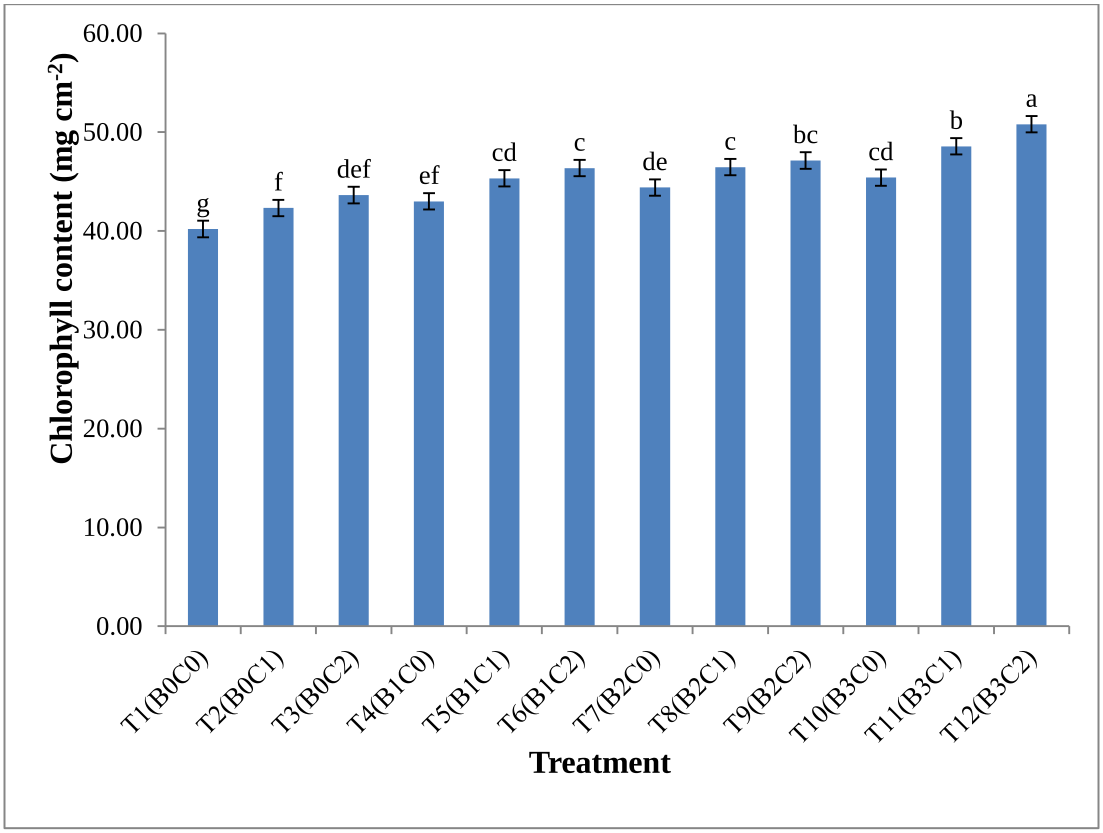

Fig. 1: Combined effect of boron and calcium treatments on chlorophyll content (mg cm^{-2}) of onion leaves

4.3 Yield contributing characters

4.3.1 Umbels $plot^{-1}$

4.3.1.1 Effect of treatments

Number of umbels per plot was significantly influenced by boron (Table 6 and Appendix VI). The highest number of umbels per plot (65.2) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest number of umbels per plot (61) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on per plot umbel number (Table 6 and Appendix VI). The maximum number of umbels per plot (85.87) was observed from C_2 (5000ppm) treatment which was statically similar to C_1 treatment and the minimum number of umbels per plot (62.33) was found in C_0 (No Calcium) treatment.

Table 6. Effect of boron and calcium treatments on umbels plot^{-1} of onion

Effect of boron	
Treatment	**Umbels plot^{-1}**
B_0	61 b
B_1	63.9 b
B_2	63.8 ab
B_3	65.2 a
$LSD_{(0.05)}$	**3.4180**
CV (%)	**1.80**
Effect of calcium	
Treatment	**Umbels plot^{-1}**
C_0	62.33 b
C_1	64.00 ab
C_2	65.87 a
$LSD_{(0.05)}$	**2.3044**
CV (%)	**2.35**

4.3.1.2 Combined effect of treatments

In case of combined treatments of boron and calcium showed a significant variation on numbers of umbel per plot (Figure 2 and Appendix VI). Number of umbels per plot from combined treatment ranged from 62.33to 68.03. B_2C_2 (boron 1000ppm and calcium 5000ppm) treatment showed the highest number of umbel per plot (68.03). B_1C_1, B_2C_1, B_3C_1 and B_3C_2 gave the statically similar result. And the lowest number of umbel per plot was recorded in B_0C_0 treatment (62.33). B_2C_2 treatment increased the umbel number per plot 9.14% over B_0C_0 treatment.

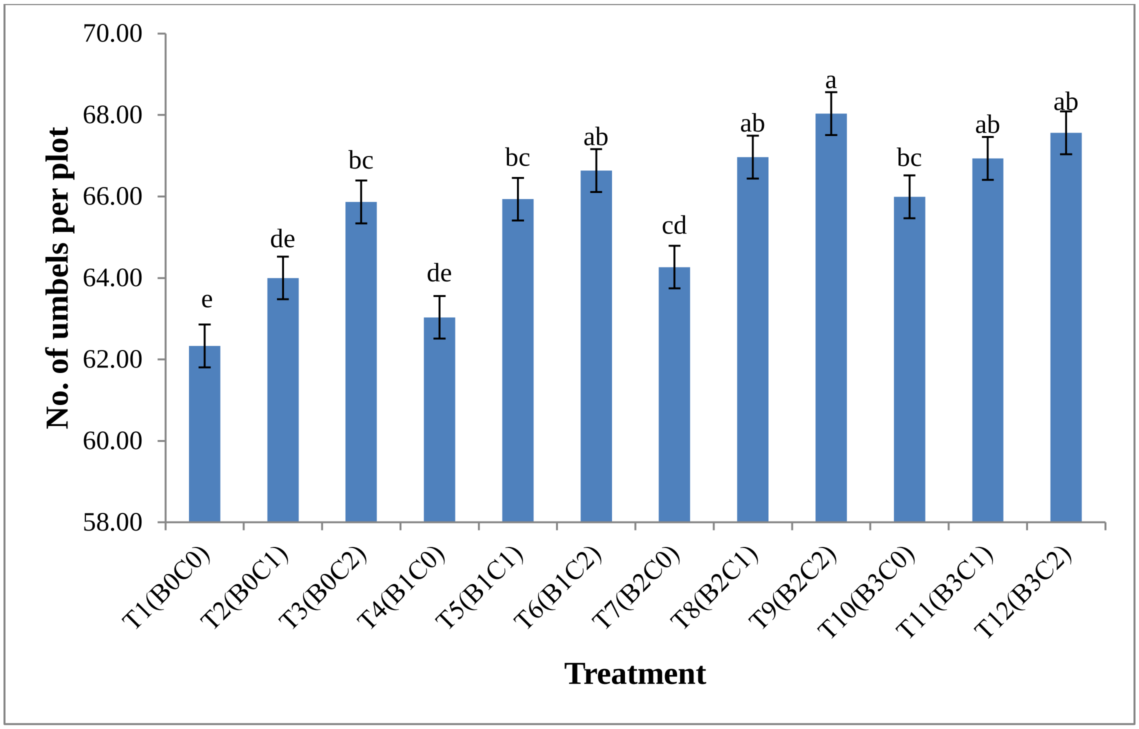

Fig. 2: Combined effect of boron and calcium treatments on umbels per plot of onion

4.3.2 Flowers per umbel

4.3.2.1 Effect of treatments

Number of flowers per umbel was significantly influenced by boron (Table 7 and Appendix VI). The highest number of flowers per umbel (156.33) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest number of flowers per umbel (149.03) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on number of flowers per umbel (Table 7 and Appendix VI). The maximum number of flowers per umbel (151.70) was observed from C_2 (5000ppm) treatment which was statically similar with C_0 (149.03 flowers) and C_1 (150.77 flowers) treatment.

