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Effect of calcium-boron solution rate in foliar spray on muskmelon (*Cucumis melo* L.)

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ABSTRACT: The effect of calcium (Ca) and boron (B) was investigated on the quality of muskmelon. The experiment was set out as a 5 x 4 factorial in a randomized complete block design, with five repetitions as a 2-factor experiment. Factor 1 was Ca-B solution at 5 rates: spraying with plain water and spraying with Ca-B solution (0.75, 1.50, 2.25, or 3.00 ml/l). Factor 2 was 4 cultivars of muskmelon: Honeydew 1348 (Hon), Kanokkan 108 (Kan), Emerald Sweet (Eme), and TML-052 (Tml). The results showed that planting muskmelon cultivar TML-052 and spraying with 3.00 ml/l Ca-B solution produced the highest fruit weight of muskmelon (1,962.57 g). Spraying with Ca-B solution reduced the peel thickness, but the thickness of pulp and the level of sweetness increased, which affected the quality of the muskmelon. Spraying Ca-B solution at the rate of 1.50 ml/l or more had a positive effect on preventing fruit cracking. The level of Ca in the leaves, stalk, peel, and pulp following spraying with Ca-B solution increased compared with the plain water spray. Spraying with a Ca-B solution at the rate of 3.00 ml/l resulted in the highest mean levels of Ca in the leaves, stalk, peel, and pulp (9.03, 2.59, 0.52, and 0.17%, respectively). The spray rate of Ca-B solution at 3.00 ml/l produced the highest B levels in the leaves, stalk, peel, and pulp (73.92, 64.11, 57.42, and 26.67 mg/kg, respectively). The recommended spraying rate of Ca-B solution for Hon and Kan, which are smooth muskmelon cultivars, was at 1.50–2.25 ml/l, while for the cultivars of Eme and Tml, which are netted muskmelon, the rate was 0.75–1.50 ml/l can reduce fruit cracking and improved the quality of the muskmelon.
Keywords: calcium; boron; melon

Introduction

Muskmelon (*Cucumis melo* L.), commonly known as the ‘queen of the Cucurbitaceae’, with many cultivars was developed to grow in Thailand. Currently, two cultivars of muskmelon are commonly grown in Thailand: 1) C. *melo* var. *reticulatus* Naudinn is a cultivar that has a netted skin called muskmelon or netted melon, and 2) C. *melo* var. *inodorus* Naudin has a smooth skin called Honeydew (Srisaart and Samrongyen, 2016). The difference between these cultivars affects the nutritional requirements of muskmelon growth (Thongket, 2006). Successful fruit production from a muskmelon requires suitable nutrient consisting of primary macronutrients (nitrogen, phosphorus and potassium) for growth, secondary macronutrients (calcium, magnesium, and sulfur) and micronutrients (iron, manganese, boron, molybdenum, copper, zinc, chlorine and nickel) in suitable quantities and at appropriate times to improve the quality of the products. Nowadays, the most common problem in Muskmelon production is that

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the bottom and skin cracks of Muskmelons that affect yield and harvest quality. Calcium (Ca) and boron (B) are claimed to be the reasons for this issue because Ca is a component of cell walls, speeding up the growth and absorption of other nutrients, especially nitrogen, while B has an important role to help the roots absorb Ca and plays a prominent role in the synthesis and integrity of the cell wall and the movement of sugar (Osotsapa, 2009). B deficiency in the reproductive stage has a significant impact on product decline because it harms flowering, fruiting, and seeding. Ca also has an impact on tissues and cell wall strength, increasing the crunchiness and firmness of the fruit. In the fruiting phase, Ca helps to regulate plant respiration and creates sugar and starch, while B transports sugars and starches from the leaves to the fruit.

If plants receive insufficient amounts of Ca and B during maturity, there will be unusual plant outcomes because these two elements are non-transportable in plants. Therefore, for optimum growth and fruit production, a plant needs Ca and B throughout the entire growth period of the plant. Saeheng et al. (2018) studied the effect of Ca and B on the prevention of cracking of Fu Yu persimmons using foliar spraying with calcium chloride and boric acid at different rates. In total, 6 sprays every 2 weeks showed that foliar spraying of calcium chloride at a concentration of 0.5 % w/v gave the significantly highest persimmon yield (82.5 fruits/plant). Furthermore, foliar spraying with boric acid at 0.15 and 0.30 % w/v had a significant effect on the width, length, height, weight, and fruit maturity of the persimmon, producing significant peak B concentrations of 30.7 and 23.4 mg/kg, respectively. Khamwaree and Khurnpoon (2016) found that calcium and boron contribute on cell elongation and metabolism of carbohydrates and quality improvement. The use of calcium boron solution improves on chlorophyll content, weight, total soluble solids and firmness. Srilatha and Kumar (2019) investigated the foliar application of fertilizers on flowering and yield of muskmelon (*Cucumis melo*) CV. Madhuras and found spraying of 1% borax + 6 % calcium nitrate twice at 30 and 50 days after planting significantly enhanced the fruit yield by recording early flowering, more number of fruits per plant.

However, different cultivars of Muskmelon need different nutrient requirements. Therefore, the current research investigation the spray concentrations of Ca and B on Muskmelons to enhance the quality of the melon and to increase the value of products in terms of quality for farmers.

