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Effects of foliar application of calcium (Ca) and boron (B) on yield, quality, and postharvest shelf-life of Indian jujube (*Ziziphus mauritiana* L.) c.v. TN01 in Ninh Thuan Province, Vietnam

P.M. Lien[1], N.Q.Hung[2], P.C.Kien[3], M.V.Hao[3], N.V.Chinh[3], P.N.H.Quan[4], N.N.N.Hao[5], T.T.H.Huong[6], T.D. Khanh[7], N.T.N.Minh[8], P.V.Dan[9]*

[1]Institute of Agricultural Science for Southern Vietnam;
[2]Fruit and Vegetable Research Institute;
[3]Nhaho Research Institute for Cotton and Agriculture Development;
[4]Luong The Vinh High School for the Gifted;
[5]Gia Dinh High School;
[6]Vietnam Academy of Agricultural Sciences;
[7]Vietnam National University of Agriculture, Hanoi, Vietnam;
[8]Agricultural Genetics Institute, Hanoi, Vietnam
[9]Center for Technology Development and Agricultural Extension (CETDAE), Vinh Quynh, Thanh Tri, Hanoi.

Corresponding author: danphamvan944@gmail.com

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ABSTRACT

This study aimed to investigate the effects of Calcium (Ca) and Boron (B) on the yield, quality and postharvest shelf-life of Indian jujube TN01 (*Ziziphus mauritiana* L.). The experiments were conducted on a 6-year-old apple garden. A split-plot design was used with the main plot focusing on B with four concentrations (0.0%, 0.2 %, 0.4 %, and 0.6 %), and the Ca sub-plot (0.0%, 0.5 %, 1.0 %, and 1.5 %), respectively. This study was carried out for two consecutive years. The results showed that the application of Ca increased the fruit quality. The vitamin C content was higher (47.6 mg/100g and 48.3 mg/100g) compared to the control treatments. Additionally, Ca also helps to preserve the fruits better by reducing the rate of dry fruit (7.8%) and rotten fruit (9.2%) to the lowest level compared to the control. Moreover, using B to spray through apple leaves increased the fruiting rate (6.2% and 7.4%), fruit weight (83.2 g/fruit and 86.8 g/fruit), fruiting density (57.7 fruits/m^2 and 59.8 fruits/m^2), productivity (41.1 tons/ha and 43.4 tons/ha), and fruit quality such as increasing in ºBrix (11.8 ºB and 12.6 ºB), vitamin C content (47.6 mg/100g and 48.3 mg/100g) and decreasing acid content (0.4% and 0.5%) at B concentration of 0 .4% for the highest efficiency. Spraying the combination of Ca and B on apples increases the fruiting rate, fruit weight, yield and quality. This includes higher levels of ºBrix, vitamin C concentration, acidity reduction and reduction of damage during storage.

Keywords: *Ziziphus mauritiana,* c.v. TN01, Canxi, Boron, Ninh Thuan province

Introduction

Indian jujube or Ber (*Ziziphus mauritiana* L.) is an easy-to-grow tree, widely adaptable, quick to bear fruit, well adapted to arid and semi-arid regions with slow rainfall, high temperatures, and lots of wind on many different soil types (Sing et al., 2021). Apples are also nutritionally valuable, as they contain high levels of potassium, phosphorus, manganese, calcium, vitamin C, riboflavin, and thiamin (Morton, 1987; Pareek and Dhaka, 2008). However, Ber fruit (*Z. mauritiana* L.) has even more nutritional value contents compared to apples (*Malus domestica*). It contains higher levels of protein, phosphorus, calcium, carotene and vitamin C (Bakhshi and Singh, 1974), and is richer than orange in phosphorus, iron, and vitamin C and carbohydrates, and is higher than both fruits in calorific value. Moreover, Ber fruit has high medicinal properties comparing other varieties. Many studies have examined the biological properties of different parts of the tree in antioxidant, anticancer, antimicrobial, and antidiabetic studies (Sishu et al., 2023). It is a notably versatile fruit tree in arid and semi-arid areas due to its highly climatic adaptability, where other fruits are difficult to grow. This characteristic makes *Z. mauritiana* a high economic return crop and has made great contributions to poverty reduction (Shisu et al., 2023). The fruit tree often has a low fruiting rate under high and arid temperature conditions leading to the reduction of fruit quantities obtained on the tree and reduction of productivity, especially in semi-arid areas in Ninh Thuan province (Hao et al., 2022). Therefore, the research of appropriate farming techniques contributes to the improvement of fruiting rate, productivity as well as efficiency of greenhouse production. Fruit quality is particularly important to consumers such as taste, appearance and high nutritional content. However, Jujube fruit, belonging to a climacteric group, has a short shelf-life, stays fresh for only about 3 days in ambient temperature before aging, and is characterized by softness and reduction in soluble solid function, skin browning, quality deteriorates (Jiang et al., 2004; Moradinezhad et al., 2019). Jujube fruit is also susceptible to fungal diseases and easily rots and dehydrates during transportation and storage (Wang et al., 2011) and susceptible to fungal diseases (Tian et al., 2005; Cao et al., 2013). For this reason, implementing technical measures to enhance the quality and extend the time for post-harvest management time is an urgent task and is crucial for fruit growers in order to increase their profits.

