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Comparing the Effect of Foliar Spraying by Calcium and Boron on Productivity and Quality of Strawberry Fruits under Organic Hydroponic System

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Abstract
The availability of slow-moving elements within the plant is very important for the growth and productivity of crops, the most important of which are calcium and boron, and the deficiency of any of them leads to a significant imbalance in growth and productivity. This experiment was conducted inside a greenhouse at the National Organic Agriculture Center, Unaiza, Qassim, Ministry of Environment Water and Agriculture, Saudi Arabia to investigations made on the effects of foliar applications levels of calcium (Ca) and boron (B) on yield and quality of strawberries (*Fragaria X ananassa Duch*.). Factorial experiment was used in a randomized complete block design (RCBD) with four levels of calcium (Ca1=100, Ca2 = 200, Ca3= 400 mg/l), and four levels of boron (B1= 5, B2= 10, B3= 20 mg/l), as well as control treatment (C=0), each treatment was replicated three times. Different treatments with different combinations of both elements were studied. Addition of B and Ca influence vegetative growth parameters, yield attributes and fruit quality parameters significantly compare to the control such as the percentages of Glucose%, Fructose%, vitamin C and Sucrose%. Therefore, results indicated that sprays of mixture contained calcium and boron at different levels of Ca2B1, Ca1B1 and Ca3B1 increased fruit diameter, fruit length, weight /plant, and total weight (g), while with Ca3B1 and Ca3B2 were showed high increment of sugar percentages. According to results authors recommended foliar application of combination of calcium and boron as follow Ca2B1, Ca3B1 and Ca3B2 to improve yield attributes and fruit quality parameters.
Keywords: Strawberry, Foliar application, Calcium, Boron, Organic hydroponics
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1.Introduction:

The strawberry plant (*Fragaria ananassa Duch*.) belongs to the Rosaceae family, which includes about 100 genera and 2,500 species. It is one of the most important crops with small fruits after grapes widespread in different regions of the world due to its many varieties and its ability to grow and adapt to different environmental conditions. Strawberries are cultivated worldwide on an area of 255 thousand hectares with an annual production of 7.7 MT. Strawberry (*Fragaria x ananassa*) is the world's most delicious and nutritious fruit (Bibi et al., 2016). It is widely consumed as fresh and/or used as a flavor in food products i.e., ice creams,

jams, jellies, cakes, and milkshakes (Codrea et al., 2019). Strawberries serve as an important source of vitamins (A, B1, B2, and C) fiber, calories, and minerals (Kazemi, 2015; Singh et al 2015 Hossain et al., 2016). Moreover, it also possesses some medicinal properties like anticarcinogenic antidiabetic, and antioxidant (Kumar et al., 2017). This fruit is achieving popularity among consumers of all age groups. The nutritional studies suggest that one hundred grams edible portion of strawberries may contain about 90 g water, 0.5 g fats, 59 g ascorbic acid, 8.4 g carbohydrates, and 0.07 g proteins (Hossain et al., 2016; Tariq et al., 2018).

Strawberries are unique in highly desirable taste, flavor, and an excellent source of vitamins, potassium, fiber, and sugars**,** Strawberry as a crop has specific nutritional requirements during the phases of flower differentiation within buds, bloom, and fruit ripening, strawberries respond significantly to fertilization, as it is one of the most important operations for regulating physiological processes and plant yield, due to the plant, small size**,** high yield, and the long production period, researchers pointed to the effect of macro and micro mineral nutrients in strawberry, most notably N, P, K, and Ca are of great importance in strawberry plant growth and production. The foliar nutrition of micro-nutrients is very important in improving fruit set, productivity, and quality of fruits. Foliar nutrition at the proper time improved the quality and quant strawberries (Kazemi *et al.*, 2011).

Foliar fertilization is an important tool for the sustainable and productive management of crops. Foliar spray is a way to reduce the use of chemical fertilizers and their environmental hazards (Niu et al. 2021). Besides, by foliar feeding, nutrients can be delivered directly and quickly to the plant or fruit if needed. Some of the plant organs, like fruits, need nutrients such as calcium and potassium more than the whole plant; or in early spring, when the roots are still unable to absorb nutrients due to low soil temperatures, foliar spraying is vita Fernández et al. 2013).