Material and methods

The experimental design Employed in this study was 5 x 4 factorial in a randomized complete block design with five replications, using 2 factors: 1) spraying of Ca-B solution at 5 rates—spraying with water (Control), spraying Ca-B at 0.75, 1.50, 2.25, or 3.00 ml/l (prepared from Ca-B solutions 10.5% CaO and 1.5% B). All spraying solutions were mixed with surfactant and spraying for 4 weeks, 1 time per week after the flowering period; and 2) 4 cultivar of Muskmelon—Honey Dew 1348 (Hon), Kanokkan 108 (Kan), Emerald Sweet (Eme), and TML-052 (Tml)—represented Muskmelons that are widely grown and consumed in Thailand. Specifically, Hon and Kan are smooth muskmelon with green and orange pulp, while Eme and Tml are Muskmelons with a net skin and have green and orange pulp. All experimental plants were grown in greenhouses of the Faculty of Agriculture, Kamphaeng Saen, Kasetsart University, Thailand.

Preparation of planting materials: Brown coconut flakes were soaked in water until completely saturated, with the water changed every 2 days for 3 cycles until the electrical conductivity (EC) was lower than 1.0 dS/m. Then the samples were packed into 14 inch diameter plastic plant pots, with 6 kg per pot.

Muskmelon seeds of the 4 cultivars were planted in seedling trays using peat moss as the germination material. When the seedlings were 10 days old, they were transplanted into pots with various planting materials, with 1 plant per pot before being left in a netted greenhouse (sized 6x15x3.5 m) with a thatched roof of clear plastic and 40 mesh insect-net covering on the plastic pots. The pots were placed in a double row with the distance between the pots in the row being 30 cm, the distance between the rows being 30 cm and the distance between the double rows being 1.0 m.

The plants were fertilized using a drip irrigation system for growing Muskmelons with Enshi Solution Standard Plant Nutrient Solution (Yutaka, 1990) containing solutions A and B. Nutrient solution A contained $Ca(NO_2)_3{\cdot}4H_2O$ 950 mg/l and Fe-EDTA 23.6 mg/l. Nutrient solution B contained KNO_3 810 mg/l, $NH_4H_2PO_4$ 155 mg/l, $MgSO_4$ 500 mg/l and a micronutrient group (H_3BO_3 2.86 mg/l, $MnSO_44H_2O$ 2.11 mg/l, $ZnSO_47H_2O$ 0.22 mg/l, $CuSO_45H_2O$ 0.08 mg/l and $NaMoO_42H_2O$ 0.025 mg/l). Both nutrient solutions were mixed with filtered water. In the first phase, the EC values were in the range 1.7–1.8 dS/m for the 35 days of the study. In the second phase with the mixtures of nutrient solutions A and B, the EC value was 2.5 dS/m for 28 days. In the third phase, with the nutrient solutions A and B, the EC value was 2 dS/m until the harvesting period (Chanthaprom, 2015). Every plant was watered and fertilized with 0.5 liters/plant/day after moving the seedlings, and during the flowering and fruiting periods with 2 liters/plant/day.

Branches 1-8 were pruned, with the remaining rows 9–12 pollinated between 6:00 AM and 10:00 AM. When the muskmelon plant had 25 leaves, the main vine tops were cut and 1 fruit was selected for 1 fruit per plant.

Harvesting of muskmelons in each experiment: Hon was harvested 80 days post-germination (40-45 days after pollination), Kan at 65 days post-germination (35-40 days after pollination), Eme at 80 days post-germination (50-55 days after pollination), and Tml at 80 days post-germination (40-45 days after pollination).

For Ca and B analysis of the crops in the harvesting phase, samples were collected from: 1) 14^{th} muskmelon leaf counted from the lower stem (Seangngam, 2021); 2) the stem, and 3) the fruit. The fruit was separated into peel and pulp and these were oven dried at 70 °C for 72 h. After that, these dry samples of plants were finely ground For Ca analysis, plant samples were digested by nitric-perchloric acid (Jones et al., 1991*)* and measured by Atomic Absorption Spectrophotometer. For B analysis, plant samples were dry combustion and measured by colorimetric method. *(*Attanan and Chanchareonsuk, 1999*)*.

Yield and yield components were collected for fruit size, fruit weight, firmness and absoluteness, with scoring based on fruit cracking (skin crack 81–100% = 1; 61–80% = 2; 41–60% = 3; 21–40% = 4,1-20% = 5; and 0% (no cracking) = 6). Total soluble solid (%Brix) was measured by digital refractometer.

The data was subjected to the analysis of variance (ANOVA). The F-test was used to identify the treatments main effects and interactions followed by Duncan's multiple range tests at the 0.05 probability level (Steel and Torrie, 1980). The relationship between nutrient contents and yield components was examined by Pearson's correlation coefficient. Shapiro-Wilk test was carried out to test the normality of data prior to analysis.

Results and discussion

Concentration of calcium in components of muskmelons during harvesting phase

There were significant differences in the average amount of Ca in the leaves **(Table 1)**. Emerald Sweet, Kanokkan 10, and Honey Dew 1348 had the highest Ca amount in the leaves at 8.27, 8.22, and 8.17%, respectively. In contrast, the TML-052 cultivar had the lowest calcium amount at 7.76%. Spraying the Ca-B solution at different rates produced significantly different effects on the average Ca amount in the leaves. Spraying the Ca-B solution at 3.00 ml/l produced the highest average calcium amount in the leaves (9.03%), followed by spraying the Ca-B solution at 2.25 ml/l (8.61%) 1.50 ml/l (8.19%), 0.75 ml/l (7.38%), and no spray (7.25%). Thus, as the rate of Ca-B solution increased, the average Ca amount in the Muskmelon leaves significantly increased.