Table 7. Effect of boron and calcium treatments on flowers per umbel of onion

Effect of boron	
Treatment	**Flowers umbel^{-1}**
B_0	149.03 c
B_1	151.67 b
B_2	154.67 a
B_3	156.33 a
$LSD_{(0.05)}$	**2.2591**
CV (%)	**0.74**
Effect of calcium	
Treatment	**Flowers umbel^{-1}**
C_0	149.03 a
C_1	150.77 a
C_2	151.70 a
$LSD_{(0.05)}$	**4.1595**
CV (%)	**1.22**

4.3.2.2 Combined effect of treatments

The variation in the number of flowers per umbel was highly significant due to the combined effect of boron and calcium (Figure 3 and Appendix VI). Number of flowers per umbel from combined treatment ranged from 149.03 to 169.77.Figure 3 showed that B_2C_2 (boron 1000ppm and calcium 5000ppm) treatment produced the highest number of flowers per umbel (169.77). Second highest flowers per umbel were found in B_3C_2 (2000ppm boron and 5000ppm calcium) treatment was 165.67. B_0C_0 gave the lower flowers per umbel (149.03) which was statically similar with B_0C_1 treatment (150.77). B_2C_2 treatment increased the number of flowers per umbel 13.92% over B_0C_0 treatment.

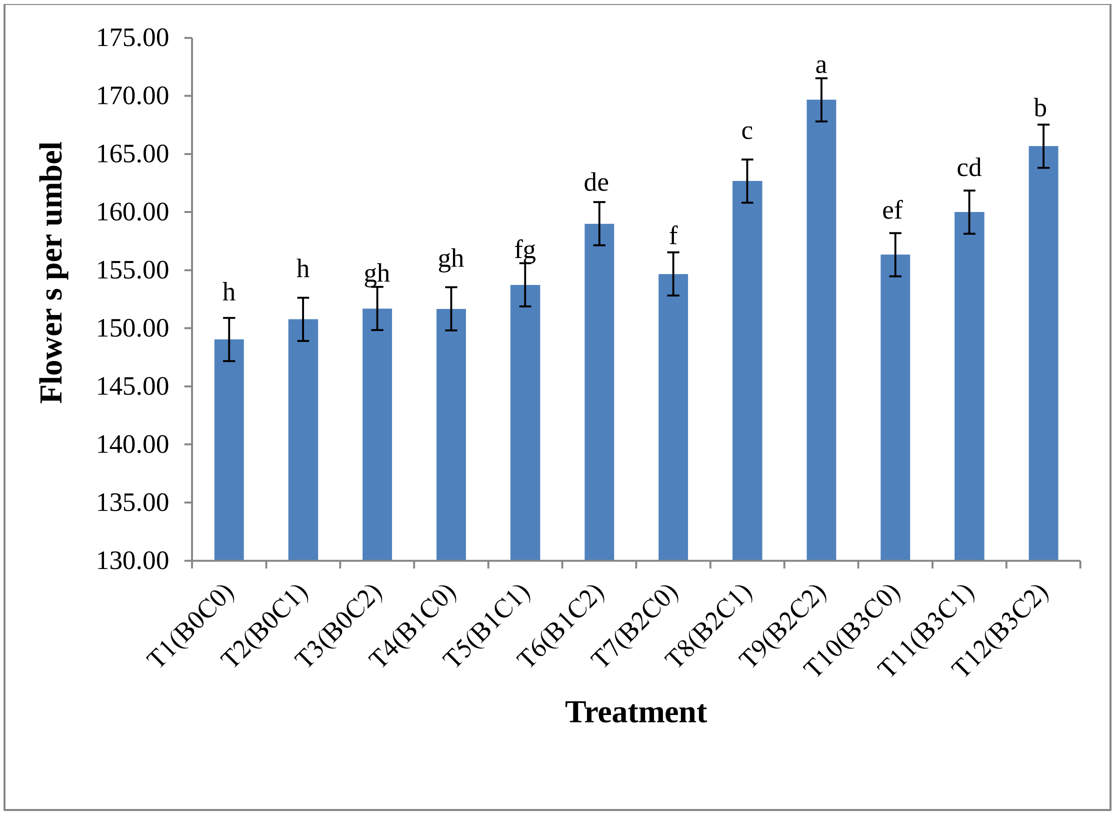

Fig. 3: Combined effect of boron and calcium treatments on flowers umbel^{-1} of onion

4.3.3 Fruits per umbel

4.3.3.1 Effect of treatments

Number of fruits per umbel was significantly influenced by boron (Table 8 and Appendix VI). The highest number of fruits per umbel (130.67) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest number of fruits per umbel (110.33) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on number of fruits per umbel (Table 8 and Appendix VI). The maximum number of fruits per umbel (131.03) was observed from C_2 (5000ppm) treatment and the minimum number of fruits per umbel (110.33) found in C_0 (No Calcium) treatment.

Table 8. Effect of boron and calcium treatments on fruits per umbel of onion

Effect of boron	
Treatment	**Fruits per umbel**
B_0	110.33 c
B_1	116.07 b
B_2	130.00 a
B_3	130.67 a
$LSD_{(0.05)}$	**1.8982**
CV (%)	**0.69**
Effect of calcium	
Treatment	**Fruits per umbel**
C_0	110.33 c
C_1	123.67 b
C_2	131.03 a
$LSD_{(0.05)}$	**3.9416**
CV (%)	**1.62**

4.3.3.2 Combined effect of treatments

Combined treatment of boron and calcium showed the highly significant variation on fruits per umbel (Figure 4 and Appendix VI). Number of fruits per umbel from combined treatment ranged from 110.33 to 157.67. B_2C_2 (boron 1000ppm and calcium 5000ppm) treatment produced the highest number of fruits per umbel (157.67). Second highest fruits per umbel (152.67) were found in B_3C_2 (2000ppm boron and 5000ppm calcium) treatment. Lower fruits per umbel (110.33) were recorded in B_0C_0 treatment. B_1C_1, B_2C_0 and B_3C_0 gave the statically similar result on fruits per umbel. B_2C_2 treatment increased 42.91% fruits per umbel over B_0C_0 treatment.

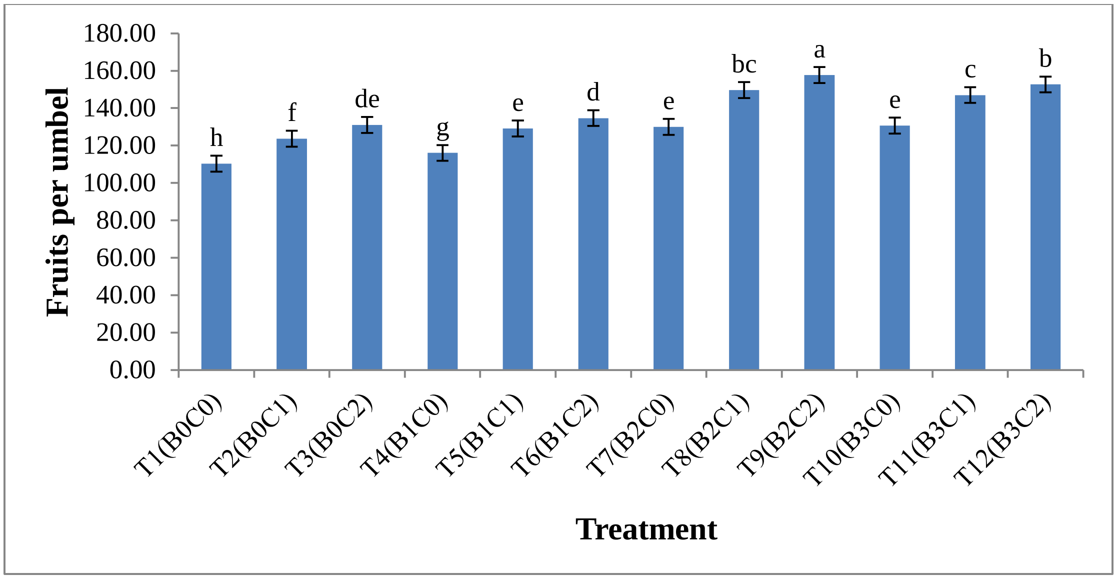

Fig. 4: Combined effect of boron and calcium treatments on fruits umbel^{-1} of onion

4.3.4 Fruit set (%)

4.3.4.1 Effect of treatments

Percentage of fruit set was significantly influenced by boron (Table 9 and Appendix VI). The highest percentage of fruit set (84.05%) was recorded from B_2 (1000ppm) treatment which was statically similar to B_3 treatment and the lowest percentage of fruit set (74.03%) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on percentage of fruit set (Table 9 and Appendix VI). The maximum percentage of fruit set (86.38%) was observed from C_2 (5000ppm) treatment and the minimum percentage of fruit set (74.03) found in C_0 (No Calcium) treatment.