The availability of calcium and boron is very important for the growth of plants as the lack of any of them lead to a significant imbalance in growth and yield. Low fruit calcium concentration particularly in fleshy fruit, results from the fact that calcium is immobile in the phloem Increased calcium level in fruits usually improves their storage life. Calcium treatment helps to retain fruit firmness, increase vitamin C content, and decreased storage breakdown rotting and browning in apples (Kazemi et al., 2011). The spray of Calcium during fruit development provides a safe mode of supplementing endogenous calcium to fresh fruits (Raese and Drake 2000). Also, Vicente et al., (2007) showed that calcium application can significantly reduce postharvest decay by increasing TSS, total sugar and strengthening the cell wall matrix and presumably enhancing resistance to attack by fungi and bacteria affecting fruit quality and preservation.

Boron is an essential and important micronutrient in the vegetative and reproductive growth of fruit and vegetables. Boron deficiency first appears on the terminal younger leaves in plants; plants fail to produce functional flowers and may produce no seeds. Plants subjected to boron deficiency suffered from low germination of pollen. Failure to set fruit is common, and the fruit may be ridged, show corky patches, and ripens unevenly (Gupta, and Philip, 2006). While, the increase in boron level resulted in a significant increase of all growth traits; canopy fresh and dry weight, shoot and root length, and leaf area/plant in strawberry plants (Wójcik, and Lewandowski2003). Further, boron is an essential nutrient element and its deficiency reduces pollen germination and growth of pollen tubes, which consequently results in the development of malformed fruits, which lowers crop yield and deteriorates fruit quality. Boron is considered one of the important and necessary micronutrients in plant production and growth, and it is no less important than the major nutrients, it has many physiological functions in plants, as it has a role in the processes of differentiation and cellular morphology and in the fertilization process as it is necessary for the production of pollen, flowering and seed formation, It affects the formation of the cell wall and the formation of pectin and lignin, as it was found that 50% of the boron present in the plant is concentrated in the cell wall. Moreover, it is generally accepted that soil boron application is less successful in increasing fruit yield than B spray. Therefore, boron sprays are most frequently recommended in fruit production with a high risk of boron deficiency. However, little is known about the effect of boron sprays on strawberry yield and fruit quality (Guttridge and Turnbull, 1975; Lieten, 1989, 1998, 2002; Sharma and Sharma, 2004). In this concern, the present study was undertaken to determine the effect of calcium and boron on the level of sugars and total acidity of strawberries.

2. Materials and Methods:

2.1 Experiment Location and Plant Description:

The experiment was conducted inside a greenhouse at the National Organic Farming Centre, Unaiza, Kingdom of Saudi Arabia, in January 2023. Seedlings of the Strawberry plants (Festival cultivar) were brought from one of the certified organic nurseries, roots of the seedlings were sterilized before planting. 24 seedlings were planted per experimental plot.

2.2 Experiment design:

The greenhouse is equipped and sterilized as well as sterilization of the hydroponic system (vertical tower) and

the growing medium used in agriculture (volcanic stone). The experiment included 30 experimental plots (vertical tower) in a completely randomized plot design (RCBD), and each plot included 40 plants. Three levels of calcium and boron were used as a spray. Each treatment included three replicates for each experimental plot in addition to the control treatment (without spraying). Root and foliar organic fertilizer solutions (NPK) were used according to different plant stages' needs. The pH of the nutrient solution was maintained at 6.5-7.5, the concentration of salts at 600-700 ppm, and the temperature and humidity at 18 - 25 and 60 - 70 %, respectively. Organic nutrient solutions were added to the system after four days after planting. The transactions were distributed as follows:1). Calcium (Ca), and is added at levels Ca1 (100 mg/L), Ca2 (200 mg/L), and Ca3 (400 mg/L), and Boron was added at levels B1 (5 mg / L), B2 (10 mg / L), and B3 (20 mg / L). 2), as well as control treatment (C=0). Also, the symbols Ca and B denote overlap between the two treatments .

2.3 Analysis of plant and fruits parameters:

leaf area (cm2) (measured by Digital Image Analysis Software according to (Bakr, (2005), Chlorophyll content (SPAD), the SPAD meter is a promising tool for diagnosing the N status of crops (**Lemaire et al., 2008**). Fruit diameter (cm) The diameter of four fruits was taken from each experimental unit by means of the peduncle (Vernia modified), Fruit length Fruit weight (g), total yield weight, and total acidity was measured by using the sodium hydroxide solution according to (A. O. A. C., 2000). Total sucrose percentage (Brix %) by refractometer method according to I. S 13815, (1993) determined glucose, fructose, sucrose, and vitamin C by liquid chromatographic methods (Scherer et al., 2012).