Spraying different rate of Ca-B solution resulted in significant differences in the average Ca accumulation in the plant **(Table 1)**, with spraying Ca-B solution at rates of 3.00, 2.25, 0.75, and 1.50 ml/l resulted in the highest Ca accumulation levels in muskmelon of 2.59, 2.58, 2.57, and 2.52%, respectively. The lowest was 2.47% for no spray.

The mean calcium quantity in the peel was significantly different **(Table 1)**. Emerald Sweet and TML-052 had the highest mean Ca amounts in the peel at 0.62 and 0.58%, respectively. Kanokkan 108 and Honey Dew 1348 had mean calcium accumulation in the peel of 0.31 and 0.29%, respectively. The rate of Ca-B solution affected the average calcium in the peel. Spraying Ca-B solution at rates of 3.00 and 2.25 ml/l produced the highest mean calcium accumulation in the peel at 0.52 and 0.50 %, respectively. The cultivation of Emerald Sweet and TML-052 with spraying Ca-B solutions at rates of 3.00, 2.25, 1.50, and 0.75 ml/l resulted in the highest calcium accumulation in the peel of muskmelon in the range 0.56 –0.69 % and in the pulp. The study found that the cultivar of muskmelon and the level of Ca-B solution spraying produced significant differences in the calcium amount in the pulp of muskmelon. Spraying Emerald Sweet Muskmelons with Ca-B solution at rates of 3.00 and 2.25 ml./l produced the calcium amounts in the pulp of muskmelon of 0.27 and 0.22%, respectively, followed by the spraying TML- 052 with 3.00 ml/l Ca-B solution with an average of 0.19 %.

Boron concentrations in components of Muskmelons during harvesting phase

The average B amount in the leaves was not significantly different among cultivars. However, the spray rate of Ca-B solution at different levels resulted in B accumulation in the leaves **(Table 1)**. Spraying Ca-B solution at the rate of 3.00 ml/l resulted in the highest B accumulation in the leaves of the muskmelon (73.92 mg/kg), followed by spraying Ca-B solution at the rates of 2.25, 1.50, and 0.75 ml/l, and no spray with 71.04, 56.61, 46.26, and 14.65 mg/kg, respectively.

There were significant differences in the average Boron amount in the stem. The TML-052 cultivar had the highest B accumulation in the stem (51.14 mg/kg). Muskmelons with B-solution foliar spray at the rate of 3.00 ml/l had the highest Boron accumulation (64.11 mg/kg). Spraying Emerald Sweet muskmelons with 3.00 ml/L Ca-B solution spraying resulted in the highest B amount in the stem (76.85 mg/kg).

There were no significant differences in the average B amount in the peel based on cultivar. However, the spraying rate of Ca-B solution resulted in different amounts of B accumulation in the peel. Spraying Ca-B solution at 3.00 ml/l produced the highest B accumulation (57.42 mg/kg), followed by the spraying Ca-B solution at 2.25, 1.50, and 0.75 ml/l and no spray (41.68, 36.63, 22.40, and 15.30 mg/kg, respectively).

There were significant differences in the average Boron amount in pulp among the cultivars. The Emerald Sweet and TML-052 cultivars had the highest B accumulation in the muskmelon peel (19.43 and 18.46 mg/kg, respectively), followed by Kanokkan 108 melon and Honey Dew 134 (14.66 and 12.81 mg/kg, respectively), while spraying 3.00 and 1.50 ml/l of Ca-B solution produced the highest B amounts (24.67 and 20.34. %, respectively). Spraying Ca-B solution at the rates 0.75 and 1.50 ml/l produced B amounts in the pulp of 17.58 and 13.90 mg/kg, respectively. Spraying Ca-B solution yielded the lowest boron accumulation in the pulp (5.21 mg/kg). Spraying Emerald Sweet muskmelons with 3.00 ml/l Ca-B solution spraying resulted in the highest B amount in the pulp of muskmelons in the range 32.20 mg/kg.

Table 1 Effect of Ca-B solution rate of spraying and of melon cultivar on Ca and B concentrations in leaf, stem, peel, and pulp of melon