Table 9. Effect of boron and calcium treatments on fruit set (%) of onion

Effect of boron	
Treatment	**Fruit set (%)**
B_0	74.03 b
B_1	76.52 b
B_2	84.05 a
B_3	83.60 a
$LSD_{(0.05)}$	**2.7650**
CV (%)	**1.74**
Effect of calcium	
Treatment	**Fruit set (%)**
C_0	74.03 c
C_1	82.02 b
C_2	86.38 a
$LSD_{(0.05)}$	**1.9898**
CV (%)	**1.09**

The variation in percentage of fruit set was highly significant due to the combined application of boron and calcium (Figure 4 and Appendix VI). Percentage of fruit set from combined treatment ranged from 74.03 to 92.93. B_2C_2 gave the highest percentage of fruit set (92.93%). Also B_2C_1, B_3C_1 and B_3C_2 gave the statically similar result. Lowest percentage of fruit set (74.03%) was found in the B_0C_0 treatment. B_0C_0 and B_1C_0 showed the statically similar result. Also B_1C_1 and B_2C_0 gave the statically similar result.

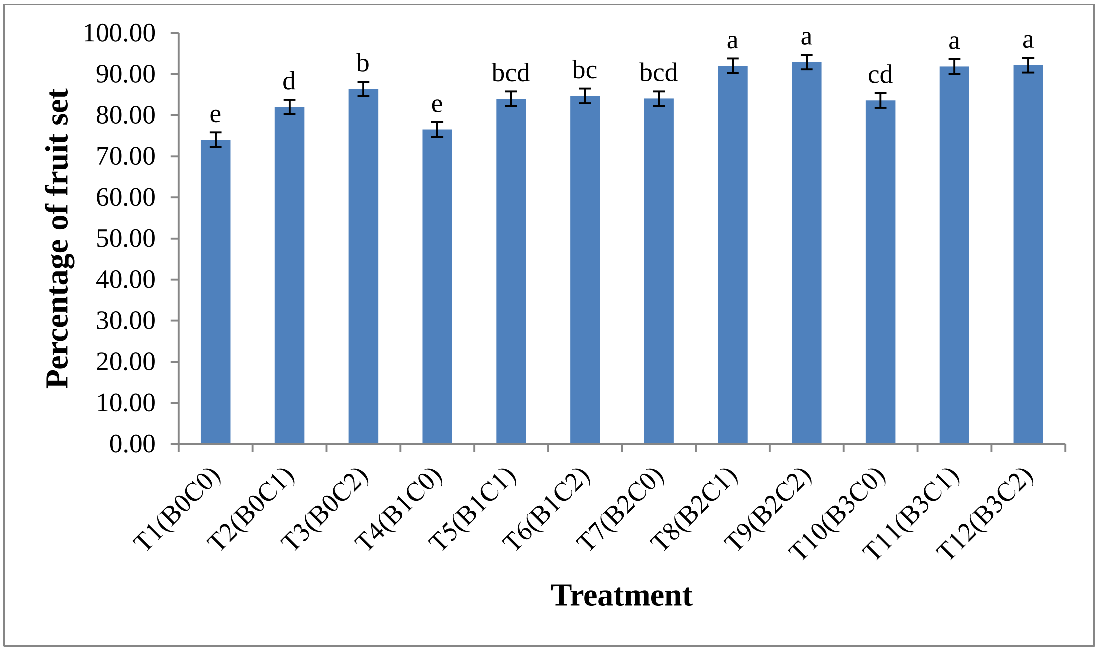

Fig. 5: Combined effect of boron and calcium treatments on fruit set (%) of onion

4.3.5 Seed yield per plant

Seed yield per plant was significantly influenced by boron (Table 10 and Appendix VII). The highest seed yield per plant (2.32g) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest seed yield per plant (1.95g) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on seed yield per plant (Table 10 and Appendix VII). The maximum seed yield per plant (2.08g) was observed from C_2 (5000ppm) treatment which was statically similar to C_1 treatment and the minimum seed yield per plant (1.95g) found in C_0 (No Calcium) treatment.

Table 10. Effect of boron and calcium treatments on seed yield per plant (g) of onion

Effect of boron	
Treatment	**Seed yield per plant (g)**
B_0	1.95 c
B_1	2.16 b
B_2	2.27 a
B_3	2.32 a
$LSD_{(0.05)}$	**0.0726**
CV (%)	**1.69**
Effect of calcium	
Treatment	**Seed yield per plant (g)**
C_0	1.95 b
C_1	2.02 ab
C_2	2.08 a
$LSD_{(0.05)}$	**0.1071**
CV (%)	**2.34**

4.3.5.2 Combined effect of treatments

Combined treatment of boron and calcium was significantly influence the seed yield per plant (Figure 6 and Appendix VII). Seed yield per plant from combined treatment ranged from 1.95 to 3.14g. B_2C_2 gave the highest seed yield per plant (3.14g). Second highest seed yield per plant (3g) was found in B_3C_2 treatment. B_0C_1 and B_0C_2 gave the statically similar result. Lowest seed yield per plant (1.95g) was found from B_0C_0 treatment. Application of B_2C_2 treatment increased 61.02% seed yield per plant over B_0C_0 treatment.

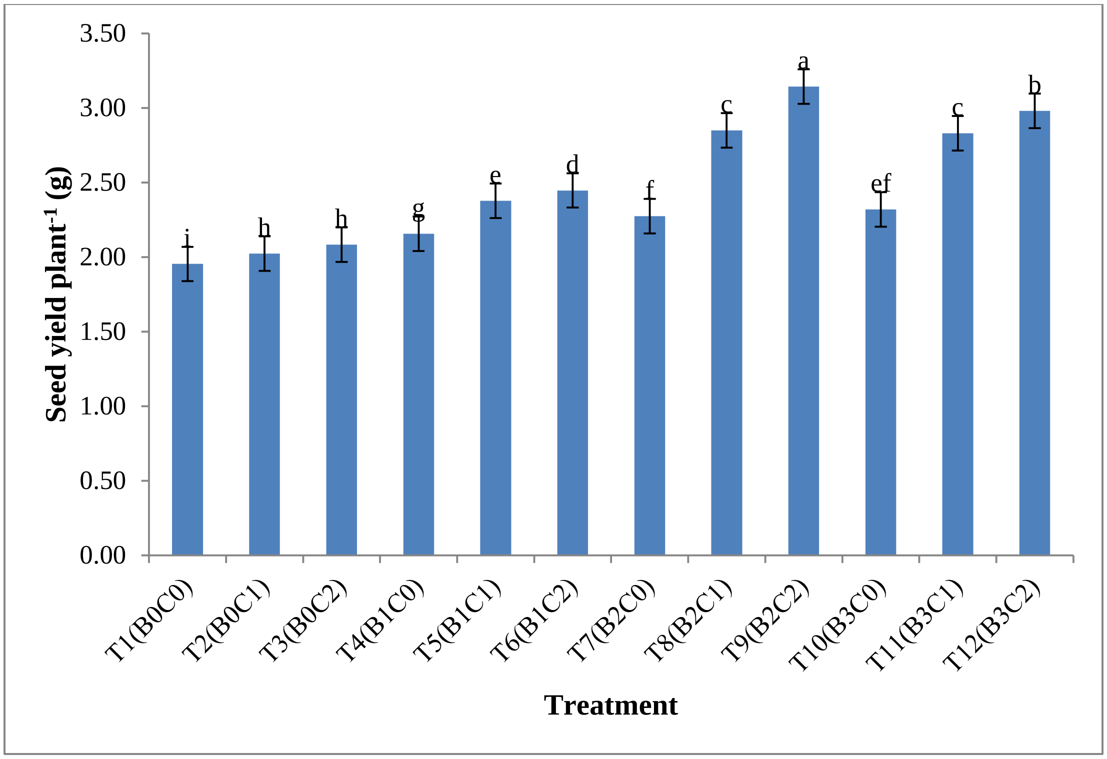

Fig. 6: Combined effect of boron and calcium treatments on seed yield per plant (g) of onion

4.3.6 Seed yield plot^{-1}

Seed yield per plot was significantly influenced by boron (Table 11 and Appendix VII). The highest seed yield per plot (120.64g) was recorded from B_3 (2000ppm) treatment which was statically similar to B_2 treatment and the lowest seed yield per plot (101.57g) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on seed yield per plot (Table 11 and Appendix VII). The maximum seed yield per plot (108.33g) was observed from C_2 (5000ppm) treatment which was statically similar to C_1 treatment and the minimum seed yield per plot (101.57g) found in C_0 (No Calcium) treatment.

