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Full Length Research Paper

Foliar application of calcium chloride and borax affects the fruit skin strength and cracking incidence in litchi (*Litchi chinensis* Sonn.) cultivars

Ihsan-ul- Haq[1] and Abdur Rab[2]*

[1]Hazara Agriculture Research Station, Abbottabad, Pakistan.
[2]Department of Horticulture, KP Agricultural University, 25130, Peshawar, Pakistan.

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The influence of foliar application of calcium chloride and borax calcium on fruit skin strength and cracking incidence in litchi (*Litchi chinensis* Sonn.) fruit was investigated at 25 days interval and also the evaluation of fruit skin calcium and boron contents, skin strength, ion leakage from skin discs and fruit cracking in four litchi cultivars. Significant variations were observed in different litchi cultivars and $CaCl_2$ and borax treatments. The means revealed that cultivar Gola had the highest fruit skin calcium content (7.67 mg/100 g DW), ion leakage from skin discs (31.11%) and fruit cracking (21.91%) but the least skin strength (2.44 kg cm^{-2}). Skin boron content was the highest in cultivars Gola (0.203 mg/100 g DW). Cultivar Bedana had the highest fruit skin strength (3.39 kg cm^{-2}) and the least mean ion leakage (18.86%) and fruit cracking (13.26%). Foliar application of $CaCl_2$ and borax significantly increased the mean fruit skin calcium content (4.79 mg/100 g DW), boron content (0.109 mg/100 g DW), and skin strength (2.43 kg cm^{-2}) from the least in the control to the highest 8.88 mg/100 g DW , 0.247 mg/100 g DW and 3.01 kg cm^{-2} with $CaCl_2$ 3 + boron 1.5% treatment respectively, while ion leakage (35.17%) and fruit cracking (25.40%) in the control decreased to 16.17 and 11.14% respectively with $CaCl_2$ 3% + boron 1.5% treatment. The Ca content of the litchi fruit skin in the control vs. Rest, control vs. $CaCl_2$ and control vs. $CaCl_2$ + borax increased from 4.79 to 7.36 mg/100 g DW, 4.85 and 8.20 mg/100 g DW respectively. The boron content of the fruit skin also increased in the control vs. Rest (0.11 vs. 0.21 mg/100 g DW), control vs. $CaCl_2$ (0.11 vs. 0.14 mg/100 g DW), control vs. $CaCl_2$ + Borax (0.11 vs. 0.23 mg/100 g DW) and $CaCl_2$ vs. $CaCl_2$ + Borax (0.14 vs. 0.23 mg/100 g DW) treatments. The mean ion leakage decreased from 35.17 in the control to 24.10% in control vs. Rest, 30.26% in control vs. $CaCl_2$ and 22.05% in control vs. $CaCl_2$+Borax. Similarly, the ion leakage decline from 30.06 to 22.05 in $CaCl_2$ vs. $CaCl_2$ + Borax means.

Key words: Boron, calcium, fruit cracking, litchi, skin strength, ion leakage.

INTRODUCTION

The litchi (*Litchi chinensis* Sonn.) is a popular fruit of the family *Sapindaceae* (Huang et al., 2005). The fruits are high in sugar and contain several vitamins and minerals (Robert et al., 2000). It can be processed into juice, wine, pickles, preserves, ice cream and yoghurt (Huang et al., 2004). In Pakistan it is being grown in the Sind, Punjab and parts of KP province on a reported total area of 572 ha with a production average of 9250 tons (Shah, 2003). The litchi is in high demand due to its unique taste, health benefits and cuisine value. It therefore, captures good price in the markets. Much of the litchi fruit is used in fresh form but a small percentage is processed (Rajwana et al., 2010). The litchi is a non-climacteric fruit, which is characterized by low rates of respiration and ethylene production (Chen et al., 1986). The edible portion of the fruit is well protected against water loss, insects and pests by a rough skin. Yet, the litchi fruits have a short

*Corresponding author. E-Mail: abdurrabaup@gmail.com. Tel: 092-91-9216541, 092-300-9055870. Fax: 092-91-9216520.

post-harvest life (Kaiser, 1994). The pericarp of litchi fruit rapidly turns brown and brittle resulting in skin cracking, which exposes the aril to pathogens (Kaiser, 1994). While, significant variations are reported in fruit's resistance to cracking in different litchi cultivars (Huang et al., 2005), yet fruit cracking is a major physiological disorder in litchi (Huang, 2005). The cracking of litchi pericarp is generally initiated at the early stage of fruit development (Huang et al, 2005). Research on fruit cracking in litchi, reveals that low relative humidity, high temperature, hot dry winds, drought or excessive irrigation are the major environmental factors that promote fruit cracking (Li et al., 2001). Evidence suggests that calcium is involved in cracking resistance in litchi fruit because trees with lower cracking incidence have higher calcium levels, while, a low exchangeable calcium in plants results in high cracking incidence (Li et al., 2001). Similarly, the cracked fruits have significantly lower concentrations of calcium in fruit as compared to the unaffected fruit of the same cultivars (Li et al., 2001). Furthermore, cultivars characterized by resistance to cracking have higher calcium concentration in the pericarp than the cracking-susceptible cultivars (Huang et al., 2005). The calcium movement within the plant is generally from the soil to the leaves and with very little from the leaves to the fruit (Kadir, 2005). Therefore, foliar application of calcium on the fruit is essential to decrease the calcium related physiological disorders (Fallahi et al., 1997).

