ITALUS HORTUS
Vol. 30 (2023), Pages 25-36
doi: 10.26353/j.itahort/2023.3.2536
Original Research Paper

Foliar applications of calcium and potassium increase cracking resistance and enhance fruit quality in sweet cherries

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Received:26 October 2023; Accepted: 21 December 2023; Published: 31 December 2023

Abstract: Sweet cherry production represents a competitive sector with important economic prospects but faces many challenges. Rain-induced cracking stands out as a particular issue, as it has been linked to yield losses of up to 90%. To address this concern and meet consumer demand, foliar treatments, involving a mixture of commercial products rich in calcium and potassium salts, have been tested in sweet cherry commercial orchards. This study was a randomized block experiment consisting of three blocks (ten plants each), five of which were treated and five were controls. The treatments were applied in addition to the standard cultivation practice throughout the season. Observations were made on the SPAD index and shoot elongation, and in post-harvest, cherries were analyzed for qualitative characteristics (skin color, caliber, firmness, total soluble content, titratable acidity and cracking index) and nutraceutical parameters (total anthocyanin content, total phenols content and antioxidant activity). Results indicate that foliar salt application can facilitate the maturation process, indicated by a higher soluble solid content (TSS), softening, and darker pigmentation in treated fruits. The applied formulations also provided increased shoot growth and enhanced SPAD index. Furthermore, the treated fruits exhibited a significantly lower incidence of cracking compared to the control treatment and showed improved nutraceutical properties.

Keywords: induced-cracking; calcium treatments; potassium treatments; fruit quality; bioactive compounds

1. Introduction

Sweet cherry production constitutes a competitive sector characterized by significant commercial potential (Salvadores et al., 2023). This potential is mainly due to the increasing consumer demand observed in numerous nations, especially in Italy, which is a leading producer in Europe (Palasciano et al., 2023).

Consumers have recently become increasingly aware of the nutritional value of food. Cherries, in particular, have garnered promising attention due to their abundance of bioactive compounds, primarily polyphenols, including anthocyanins, which are highly regarded for their nutritional benefits (Cruz-Carrión et al., 2020). Numerous research demonstrate that their inclusion in the daily diet can counteract oxidative stress or mitigate anti-inflammatory-related disorders (Faienza et al., 2020; Gonçalves et al., 2019).

Despite the considerable successes achieved in the sweet cherry industry, cultivation faces many challenges, including physiological disorders, and biotic and abiotic stresses. Of particular concern is the rain-cracking, the mechanisms and pathways of which are poorly understood. Based on the recently proposed “zipper hypothesis”, fruit cracking arises from highly localized events, specifically originating from a localized skin anomaly. In this context, a singular defect instigates a zipper-like progression of a

microcrack, leading to the development of a visible macroscopic crack, analogous to the way a "ladder" manifests in intricately woven textile structures (Knoche et al., 2022).

The incidence of cracking has become a major challenge for growers, as it is associated with significant yield losses, potentially up to 90% (Ranjan et al., 2020). Although improved breeding has resulted in new varieties with greater resistance to fruit cracking, the effects of climatic change, characterized by alternating periods of drought and heavy rainfall, cause production losses even in the new varieties (Fischer et al., 2021). Furthermore, the adoption of anti-rain nets in orchards may occasionally prove inadequate in mitigating the occurrence of fruit rain-cracking. In this latter case, cherries are protected from mechanical cracks caused by rainfall. Nevertheless, they remain susceptible to hygroscopic cracking owing to fruit surface wetness (Winkler et al., 2020).

This physiological disorder leads to both production and economic implications and results from excessive moisture absorption by the fruit surface, mostly during ripening, culminating in localized cracks in the skin (Correia et al., 2018). Conversely, other studies claim that fruit cracking arises from skin contraction following rapid cooling induced by precipitation or abrupt temperature changes (Koumanov, 2015). Others (Winkler et al., 2020) claim that skin crack is a consequence of fruit Ca^{+} deficit.

In order to meet consumer demand and to contrast the challenges of field management, recent studies have focused on treatments aiming to improve the nutritional and mechanical properties of fruits. Many studies (Breia et al., 2020; Dong et al., 2019; Michailidis et al., 2017; Winkler and Knoche, 2021) claimed that calcium application can reduce cherry cracking occurrence, but there is a lack of knowledge on how these improvements also affect the quality and the shelf life.