Table 11. Effect of boron and calcium treatments on seed yield per plot (g) of onion

Effect of boron	
Treatment	**Seed yield per plot (g)**
B_0	101.57 c
B_1	112.15 b
B_2	118.21 a
B_3	120.64 a
$LSD_{(0.05)}$	**3.7777**
CV (%)	**1.67**
Effect of calcium	
Treatment	**Seed yield per plot (g)**
C_0	101.57 b
C_1	105.21 ab
C_2	108.33 a
$LSD_{(0.05)}$	**5.5709**
CV (%)	**2.34**

There was a significant difference noticed in combined treatment of boron and calcium on the seed yield per plot (Figure 7 and Appendix VII). Seed yield per plot from combined treatment ranged from 163.45 to 101.57g. B_2C_2 gave the highest seed yield per plot (163.45g). The second highest seed yield per plot (154.96g) was found in B_3C_2 combined treatment. B_0C_1 and B_0C_2 treatments gave the statically similar result. Lowest seed yield per plot (101.57g) was observed from B_0C_0 treatment. Application of B_2C_2 treatment increased 60.92% seed yield per plot over B_0C_0 treatment.

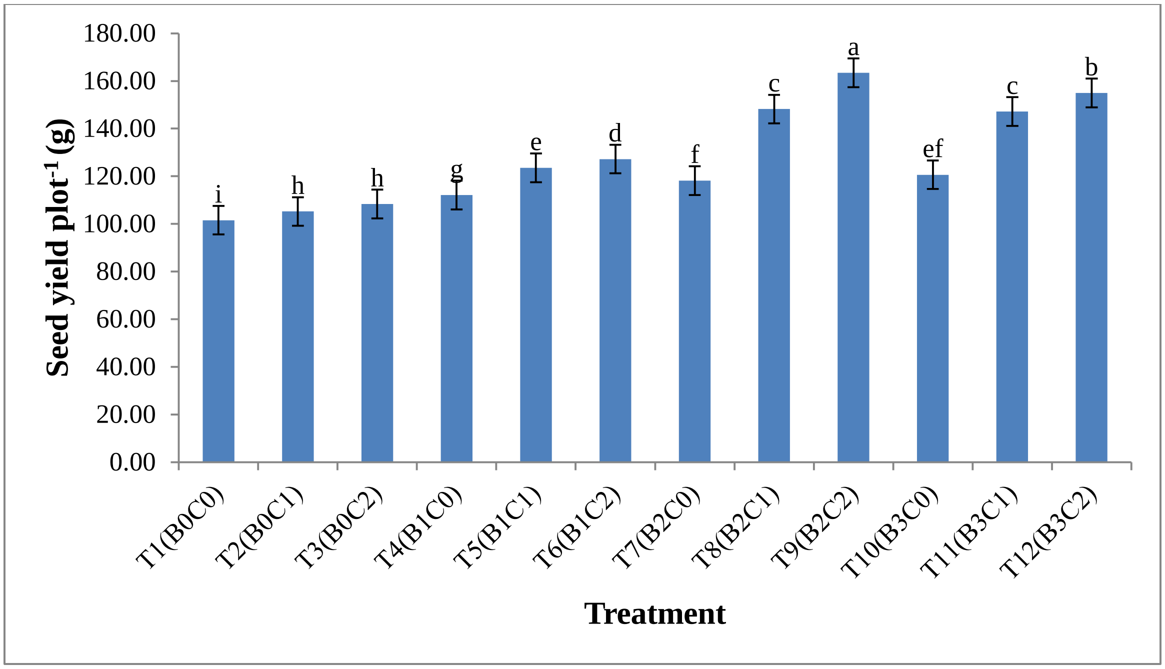

Fig. 7: Combined effect of boron and calcium treatments on seed yield per plot (g) of onion

4.3.7 1000-seed weight

1000-seed weight was significantly influenced by boron (Table 12 and Appendix VII). The highest 1000-seed weight (2.39g) was recorded from B_3 (2000ppm) treatment. B_1 and B_2 treatment showed statically similar and the lowest 1000-seed weight (2.03g) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on 1000-seed weight (Table 12 and Appendix VII). The maximum 1000-seed weight (2.18g) was observed from C_2 (5000ppm) treatment which was statically similar to C_1 treatment and the minimum 1000-seed weight (2.03g) found in C_0 (No Calcium) treatment.

Table 12. Effect of boron and calcium treatments on 1000-seed weight (g) of onion

Effect of boron	
Treatment	**1000-seed weight (g)**
B_0	2.03 c
B_1	2.23 b
B_2	2.30 b
B_3	2.39 a
$LSD_{(0.05)}$	**0.0706**
CV (%)	**1.58**
Effect of calcium	
Treatment	**1000-seed weight (g)**
C_0	2.03 b
C_1	2.13 ab
C_2	2.18 a
$LSD_{(0.05)}$	**0.1191**
CV (%)	**2.49**

Combined treatment of boron and calcium was highly significant on 1000-seed weight of onion (Figure 8 and Appendix VII). Thousand seed weight from combined treatment ranged from 2.03 to 3.70g. Higher thousand seed weight (3.70g) was observed in the treatment of B_2C_2. Second highest thousand seed weight (3g) was seen in B_2C_1 treatment. B_2C_1 and B_3C_2 treatment gave the statically similar result for thousand seed weight. B_3C_1 gave the third highest 1000-seed weight (2.89g). Lowest 1000-seed weight (2.03g) was found in B_0C_0 treatment. Application of B_2C_2 treatment increased 82.27% seed yield per plant over B_0C_0 treatment.

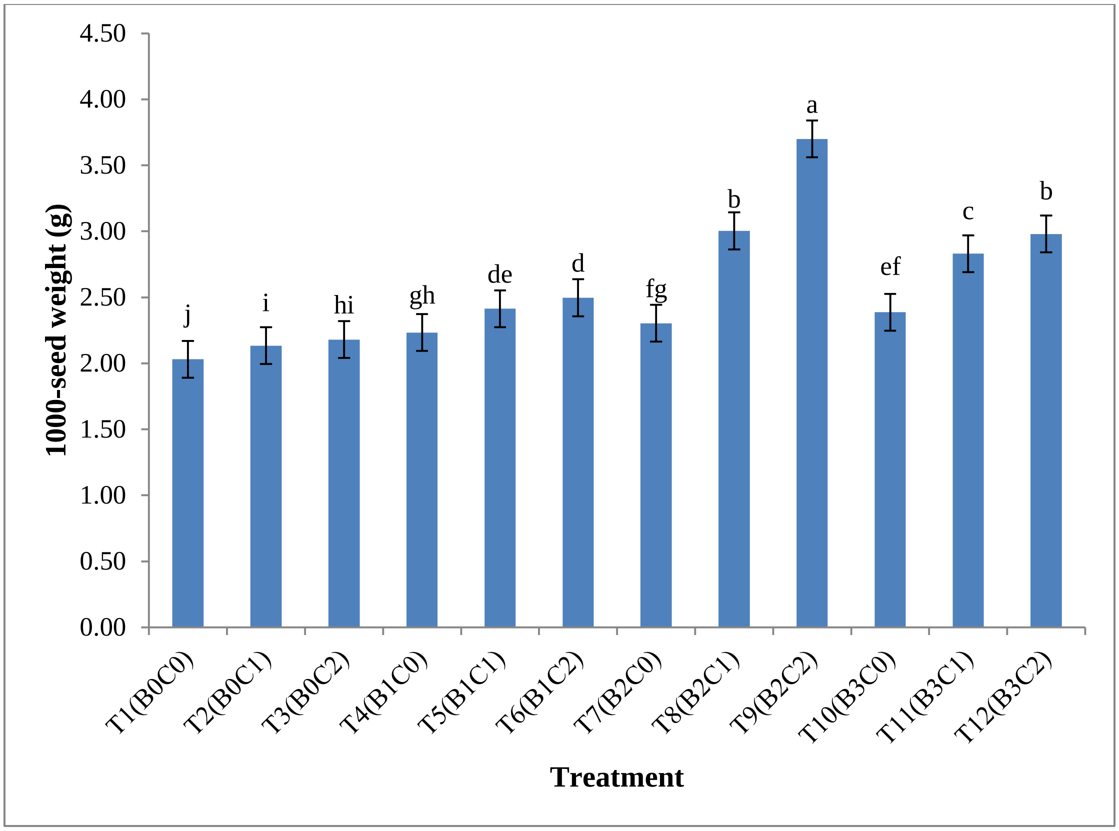

Fig. 8: Combined effect of boron and calcium treatments on 1000-seed weight (g) of onion

4.3.8 Seed yield ha^{-1}

Seed yield per hectare was significantly influenced by boron (Table 13 and Appendix VII). The highest seed yield per hectare (502.67kg) was recorded from B_3 (2000ppm) treatment. 492.56kg and 467.28kg seed yield per hectare was observed in B_2 and B_1 treatment, respectively. The lowest seed yield per hectare (423.22kg) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on seed yield per hectare (Table 13 and Appendix VII). The maximum seed yield per hectare (451.39kg) was observed from C_2 (5000ppm) treatment and the minimum seed yield per hectare (423.22kg) found in C_0 (No Calcium) treatment.