Boron is another important micronutrient involved in cell wall development, cell division, phloem development, and movement of sugars, metabolism of nitrogen and phosphorus and absorption of salts (Dale and Krystyna, 1998). Experiment with litchi fruit indicates that borax at 0.4% not only decreased the fruit cracking but total soluble solids (TSS) and total sugar contents of the fruits were also higher (Ruby et al., 2001). Boron deficiency causes a decrease in the amount of Ca associated with pectin constituents of the cell wall suggesting that boron may be important in Ca metabolism in the cell wall (Yamaguchi et al., 1986). When different litchi cultivars were treated with borax, it was found that 0.8% boron resulted in significant decline in fruit cracking (Kumar et al., 2001).

The present study was initiated to explore the possibility of using foliar application of calcium chloride and borax to enhance fruit quality especially by decreasing fruit cracking.

MATERIALS AND METHODS

Experiment location

The study on the influence of foliar applications of calcium chloride and borax on fruit skin strength and cracking incidence in litchi fruit in four litchi cultivars that is, China, Gola, Surahi and Bedana was conducted in the agroclimatic conditions of Haripur, Hazara region of KP Province, Pakistan during the years 2007 and 2008.

Experiment planning

The experiment was planned in randomized complete block design (RCBD) two factors factorial arrangement having litchi cultivars as factor A in main block while different calcium chloride and Borax concentrations in subplots. Each treatment comprised three trees. Data was recorded on fruit skin calcium and boron contents, skin strength, ion leakage from skin discs and fruit cracking.

Preparation of chemicals and application

All nutrient solutions were prepared from AnalaR Grade chemicals. Since calcium chloride dehydrate was being used, therefore, the molecular weight of $2H_2O$ was subtracted from the total molecular weight of $CaCl_2.2H_2O$ (147 g) to the weight of $CaCl_2$ only (111 g). Calcium chloride (1, 2 and 3%) and Borax (0.5, 1 and 1.5%) solutions were made. The calcium chloride solutions were applied either alone or in combination with 0.5, 1 and 1.5% borax. A power sprayer was used to carry out the foliar sprays. After each treatment, the pump was washed thoroughly. A teaspoon of a commercial washing powder was added as wetting agent. Plain water was sprayed on the plants in the controlled treatment. All the foliar sprays were carried out early in the morning starting immediately after fruit set with 21 days interval till harvest.

All other agronomic practices were kept uniform throughout the experiment. For recording the physical and chemical characters, the same procedures were adopted as described in experiment-1 while for recording the ion leakage from the skin disc, the procedure described in experiment 2 was adopted.

Calcium determination in fruit skin

Fruit skin calcium content (mg/100 g DW) was determined by the technique suggested by Isaac and Kerber (1971). The fruits were harvested and thoroughly washed for 10 min with tap water and then with distilled water. The fruit skins from the samples were peeled and once again washed with distilled water and allowed to oven dry at 70°C until the achievement of a constant weight. The dried samples were ground to powder and sealed in Petri dishes for chemical analysis. The calcium percentage in the fruit skin was determined by the atomic absorption flame spectrophotometer (GBC AA, 932). The spectrophotometer was calibrated with a standard solution of 5 μgml^{-1} as per recommendations of the manufacturer.

Boron determination in fruit skin

For fruit skin Boron content (mg/100 g DW**)** determination, the skins of the selected fruits were washed thoroughly first with tap water and then with distilled water. Ten grams (10 g) of the sample was taken and dried for 12 h at 75°C in oven and then ashed for 3 h at 525°C. Ashes were extracted with 10 ml of 2M HNO_3 and were heated on a hot plate. Filtered contents after dissolution were diluted to a final volume of 50 ml. This solution was used for the determination of boron content in the fruit skin by the azomethine - H method using atomic absorption flame spectrophotometer (GBC AA 932) as described by (Harp, 1997). Boric acid standard solution (1000 mgl^{-1}) was used for standardization.

Ion leakage

Ion leakage was recorded by incising 1 cm^2 skin discs made of the skin taken from the equatorial regions of the selected fruits and putting them into 45 ml copolymer polypropylene vials having 20 ml

of double distilled water. The base line conductivity of the double distilled water was recorded with the help of HI 9813 Portable conductivity meter (Hanna Instruments, Inc) in μScm^{-1}. Each vial containing double distilled de-ionized water was then added 3 discs and the vials were then fixed in a stand and vibrated for 30 min on a rotary shaker. On completion of 30 min, the conductivity of the water, representing ion leakage from cell walls was recorded (Saltveit, 2005). The vials were then given three freeze - thaw cycles to determine the total conductivity as described earlier (Saltveit, 2005). The ion leakage from the cell was approximated by the formula:

$$\% \text{ Ion leakage} = \frac{(\text{conductivity of water with discs after 30 min}) - (\text{conductivity of water})}{\text{Total conductivity after 3 freeze thaw cycles}} \times 100$$

Fruit skin strength determination

Fruit skin strength was determined using hand held penetrometer as described by data pertaining to fruit firmness (Effigi, 11 mm Prob). The fruit were punctured at the equatorial area and the resistance to puncturing pressure was taken as skin strength of litchi fruit (Pocharski et al., 2000).

Fruit cracking

Fruit skin cracking percentage was recorded by visually observing and counting the number of total and cracked fruits on the tagged branches and converting the differential into percentage. Fruits with even the slightest of cracks were counted as cracked fruits.