Considering this, foliar treatments with calcium and potassium salts were carried out on sweet cherry trees. The goal was to investigate the effects of calcium and potassium-based foliar applications on fruit cracking and the quality of sweet cherries.

2. Materials and Methods

2.1. Experimental Design

Trials were performed during the 2023 season in a commercial plot of sweet cherry cv. 'Regina' located in Lagnasco (Piedmont, Italy). The sweet cherry trees, used in this study, were grafted on 'Gisela 5' rootstock under anti-rain and anti-hail cover nets. The experiment was arranged in three blocks consisting of 10 trees (10 × 3 blocks = 30 trees) , five of which were used for the foliar application treatment (SPRAY) and the remaining five were used as a control group where foliar treatments were not applied (CTRL). Foliar applications were added to the standard farm agronomic practices.

Foliar applications were carried out with the following three commercial products: Stimulante Plus® (12% w/w Calcium oxide), Set® (12% w/w Calcium oxide + 1% w/w Boron), and Abundantia® (16% w/w Potassium oxide + 4% w/w Nitrogen). These products were applied in four applications and at different concentrations, from bud break to fruit set phenological stages as reported in Table 1. Sweet cherries were hand-harvested at the commercial ripening stage on 20 June, based on the skin color characteristics typical of the 'Regina' cultivar.

Table 1. Foliar applications calendar for the 2023 season.

Phenology	Bud breaks	Flower buttons	Petals falls	Fruit set
Date	23 March	31 March	9 April	16 April
Commercial products	Stimulante Plus® (1 L/ha) + Set® (3 L/ha)	Stimulante Plus® (1 L/ha) + Set® (3 L/ha)	Stimulante Plus® (1 L/ha) + Set® (3 L/ha)	Stimulante Plus® (1 L/ha) + Abundantia® (7 L/ha)

2.2. Plant biometrical measurements and tree yield

2.2.1. Shoot growth

The shoot elongation was monitored weekly from the last foliar application (16 April) until harvest (20 June). The measurements were carried out on two pre-marked shoots per plant (30 shoots per treatment). Results were expressed in cm shoot^{-1} compared to the first day of observation using the following equation:

$$\text{Growth} = \text{Lenght}_{day\_x} - \text{Lenght}_{day\_1} \qquad \text{(eq. 1)}$$

Where *day_x* is the length measured of the monitoring day (12 May, 26 May, 01 June, 08 June, and 16 June) and *day_1* is the first day of measurement (12 May).

2.2.2. SPAD index

The leaf chlorophyll concentration was weekly measured on 20, randomly selected, leaves per plant (300 leaves per treatment), using the Chlorophyll Meter SPAD-502 (Konica Minolta Sensing Inc., Osaka, Japan). The measure of each leaf was deduced from a single measurements and results were expressed as the monthly average of the SPAD index.

2.2.3. Plant yield

Plant production was weighted at harvest for each plant (15 per treatments), results were expressed in kg per tree.

2.3. Quality analysis of cherries

Sample batches for each block were mixed and transported to the laboratory. The quality of the sweet cherries was evaluated at the DISAFA laboratory, University of Turin (Grugliasco, TO) after transport from the field to the laboratory. Approximately 2 kg of fruits homogenous in color and without visual defects were then randomly selected from every block and used for the following analyses.

2.3.1. Skin color

The color of the surface was determined on 60 fruits per treatment with a colorimeter CR400 (Minolta, Singapore, Japan) in similar lighting conditions. The results were expressed as CIE (L*, a*, b*) color space with (C) standard illuminant and an observation angle of 2°. L* (Lightness) represents the brightness of the color. L* = 0 indicates black, and L* = 100 indicates white. Values between 0 and 100 represent various shades of gray, ranging from black to white. The a* component represents the color's position on the green-red axis. Positive values indicate a reddish color, while negative values indicate a greenish color. The b* component indicates the color's position on the blue-yellow axis. Positive values signify a yellowish color, while negative values indicate a bluish color.

The values of C^* and h° (Chroma/saturation and Hue angle) were calculated from the parameters a* and b* using the equations $C^* = (a^{*2}+b^{*2})^{1/2}$ and $h^\circ = \tan^{-1}(b^*/_{a^*})$ (Clydesdale and Ahmed, 1978). C^* expresses a measure of color intensity and h° is an angular measure that identifies the hue of a color.

2.3.2. Fruit caliber

The measurement was carried out using a cherry caliber with a diameter of 24 mm to 30 mm, with a two-millimeter pitch. The measurement was carried out on 900 fruits per treatment.