Factor	Calcium concentration (%)				Boron concentration (mg./kg.)			
	Leaves	Stem	Peel	Pulp	Leaves	Stem	Peel	Pulp
Melon cultivar (C)								
HONEY DEW 1348 (Hon)	8.17^{a}	2.59	0.29^{b}	0.10^{c}	40.27	29.26^{d}	16.88	12.81^{b}
KANOKKARN 108 (Kan)	8.22^{a}	2.74	0.31^{b}	0.07^{d}	64.99	38.75^{c}	50.82	14.66^{b}
EMERALD SWEET (Eme)	8.27^{a}	2.37	0.62^{a}	0.20^{a}	51.58	42.05^{b}	48.56	19.43^{a}
TML- 052 (Tml)	7.76^{b}	2.50	0.58^{a}	0.15^{b}	49.87	51.14^{a}	22.47	18.46^{a}
F-test	**	ns	**	**	ns	**	ns	**
Spray rate of solution								
0	7.25^{D}	2.47^{B}	0.36^{BC}	0.10^{D}	14.65E	15.93^{E}	15.30E	5.21^{C}
0.75	7.38^{D}	2.57^{A}	0.42^{B}	0.11^{D}	46.26D	34.54^{D}	22.40D	17.58^{B}
1.50	8.19^{C}	2.52^{A}	0.44^{B}	0.12^{C}	56.61C	38.38^{C}	36.63C	20.34^{A}
2.25	8.61^{B}	2.58^{A}	0.50^{A}	0.14^{B}	71.04B	48.55^{B}	41.66B	13.90^{B}
3.00	9.03^{A}	2.59^{A}	0.52^{A}	0.17^{A}	73.92A	64.11^{A}	57.42A	24.67^{A}
F-test	*	**	**	**	**	**	**	**
Interaction (CxCa-B)								
Hon^{x}0	6.71^{g}	2.73	0.22^{b}	0.08^{i-j}	11.09	14.67^{j}	14.32	1.21^{g}
Hon^{x}0.75	7.04^{f-g}	2.38	0.25^{b}	0.07^{i-j}	44.97	22.13^{i}	15.47	17.79^{d}
Hon^{x}1.50	8.83^{a-b}	2.61	0.29^{b}	0.09^{h-i}	49.05	28.93^{g-h}	16.37	16.80^{d-e}
Hon* 2.25	9.06^{a}	2.53	0.33^{b}	0.10^{h}	62.75	34.72^{g}	17.81	12.70^{e}
Hon^{x}3.00	9.19^{a}	2.69	0.34^{b}	0.12^{g}	42.26	45.86^{e-f}	20.45	15.53^{d-e}
Kan^{x}0	7.98^{c-e}	2.76	0.26^{b}	0.05^{k}	22.33	15.53^{j}	14.31	5.38^{f}
Kan^{x}0.75	7.52^{e-f}	2.59	0.28^{b}	0.05^{k}	60.50	40.43^{f}	40.21	13.21^{e}
Kan^{x}1.50	8.42^{b-c}	2.83	0.29^{b}	0.05^{k}	63.87	41.91^{e-f}	43.95	17.75^{d}
Kan^{x}2.25	8.13^{c-d}	2.71	0.33^{b}	0.06^{j-k}	86.01	41.48^{e-f}	58.75	13.99^{d-e}
Kan^{x}3.00	9.06^{a}	2.81	0.37^{b}	0.09^{h-i}	92.27	54.38^{c}	96.89	22.95^{c}
Eme^{x}0	7.43^{e-f}	2.27	0.49^{a-b}	0.15^{e}	14.19	18.80^{i-j}	17.04	8.52^{f}
Eme^{x}0.75	7.46^{e-f}	2.49	0.59^{a}	0.16^{d-e}	36.81	28.08^{h}	17.98	15.24^{d-e}
Eme^{x}1.50	7.87^{d-e}	2.07	0.61^{a}	0.18^{c-d}	53.37	30.67^{g}	67.58	32.20^{a}
Eme^{x} 2.25	9.10^{a}	2.62	0.69^{a}	0.22^{b}	70.78	55.86^{c}	67.32	14.11^{d-e}
Eme^{x}3.00	9.22^{a}	2.37	0.72^{a}	0.27^{a}	82.74	76.85^{a}	72.89	27.10^{b}
Tml^{x}0	6.87^{g}	2.12	0.47^{a-b}	0.12^{g}	10.99	14.72^{j}	15.50	5.733^{f}
Tml^{x}0.75	7.50^{e-f}	2.82	0.56^{a}	0.14^{e-f}	42.76	47.53^{d-e}	15.95	24.09^{b-c}
Tml^{x}1.50	7.63^{d-e}	2.57	0.57^{a}	0.15^{e}	52.59	51.99^{c-d}	18.65	14.59^{d-e}
Tml^{x}2.25	8.14^{c-d}	2.46	0.65^{a}	0.16^{d-e}	64.62	62.12^{b}	22.77	14.78^{d-e}
Tml^{x}3.00	8.66^{a-b}	2.50	0.66^{a}	0.19^{c}	78.40	79.34^{a}	39.47	33.10^{a}
F-test	**	ns	**	**	ns	**	ns	**
C.V. %	13.66	12.21	14.98	19.51	19.85	17.42	11.52	21.57

Different letters indicate significant differences based on DMRT, * = significant at p≤0.05; ** = significant at p≤0.01; ns = not significant at p>0.05 capital letters = significant different among the rate of Ca-B solution, letter lowercase = significant different among the variety of melon, italic lowercase = interaction between two factors.

It was observed that the concentrations of calcium and boron accumulated in the leaves, stems, peels, and pulp varied with the concentration of foliar spraying with calcium and boron solution, consistent with the respectively. Laopawang et al. (2019) study to increase the yield quality of Fu Yu persimmon by spraying a solution of gibberellic acid with a concentration of 10 mg/l (GA3) in the flowering phase, spraying a solution of Ca ($Ca(NO_3)_2$) and B ($Na_2B_4O_7$) with a concentration of 50 and 5 mg/l, respectively], spraying Ca-B and gibberellic acid solution (Ca-B + GA3) at 1 week pre-flowering, in the flowering phase, and at 1 week post-flowering. Persimmons sprayed with the GA3 solution had the lowest seed number. Persimmons sprayed with Ca-B, GA3, or Ca-B + GA3 produced heavier firm of pulp. Spraying Ca-B and gibberellic acid (GA3) solution increased the yield quality of Fu Yu persimmons.

In addition, we found the concentration of Ca and B in netted muskmelon (Eme and Tml) were higher than smooth melon (Hon and Kan) **(Table 1).** Similarly, fruit cracking in netted muskmelon was lower than smooth muskmelon **(Table 3)**. Overall, these suggest that the accumulation of Ca and B in netted muskmelon was higher than smooth muskmelon.