Data analysis

The data was analyzed using M. Stat-C Software and means were separated by LSD α = at 0.05.

RESULTS AND DISCUSSION

Calcium content of litchi fruit skin (mg/ 100 g DW)

The mean calcium content of litchi fruit skin varied significantly with the highest (7.67 mg/ 100 g DW) in cultivar Gola followed by cultivar China and Surahi with 7.59 and 7.32 mg Ca / 100 g DW respectively while the least calcium content (4.375 mg/100 g DW) was recorded in cultivar Bedana (Table 1). Treatment with $CaCl_2$ and borax also resulted in significant increase in Ca content of the litchi fruit skin. The minimum mean calcium content in the control (4.79 Ca /100 g DW) increased significantly to 4.88 with 3% $CaCl_2$ application. The calcium content of the litchi fruit skin increased further with $CaCl_2$ + borax treatments to the maximum of 8.88 mg Ca / 100 g dry weight with application of $CaCl_2$ 3 + 1.5% Borax treatment (Table 1). The cultivar × treatment interaction revealed significant differences among cultivars and treatments in calcium content of litchi fruit skin. The minimum calcium content (4.21 mg/100 g DW) in cultivar Bedana increased to the maximum of 7.38 mg/100 g DW $CaCl_2$ 3 + borax 1.5% treatment. In the control treatment, cultivar China had the highest calcium content (5.25 mg/100 g DW) but it was the highest (9.75 mg/100 g DW) in cultivar Gola with $CaCl_2$ 3 + Borax 1.5% treatment, the differences with cultivar China (9.63) with the same treatment was, however, non significant (Figure 1). The application of $CaCl_2$ 3% alone resulted in 0, 5.62, 0.68 and 1.06% increase in skin calcium content in cultivars, China, Gola, Surahi and Bedana, which increased by 46.46, 52.81, 41.84, 42.99% with $CaCl_2$ 3 + 1.5% H_3BO_3 treatment (Figure 1). The planned paired means comparison revealed that the calcium content in litchi fruit skin increased significantly from 4.79 to 7.36 in control vs. Rest comparison. The control vs. $CaCl_2$ and control vs. $CaCl_2$ + borax treatment means also revealed significant increased from 4.79 to 4.85 and 4.79 to 8.20 respectively (Table 1). The calcium content in litchi fruit skin was significantly higher (4.85 vs. 8.20 mg/100 g DW) in $CaCl_2$ vs. $CaCl_2$ + Borax treatments means (Table 1).

Calcium is an important nutrient involved in the structure of cell walls and cell membranes (Peter, 2005). The calcium concentration in healthy plant tissues is about 0.1 to 1% of the dry matter (White and Broadley, 2003). Thus, a regular calcium supply is needed to ensure vigorous growth, avoid physiological disorders and enhance tolerance to abiotic stresses (White and Broadley, 2003; Del-Amor and Marcelis, 2006). Litchi cultivars may exhibit significant variation in mobilization of calcium to cell in the skin tissue (Huang et al., 2004). It was reported earlier that preharvest application of calcium chloride increase the calcium content of the fruit (Cronje et al., 2009). The relative small increase in calcium content in the skin tissue with only $CaCl_2$ application can be attributed to low absorption and incorporation of calcium in the skin cell wall (Huang et al., 2005). The control vs. $CaCl_2$ + borax resulted in 41.54% increase in calcium content of litchi fruit skin as compared to 40.85% in $CaCl_2$ vs. $CaCl_2$ + borax treatments (Table 1) indicating that boron might promote calcium incorporation into the cell wall (Wojvik et al., 1999). The control vs. $CaCl_2$ + Borax resulted in 41.54% increase in calcium content of litchi fruit skin as compared to 40.85% in $CaCl_2$ vs. $CaCl_2$ + Borax treatments (Table 1) indicating that boron might help in the incorporation of calcium in the cell wall (Wojvik et al., 1999; Khalifa et al., 2009).

Boron content of litchi fruit skin (mg/ 100 g DW)

Significant differences among litchi cultivars were observed in mean boron content of fruit skin with the highest boron content (0.203 mg/ 100 g DW) in cultivar Gola followed by cultivar China and Bedana with 0.202 and 0.198 mg/ 100 g DW respectively. Cultivar Surahi had the lowest boron content with 0.196mg / 100 g DW (Table 1). The boron content in litchi fruit skin was not affected by calcium chloride alone but increased significantly with $CaCl_2$ + borax treatments. The minimum

Table 1. Influence of calcium and boron application on specific gravity, reducing and non reducing sugars (%), calcium and boron content (mg/100 g DW) of skin in Litchi fruit.