2.3.3. Fruit Firmness

The fruit firmness was evaluated by performing a digital durometer test using a digital durometer TP-53215 (TP-Turoni, Forlì, Italy), with firmness measurements expressed on the Shore scale (10–90). The analyses were performed at room temperature in the equatorial zone on 90 fruits per treatment (30 per each block).

2.3.4. Total soluble solids (TSS)

The total soluble solid content (TSS) of clear cherry juice was determined using a digital refractometer (ATAGO-PR-32, Italy). The juice was obtained from 10 fruits with a juice extractor and then centrifuged at 2,500 rpm for 10 minutes using an AVANTIM J-25 centrifuge (Beckamn Instruments Inc.) to obtain clear juice. The analysis was performed on the ninefold supernatant per treatment (3 replicates per block), and the results were expressed in °Brix.

2.3.5. Cracking incidence (CI)

The cracking susceptibility was determined according to the Cracking Index (CI) protocol (Christensen, 1972). A sample of 50 cherries per treatment, without defects, were immersed in 2 L of deionized water for 6 h. After 2, 4, and 6 h fruits were observed for macroscopic cracks and counted and weighed. The test was performed for every block and CI was determined using the following formula:

$$CI = \frac{(5a+3b+c)\times 100}{250} \qquad \text{(eq. 2)}$$

where *a*, *b*, and *c* represent the number of cracked fruits respectively after 2, 4, and 6 h of dipping.

2.3.6. Nutraceutical composition

For the tests, nine fruit extracts per treatment were prepared for each treatment (three per block). Extraction (Šavikin et al., 2009) was performed by adding 10 mL of extraction solvent (500 mL MeOH, 1.4 mL HCl, and 24 mL H_2O) to 4 g of fruit and homogenizing the result for 1 min with an Ultra-Turrax T18 basic (Janke and Kunkel, IKA®-Labortechnik, G). The samples were then placed in an ultrasonic bath (VWR Ultrasonic cleaner, Germany) containing water at 50 °C for 20 minutes. The solutions were centrifuged at 2.5 g for 10 minutes using an AVANTIM J-25 centrifuge (Beckamn Instruments Inc.). The clear juice (supernatant) was collected and stored at -26 °C until analysis.

The total anthocyanin content (TAC) analysis followed the pH differential protocol (Robles-Flores et al., 2018). The extract (50 µL) was diluted separately with 5 mL each of pH 1 (potassium chloride 0.025 mol/L) and pH 4.5 (sodium acetate 0.4 mol/L) buffer solution. The absorbance values of the solution were determined spectrophotometrically at both λ 520 nm and λ 700 nm (U-5100, Hitachi, Japan).

The TAC was calculated using the following formula:

$$TAC = A \times MW \times DF \times \frac{10^3}{\varepsilon} \times L \qquad \text{(eq. 3)}$$

Where TAC is the total anthocyanin content in mg pelargonidin-3-glucoside/100 g of fresh cherries, A is the difference in absorbance, MW is the molecular weight of pelargonidin (433.2 g/mol), DF is the dilution coefficient (10), L is the optical path in cm, and ε is the extinction coefficient (48,340 L/mol×cm).

Nine replicates per treatment were performed.

Total phenol compounds (TPC) were determined with the Folin-Ciocalteu reagent (Pantelidis et al., 2007), using gallic acid as a standard. Absorption was measured at 760 nm. The results were expressed as mg gallic acid equivalents (GAE) per 100 g of fresh cherries. Nine replicates of each treatment were performed.

Antioxidant activity (AA) was determined according to the ferric-reducing antioxidant power (FRAP) method (Benzie and Strain, 1996) modified for fruits (Pellegrini et al., 2003). It is based on the reduction of the Fe^{3+}-TPTZ (2,4,6-tripidyl-s-triazine) complex to a Fe^{2+} (ferrous) iron form at a low pH. The reduction of iron in the TPTZ-ferric chloride solution (FRAP reagent) results in the formation of a blue-colored product (ferrous tripyridyltriazine complex), the absorbance of which was read spectrophotometrically at 595 nm 5 min after the addition of cherry extract to the FRAP reagent. The results were expressed as $mmol_{Fe2+}$/kg of fresh cherries. Nine replicates per treatment were performed.