2.4 Statistical analysis:

For this experiment, a RCBD was considered and the results were analyzed statistically using analysis of variance (ANOVA). All statistically significant main effects and interactions were considered. To determine the significance of the difference between the means of the two treatments, the least significant differences (LSD), estimated at the 5% probability level were used. Statistical information such as coefficient of variation (CV), standard error (SE), least significant differences (LSD), and level significance (P<) was recorded for the main effect and interactions. All data were analyzed by GenStat (v16) statistical software.

3. Results and Discussion

3.1 Chlorophyll content and Leaf area

The results in Table (1) showed significant difference between treatments in the leaf area. Treatment Ca2 (2 mL/L) gave the highest leaf area (31.3 cm^2) followed by the combined effect of Ca2B1 that gave (30.69 cm^2). High significant differences were observed on the effect of calcium and boron and their combination on the average of chlorophyll content. Obliviously, it's clear that only ca increased the chlorophyll content to high levels, the increment is dose wise viz Ca3 gave (79.48), Ca2 gave (71.36) and Ca3 gave 64.38 (SPAD). Only high doses of calcium combined with boron gave high content of chlorophyll l but its less than that of use of calcium alone on the three doses Table 1.

Also, the significant effect of calcium concentration on the total chlorophyll content of leaves, may be due to the role of calcium in the formation of chlorophyll in activating and preventing the inhibition of some enzyme systems in the plant by preventing the accumulation of oxalate in the dissolved forms of leaves, as well as the high concentrations of calcium lead to competition between ammonia and calcium ions for absorption sites on Competitive absorption, which reduces the absorption of nitrogen, which enters the composition of the chlorophyll molecule (Chow et al., 2002 and Morris et al., 2007).

In this study all Ca: B: levels significantly increase all growth traits (leaf area and Chlorophyll content (SPAD)) of the strawberry cultivar compared with control.

Table 1. Effect of foliar spraying with Ca and B on vegetative growth parameters of the strawberry plant.

Treatments	Leaf area (cm^2)	Chlorophyll content (SPAD)
C	21.13^{f}	44.28^{j}
Ca1	29.45^{abc}	64.38^{c}
Ca2	31.35^{a}	71.36^{b}
Ca3	$28.65^{a\ b\ c\ d}$	79.48^{a}
B1	25.71^{abcdef}	49.91^{hi}
B2	21.31^{f}	50.90^{ghi}
B3	23.33^{def}	47.27^{ij}
Ca1B1	27.62^{abcde}	53.74^{fgh}
Ca1B2	25.87^{abcdef}	54.91^{fg}
Ca1B3	22.49^{ef}	49.46^{i}
Ca2B1	30.69^{ab}	53.60^{fgh}
Ca2B2	25.37^{abcdef}	56.84^{ef}
Ca2B3	21.66^{f}	54.80^{fg}
Ca3B1	23.98^{cdef}	59.00^{de}
Ca3B2	26.14^{abcdef}	61.45^{cd}
Ca3B3	21.58^{f}	61.65^{cd}
Mean	25.40	57.06
SE+	1.97	1.444
CV%	13.40	4.4
LSD	5.69	4.172

3.2 Effect of Ca and B on some yield attributes of strawberry plants.

Significant differences were observed due to the application of calcium and boron on the fruit diameter (mm), fruit length, Weight /plant total weight (g) and fruit total acidity of strawberry in comparison with the control in Table (2). For all the above-mentioned traits except fruit acidity, the combined effect of ca and boron for the doses Ca3B1, Ca2B1 and Ca1B1 respectively was found the best among others on increasing fruit diameter, fruit length, fruit weight as well as total weight. In Table 2. It's clear that, the fruit acidity was positively associated with the combined doses from both elements; especially Ca3B3, Ca3B2, Ca1B3 and Ca2B3, respectively.

Table 2. Effect of foliar spraying of Ca and B levels on yield attributes of strawberry plants.