Cultivar	Calcium (mg/100 g DW)	Boron (mg/100 g DW)	Skin strength (kg cm^{-2})	Ion leakage (%)	Cracking (%)
China	7.59 ^{b}	0.202 ^{b}	2.55 ^{c}	21.60 ^{c}	15.12 ^{c}
Gola	7.67 ^{a}	0.203 ^{a}	2.44 ^{d}	31.11 ^{a}	21.91 ^{a}
Surahi	7.32 ^{c}	0.196 ^{d}	2.63 ^{b}	28.24 ^{b}	19.13 ^{b}
Bedana	6.09 ^{d}	0.198 ^{c}	3.39 ^{a}	18.86 ^{d}	13.26 ^{d}
LSD	0.108	0.0006	0.103	0.531	0.719
Treatments (%)					
Control	4.79 ^{i}	0.109 ^{c}	2.43 ^{e}	35.17 ^{a}	25.40 ^{a}
$CaCl_2$ 1	4.88 ^{h}	0.142 ^{c}	2.48 ^{d}	32.43 ^{b}	22.55 ^{b}
$CaCl_2$ 2	4.81 ^{i}	0.144 ^{c}	2.44 ^{e}	30.71 ^{c}	21.27 ^{c}
$CaCl_2$ 3	4.88 ^{h}	0.146 ^{c}	2.46 ^{d}	27.64 ^{d}	19.15 ^{e}
$CaCl_2$ 1 + borax 0.5	7.41 ^{f}	0.213 ^{b}	2.79 ^{c}	29.08 ^{c}	20.14 ^{d}
$CaCl_2$ 1 + borax 1	8.63 ^{c}	0.212 ^{b}	2.79 ^{c}	25.06 ^{e}	17.07 ^{f}
$CaCl_2$ 1 + borax 1.5	8.50 ^{d}	0.218 ^{b}	2.76 ^{c}	22.76 ^{f}	14.75 ^{h}
$CaCl_2$ 2 + borax 0.5	7.34 ^{g}	0.224 ^{ab}	2.87 ^{b}	24.40 ^{e}	17.12 ^{f}
$CaCl_2$ 2 + borax 1.0	8.63 ^{c}	0.229 ^{ab}	2.89 ^{b}	21.24 ^{g}	14.90 ^{h}
$CaCl_2$ 2 + borax 1.5	8.72 ^{b}	0.230 ^{ab}	2.86 ^{b}	19.17 ^{h}	13.45 ^{i}
$CaCl_2$ 3 + borax 0.5	7.50 ^{d}	0.241 ^{ab}	3.02 ^{a}	21.82 ^{g}	15.31 ^{g}
$CaCl_2$ 3 + borax 1.0	8.22 ^{e}	0.246 ^{ab}	3.02 ^{a}	18.76 ^{h}	13.16 ^{i}
$CaCl_2$ 3 + borax 1.5	8.88 ^{a}	0.247 ^{ab}	3.01 ^{a}	16.17 ^{i}	11.34 ^{j}
LSD (5%)	0.0367	0.036	0.350	0.719	0.5310
Interactions					
Treatment x cultivar	*	NS	*	*	*
Control vs. Rest	*	*	*	*	*
Control	4.79	0.11	2.43	35.17	25.40
Rest	7.36	0.21	2.78	24.10	16.68
Control vs. $CaCl_2$	*	*	NS	*	*
$CaCl_2$	4.85	0.14	2.46	30.26	20.99
Control vs. $CaCl_2$+borax	*	*	*	*	*
$CaCl_2$ + borax	8.20	0.23	2.89	22.05	15.25
$CaCl_2$ vs. $CaCl_2$+borax	*	*	*	*	*

Means followed by similar letters in a column are non significantly different from each other at α 0.05. NS, Non significant.

boron content in litchi fruit skin in the control (0.109 mg/100 g DW) increased but non significantly to 0.146 mg/100 g DW with increasing $CaCl_2$ concentration to 3%. Calcium chloride 1% + borax increments (0.5 to 1.5%) resulted in significant increase in boron content of the skin (0.213 to 0.218 mg/100 g DW) but the difference among borax doses being non significant. Increased $CaCl_2$ concentration to 2% resulted in further increase in boron content of litchi fruit skin which continued to increase with increasing borax increments from 0.5 to 1.0 and 1.5%. At $CaCl_2$ 3%, the maximum boron content in litchi fruit skin was observed with $CaCl_2$ 3 + borax 1.5% (Table 1). The planned paired means comparison of control vs. Rest revealed significant increased in boron content from 0.11 to 0.21 mg/100 g DW and from 0.11 in control to 0.14 in control vs. $CaCl_2$ treatment means. The control vs. $CaCl_2$ + borax comparison revealed further increase in boron content from 0.11 to 0.23 mg/100 g DW. The boron content of the litchi fruit skin was also significantly higher (0.23 mg/100 g DW) with $CaCl_2$ + borax as compared to 0.14 mg/100 g DW, recorded with $CaCl_2$ alone (Table 1). Boron is an important micro-nutrient involved in cell wall development, cell division, phloem development, and the movement of sugars and metabolism of nitrogen, phosphorus (Patile et al., 2008). Application of boron increases the fruit set and fruit yield (Dale and Krystyna, 1998) and improve fruit quality (Ruby et al., 2001) while its deficiency has been associated with fruit discoloration, cracking, or rotting tubers and roots (Dale and Krystyna, 1998). Application of boron has