Productivity and product components

The cultivars had differences in pulp weight, fruit size, peel thickness, pulp thickness, firmness and the sweetness of muskmelons. Insoluble solids (dissolved solids) were significantly different. The Emerald Sweet and TML-052 cultivars had the highest fruit weights (1,775.18 and 1,770.69 g, respectively), followed by Honey Dew 1348 (1,660.38 g), while Kanokkan 108 had a low average fruit weight (1532.67 g). In addition, different levels of Ca-B solution spraying resulted in different fruit weights of muskmelons. Spraying Ca-B solution at the rate of 3.00 ml/l resulted in the highest fruit weight of muskmelons (1,847.69 g), followed by melon with a spraying of Ca-B solution at the rate of 2.25 ml/l. The mean fruit weight was 1,709.56 g, while the muskmelon sprayed with Ca-B solution at rates of 0.75, 0 and 1.50 ml/l resulted in the lowest mean fruit weights (1,656.52, 1,619.21, and 1,590.63 g respectively). TML-052 sprayed with 3.00 ml/l of Ca-B solution produced the highest fruit weight of muskmelons at 1,962.57 g **(Table 2)**.

The fruit size of the melons was significantly different in both width and length. The Emerald Sweet and TML-052 cultivars had the maximum widths of the muskmelons (15.67 and 15.21 cm, respectively), followed by Kanokkan 108 and Honey Dew 1348, with minimum widths of 14.58 and 14.45 cm, respectively. Honey Dew 1348 had the longest muskmelon fruit length (17.31 cm), followed by Kanokkan 108 (16.65 cm). The TML-052 and Emerald Sweet cultivars had the lowest fruit length was 16.11 and 15.65 cm, respectively. In addition, different spray levels of Ca-B solution resulted in different fruit width and lengths. The melons sprayed with Ca-B solution at the rate of 3.00 ml/l had the greatest fruit width (16.04 cm) compared with the muskmelon sprayed with Ca-B solution at the rates of 2.25, 1.50, 0.75 ml/l and no spray with Ca-B solution (14.93, 14.83, 14.82, and 14.27 cm, respectively). Spraying with Ca-B solution produced the greatest fruit length (17.06 cm) compared with muskmelons sprayed with Ca-B solution at rates of 0.75, 1.50, 2.25, or 3.00 ml/l that produced means of at 16.41, 16.36, 16.23, and 16.09 cm, respectively.

The muskmelon cultivar and rate of Ca-B solution spray had a significant impact on the pulp thickness of muskmelons. TML-052 and Emerald Sweet had the thickest pulp (33.81 and 33.36 mm, respectively), followed by

Honey Dew 1348 (31.76 mm), whereas Kanokkan 108 had the thinnest mean pulp thickness (29.06 mm). This is a reported characteristic of the *Cucumis melo* L. *reticulatus* Naudin (netted melon) that produced fruit weight, fruit size, pulp thickness, and peel thickness values that were higher than for *Cucumis melo* L. *cantaloupensis* (cantaloupe) (Tira-umphon, 2003). The comparison by Arak (2003) of 8 cultivars of muskmelons suitable for growing in greenhouses (Honda 541, Supersalmon, Sunlady, Goldenlady, Emerald Sweet, Sunnet 858, Neon 022, and Arko 434s) showed that the netted muskmelons, such as Emerald Sweet and Arko 434, were well grown, yielded good weight, and had thick pulp and peel, compared to the non-netted types of muskmelons, such as Supersalmon and Neon 022, that had good weight and medium pulp and peel thickness. This was in line with Chikh-Rouhou et al. (2019) who said that qualitative changes in muskmelon were caused by complex genes, plant physiology, and the environment. Therefore, the growth, weight, size, and thickness of the pulp, peel thickness, and amount of soluble solids might be controllable via the cultivar characteristics of the muskmelon. It was found that netted muskmelon group was more absolute than cantaloupe-muskmelons.

Spraying Ca-B solution at the rate of 3.00 ml/l resulted in mean muskmelon fruit thickness of 34.86 mm, which was not different from spraying the Ca-B solution at the rate of 2.25 ml/l (mean pulp thickness of 33.30 mm), followed by spraying of Ca-B solution at rates of 1.50 and 0.75 ml/l (thicknesses of 32.22, and 31.78 mm, respectively). Muskmelons that were not sprayed with Ca-B solution had the thinnest pulp (27.83 mm). Spraying TML-052 with 3.00 ml/l Ca-B solution resulted in the thickest muskmelon pulp (40.34 mm). It was observed that spraying the Ca-B solution at a higher rate reduced the peel thickness but increased the thickness of the pulp. In addition, the sweetness of the muskmelon increased if the levels of Ca and B increased. For example, Kahu (2002) studied spraying $CaCl_2$ and $Ca(NO_3)_2$ on apple cultivars compared to not spraying and found that the sprayed apples had better quality and shelf life than non-sprayed apples. Emani et al. (2002) studied spraying 0.5 % $CaCl_2$ on Gala, an apple cultivar in Southern Brazil and found that the apple fruit size was larger and the leaf-to-fruit ratio was higher. Garcia (2003) investigated the influence of calcium chloride spray on the quality of the Golden Delicious cultivar of apples; the study reported that the incidence of dimples was reduced, but the calcium quantity of peel was increased, compared to plants without calcium chloride spray. Broom (2003) investigated the relationship between the Ca concentration, abnormal characteristics of fruit, total products, and the mean size of Braeburn apples at harvest in New Zealand. It was concluded that as the Ca concentration in the fruit increased, the percentage of abnormalities within the fruit decreased.

There were significant differences in the firmness of the muskmelon pulp among cultivars. However, for TML-052, the firmness of the muskmelon was 2.76 N and not significantly different from Emerald Sweet (2.63 N). Honey Dew 1348 and Kanokkan 108 had the lowest firmness (2.47 and 2.25 N, respectively). Spraying with Ca-B solution yielded the highest melon firmness, with an average of 2.88 N.