Table 13. Effect of boron and calcium treatments on seed yield ha^{-1} (kg) of onion

Effect of boron	
Treatment	**Seed yield ha^{-1} (kg)**
B_0	423.22 d
B_1	467.28 c
B_2	492.56 b
B_3	502.67 a
$LSD_{(0.05)}$	**5.9057**
CV (%)	**0.63**
Effect of calcium	
Treatment	**Seed yield ha^{-1} (kg)**
C_0	423.22 c
C_1	438.39 b
C_2	451.39 a
$LSD_{(0.05)}$	**12.233**
CV (%)	**1.23**

On exposure to combined treatment of calcium and boron significantly influenced the per hectare seed yield of onion (Figure 9 and Appendix VII). Seed yield per hectare from combined treatment ranged from 423.22 to 681.05kg. Highest seed yield per hectare (681.05kg) was seen in the B_2C_2 combined treatment and second highest seed yield per hectare (645.67kg) was found in B_3C_2 treatment. B_2C_1 and B_3C_1 combined treatment gave the statically similar result for seed yield per hectare. The lowest seed yield per hectare (423.22kg) was noticed in B_0C_0 treatment. Application of B_2C_2 treatment increased 60.92% seed yield per hectare over B_0C_0 treatment.

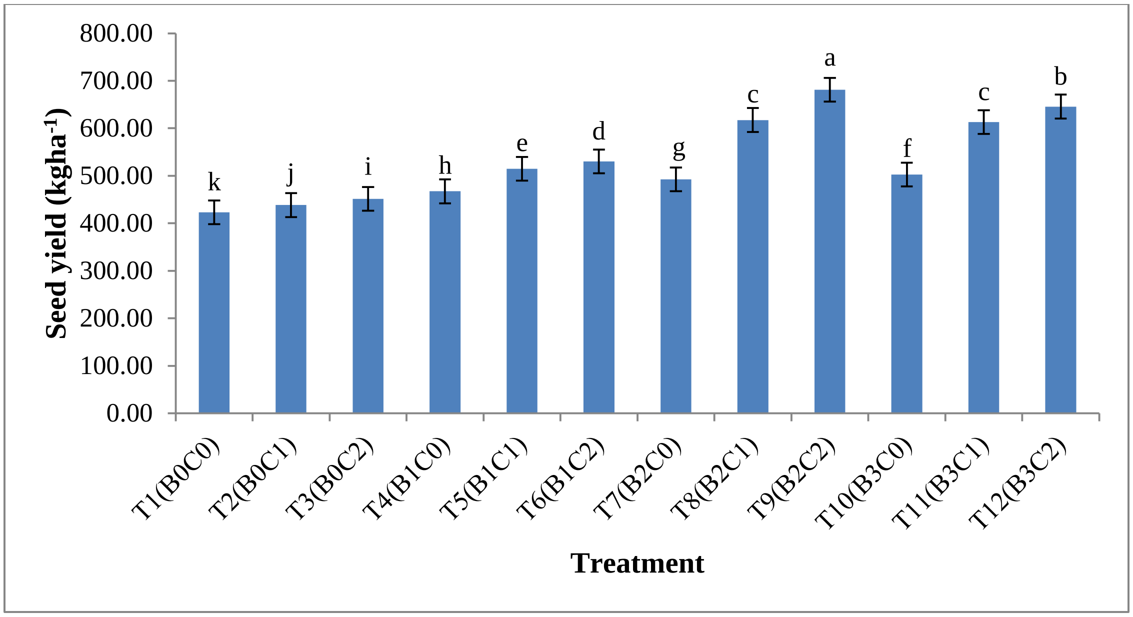

Fig. 9: Combined effect of boron and calcium treatments on seed yield ha^{-1} (kg) of onion

4.4 Germination parameters

4.4.1 Germination percentage

4.4.1.1 Effect of treatments

Germination percentage was significantly influenced by boron (Table 14 and Appendix VIII). The highest germination percentage (85.67%) was recorded from B_3 (2000ppm) treatment. B_2 and B_1 treatment showed the statically similar result. The lowest germination percentage (71.67%) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on germination percentage (Table 14 and Appendix VIII). The maximum germination percentage (80%) was observed from C_2 (5000ppm) treatment and the minimum germination percentage (71.68%) found in C_0 (No Calcium) treatment.

Table 14. Effect of boron and calcium treatments on germination percentage of onion seed

Effect of boron	
Treatment	**Germination percentage of seed**
B_0	71.67 c
B_1	79.11 b
B_2	81.00 b
B_3	85.67 a
$LSD_{(0.05)}$	**2.6915**
CV (%)	**1.70**
Effect of calcium	
Treatment	**Germination percentage of seed**
C_0	71.68 c
C_1	77.78 b
C_2	80.00 a
$LSD_{(0.05)}$	**1.1405**
CV (%)	**0.66**

4.4.1.2 Combined effect of treatments

Combined application of calcium and boron significantly increased the germination percentage (Figure 10 and Appendix VIII). Germination percentage from combined treatment ranged from 96 to 71.67%. Germination percentage was higher in B_2C_2 (boron 1000ppm and calcium 5000ppm) treatment. Application of this treatment 96% germination was observed. 93.11% of germination was found from B_3C_2 treatment. B_2C_1 and B_3C_0 treatment gave the statically similar result on germination percent. Lowest germination percentage (71.67%) was observed in B_0C_0 combined treatment. B_2C_2 treatment increased 33.94% of seed germination over B_0C_0 treatment.