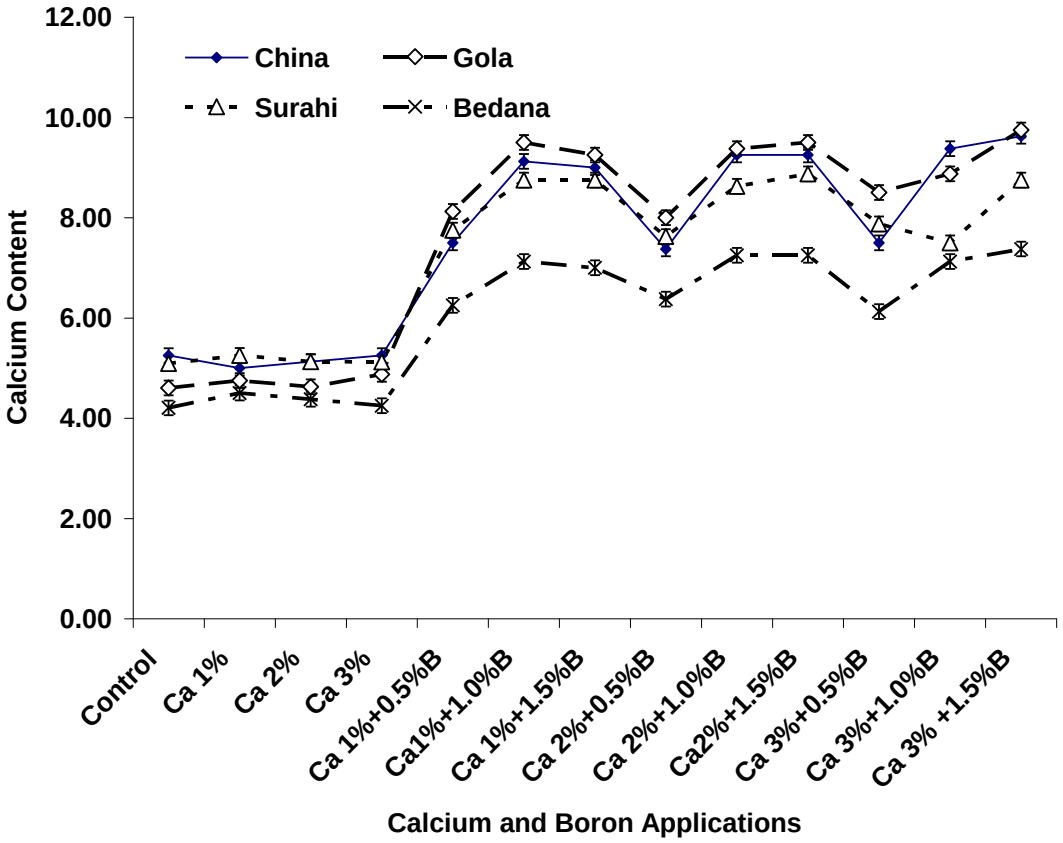

Figure 1. Calcium content of litchi fruit skin (mg/100 g DW).

been shown to decrease litchi fruit cracking, a disorder associated with calcium levels (Kumar et al., 2001; Ruby et al., 2001), yet the increased levels of boron in fruit skin could be significant in strengthening the cell walls (Loomis and Durst, 1992). The application of B increased Ca uptake by the fruits, thus, decrease Ca deficiency related disorders (Wojvik et al., 1999) such as fruit cracking (Kumar et al., 2001), probably by enhancing Ca uptake by the fruits or its metabolism in cell wall (Wojvik et al., 1999) but increase in boron content was more with $CaCl_2$ + borax rather than $CaCl_2$ alone.

Skin strength (kg cm^{-2})

The mean fruit skin strength in cultivar Bedana (3.39 kg cm^{-2}) was significantly higher than the rest of the cultivars, while it was the least in cultivar Gola (2.44 kg cm^{-2}). The skin strength increased significantly from 2.43 kg cm^{-2} in control to 2.46 kg cm^{-2} with the application of 3% calcium chloride but then further to 2.79 kg cm^{-2} and 2.8 kg cm^{-2} when 1.0 and 2% calcium chloride was added with 1% borax and finally reached the maximum of 3.02 kg cm^{-2} with $CaCl_2$ 3 + 0.5 or 1.0% borax (Table 1). The interaction of cultivars and calcium chloride + borax treatments was also significant. The skin strength was the highest in cultivar Bedana in the control, which increased 3.58 kg cm^{-2} with $CaCl_2$ 2 + borax 0.5% but thereafter remained non significant. By contrast, the skin strength in the other cultivars continued to increase with increasing calcium chloride or borax concentrations (Figure 2). The control vs. Rest paired means also showed significantly higher skin strength (2.43 vs. 2.78 kg cm^{-2}). Similarly, increased skin strength was observed in control vs. $CaCl_2$ + borax (2.43 vs. 2.89 kg cm^{-2}) and $CaCl_2$ vs. $CaCl_2$ + borax (2.46 vs. 2.89 kg cm^{-2}), while control vs. $CaCl_2$ means were not significant (Table 1). The tensile characteristic of fruit skin is important in cracking resistance (Hershko et al., 1994). The skin strength in litchi fruit is an important and desirable characteristic (Christensen, 1994) because an imbalance in cell turgidity (Peter, 2005) and extensibility (Pilling and Hofte, 2003) could lead to fruit cracking (Christensen, 1994). The greater strength in cultivar Bedana may be due its high calcium content (Leyla and Husnu, 2004).