2.4. Statistical analysis

Statistical analysis was conducted using R Studio software version 4.1.2 (Integrated Development for R., R Studio, PBC, Boston, MA, USA). One-way ANOVA was conducted on the entirety of the data except for shoot growth and SPAD index. The factors considered were the treatment: sprayed (SPRAY) and control (CTRL). Conversely, for the shoot growth and SPAD index datasets, a two-way ANOVA was exclusively employed, considering the interaction between treatments (SPRAY/CTRL) and time (month of sampling). In all analysis, the 'block' factor was treated as a random variable, representing variability attributed to the block's position within the field. Significant differences between treatments at a significance level of 0.05 ($p \leq 0.05$) were assessed using the Tukey test.

3. Results and discussion

3.1. Shoot growth and SPAD index

Foliar treatments have elicited a remarkable impact on shoot growth (Figure 1A) and leaf chlorophyll concentrations (Figure 1B), whereas they did not affect fruit yield (data not shown). Notably, there was an increase in shoot elongation in the SPRAY compared to CTRL on each measurement. The statistically highest shoot growth was found in the SPRAY treatment on June 1st, 8th, and 16th. Conversely, the lowest shoot extension growth was observed in the CTRL on May 26th.

Regarding the SPAD index, the statistically highest chlorophyll concentrations were observed in the SPRAY treatment during the month of June. On the contrary, the statistically maximum concentrations were evident in the SPRAY in April and in the CTRL during May and June. Furthermore, while the SPAD index remained relatively constant in the control plants throughout April, May, and June, it showed an increase in the sprayed treatment. These findings indicate increased shoot growth and a higher SPAD index during the final assessments in the month of June. This result may be associated with the last foliar application administered on April 16th, wherein Abudantia® composition included a N component (4% w/w).

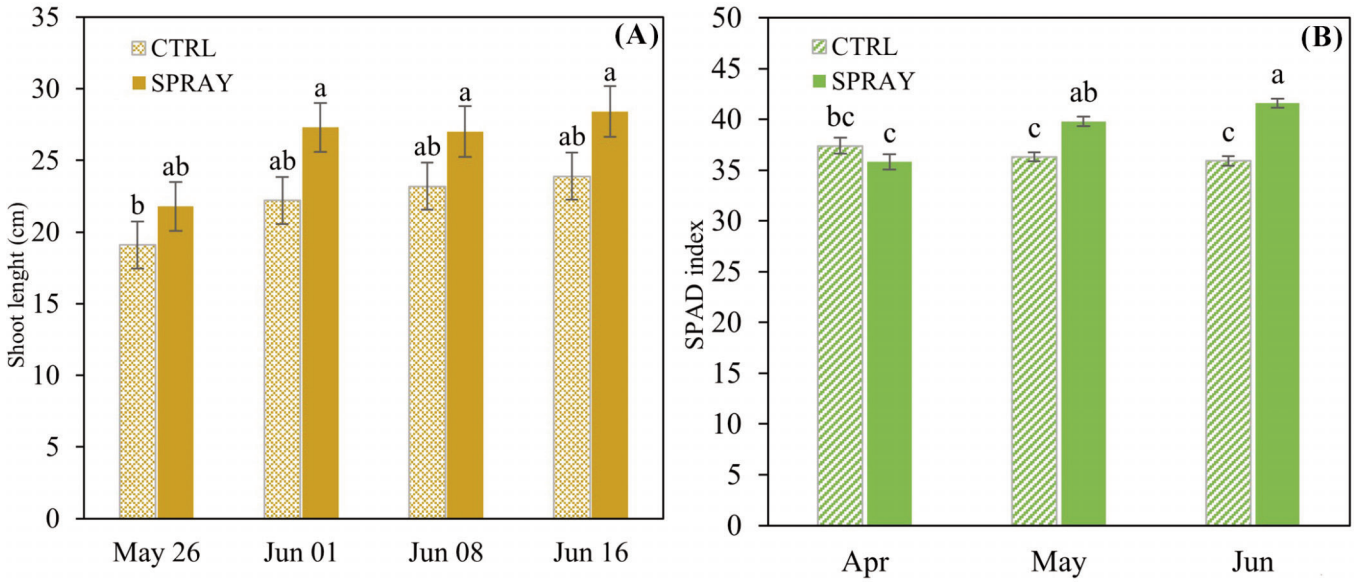

Figure 1. Effect of foliar applications of calcium and potassium on (A) shoot growth (means of 30 shoots per treatment ± SD) and (B) monthly averages of SPAD index (means of 300 leaves per treatment ± SD) measured on different dates in 'Regina' sweet cherries. Same letters indicate no statistical differences between treatments at $p<0.01$ (shoot growth) and $p<0.001$ (SPAD index) according to the Tukey test.