Table 2 Effect of Ca-B solution rate of spraying and of melon cultivar on yield and yield component of melon

Factor	Fresh fruit weight (g)	Fruit width (cm)	Fruit length (cm.)	Peel thickness (mm)	Pulp thickness (mm)	Firmness (N)	Total soluble solids (%brix)
Melon cultivar (C)							
HONEY DEW 1348 (Hon)	1660.38^{b}	14.45^{b}	17.31^{a}	8.00^{c}	31.76^{b}	2.47^{b}	12.33^{b}
KANOKKARN 108 (Kan)	1532.67^{c}	14.58^{b}	16.65^{b}	7.80^{c}	29.06^{c}	2.25^{c}	16.01^{a}
EMERALD SWEET (Eme)	1775.18^{a}	15.67^{a}	15.65^{c}	11.02^{b}	33.36^{a}	2.63^{ab}	11.73^{c}
TML- 052 (Tml)	1770.69^{a}	15.21^{a}	16.11^{c}	11.30^{a}	33.81^{a}	2.76^{a}	12.49^{b}
F-test	**	**	**	**	**	**	**
Spray rate of solution of Calcium and Boron (Ca-B : ml/L.)							
0	1619.21^{C}	14.27^{B}	17.06^{A}	13.40^{A}	27.83^{C}	2.88^{A}	11.61^{D}
0.75	1656.52^{C}	14.82^{B}	16.41^{B}	10.70^{B}	31.78^{B}	2.38^{B}	12.83^{C}
1.50	1590.63^{C}	14.83^{B}	16.36^{B}	8.60B^{C}	32.22^{B}	2.43^{B}	13.02^{C}
2.25	1709.56^{B}	14.93^{B}	16.23^{B}	8.20B^{C}	33.30^{AB}	2.47^{B}	13.53^{B}
3.00	1847.69^{A}	16.04^{A}	16.09^{B}	5.90^{D}	34.86^{A}	2.49^{B}	14.72^{A}
F-test	**	**	**	**	**	**	**
Interaction (CxCa-B)							
Hon^{x}0	1658.50^{d-g}	13.90	17.60	13.80^{a-b}	25.16^{f-g}	3.13	11.22^{g-h}
Hon^{x}0.75	1703.80^{c-f}	14.17	17.17	10.70^{d-f}	32.33^{b-e}	2.23	12.25^{d-e}
Hon^{x}1.50	1420.56^{i}	14.20	17.17	5.10^{i-j}	32.86^{b-e}	2.30	12.14^{d-f}
Hon* 2.25	1663.33^{d-g}	14.40	17.37	6.50^{h-i}	34.90^{b-c}	2.33	12.47^{d}
Hon^{x}3.00	1855.71^{a-c}	15.60	17.23	4.80^{j}	33.56^{b-d}	2.33	13.57^{c}
Kan^{x}0	1430.54^{i}	14.27	17.07	11.09^{c-f}	24.70^{g}	2.50	14.20^{b-c}
Kan^{x}0.75	1550.96^{f-i}	13.80	16.13	8.10^{g-h}	28.38^{f-g}	2.13	16.50^{a}
Kan^{x}1.50	1451.67^{h-i}	13.90	16.73	8.20^{g}	29.24^{e-f}	2.27	16.23^{a}
Kan^{x}2.25	1536.65^{g-i}	14.43	16.90	6.50^{h-i}	30.75^{d-f}	2.17	16.50^{a}
Kan^{x}3.00	1693.53^{d-g}	16.50	16.40	5.40^{i-j}	32.23^{b-e}	2.20	16.60^{a}
Eme^{x}0	1603.33^{b-d}	14.30	16.37	13.90^{a}	30.93^{d-f}	2.90	10.20^{i}
Eme^{x}0.75	1630.99^{d-g}	16.00	15.60	11.20^{c-e}	33.61^{b-d}	2.53	11.27^{g-h}
Eme^{x}1.50	1886.55^{a-b}	15.83	15.27	9.50^{e-f}	35.46^{b}	2.47	11.43^{f-h}
Eme^{x} 2.25	1876.07^{b-e}	15.57	15.63	9.00^{f-g}	33.48^{b-d}	2.56	11.63^{e-g}
Eme^{x}3.00	1878.95^{a-b}	16.63	15.40	6.20^{i}	33.32^{b-d}	2.67	14.13^{b-c}
Tml^{x}0	1784.48^{b-d}	14.60	17.20	13.70^{a-b}	30.53^{d-f}	2.97	10.83^{h-i}
Tml^{x}0.75	1740.33^{b-e}	15.30	16.73	12.60^{b-c}	32.80^{b-e}	2.60	11.30^{g-h}
Tml^{x}1.50	1603.74^{e-h}	15.40	16.27	11.50^{c-d}	31.30^{c-f}	2.70	12.27^{d-e}
Tml^{x}2.25	1762.33^{b-e}	15.30	15.03	11.06^{d-f}	34.07^{b-d}	2.80	13.50^{c}
Tml^{x}3.00	1962.57^{a}	15.43	15.33	8.20^{g}	40.34^{a}	2.75	14.56^{b}
F-test	**	ns	**ns**	**	**	ns	**
C.V. %	7.85	9.79	17.60	3.44	3.68	5.89	13.65

Different letters were significantly different by DMRT, ** = significant at $p \leq 0.01$; ns = Not significant at $p > 0.05$, capital letters = significant different among the rate of Ca-B solution, letter lowercase = significant different among the variety of melon, italic lowercase = interaction between two factors.