Ion leakage (%)

The highest mean ion leakage percentage from fruit skin discs was in cultivars Gola (31.11%), followed by 28.24 and 21.60% in cultivars Surahi and China respectively,

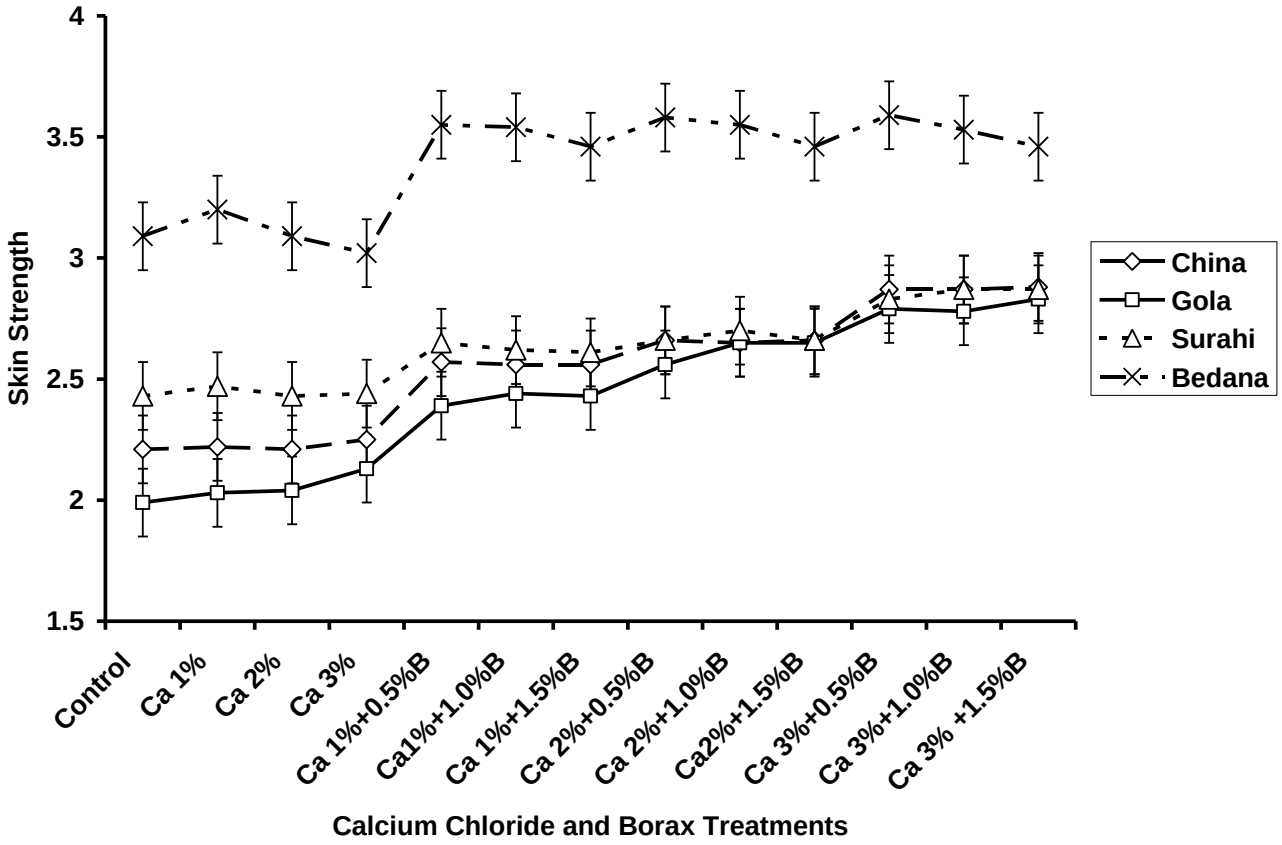

Figure 2. Effect of calcium chloride and Borax applications on skin strength (Kg/cm2) in litchi cultivars. The error bars represent the least significant difference at = 0.05.

while the lowest ion leakage (18.86%) was observed in cultivar Bedana (Table 1). The mean ion leakage from skin discs of fruit decreased significantly with $CaCl_2$ + borax treatments. The highest ion leakage from skin discs of litchi fruit in the control (35.17%) decreased significantly to 32.43, 30.71 and 27.64% with 1, 2 and 3% $CaCl_2$ applications respectively but the addition of Borax with $CaCl_2$ resulted in further decrease in ion leakage from skin discs. At 1% $CaCl_2$ concentration, the ion leakage decreased significantly to 29.08, 25.06 and 22.76% with 05, 1.0 and 1.5% borax application. The ion leakage increased to (24.40%) with 2% $CaCl_2$ concentration + 0.5% borax application but then declined with 1.0 and 1.5% Borax to 21.24 and 19.17% accordingly. Similarly, the ion leakage increased again to 21.82 at $CaCl_2$ 3 + borax 0.5% but declined to 18.76 and 16.17 with $CaCl_2$ 3 + borax 1% and $CaCl_2$ 3 + Borax 1.5% respectively (Table 1). The cultivar × treatment interaction revealed the maximum ion leakage (35.17%) in cultivar Gola which declined to the minimum of 16.17 with $CaCl_2$ 3 + Borax 1.5% treatment. However, cultivar Bedana had the lowest ion leakage at any treatment as compared to other cultivars. The ion leakage in Bedana in the control (18.86%) decreased to the minimum of 13.72% with $CaCl_2$ 3 + borax 1.5% treatment (Figure 3).

The planned paired means comparison revealed significant decrease in ion leakage in control vs. Rest (35.17 to 24.10), control vs. $CaCl_2$ (35.17 to 33.24). Borax application decreased the ion leakage more than control or $CaCl_2$ treatments means as evident from control vs. $CaCl_2$ + borax (33.24 vs. 22.05%) and $CaCl_2$ vs. $CaCl_2$ + borax (30.06 vs. 22.05) (Table 1). The electrolyte leakage is an indicator of integrity of cell membrane and cell wall (Saltveit. 2005) and has been shown to correlate with pericarp browning in litchi fruit (Song et al., 2006). Since the $CaCl_2$ and borax treated fruit had high calcium contents, the decreased electrolyte leakage with calcium application may be due to increased cell wall integrity and stability (Patile et al., 2008).