Treatments	F. diameter mm	F. length mm	F. weight /plant (g)	Total weight (g)	Tot. acidity %
C	31.54^{hi}	35.12^{e}	62.58^{ef}	2503.00^{ef}	0.55^{h}
Ca1	$34.75^{e\ f\ g}$	42.09 C^{d}	65.12^{ef}	2604.67^{ef}	0.86^{de}
Ca2	$36.13^{d\ ef}$	44.70^{bc}	68.28^{df}	2731.33^{de}	1.01^{b}
Ca3	$37.89^{c\ de}$	50.38^{a}	71.88^{cd}	2875.00^{cd}	0.91^{cd}
B1	33.31^{fgh}	37.34^{e}	63.73^{ef}	2549.33^{ef}	0.64^{gh}
B2	32.61^{gh}	39.30^{de}	49.53^{g}	1981.33^{g}	0.71^{fg}
B3	28.27^{j}	38.91^{de}	37.63^{i}	1505.00^{i}	0.74^{f}
Ca1B1	38.21^{cd}	44.58^{bc}	75.14^{c}	3005.67^{c}	0.79^{ef}
Ca1B2	35.78^{def}	44.07^{bc}	65.01^{ef}	2600.33^{ef}	0.87^{de}
Ca1B3	32.05^{ghi}	42.01^{cd}	43.65^{h}	1746.00^{h}	0.97^{bc}
Ca2B1	42.87^{ab}	47.24^{ab}	82.63^{b}	3305.33^{b}	0.84^{de}
Ca2B2	40.74^{bc}	39.18^{de}	62.99^{ef}	2519.67^{ef}	0.91^{cd}
Ca2B3	30.84^{hij}	37.93^{de}	37.83^{i}	1513.33^{i}	1.02^{b}
Ca3B1	44.23^{a}	48.19^{ab}	89.31^{a}	3572.33^{a}	0.88^{de}
Ca3B2	34.82^{efg}	37.20^{e}	59.80^{f}	2392.00^{f}	0.98^{bc}
Ca3B3	29.44^{ij}	35.38^{e}	33.96^{i}	1358.33^{i}	1.15^{a}
Mean	35.22	41.48	60.57	2422.67	0.86
SE+	1.065	1.487	1.95	78	0.024
CV%	5.2	6.2	5.60	5.6	4.9
LSD	3.077	4.295	5.63	225.2	0.07

According to Bakshi *et al*., 2005, Ca is one of the most important macronutrients well known to ameliorate plant growth. It plays an important role in maintaining the quality of fruits and vegetables, which our study followed. Calcium treatment helps to make plants healthier by increasing canopy density (leaves number and area), foliage fresh and dry weight, and leaves nutrients values. While Hassan (2016) and Hamail et al. (2018)

reported that foliar spraying with different forms of Ca affected plant growth parameters, such as total leaf area and fresh weight, number of leaves per plant, and leaf area, respectively. Moreover, Rafeii and Pakkish (2014) suggested that foliar spraying of B may increase vegetative growth by increasing photosynthetic compounds

Our results are in the same line with many previous studies that described the beneficial role of calcium, boron calcium, and boron fertilizers in strawberries and other crops.

Many previous studies such as; Andriolo *et al*., (2010); Kazemi *et al.* (2011); **Dineshkumar,** (2016); Aziz et al., 2017; Mahesh gowda *et al*., (2017), and EL Oualkadi; Hajjaj (2019) and Ahmed et al. (2020) who evaluated different genotypes of strawberry (Fragaria X ananassa Duch.) for growth, yield, and quality and they found that Sabrina genotype to superior Fortuna cultivar in all growth measurements. Due to the role of calcium and boron in building cell walls in addition to their entry into the synthesis of cellular membranes and controlling their permeability Cakmak, I. (2014). Thus, calcium is also considered as a necessary element for the processes of growth and cell division and plays a key role in the permeability of the plasma membranes, which is directly reflected in the growth of the plant and the number of fruits, which leads to an increase in set percentage and the number of flowers and thus an increase in the yield per area Palta, J. P. (2010). Boron also has a role in the fertilization process because it is necessary for the production of pollen, flowers, seed formation, and pollen tube growth Abu Dahi *et al* (1988), these results are consistent with the findings of (Singh *et a*l 2015, Medan, Raad Ahmed (2020).