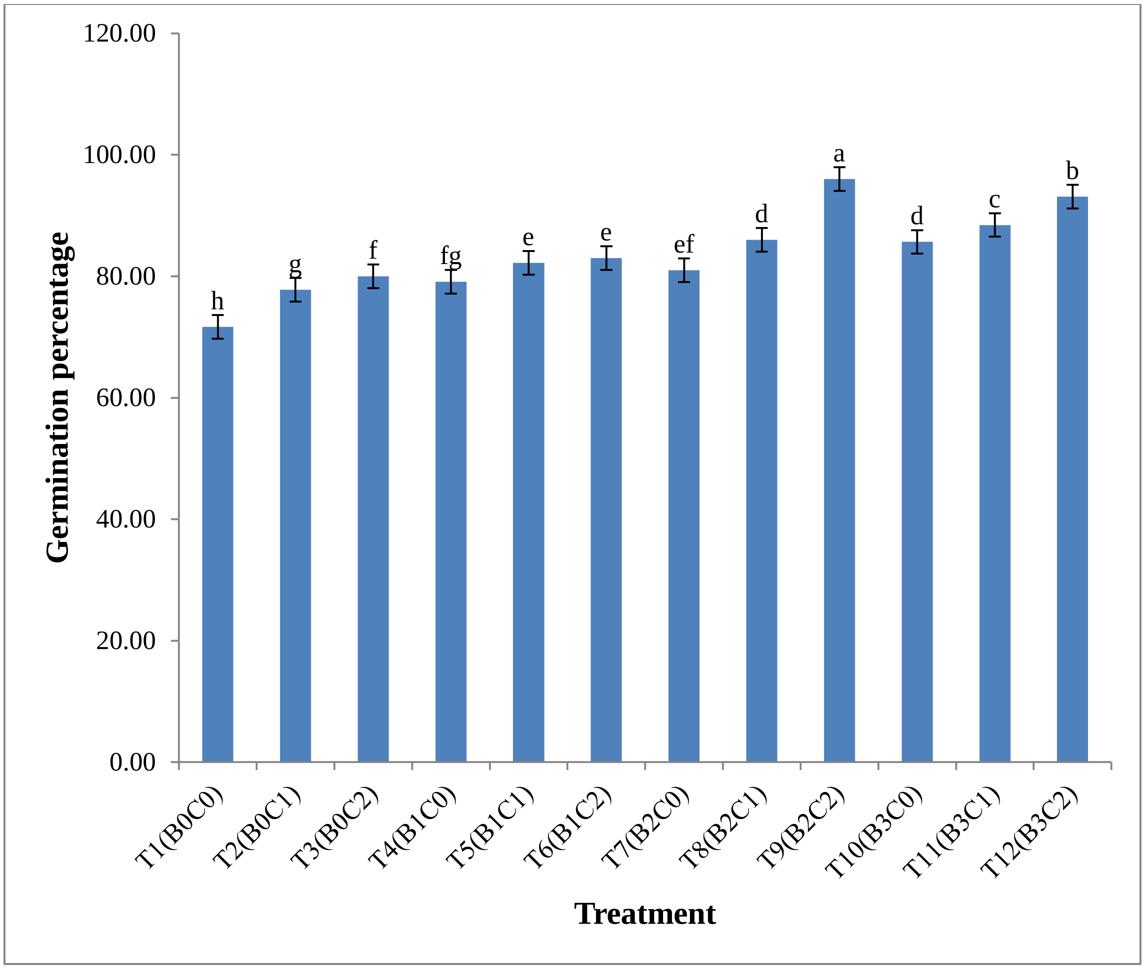

Fig. 10: Combined effect of boron and calcium treatments on germination percentage of onion seed

4.4.2 Normal seedling (%)

4.4.2.1 Effect of treatments

Normal seedling percentage was significantly influenced by boron (Table 15 and Appendix VIII). Normal seedling percentage from Boron treatments ranged from 53.67 to 78.89%. The highest normal seedling percentage (78.89%) was recorded from B_3 (2000ppm) treatment. The lowest normal seedling percentage (53.67 %) was found in B_0 (No Boron) treatment.

Calcium also significantly influenced on normal seedling percentage (Table 15 and Appendix VIII). The maximum normal seedling percentage (64.67%) was observed from C_2 (5000ppm) treatment and the minimum normal seedling percentage (53.67%) found in C_0 (No Calcium) treatment.

Table 15. Effect of boron and calcium treatments on normal seedling (%) of onion

Effect of boron	
Treatment	**Normal seedling (%)**
B_0	53.67 d
B_1	64.89 c
B_2	72.00 b
B_3	78.89 a
$LSD_{(0.05)}$	**3.0356**
CV (%)	**2.26**
Effect of calcium	
Treatment	**Normal seedling (%)**
C_0	53.67 c
C_1	62.22 b
C_2	64.67 a
$LSD_{(0.05)}$	**1.8424**
CV (%)	**1.35**

4.4.2.2 Combined effect of treatments

Momentous variation was observed for normal seedling production due to combined application of boron and calcium (Figure 11 and Appendix VIII). Normal seedling percentage from combined treatment ranged from 92.69 to 53.67%. Among all the combined treatment B_2C_2 produced the highest normal seedling (92.69%) than other treatment. B_3C_2 produced 89.32% normal seedling.

B_0C_0 produced 53.67% of normal seedling which was the lowest percentage of normal seedling. B_2C_2 treatment increased 72.70% of normal seedling over B_0C_0 treatment.

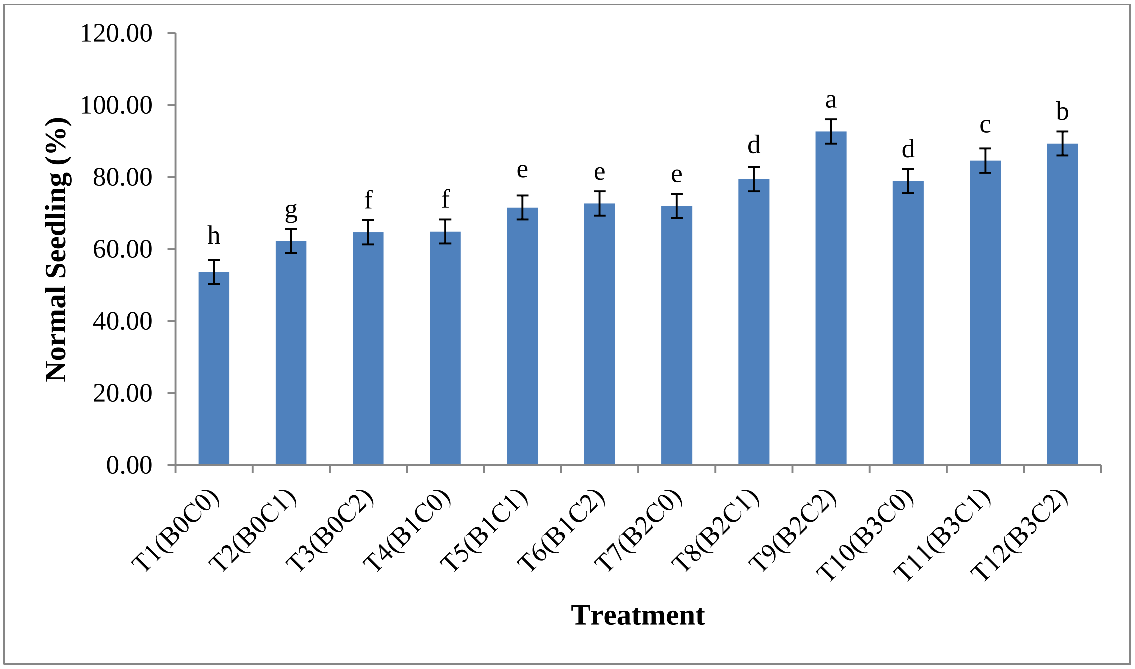

Fig. 11: Combined effect of boron and calcium treatments on normal seedling (%) of onion

4.4.3 Abnormal seedling (%)

4.4.3.1 Effect of treatments

Abnormal seedling percentage was significantly influenced by boron (Table 16and Appendix VIII). Abnormal seedling percentage from Boron treatments ranged from 6.78 to 18%. The highest abnormal seedling percentage (18%) was recorded from B_0 (No Boron) treatment. The lowest abnormal seedling percentage (6.78%) was found in B_3 (2000ppm) treatment.

Calcium also significantly influenced on abnormal seedling percentage (Table 16 and Appendix VIII). The maximum abnormal seedling percentage (18%) was observed from C_0 (No Calcium) treatment and the minimum abnormal seedling percentage (15.33%) found in C_2 (5000ppm) treatment.

Table 16. Effect of boron and calcium treatments on abnormal seedling (%) of onion

Effect of boron	
Treatment	**Abnormal seedling (%)**
B_0	18.00 a
B_1	14.22 b
B_2	9.00 c
B_3	6.78 d
$LSD_{(0.05)}$	**0.4964**
CV (%)	**2.07**
Effect of calcium	
Treatment	**Abnormal seedling (%)**
C_0	18.00 a
C_1	15.56 b
C_2	15.33 b
$LSD_{(0.05)}$	**0.7965**
CV (%)	**2.16**

4.4.3.2 Combined effect of treatments

For various combined applications of boron and calcium significant variation was observed in abnormal seedling production (Figure 12 and Appendix VIII). Abnormal seedling percentage from the combined treatment ranged from 3.33 to 18%. Large number of abnormal seedling (18%) was found from B_0C_0 treatment. B_0C_1 and B_0C_2 treatment produced 15.56 and 15.33% of abnormal seedling respectively, which were statically similar. Lower number of abnormal seedling

(3.33%) was found from B_2C_2 treatment. B_2C_2 treatment reduced the abnormal seedling by 81.5% over B_0C_0 treatment.