Calcium (Ca) is an essential nutrient required for plant growth. Ca deficiency in fruit can lead to various physiological disorders that significantly affect their economic value, such as cracked fruit and dull and bitter fruit (White and Broadley, 2003). Additionally, the use of Ca helps to increase the fruit set rate (Kassem et al., 2011), as well as increases total soluble solids (TSS), and vitamin C (Park and Kim, 2016). Ca applications are generally reported to delay ripening, decrease postharvest rots and alterations, and extend the storage period (Lara, 2013). Boron (B) plays a major role in the development from the vegetative stage to the reproductive stage of plants (Karthika, et al., 2020). B is irreplaceable in plant growth and development (Davarpanah et al., 2016) and indispensable in small amounts of 1 μg^{-1} - 1 mg^{-1} (Brdar- Jokanović, 2020). If lacking, it will cause reduced crop productivity (Nable et al., 1997). B helps to increase fruit set, which is an important factor that affects fruit quality (Cheng and Raba 2009). B also stimulates protein biosynthesis, as well as plays a role in increasing vitamin C and vitamin B. Moreover, B also has a role in stimulating some enzymes in fruit (Verma and Verma, 2010). The use of B before harvest is to minimize post-harvest fruit damage and to prolong fruit storage life (Qin et al., 2010). However, B deficiency is quite common in arid and semi-arid regions, where sandy soils are more prevalent (Zhang et al., 2015) such as conditions in Ninh Thuan province. Therefore, the objectives of this study were to apply Calcium and Broron in order to improve the fruit set, yield and fruit quality, as well as to reduce post-storage damage on apples in Ninh Thuan province.

Materials and Methods

In this study, we used the TN01 apple variety, which was previously selected and developed by Nhaho Research Institute for Cotton and Agriculture Development (Ninh Thuan province). This variety has been implemented in practical applications due to its numerous promising traits such as high yield (70 - 84 tons/ha/year), good quality, large product size (84 - 122 g/fruit), and its ability to adapt to various climate, soil and farming conditions, typically found in Ninh Thuan province.

Chemicals used: Ca (EDTA - Ca) containing 10 % Ca, B (Solubor – ETIDOT 67 – $Na_2B_8O_{13} . 4H_2O$) containing 20.5 % B.

Methods and Experimental Design

The experiment was conducted on a 6-year-old *Z. mauritiana* L. garden with a density of 500 trees/ha (5 m x 4 m spacing). The experiment was arranged with two factors in a split-plot design with three replications. Each experimental plot consisted of three plants. The main batch element was Boron (B) with four concentrations (0.0%, 0.2 %, 0.4 %, and 0.6 %) and the sub-plot was Calcium (Ca) with four concentrations (0.0%, 0.5 %, 1.0 %, and 1.5%) based on a fertilizer application of 280 kg N, 160 kg P_2O_5, and 360 kg K_2O/ha/crop. Watering was done using a drip irrigation system. The control treatments did not use any Ca or B, respectively. In addition to the experimental factors, pruning measures and other farming techniques were applied according to the technical manual for safe apple production in Ninh Thuan province.