Fruit cracking (%)

Different litchi cultivars varied significantly in tendency of fruit cracking, with the highest fruit cracking percentage observed in cultivars Gola (21.91%), followed by 19.13 and 15.12% in cultivars Surahi and China respectively, while the lowest fruit cracking (13.26) was recorded in cultivar Bedana (Table 1).

The $CaCl_2$ and borax treatments also significantly

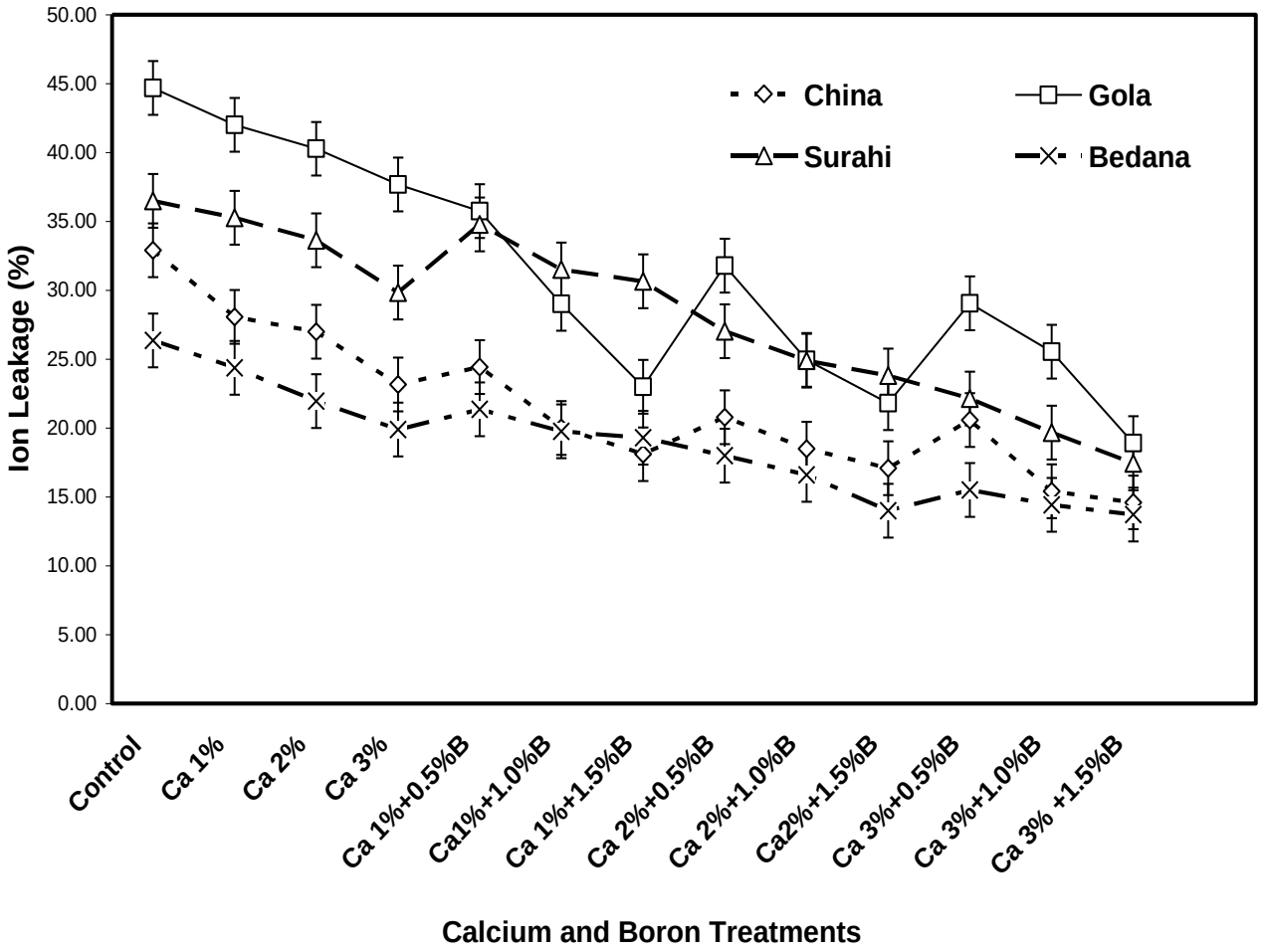

Figure 3. Influence of $CaCl_2$ and Borax application on ion leakage (%) of litchi fruit.

decreased the fruit cracking. The highest fruit cracking in control (25.40%) declined to 19.15% with 3% $CaCl_2$ application and declined further to the minimum 11.34% with $CaCl_2$ + 1.5% borax treatment. The cultivar × treatment interaction revealed the maximum fruit cracking (43.23%) in cultivar Gola which declined to the minimum of 17.87 with $CaCl_2$ 3 + borax 1.5% treatment (Figure 4). The incidence of fruit cracking was significantly decreased by calcium and boron treatments as well as the interaction of cultivars x treatment (Table 1). The planned paired means comparison of the data showed significant decrease in fruit cracking in control vs. Rest (25.40 vs. 16.68%), control vs. $CaCl_2$ (25.40 vs. 20.99), control vs. $CaCl_2$ + borax (25.40 vs. 15.25) and $CaCl_2$ vs. $CaCl_2$ + borax (20.99 vs. 15.25%) (Table 1). It is interesting to observe that the influence of $CaCl_2$ alone had much less impact on decreasing fruit cracking than in combination with borax. The relative less influence of $CaCl_2$ may be due to poor absorption of calcium by litchi fruit and its incorporation in the skin cell wall (Huang et al., 2005). The application of Borax at 0.8% has been show to decrease fruit cracking (Kumar et al., 2001).