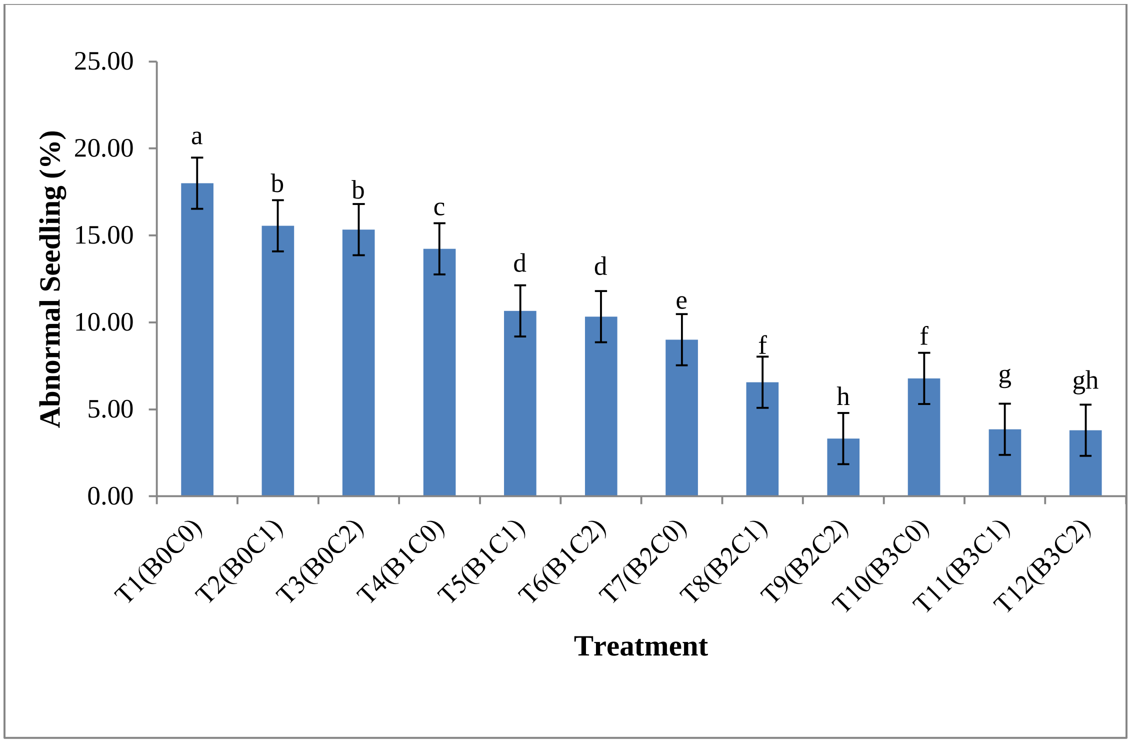

Fig. 12: Combined effect of boron and calcium treatments on abnormal seedling (%) of onion

Chapter 5

SUMMARY AND CONCLUSION

This study was conducted to know the effect of boron and calcium concentration and this combined effect on the growth and seed yield of onion. BARI Piaz-1 was used for this experiment conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from October 2017 to February 2018.

The experiment was placed out in a Randomized Completely Block Design (RCBD) with three replications. There were 36 plots all together in each replication with the given factors and treatments. There were 12 treatment combinations. The treatments were control T_1 (B_0C_0), T_2 (B_0C_1), T_3 (B_0C_2), T_4 (B_1C_0), T_5 (B_1C_1), T_6 (B_1C_2), T_7 (B_2C_0), T_8 (B_2C_1), T_9 (B_2C_2), T_{10} (B_3C_0), T_{11} (B_3C_1) and T_{12} (B_3C_2). Germination test was performed of the seeds in the laboratory. The data were collected from ten days seedlings for three times with some parameters viz. germination (%), number of normal and abnormal seedling.

The results revealed that boron and calcium treatments had significant effect on crop growth parameters e.g. plant height and leaf number at different DAP. The highest plant height and leaf number was found in B_3, C_2 and B_3C_2 treatments. The highest plant height 13.10cm at 30DAP, 16.23cm at 45DAP, 25.03cm at 60DAP, 38.43cm at 75DAP, 53.67cm at 95DAP and 53.97cm at harvest was found from B_3C_2 treatment. Also highest leaf number 3.95 leaves at 30DAP, 6.73 leaves at 45DAP, 7.47 leaves at 60DAP, 8.63 leaves at 75DAP, 9.03 leaves at 90DAP and 8.17 leaves at harvest was seen in B_3C_2 treatment. Different boron and calcium treatments also had significant effect on the physiological parameters viz. chlorophyll content was highest in B_3C_2 treatment (50.80 mg cm^{-2}).

Also boron and calcium treatments had significant effect on yield and yield contributing characters viz. umbel $plot^{-1}$, flowers $umbel^{-1}$, fruits $umbel^{-1}$, fruit set (%), yield $plant^{-1}$, yield per plot, 1000-seed weight, yield ha^{-1} was highest in B_2C_2 treatment. The highest seed yield $plant^{-1}$ (3.14g), highest seed yield $plot^{-1}$ (163.45g), highest seed yield ha^{-1} (681.06kg) was found in B_2C_2 treatment.

Germination (%) was also affected by the boron and calcium treatments. The highest germination percentage (96%) was observed in B_2C_2 treatment. B_2C_2 treatment also increased the normal seedling percentage (92.69%) and reduced the abnormal seedling percentage (3.31%).

Based on result of the present experiment, together with results found in the available literature, we therefore concluded that boron and calcium application is an effective way to increased growth, physiology, yield components, germination (%) and normal seedling of onion effectively and reduced abnormal seedling in a certain level of treatment. For wider acceptability, the same experiment should be repeated at different agro-ecological zones (AEZ) of the country.

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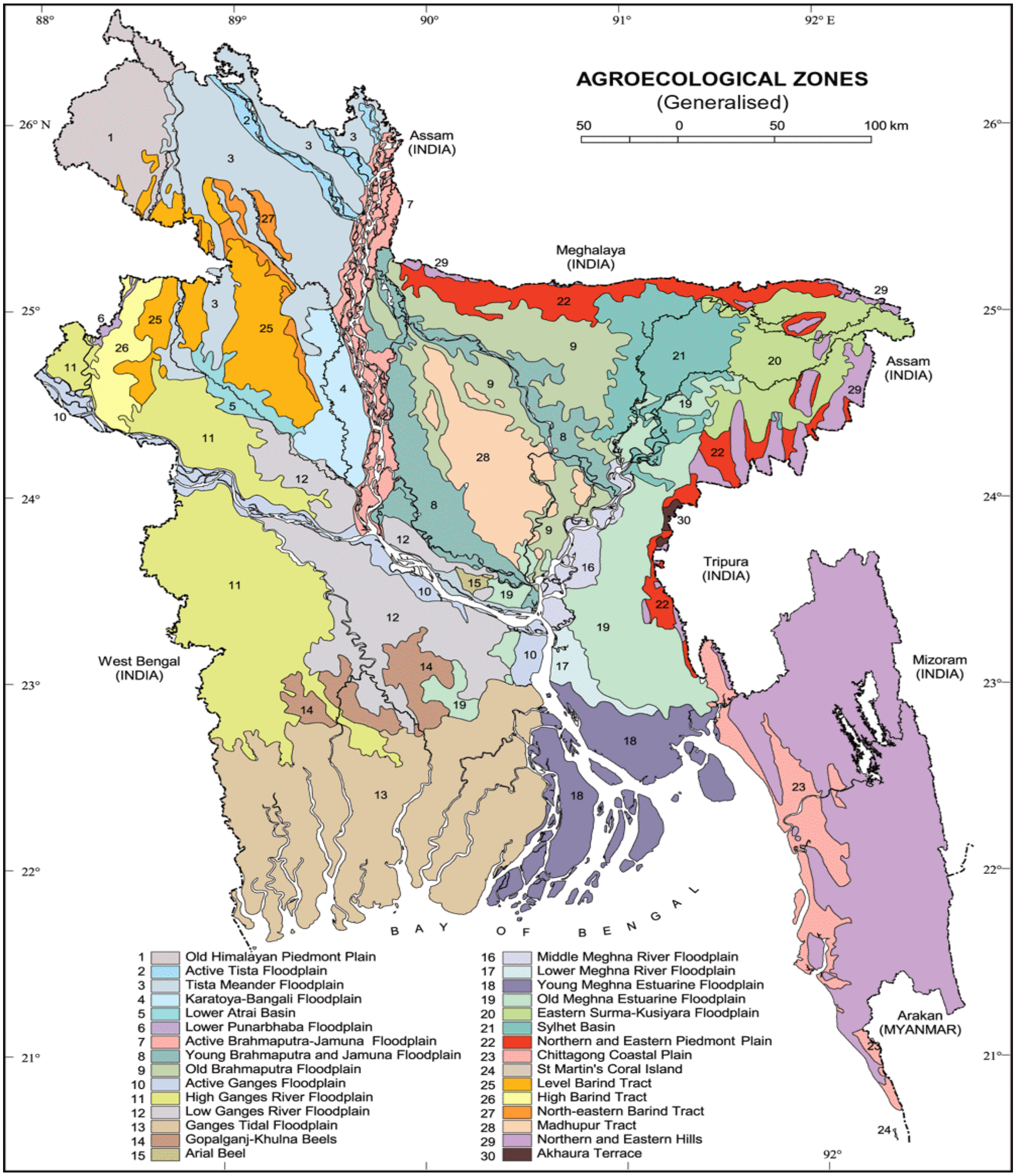
APPENDICES