Ca and B were sprayed at least three times: The first application was applied when the first flower bud appeared on the plant; The second application was done 30 days after the plant blooms occurred. The third time was applied 30 days after the first fruit formed. The soil condition before the experiments was as follows: pH_{H2O}: 6.5; CEC: 9.1 meq/100g; Organic matter: 2.8% (The Center for Agricultural Science and Technology Analysis and Services).

Data collection

The evaluation criteria for monitoring the quantity and quality of harvested fruits included the fruiting rate (%), fruit weight (g/fruit), fruit density (fruit/m^2) and actual yield (tons/ha). Additionally, two indicators were used to assess fruit quality (vitamin C content) (mg/100g), Brix (%) and fruit acidity (%). The effects of Ca and B on the preservation quality of the TN01 variety were measured through independent variables such as weight loss rate (%) and rotten fruit rate (%), which were outcomes of the preservation method.

We selected and marked four branches/tree in four directions to monitor and harvest fruit samples using the method described in TCVN 12720:2019). Fruiting rate (%): For each monitoring period, which occurred every five days, we counted the total number of blooming flowers and the total number of fruit sets; each monitoring period was 5 days apart, and the fruit set was monitored in 32 monitoring periods. Fruit diameter, fruit height and fruit weight: We randomly harvested 30 fruits/batch/experimental plot, and collected 3 batches (at the beginning of the season, in mid-season and at the end of the season). Fruit density (fruit/m^2): To determine fruit density, we used a 0.25 m^2 frame (frame size: 0.5 m x 0.5 m). We randomly selected five even points on the tree canopy of the experimental plot and calculated the fruit density per square meter based on these points. The yield was calculated by considering all fruits on the tree. Additionally, we randomly selected 30 fruits from each treatment to analyze fruit quality indicators.

Actual yield (tons/ha): the total number of fruits collected from each tree during each harvest was weighed and recorded. Brix degree (ºBrix): Taken 30 fruits/batch/experimental plot, squeezed and mixed together the fruit juice of 03 fruits to measure and measure 10 times/batch/experimental plot, measured with a hand-held refractometer (ºBrix). Vitamin C content (mg/100g): analyzed according to AOAC 2012.21 method. Total acid content was calculated and analyzed according to the A.O.A.C.1990 method. Rate of fruit weight loss and rotten fruit rate after 5 weeks of storage at 5ºC (%): Collected 10 fruits/replication, 30 fruits/treatment. After collecting the fruit, put it in a perforated paper bag (10 holes). Before storing, the weight of the fruits was measured, and the number of rotten fruits was calculated. Fruits were then stored at a temperature of 5ºC. After 5 weeks of storage, the weight of the fruits was measured again and the rotten fruits (Al-Obeed, 2012; Dhia, 2011). The rate of fruit weight loss (%) = (initial fruit weight – fruit weight after storage for 5 weeks)/initial fruit weight x 100. The percentage of rotten fruits (%) = Number of rotten fruits/number of preserved fruits *100

Statistical Analysis

Experimental data were calculated using the statistical method of Gomez and Gomez (1984). The average monitoring criteria of each repetition between experimental treatments were processed by analysis of variance (ANOVA), then compared with Duncan's test at the confidence level of $P \leq 0.05$ using SAS 9.4 software.

Time and Studied Site

The study was carried out in two consecutive seasons (Summer-Autumn 2021 and Winter-Spring 2021/2022 at the experimental station of Nhaho Research Institute for Cotton and Agriculture Development (Nhon Son, Ninh Son, Ninh Thuan).

Results and Discussion

Effects of Ca and B on yield and yield components of TN01 variety

An adequate supply of Calcium (Ca) and Boron (B) is necessary to improve fruit quality and yield. The application of Ca and B can be done through soil or foliar methods, depending on the soil type, crop stage, and environmental conditions. Foliar application of Ca and B is more effective in enhancing fruit quality, as it can overcome the limitations of soil and root uptake. In this study, the analysis variance of fruiting rate, fruit weight, fruit density, and actual yield were evaluated among the different concentrations of Ca and B (see Table 1, 2, 3, 4).