The fruit cracking in litchi fruit is a serious postharvest problem (Li et al., 2001) that leads to poor visual quality due to browning in exposed aril (Huang et al., 1985). The fruit cracking also enhances desiccation (Underhill and Simons, 1993). It is reported that differences in the thickness of cuticle and spongy layers in different cultivars could contribute to susceptibility of a cultivar to cracking (Huang et al., 2004). Since the litchi cultivars also show significant variation in calcium accumulation in cell walls of the fruits and skin, it is likely to observe variation in cracking susceptibility (Leyla and Husnu, 2004). Since calcium is required for the stability and extensibility of the cell wall, it has been wide studied and considerable evidence suggest that calcium is involved in cracking resistance in litchi (Huang et al., 2005). For example, the pericarp of cracked fruit has significantly lower concentrations of calcium than those of the unaffected fruit within the same cultivars (Lin, 2001), the lower cracking incidence in plant having higher calcium content or trees in calcium rich soil (Li et al., 2001), litchi fruit with high calcium content have greater resistance to fruit cracking (Huang et al., 2004; Leyla and Husnu, 2004). Similarly,

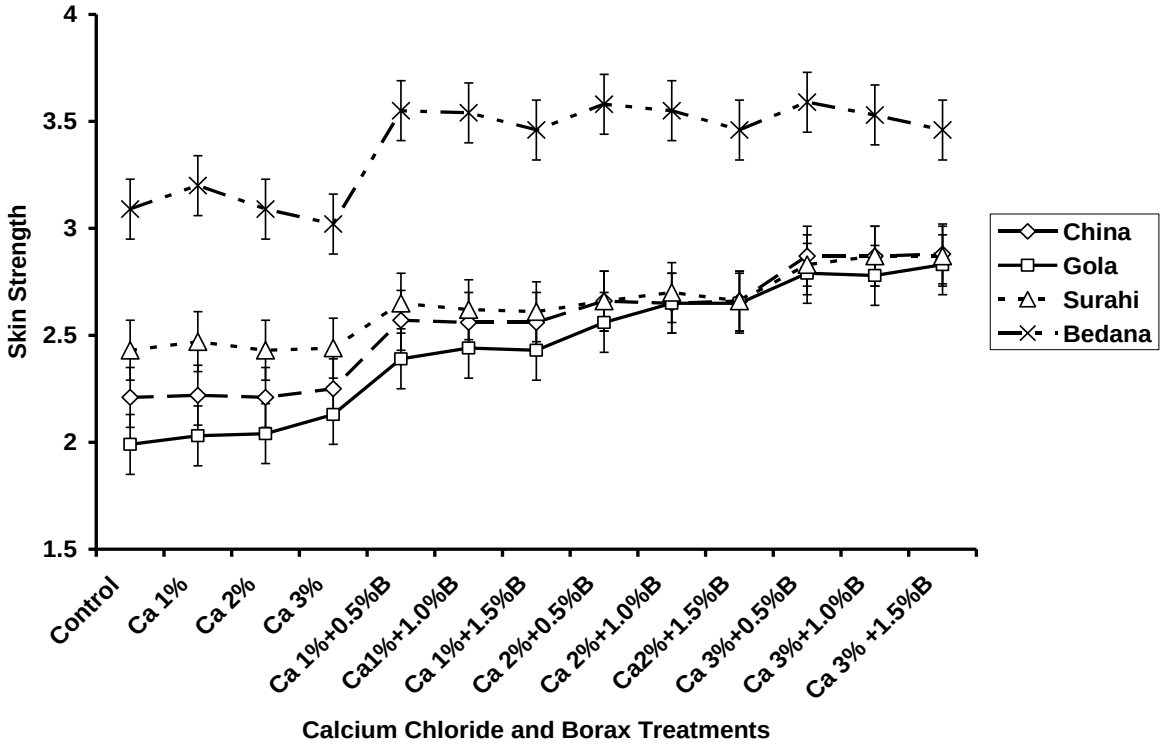

Figure 4. Influence of $CaCl_2$ and Borax application on fruit cracking incidence in litchi cultivars.

treatment with 0.5 and 1% calcium nitrate and 0.4 and 0.8% borax have been shown to decrease fruit cracking (Kumar et al., 2001). Thus, it can be attributed to a synergism as application of borax may help in calcium metabolism in cell wall (Wojvik et al., 1999).

Conclusions

The litchi cultivars varied significantly in the skin calcium and born contents, skin strength, ion leakage and fruit cracking. Cultivar Bedana had the highest skin strength, least ion leakage and least fruit cracking, despite relatively lower calcium and boron content in fruit skin. The foliar application of $CaCl_2$ and borax increased the calcium and boron content of the litchi fruit skin with a concomitant increase in skin strength and decrease in ion leakage and fruit cracking percentage.

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