Appendix I. Experiment was conducted in Sher-e-Bangla Agricultural University, Dhaka (AEZ-28) on the map of Agro-ecological Zones of Bangladesh



Appendix II. Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Characteristics	Value
Particle size analysis	
%Sand	26
%Silt	41
%Clay	33
Textural class	Silty-clay
pH	5.7
Organic carbon (%)	0.45
Organic matter (%)	0.72
Total N (%)	0.04
Available P (ppm)	18.00
Exchangeable K (me/100 g soil)	0.12
Available S (ppm)	42

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from October 2017 to February 2018

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
October, 2017	34.3	28.1	71.3	67.06
November, 2017	32.3	27.1	67.3	59.06
December, 2017	30.6	23.1	57.5	51.06
January, 2018	32.3	28.1	66.3	48.06
February, 2018	34.3	30.1	63.3	56.06

Source: SAU Meteorological Yard , Sher-e-Bangla Nagar, Dhaka-1207.

Appendix IV. Mean square values for plant height of onion

Source of variation	Degrees of freedom	Mean square values for single boron effect on plant height					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	0.11583	0.02083	0.36750	0.10750	3.90250	3.36583
Variety	3	3.84972	2.99639	2.93556	4.55861	5.78750	7.42750
Error	6	0.04472	0.13639	0.19639	0.64528	0.37583	0.30250
CV (%)		2.22	2.71	2.03	2.58	1.39	1.24

Source of variation	Degrees of freedom	Mean square values for single calcium effect on plant height					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	0.03444	0.07111	0.12333	1.37333	3.87111	3.44333
Variety	2	0.77778	0.40444	1.08333	0.76000	2.13778	2.12333
Error	4	0.05111	0.07444	0.29667	0.28833	0.80444	0.73167
CV (%)		2.63	2.13	2.60	1.79	2.08	1.99

Source of variation	Degrees of freedom	Mean square values for combined effect on plant height					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	0.43694	0.11083	0.32710	0.5078	5.3678	4.1186
Variety	11	6.94869	5.23152	6.08705	20.3502	26.8821	28.9160
Error	22	0.04937	0.11689	0.27946	0.5181	1.0026	0.8650
CV (%)		2.12	2.36	2.32	2.20	2.19	2.02

Appendix V. Mean square values for leaves plant^{-1} of onion

Source of variation	Degrees of freedom	Mean square values for single boron effect on leaves plant^{-1}					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	0.00098	0.01463	0.01351	0.00480	0.04083	0.03250
Variety	3	0.05308	0.83991	0.67652	0.34836	0.11778	0.86306
Error	6	0.00089	0.01041	0.02762	0.04036	0.04528	0.01139
CV (%)		1.17	2.06	2.83	3.01	2.86	1.80

Source of variation	Degrees of freedom	Mean square values for single calcium effect leaves plant^{-1}					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	5.733	0.01444	0.00444	0.02014	0.03111	0.01333
Variety	2	6.933	0.33778	0.14778	0.15114	0.36778	1.63000
Error	4	1.267	0.01444	0.02778	0.04801	0.02611	0.03833
CV (%)		1.47	2.64	3.04	3.33	2.14	3.25

Source of variation	Degrees of freedom	Mean square values for combined effect leaves plant^{-1}					
		30 DAP	45 DAP	60 DAP	75 DAP	90 DAP	At harvest
Replication	2	0.00539	0.03363	0.03356	0.02808	0.02694	0.04528
Variety	11	0.08913	1.59681	1.36839	1.56600	0.92081	2.25846
Error	22	0.00117	0.01597	0.02783	0.03400	0.04361	0.02801
CV (%)		1.29	2.33	2.66	2.54	2.64	2.46

Appendix VI. Mean square values for chlorophyll content, umbel plot^{-1}, flowers umbel^{-1}, fruits umbel^{-1} and fruit set (%) of onion

Source of variation	Degrees of freedom	Mean square values for single boron effect				
		Chlorophyll content	Umbel plot^{-1}	Flowers umbel^{-1}	Fruits umbel^{-1}	Fruit set (%)
Replication	2	0.7825	0.58303	12.9675	12.603	2.3145
Treatment	3	15.3100	7.72187	31.3786	310.209	76.3582
Error	6	1.0625	1.33037	1.2786	3.892	1.9154
CV (%)		2.38	1.80	0.74	1.62	1.74

Source of variation	Degrees of freedom	Mean square values for single calcium effect				
		Chlorophyll content	Umbel plot^{-1}	Flowers umbel^{-1}	Fruits umbel^{-1}	Fruit set (%)
Replication	2	0.02778	2.44000	2.00333	21.068	5.476
Treatment	2	9.01444	9.37333	5.49333	330.268	117.839
Error	4	1.61444	2.27333	3.36667	0.701	0.770
CV (%)		3.02	2.35	1.22	0.69	1.09

Source of variation	Degrees of freedom	Mean square values for combined effect				
		Chlorophyll content	Umbel plot^{-1}	Flowers umbel^{-1}	Fruits umbel^{-1}	Fruit set (%)
Replication	2	0.5769	1.25588	18.276	24.854	7.792
Treatment	11	24.6766	9.92707	124.368	646.404	113.481
Error	22	1.1742	1.12173	2.534	5.484	2.491
CV (%)		2.39	1.61	1.01	1.74	1.85

Appendix VII. Mean square values for seed yield plant^{-1}, seed yield plot^{-1}, 1000-seed weight and seed yield ha^{-1} of onion

Source of variation	Degrees of freedom	Mean square values for single boron effect			
		Seed yield plant^{-1}	Seed yield plot^{-1}	1000-seed weight	Seed yield ha^{-1}
Replication	2	0.00053	1.442	0.00206	38.37
Treatment	3	0.08016	216.763	0.06966	3763.25
Error	6	0.00132	3.575	0.00125	8.74
CV (%)		1.67	1.67	1.58	0.63

Source of variation	Degrees of freedom	Mean square values for single calcium effect			
		Seed yield plant^{-1}	Seed yield plot^{-1}	1000-seed weight	Seed yield ha^{-1}
Replication	2	0.00703	19.0181	0.00221	6.287
Treatment	2	0.01270	34.3408	0.01768	596.194
Error	4	0.00223	6.0389	0.00276	29.120
CV (%)		2.34	2.34	2.49	1.23

Source of variation	Degrees of freedom	Mean square values for combined effect			
		Seed yield plant^{-1}	Seed yield plot^{-1}	1000-seed weight	Seed yield ha^{-1}
Replication	2	0.01050	28.40	0.00436	18.5
Treatment	11	0.48235	1304.27	0.70387	22643.6
Error	22	0.00132	3.58	0.00302	18.6
CV (%)		1.48	1.48	2.15	0.81

Appendix VIII. Mean square values for germination percentage, normal seedling (%) and abnormal seedling (%) of onion

Source of variation	Degrees of freedom	Mean square values for single boron effect		
		Germination (%)	Normal seedling (%)	Abnormal seedling (%)
Replication	2	0.148	0.259	0.3333
Treatment	3	101.713	348.059	77.2099
Error	6	1.815	2.309	0.0617
CV (%)		1.70	2.26	2.07

Source of variation	Degrees of freedom	Mean square values for single calcium effect		
		Germination (%)	Normal seedling (%)	Abnormal seedling (%)
Replication	2	0.6420	1.494	0.23457
Treatment	2	55.8642	100.086	6.56790
Error	4	0.2531	0.660	0.12346
CV (%)		0.66	1.35	2.16

Source of variation	Degrees of freedom	Mean square values for combined effect		
		Germination (%)	Normal seedling (%)	Abnormal seedling (%)
Replication	2	1.361	2.022	0.1643
Treatment	11	135.300	404.679	77.8855
Error	22	1.641	1.981	0.0932
CV (%)		1.53	1.90	3.12