Table 1. Effects of Ca and B on the fruiting rate of TN01 cultivar through the two seasons of Summer-Autumn 2021 and Winter-Spring 2021/2022

Indicators	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	**0.2**	**0.4**	**0.6**	
Summer-Autumn crop	0	5.5	5.9	6.2	5.9	5.9
	0.5	5.6	6.1	6.4	6.0	6.0
	1.0	5.7	6.2	6.2	6.1	6.0
	1.5	5.5	6.0	6.1	6.1	5.9
	B average	5.6 b	6.0 a	6.2 a	6.0 a	
	$CV_{(B)}$ = 6.9; CV = 5.3; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					
Winter-Spring crop	0	6.5	6.9	7.2	6.9	6.9
	0.5	6.7	7.1	7.5	7.2	7.1
	1.0	6.6	7.1	7.4	7.3	7.1
	1.5	6.6	7.0	7.3	7.1	7.0
	B average	6.6 b	7.0 ab	7.4 a	7.1 a	
	$CV_{(B)}$ = 6.7; CV = 6.1; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.05).

The fruiting rate of the TN01 cultivar showed a statistically significant difference in the two seasons of the Summer-Autumn crop and the Winter-Spring crop when Ca and B were sprayed (Table 1). There was no statistical interaction between Ca and B treatments in both monitoring seasons. Spraying Indian jujube trees with B significantly increased the fruiting rate compared to the control. In both surveillance crop seasons, a concentration of 0.4% B resulted in the highest fruiting rate (6.2% and 7.4%), while the control had the lowest fruiting rate (5.6% and 6.6%). There was no difference in fruiting rate among Ca treatments. Spraying B also increased the fruit-setting rate of apple trees, which is consistent with research conducted by Kassem et al. (2011) on Chinese jujube (*Z. jujuba* Mill.), Wojcik et al. (2008) on Malus Domestica Borkh., and De Silva et al. (2022) on *Macadamia integrifolia*.

Table 2. Effects of Ca and B on fruit weight of TN01 cultivar through the two seasons of Summer-Autumn 2021 and Winter-Spring 2021/2022

Indicators	Ca concentration (%)	B concentration (%)				Ca average (%)
		0	0.2	0.4	0.6	
Summer-Autumn crop	0	75.5	78.4	81.5	82.4	79.4
	0.5	76.9	80.2	84.1	84.0	81.3
	1.0	76.4	79.6	82.8	83.4	80.5
	1.5	76.3	78.8	81.6	83.1	79.9
	B average	76.3 b	79.2 ab	82.5 a	83.2 a	
	$CV_{(B)}$ (%) = 5.5; CV (%) = 4.7; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					
Winter-Spring crop	0	78.5	82.9	85.8	84.0	82.8
	0.5	79.8	84.8	86.7	85.9	84.3
	1.0	80.4	83.6	87.9	85.8	84.4
	1.5	78.3	83.8	86.8	84.9	83.5
	B average	79.3 b	83.8 ab	86.8 a	85.2 a	
	$CV_{(B)}$ (%) = 5.4; CV (%) = 5.8; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.01).

The weight of the independent variables ranges from 75.5 to 87.9 g/fruit in both Summer-Autumn and Winter-Spring crops. The variables that spray Ca or B have been statistically larger product volumes compared to the control without spraying Ca or B. However, there was no statistically different interaction in fruit weight between the two factors Ca and B in both Summer-Autumn and Winter-Spring seasons. At temperatures of 0.4% and 0.6% B, the crop has the highest fruit weight (83.2 g/fruit and 86.8 g/fruit) and the lowest mass in control (76.3 g/fruit and 79.3 g/fruit) in both monitoring crop seasons. When using Ca, apple weight is not enhanced compared to the control. At a Ca concentration of 0.5%, the fruit weight was the highest (81.3 g/fruit and 88.8 g/fruit) in both monitoring crop seasons. Experimental results show that spraying B increases the fruit weight of apple cultivar, as concluded by Nakhaei, 2015. In addition, the use of B not only increases the fruit weight of apples, but it is also reported to increase the weight of *Phoenix dactylifera* L. (Shareef, 2016), (*Mangifera indica*) mango (Arvind et al., 2012; Bhatt et al., 2012), and Hass avocado (Hapuarachchi et al., 2022).