It has been noted that not spraying with Ca-B increased the firmness of the pulp and restricted expansion of the fruit (Tongumpai, 1986). George et al. (2003) studied spraying 16% calcium carbonate solution on Fu Yu persimmons and reported an increase in fruit firmness values by 20–40 % compared to the control group. Sillapaphet (2005) studied spraying Ca-B solution (Sorba Spray®, 5 % $Ca(NO_3)_2$ and 0.5 % $Na_2B_4O_7$) at the rate of 20 20 ml/20 liters of water, calcium concentration of 50 ml/l water, mixed with boron 5 mg/l. She found that the percentage fruiting of Fu Yu persimmons was higher than for not spraying (97.75 and 93.98 %, respectively). These results were consistent with the work of Wongs-Aree et al. (2004) who studied the effect of calcium chloride solution on extending the shelf life of cantaloupe. They reported that the fruit was soft during ripening because of the loss of calcium. Therefore, the addition of extra calcium strengthened cell walls and increased the tensile strength between plant cells. Calcium has been used with many ready-to-eat cut fruit and vegetables to maintain the firmness and freshness of the products. The whole cantaloupe was immersed in a 2% concentration of calcium chloride solution under 460 mm Hg at atmospheric pressure for 2 minutes to impregnate the solution more efficiently. The cantaloupe slices that had been peeled and cut for eating and stored at 10°C, effectively maintained their firmness. Ready-to-eat cantaloupe slices that were soaked directly in calcium chloride had a slightly bitter taste. In addition, intracellular calcium affects the balance among various activities. Exogenous calcification slowed the ripening and deterioration of many fruits. For example, avocados were immersed in a 2% calcium chloride solution under 250 mm Hg for 10 min at atmospheric pressure and they ripened a few days later (Wickramasinghe, 2013).

There were significant differences in sweetness among the melons, based on the soluble level of solids. Kanokkan 108 had the highest soluble solids average (16.01 percent Brix), followed by Honey Dew 1348 and TML-052 (12.49 and 12.33 percent Brix, respectively). With an average soluble solids content of 11.73 percent Brix, the Emerald Sweet variety had the lowest soluble solids. Spraying 3.00 ml/l Ca-B solution provided the greatest soluble solid content (14.72 percent Brix), followed by spraying 2.25 ml/l Ca-B solution (13.53 percent Brix), while spraying 1.50 and 0.75 ml/l Ca-B solution provided average soluble solids contents of 13.02 and 12.83 percent Brix, respectively. The sweetness of unsprayed Cantaloupes in the Ca-B solution was the lowest (11.61 percent Brix). Spraying Ca-B solution on Kanokkan 108 Cantaloupe melons at 3.00, 2.25, 0.75, and 1.50 ml/l resulted in total soluble solids levels of 16.60, 16.50, 16.50, and 16.23 percent Brix, respectively.

Overall, we found that Ca-B play important role on yield and yield components of melon. The improving of lignin, cell division, strengthen cell wall and maintaining its structure were influenced by Ca and B (McLuaghin and Wimmer, 1999 and Matoh, 1997) that could decrease fruit length, firmness and peel thickness, and increase pulp thickness and fruit weight. The increase of % brix could influenced by B due to it can stimulate sugar transportation in plant (Epstein and Bloom, 2005).

Table 3 Effect of Ca-B solution rates and melon cultivars on absoluteness of melon

Melon Cultivars (C)	Rate spraying a solution of Calcium - Boron (Ca-B: ml/L)					
	0 (control)	0.75	1.50	2.25	3.00	**Average**
Hon	2.67^{d}	4.33$^{a\text{-}b}$	6^{a}	6^{a}	6^{a}	5.00^{b}
Kan	1.67^{e}	3.33$^{c\text{-}d}$	4.67$^{a\text{-}b}$	6^{a}	6^{a}	4.33^{c}
Eme	4.00$^{b\text{-}c}$	4.67$^{a\text{-}b}$	6^{a}	6^{a}	6^{a}	5.33^{a}
Tml	3.33$^{c\text{-}d}$	4.33$^{a\text{-}b}$	6^{a}	6^{a}	6^{a}	5.13^{a}
Average	2.92^{C}	4.16^{B}	5.67^{A}	6^{A}	6^{A}	
F-test						
C	**					
Ca-B	**					
C x Ca-B	**					
C.V. (%)	8.62					

Different letters indicate significant differences based on DMRT, ** = significant at p≤0.01 capital letters = significant different among the rate of Ca-B solution, letter lowercase = significant different among the variety of melon, italic lowercase = interaction between two factors.

Absoluteness

The different levels of Ca-B solution sprayed resulted in significantly different levels of fruit maturity, as shown in Table 3. The Emerald Sweet and TML-052 cultivars had higher maturity (5.33 and 5.13, respectively) than Honey Dew 1348 and Kanokkan 108 (5.00 and 4.33, respectively), while Ca-B solution sprayed at 2.25 and 3.00 ml/l resulted in significantly different levels of maturity, there was no breakage of the melons.

When considering the interactions between the melon cultivars and different levels of Ca-B infusion, we found that the melon species had different levels of interaction with the Ca-B infusions. The melons were undamaged or had no evident skin breakage after being sprayed with Ca-B solution at a rate of 2.25 ml/l or more.