Numerous studies (Ahmad et al., 2018; El-Bassiony et al., 2010; Santos et al., 2021) reported the successful influence of potassium (K) applications after petals fall in enhancing leaf chlorophyll levels and promoting plant growth. Our findings are in good agreement with those of Zulfiqar et al. (2022), who asserted the strong correlation between chlorophyll levels, measured by the SPAD value, and plant performance. These chlorophyll quantities serve as important potential indicators of the rate of photosynthesis, which in turn is closely linked to the assimilation of carbon and the production of biomass.

3.2. Physical and biochemical fruit charateristics

Color and TSS are the most important quality traits that consumers appreciate in cherries (Emre, 2020). Foliar Ca and K salts application notably affected fruit characteristics (Table 2). Fruits of the SPRAY treatment had significantly reduced firmness, Croma and hue angle in comparison to the CTRL. As a result of these findings, the application of Ca and K salts has likely the potential to enhance the softening and the darkening of the fruit. Conversely, lower hue angle in SPRAY fruit indicate less red skin tones compared to CTRL. The decline in Chroma coordinates, as well as flesh firmness, in this context, was linked to a rise in TSS content. Although salt sprays appear to have no effect on fruit acidity (data not reported), treated plants consistently produce cherries with statistically higher sugar content.

Table 2. Effect of calcium and potassium application (SPRAY) on fruit quality parameters of 'Regina' sweet cherries: firmness, total soluble solids (TSS), color (L*, C*, and h°). CTRL represents the control treatment. Results are the means (90 replicated for the firmness, nine replicates for TSS and 60 replicates for the skin color) ± SD. Different letters indicate statistical difference among the treatments at $p < 0.05$ according to the Tukey test.

Treatment	Firmness (Shore)	TSS (°Brix)	Fruit color		
			L* (C)	C* (C)	h°
SPRAY	52.0 ± 0.63 b	14.5 ± 0.03 a	40.8 ± 0.34	11.8 ± 0.53 b	16.7 ± 0.45 b
CTRL	55.4 ± 0.59 a	13.9 ± 0.04 b	40.4 ± 0.26	18.8 ± 0.64 a	21.1 ± 0.67 a

Considering the bioactive compounds (Table 3), Ca and K salts spraying significantly ($p<0.01$) affected the nutraceutical properties. Although the foliar application did not influence the TPC accumulation, the TAC in the SPRAY cherries had significantly higher value than the CTRL, as well as the AA. The TAC showed an incongruence with hue angle parameters; in fact, an increase in the TAC corresponded to a decrease in the skin tones. These inconsistencies may stem from variations in pigment compositions influenced by the applied treatments. Furthermore, our findings align with those reported by Gonçalves et al. (2007) who showed that the lowest Chroma and hue angle values are associated with samples characterized by the highest anthocyanin content.

Table 3. Effect of calcium and potassium application (SPRAY) on cherry bioactive compounds (total phenol content: TPC, total anthocyanin content: TAC; and antioxidant activity: AA) of 'Regina' sweet cherries. CTRL represents the control treatment. Results are the mean ± SD of nine replicates. Different letters indicate statistical differences among the treatments at $p<0.05$ by Tukey test.

Treatment	TPC ($mg_{(GAE)}$/100g f.p.)	TAC ($mg_{(CYAN)}$/100g f.p.)	AA ($mmol_{Fe}^{3+}$/100g f.p.)
SPRAY	96.70 ±5.79	47.55 ±2.08 a	36.40 ±3.23 a
CTRL	90.20 ±4.33	30.49 ±3.22 b	25.20 ±2.59 b

Fruit quality analyses are in agreement with those of Matteo et al. (2022) that reported how the application Ca oxide 26 days after bloom enhanced TSS content in cherries at harvest. Moreover, other studies found that various sugars (e.g., fructose and glucose), accumulated in response to boron application before fruit setting (Michailidis et al., 2023). On the other hand, Nagy et al. (2010) claimed that, among

the all applied treatments (Ca oxide, K oxide and boron), only boron (applied at full bloom and at petal fall) had a significant positive effect on cherry sugar content. Furthermore, the authors did not observe any increase in sugar content with K application as with boron. This discrepancy may be attributed to the timing of K application, which did not occur during the cherry maturation phase but prior to it. Thus, the observed sugar increase may be likely attributable to boron application rather than potassium, contrary to the well-known effect of K during fruit ripening (Marschner, 2011). Hence, considering our findings, the TSS concentrations could be a result of the simultaneous application of calcium oxide and boron. The potential of calcium and boron to enhance fruit sugar content has been previously documented in pomegranate (Korkmaz and Aşkın, 2015), though these differences were not statistically significant.