Table 3. Effects of Ca and B on fruit density of TN01 cultivar through the two seasons of Summer-Autumn 2021 and Winter-Spring 2021/2022

Indicators	Ca concentration (%)	B concentration (%) 0	0.2	0.4	0.6	Ca average (%)
Summer-Autumn crop	0.0	53.3	54.9	56.8	54.9	55.0
	0.5	53.9	56.3	58.1	56.8	56.3
	1.0	53.6	55.5	58.9	56.5	56.1
	1.5	52.5	55.7	57.1	55.5	55.2
	B average	53.3 b	55.6 ab	57.7 a	55.9 ab	
	$CV_{(B)}$ (%) = 5.5; CV (%) = 5.3; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					
Winter-Spring crop	0	55.2	57.1	57.3	56.5	56.5
	0.5	55.5	58.9	61.9	59.5	59.0
	1.0	54.9	56.5	60.8	58.7	57.7
	1.5	54.9	56.5	59.2	56.8	56.9
	B average	55.1 b	57.3 ab	59.8 a	57.9 ab	
	$CV_{(B)}$ (%) = 5.3; CV (%) = 5.6; $Prob_B < 0.05$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.01).

The density of fruits/tree of the independent variables ranged from 53.3 - 61.9 fruits/m^2 in the Summer-Autumn and Winter-Spring crops when Ca and B were used on the TN01 cultivar. There were statistically significant differences between treatments using Ca and B for foliar spraying on apples, but there was no statistical significance (Table 3). Spray B resulted in higher fruit density and there was a statistically significant difference between concentrations. B at the concentration of 0.4% gave the highest fruit set rate and increased fruit density by more than 10% compared to the control, this result is completely consistent with the study of Wojcik et al. (2008) on *Malus Domestica* Borkh. tree. As for Ca, there was no statistically significant difference between the concentrations used in fruit density.

Table 4. Effects of Ca and B on the actual yield of TN01 cultivar through the two seasons of Summer-Autumn and Winter-Spring 2021/2022

Indicators	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	0.2	0.4	0.6	
Summer-Autumn crop	0	36.6	38.6	40.4	39.1	38.7
	0.5	37.1	39.5	41.9	40.5	39.8
	1.0	37.1	39.0	41.2	39.6	39.2
	1.5	36.8	39.3	40.9	39.1	39.0
	B average	36.9 b	39.1 ab	41.1 a	39.6 a	
	$CV_{(B)}$ (%) = 6.3; CV (%) = 5.4; $Prob_B$ < 0.05; $Prob_{Ca}$ > 0.05; $Prob_{BCa}$ > 0.05					
Winter-Spring crop	0	38.9	40.8	42.4	40.9	40.8
	0.5	39.7	42.4	44.4	42.5	42.2
	1.0	39.4	41.8	42.8	42.0	41.5
	1.5	39.5	41.6	43.8	41.7	41.6
	B average	39.4 b	41.7 a	43.4 a	41.8 a	
	$CV_{(B)}$ (%) = 5.4; CV (%) =4.8; $Prob_B$ < 0.05; $Prob_{Ca}$ > 0.05; $Prob_{BCa}$ > 0.056					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.01).

The actual yield in both Summer-Autumn and Winter-Spring crops shows that using B for apples significantly increased fruit yield (Table 4). The interaction effects between factors Ca and B were not statistically significant. At a B concentration of 0.4%, the fruit yield was the highest in both crops, with values of 41.1 tons/ha and 43.4 tons/ha, respectively. For Ca, there was no significant difference in apple yield when used. Thus, in both Summer-Autumn and Winter-Spring crops, when using B foliar spray on TN01 trees, the actual yield was much higher than not using it, which is completely consistent with the research of Meena et al., (2008) on spraying B on leaves at the growth and fruiting stage. The results recorded in this report are consistent with many other studies when spraying B helps increase the yield of some fruit trees including mango trees (Arvind et al., 2012), date palm trees (Shareef 2016; Al-Hajjaj and Ayad 2018), cv apple tree (Bhat et al., 2020), guava tree (Shreekant and Kumar 2017), and Hass avocado tree (Hapuarachchi et al., 2022).