3.3 Effect of Ca and B on glucose, fructose, sucrose, and vitamin C in strawberry fruits.

The results in Figures 1, 2, 3 showed significant differences among treatments on the percentages of Glucose %, Fructose %, Vitamin C (mg/100 ml), and Sucrose% of strawberry fruits compared to the control treatment. Combined effect of Ca3B2 gave the highest percentages of glucose, fructose and sucrose followed by Ca3B1 and Ca3B3 respectively. For total sucrose boron only was found best than calcium alone and in combination with boron. Followed by Ca1B2, Ca2B1 and Ca2B2 respectively. The result in this study revealed significant difference among treatments on the content of the Vitamin C, the combined doses Ca3B2, Ca2B2, Ca2B3, Ca3B1 and Ca3B3gave the highest content of vitamin c respectively when compared to other treatments.

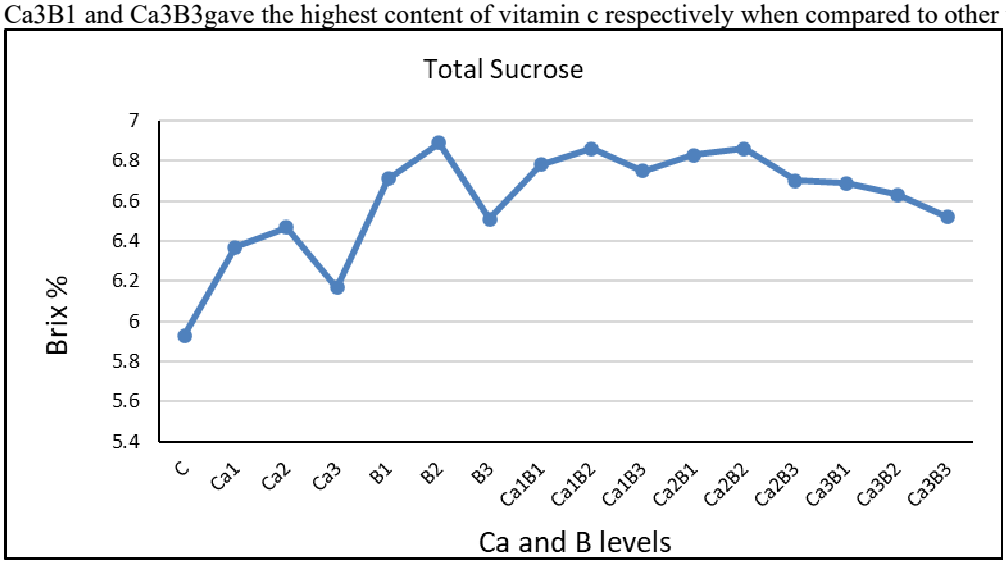

Figure 1. Effect of foliar spray of Ca and B on total sucrose in strawberry fruits

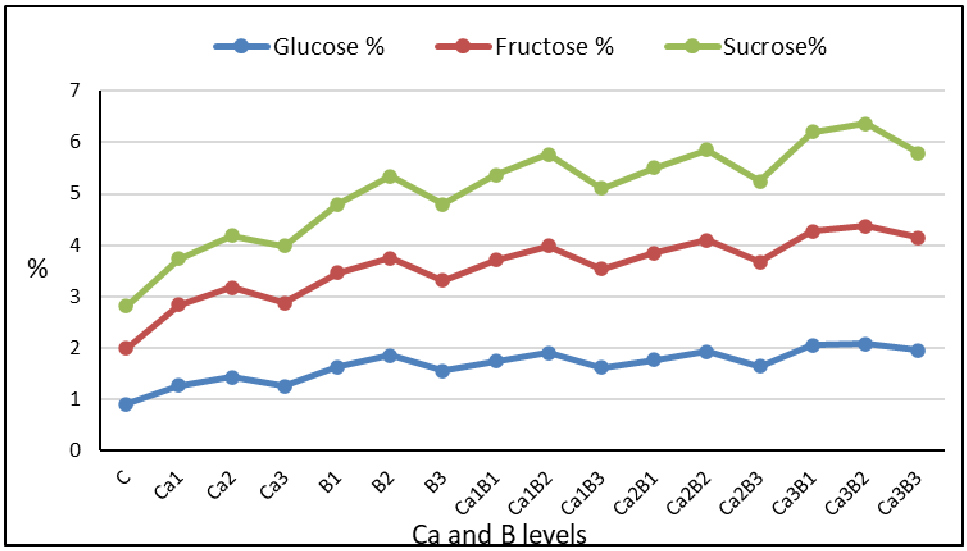

Figure 2. Effect of foliar spray of Ca and B on glucose, fructose, and sucrose in strawberry fruits.