Increasing the Ca content in the soil to enhance the Ca content in the fruit proved ineffective based on productivity and yield composition (Wongs-Aree and Srilaong, 2006). When Ca is applied pre-harvest, direct fruit calcification is the most effective technique of increasing the calcium content in fruit. On the other hand, pre- and post-harvest Ca intake can cause issues, such as inappropriate Ca concentration, which can result in insufficient Ca content in the fruit, resulting in poor fruit quality. Too much Ca in the fruit can cause it to break down. Furthermore, adding 1–2% Ca to 'Klom Salee' guava and storing the fruit at room temperature significantly slowed the peel's loss of firmness and color change.

Correlation between plant nutrients and melons yield components

The Ca concentration in the skin of the melons was favorably connected with the Ca content of the melon pulp, according to the phytochemical correlation study of melons over the storage period **(Table 4)**. The correlation coefficient was 0.9297, indicating that the higher the Ca level in the rind, the higher the Ca content in the melon pulp. Furthermore, the pulp thickness of the melons had a correlation coefficient value of 0.6251, showing that the higher the Ca content in the melon rind, the thicker the pulp and the greater the fruit maturity of the melons. The correlation was 0.4693; the higher the Ca level in the rind of the melons, the higher the fertility of the melons. Similarly, the Ca level of the melon pulp was considerably higher. The associations between melon pulp thickness and fruit maturity had correlation coefficients of 0.4874 and 0.4820, respectively. In the experiment conducted by Ho (1980), adding calcium silicate increased the skin thickness. Because Ca aids in the shape of the fruit, the thickness of the pulp of melons was significantly different, indicating that Ca is a necessary component (calcium pectate), which functions as a glue to hold cell walls together and strengthens cells, tissues, and plants.

The amount of B in the rind of the melons was not significant regarding the thickness of the melon peel as the more B that accumulated in the fruit peel, the lower the thickness of the sheath (r = -0.5163). Hu et al. (1996) reported that the effect of B, boron was more convoluted than for other micronutrients. However, it could be deduced from the data of physiological changes in plants suffering from B shortage that B has a crucial function in the synthesis and integrity of the cell wall. Membrane integrity is linked to the fusion of boron and glycolipids in the membrane, and when plants lack B, the flexibility of the cell wall decreases. Moreover, B spraying could contribute B accumulated in peel **(Table 1)** and negative correlation between B and peel thickness was found **(Table 4)**. Possibly, boron can tightening among plant cell and resulting in reduce peel thickness. (Osotsapa, 2009).

The B concentration in the melon pulp was significantly and positively correlated with the melon pulp thickness (r = 0.7544). Furthermore a greater boron concentration in the pulp was positively linked with fruit maturity (r = 0.6244). Chikh-Rouhou et al. (2019) reported an increase in the thickness of the melon, as well as an increase in fruit fertility of melons with added B.

Melon peel thickness was inversely related to melon fruit maturity (r = -0.6238), so that the thicker the melon rind, the lower the melon fruit maturity. According to Matoh et al., (1996), B has a function in the manufacture of cell wall substances that aid in the proper arrangement of those elements as parts of the complex rhamnogalacturonan II, which are pectic-containing polysaccharides that bind the complex in the cell wall. The pectic chemicals in the cell wall become more networked and stronger as a result of this.

Melon pulp thickness was significantly and positively correlated with melon fruit maturity (r = 0.7748). Khamwaree and Khurnpoon (2016) reported that the thicker the pulp, the greater the maturity effect on melons. They evaluated the effect of Ca-B solution and pre-harvest dehydration on Muskmelon growth and quality (*Cucumis melo* L. var. *reticulatus*). The sweetness of muskmelon was affected by experimental formulations that sprayed 500 ppm of Magic®calcium boron foliar in combination with no watering for 5 days prior to harvesting. Compared to the highest levels for melons in the other experimental regimens, the firmness of the melons was reduced, confirming the findings of Saeheng et al. (2018), who studied the effects of Ca and B on fruit cracking prevention. Foliar application of calcium chloride at 0.5% concentration resulted in the significantly highest number of viable fruit (82.5 fruits/plant) in Fuyu persimmons, when 0.15% and 0.30% boric acid were applied. Persimmon breadth, length, height, weight, and fruit integrity were significant greater when 5 l of water/tree were applied.

Table 4 Correlation coefficient (r) between nutrient contents and yield components in melon

	%Ca in Peel	%Ca in Pulp	%B in Peel	%B in Pulp	Peel thickness	Pulp thickness	Absoluteness
%Ca in Peel	1	**0.9297****	0.2893	**0.5172***	0.1333	**0.6251****	**0.4693***
%Ca in Pulp		1	0.2944	**0.4874***	**0.0300**	**0.6063****	**0.4820***
%B in Peel			1	**0.5347***	**-0.5163***	0.2284	**0.4651***
%B in Pulp				1	-0.4310	**0.7544****	**0.6244****
Peel thickness					1	-0.3466	**-0.6238****
Pulp thickness						1	**0.7748****
Absoluteness							1

Note: Correlation is * = significant different at $P < 0.05$ level, ** = significantly different at $P < 0.01$

Conclusion

From the study on the effect of calcium-boron solution rate in foliar spray on muskmelon (*Cucumis melo* L.), we found that foliar spray on the muskmelon could increase the amount of Ca and B accumulation in the leaves and stalk. As a result, the quality of the muskmelon increased.

The recommended spraying of Ca-B solution for Honey Dew 1348 and Kanokkan 108, which are smooth muskmelon cultivars, was at the rate of 1.50–2.25 ml/l. For the cultivars Emerald Sweet and TML-052, which are netted muskmelon, the rate was 0.75–1.50 ml/l.

Spraying Honey Dew 1348 and TML-052 with 3.00 ml/l Ca-B solution resulted in the pulp thickness muskmelon.

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