Effects of Ca and B on the characteristics of fruit quality TN01 cultivar

In this experiment, we focused on evaluating the effects of Ca and B on the Brix, fruit acidity and vitamin C content. Ca and B treatments are expected to enhance the sugar accumulation and metabolism in fruits by regulating the enzyme activity and the transport of sucrose and hexoses. Ca and B also improve the water balance and the osmotic pressure in fruits, which affects the Brix value (Li et al., 2024).

Table 5. Effects of Ca and B on the °Brix in the fruit of TN01 cultivar through the two seasons of Summer-Autumn and Winter-Spring 2021/2022

Indicators	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	0.2	0.4	0.6	
Summer-Autumn crop	0	11.1	11.3	11.4	11.5	11.3
	0.5	11.1	11.8	12.1	12.2	11.8
	1.0	11.1	11.6	11.7	11.9	11.6

	1.5	11.1	11.7	11.8	11.7	11.6
	B average	11.1 b	11.6 ab	11.8 a	11.8 a	
	CV(B) (%) = 4.6; CV (%) = 4.9; $Prob_B$ < 0.05; $Prob_{Ca}$ > 0.05; $Prob_{BCa}$ >0.05					
Winter-Spring crop	0	11.8	12.4	12.4	12.5	12.3
	0.5	11.9	12.8	12.8	13.0	12.6
	1.0	11.8	12.6	12.6	12.9	12.5
	1.5	11.8	12.6	12.5	12.5	12.4
	B average	11.8 b	12.6 a	12.6 a	12.7 a	
	CV(B) (%) = 5.0; CV (%) = 4.6; $Prob_B$ < 0.05; $Prob_{Ca}$ > 0.05; $Prob_{BCa}$ > 0.05					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.01).

The Brix degree is one of the important factors in determining the quality and marketability of apples. The interaction effect between the two factors Ca and B was not statistically significant on the Brix levels of the fruit during the Summer-Autumn and Winter-Spring seasons when used (Table 6). However, when B was foliar sprayed on apple trees, it led to an increase in the Brix level of the fruits. There was a statistically significant difference between different concentrations of B. In both the Summer-Autumn and Winter-Spring crops, the highest Brix levels of the fruit were observed at concentrations of 0.4% and 0.6% of B, respectively (11.8 ºBx and 12.7 ºBx). Additionally, the use of Ca also increased the Brix level of the fruit, with an increment of 1 Brix unit higher than the control group. A study conducted by Mao et al. (2016) on apple trees in China demonstrated that spraying B and Ca individually or in combination significantly increased sweetness and improved fruit quality. Similarly, Meena et al. (2008) reported spraying B on the apple trees at the growth and fruiting stages resulted in the highest levels of total sugar, reducing sugar, and non-reducing sugar, which was consistent with the findings of this study.

Table 6. Effects of Ca and B on Vitamin C content in fruit of TN01 cultivar through the two seasons of Summer-Autumn and Winter-Spring 2021/2022

Indicator	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	**0.2**	**0.4**	**0.6**	
Summer-Autumn crop	0	41.1	42.5	45.8	42.8	43.1 b
	0.5	44.2	46.9	50.3	47.4	47.2 a
	1.0	42.7	45.1	47.7	46.3	45.5 ab
	1.5	42.6	45.3	46.6	45.9	45.1 ab
	B average	42.7 b	44.9 ab	47.6 a	45.6 a	
	CV(B) (%) = 6.0; CV (%) = 6.4; $Prob_B$ < 0.05; $Prob_{Ca}$ < 0.05; $Prob_{BCa}$ > 0.05					
Winter-Spring crop	0	41.6	45.1	45.9	43.8	44.1 b
	0.5	45.3	47.3	50.8	47.3	47.7 a
	1.0	45.0	45.2	48.8	46.4	46.4 ab
	1.5	44.5	46.3	47.9	46.0	46.2 ab
	B average	44.1 b	46.0 ab	48.3 a	45.9 b	
	CV(B) (%) = 6.0; CV (%) = 6.1; $Prob_B$ < 0.05; $Prob_{Ca}$ < 0.05; $Prob_{BCa}$ > 0.05					

Note: In the same row, values followed by the same letter are not statistically different (P < 0.01).