An important determinant of fruit quality is the availability of essential nutrients during growth and development. Among them, calcium (Ca) slows down the ripening and senescence processes in many fruits including strawberries Singh *et a*l 2007. Nestby et al. (2005) and Prange and De Ell 1995, report that research conducted over the past 25 years on the effect of Ca on the postharvest quality of strawberries has provided contradictory conclusions. In some studies, foliar applications and soil amendments of Ca did not affect fruit quality, regardless of cultivar, yet other studies have shown increased shelf life due to Ca application Singh *et a*l 2007. Strawberry fruits from Ca-deficient plants are small, hard textured, acidic, seedy, or with patches covered densely with achenes, with increased

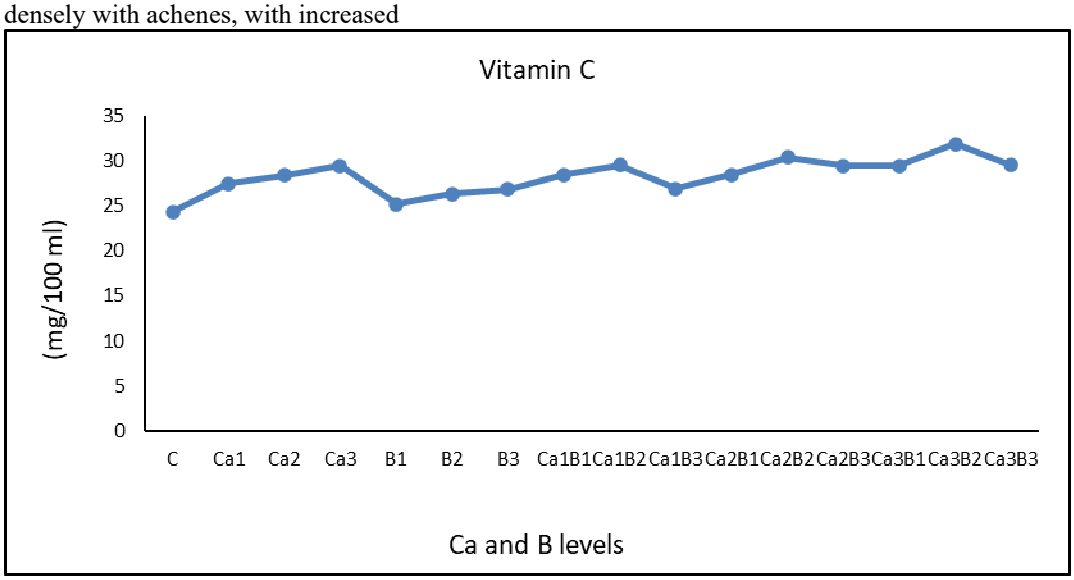

Figure 3. Effect of foliar spray of Ca and B on vitamin C in strawberry fruits.

deformity (Maas *et al* 1996). Calcium sprays increase fruit firmness, vitamin C, and shelf life during storage (Dunn and Able 2006). The application of gypsum at planting time did not influence fruit Ca content. Therefore, the cultivar, form of Ca applied, and environmental factors must be considered during the Ca fertilization of strawberries (Dunn and Able 2006). Among microelements, boron (B) has a direct effect on fruit quality. For example, B deficiency causes distorted flowers and fruits, reduces fruit size and number, and increases malformation (Kays 1999 and Nestby et al. (2005). The influence of B on phenol metabolism has also been well-studied (Anttonen et al., 2006). Fewer malformed fruit in plants receiving B can be correlated with a higher concentration of B both in leaves and fruit Singh *et a*l 2007, which may be due to the significant role of B in pollen germination and pollen tube growth.

Conclusions

Finally, this study demonstrated a significant variation in vegetative growth parameters, yield and quality characteristics. Therefore, our studies have clearly indicated that a combination of calcium and boron can be

recommended for vegetative growth, yield parameters and fruit quality parameters in strawberries.

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