The results indicated that the vitamin C content in the independent variables, using Ca and B, which was higher than that of the control, and this difference was statistically significant in both the Summer-Autumn and Winter-Spring crops (Table 6). However, there was no remarkably significant difference in the interaction level between the two factors, Ca and B. All of the Ca spray treatments had higher vitamin C content than the control in both monitoring seasons. The highest vitamin C content in apples, reaching 47.2 mg/100g and 47.7 mg/100g, was obtained at Ca concentration of 0.5%. These results are consistent with the studies conducted by Al-Obeed (2012), and Zeraatgar et al. (2018) on apple trees. In the B treatment variables, the vitamin C content increased covariantly with increasing B concentration. The vitamin C content in the B spray treatments was higher than in the control treatment in both monitoring seasons. The highest vitamin C content (47.6 mg/100g and 48.3 mg/100g) was achieved at a B concentration of 0.4%, while the control treatment had the lowest content (42.7 mg/100g and 44.1 mg/100g). These results align with the research conducted by Verma & Verma (2010). Micronutrient fertilizers of Ca and B were reported to play a significant role in apple quality (Majid et al., 2019).

Table 7. Effects of Ca and B on fruit acidity of TN01 variety through the two seasons of Summer-Autumn and Winter-Spring 2021/2022

Indicators	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	**0.2**	**0.4**	**0.6**	
Summer-Autumn crop	0	0.48	0.46	0.45	0.42	0.45
	0.5	0.47	0.46	0.45	0.39	0.44
	1.0	0.47	0.46	0.45	0.40	0.45
	1.5	0.46	0.46	0.46	0.40	0.45
	B average	0.47 a	0.46 a	0.45 a	0.40 b	
	$CV_{(B)}$ (%) = 6.0; CV (%) = 6.8; $Prob_B < 0.01$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					
Winter-Spring crop	0	0.46	0.46	0.46	0.41	0.45
	0.5	0.46	0.45	0.45	0.38	0.44
	1.0	0.46	0.46	0.46	0.39	0.44
	1.5	0.45	0.46	0.45	0.39	0.44
	B average	0.46 a	0.46 a	0.46 a	0.39 b	
	$CV_{(B)}$ (%) = 6.8; CV (%) = 6.1; $Prob_B < 0.01$; $Prob_{Ca} > 0.05$; $Prob_{BCa} > 0.05$					

Note: Values of the same row followed by the same letter are not statistically significant (P < 0.01).

Regarding fruit acidity, the results showed that there was a statistically significant difference between the treatments using B in both Summer-Autumn and Winter-Spring crops (Table 7). However, the interaction between the two factors Ca and B was not statistical significance. When B was sprayed through the leaves of apple trees, the acidity of the fruit decreased significantly compared to the control. A concentration of 0.6% B had the lowest acidity (0.40% and 0.39%), while the control had the highest acidity (0.47% and 0.46%). When Ca was sprayed, the acidity in the concentration treatments had similar values (0.44-0.45%). These experimental results are consistent with the research conducted on apple trees (Xuan et al., 2003). At harvest time, fruits sprayed with B or both B and Ca were greener, firmer, and had lower acidity compared to unsprayed fruit. Similar results were observed in papaya (Chandra et al., 2010).

Effects of Ca and B on the preservation quality of TN01 variety

Ca and B have an impact on the biosynthesis and preservation of vitamin C in fruits by regulating the enzyme activity and the redox state. Additionally, Ca and B also help to protect vitamin C from degradation caused by oxidative stress and high temperature. As mentioned earlier, fruits with higher Ca and B levels tend to have higher vitamin C, which has generally obtained more vitamin C content.

Table 8. Effects of Ca and B on fruit weight loss and rotten fruit of TN01 variety stored 5 weeks after harvest at 5°C

Indicators	**Ca concentration (%)**	**B concentration (%)**				**Ca average (%)**
		0	0.2	0.4	0.6	
Rate of fruit weight loss (%)	0	13.0	12.2	12.4	11.8	12.4 a
	0.5	8.2	7.9	7.5	7.6	7.8 c
	1.0	9.3	9.2	9.1	8.8	9.1 b
	1.5	10.0	10.1	9.8	9.7	9.9 b
	B average	10.1	9.9	9.7	9.5	
	$CV_{(B)}$ (%) = 6.8; CV (%) = 10.1; $Prob_B$ > 0.05; $Prob_{Ca}$ < 0.01; $Prob_{BCa}$ > 0.05					
Rate of rotten fruit (%)	0	15.6	14.4	13.3	14.4	14.4 a
	0.5	10.0	8.9	8.9	8.9	9.2 c
	1.0	11.1	11.1	10.0	10.0	10.6 bc
	1.5	12.2	11.1	11.1	12.2	11.7 b
	B average	12.2	11.4	10.8	11.4	
	$CV_{(B)}$ (%) = 13.9; CV (%) = 15.1; $Prob_B$ > 0.05; $Prob_{Ca}$ < 0.05; $Prob_{BCa}$ > 0.05					

Note: In the same row or column, values followed by the same letter are not statistically significant (P <0,01 and P < 0.05).

The experimental results indicated a statistically significant difference in the rate of fruit weight loss after 5 weeks of storage at 5°C when Ca and B were applied (Table 8). Among the Ca concentrations tested, there was a notable difference in the rate of fruit weight loss. The concentrations ranging from 7.8% to 9.9% demonstrated a lower rate of weight loss compared to the control group, which did not use Ca (12.4%). Specifically, the lowest rate of fruit weight loss (7.8%) was observed with a Ca concentration of 0.5%, while the control group had the highest rate (12.4%). On the other hand, no significant difference was observed for the treatments involving B.

The ratio of rotten fruit is particularly important for fruit quality during storage because it greatly impacts output and economic efficiency. The use of Ca and B for apples has proven to be quite effective in addressing this issue (Table 8). The rate of rotten fruit after 5 weeks of storage significantly differed between the treatments sprayed with Ca and the controls. The most effective Ca concentration was found to be 0.5%, resulting in the lowest rate of rotten fruit (9.2%), while the control group had the highest rate (14.4%). On the other hand, spraying B has not had as much of an impact as Ca, and there was no statistically significant difference between the treatments. However, all the treatments using B demonstrated a lower rate of rotten fruit compared to the treatment without it, with the lowest rate of 10.8% observed in the 0.4% B treatment, while the control group had the highest rate of 12.2%. Other studies have also shown that spraying Ca before harvest can help reduce the rate of post-harvest rot (Ernani et al., 2008). This treatment has been found to enhance fruit quality after storage compared to the control (Moradinezhad et al., 2019), (Fatemeh et al., 2020; Huanhuan et al., 2017; Park and Kim, 2016; Lara, 2013; Lokesh and Kumar, 2021). Additionally, Ashok et al. (2021) reported that pre-harvest foliar application of 0.4% B combined with 50 ppm GA3 improved storage time and apple quality when stored at room temperature.

Conclusions

In conclusion, the use of Ca as a foliar spraying on apples grown in Ninh Thuan province during the Summer-Autumn crop of 2021 and the Winter-Spring crop of 2021/2022 increases apple quality and boosts vitamin C content (47.6 mg/100g and 48.3 mg/100g) compared to the control group (42.7 mg/100g and 44.1 mg/100g). It also helps preserve the apples better by reducing the rate of wilted fruit (7.8%) and minimizing the rate of rotten fruit (9.2%), which are the lowest levels observed compared to the control group (12.4% and 14.4%), especially when stored at 5°C for 5 weeks after harvest with a concentration of 0.5% Ca for optimal efficacy. Furthermore, the use of B as a foliar spray on apples increases the fruit set rate (6.2% and 7.4%), fruit weight (83.2 g/fruit and 86.8 g/fruit), fruit density (57.7 fruits/m2 and 59.8 fruits/m2), and productivity (41.1 tons/ha and 43.4 tons/ha). It also enhances apple quality by increasing Brix levels (11.8°B and 12.6°B), vitamin C content (47.6 mg/100g and 48.3 mg/100g), and decreasing acid content (0.4% and 0.5%), particularly when using a B concentration of 0.4% for optimal results across both the Summer-Autumn 2021 and Winter-Spring 2021/2022 crops. Lastly, the combination of Ca and B spray on apples increases the fruit set rate, fruit weight, yield, and fruit quality in terms of °Brix and vitamin C. It also reduces acidity and minimizes damage during storage.

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