Moreover, it was reported that the amount of anthocyanin are strongly negatively correlated with the fruit darkness, which is associated to an increase in opacity and TSS (B. Gonçalves et al., 2007). Therefore, based on our result, foliar salt treatments significantly stimulated fruit ripeness compared to the CTRL. This result is further supported by the observed softening of the treated cherry flesh. Softening is indeed a typical process occurring in fruit ripening, due to the enzymatic activity of cell wall-degrading enzymes, i.e. polygalacturonase and pectin methyl esterase (Giné-Bordonaba et al., 2017). Moreover, the use of K together with Ca compound has the capability to improve the skin pigmentation as well as the achievement of commercial maturity (Ateş et al., 2022).

Fruit softening appears to contradict the expected role of Ca application, which typically hardens the cell wall and limits its degradation (Bustamante et al., 2021; Michailidis and Tanou, 2022). The calcium content in cellular walls increases until the fruit reaches complete maturation. An augmentation in its content during the growth phase enhances the firmness of the fruit. In this study, calcium applications were conducted both before and after the flowering stage, as recommended by the product's manufacturer, as indicated on the label. Based on our current understanding, the quantities administered may suffice to achieve an enhancement in fruit texture. However, an additional treatment (beyond those already administered) post-flowering might have yielded promising results in achieving this objective.

Furthermore, considering that the experiment was conducted in an orchard shielded by rain nets, these might have contributed to the increased fruit softening. Previous studies (Bastías et al., 2014) have indeed shown that covering nets may result in higher temperatures compared to uncovered orchards. This increased temperature, resulting in an accelerated accumulation of warmer days, could also elucidate the reduced firmness observed in cherries and thus may have attenuated the effect of calcium. Moreover, the diminished firmness of sweet cherry fruits when using plastic covers has been already documented in previous studies (Blanco et al., 2019; Bustamante et al., 2021). This observations have been attributed to the decreased levels of calcium observed in fruits cultivated under such plastic covers. This condition might have occurred in the case of our study as well.

Considering the latter treatment of the trial, made with Abundantia®, containing a combination of potassium oxide and nitrogen, it is plausible that the cherries softening could be related to the N application. Nitrogen has been recognized for its potential to reduce fruit firmness, as studies have shown that higher nitrogen doses correlate with decreased cherry firmness and increased fruit respiration (Swarts et al., 2017). Nitrogen is the most crucial element for cherry development; however, it must be administered wisely to prevent fruit predisposition to splitting, especially following rain events. For effective production fertilization, it is imperative to ensure optimal foliar fertilization immediately after fruit set, as it has been done in present work. Thus, taking into account the potential of nitrogen fertilization to enhance fruit growth, our findings indicate that cherry fruits might have suffered a rapid cell expansion, potentially compromising the structural integrity of the cell wall.

The analysis of fruit caliber revealed that the majority of SPRAY fruits belonged to the 28 mm caliber category, while the majority of CTRL fruits were in the 30 mm category (Table 4). The results indicate that nitrogen fertilization did not lead to an increased fruit size at harvest, despite the fruits exhibiting reduced firmness. Furthermore, these data are consistent with the fruit load, which did not differ statistically among the treatments (data not reported). However, these findings are of particular interest, as

the existing literature (Penzel et al., 2021) claims that cherries achieving higher levels of commercial success and consumer preference tend to have a caliber of 28 mm. Within the supply chain, cherries with a caliber of 28 mm are categorized under the "extra" classification. This observation holds significance for the marketability of the fruits, as suggested by Michailidis and Tanou (2022) who indicated that cherries having a caliber of 28 mm exhibit a favorable TSS/TA ratio. Consequently, these cherries may be more highly valued by consumers.

Table 4. Effect of calcium and potassium application (SPRAY) on cherry distribution into caliber categories (26 - 28 - 30 - >30 mm) evaluated on a sample of 900 fruits per treatment. CTRL represents the control treatment.

Caliber (mm)	Fruit amount	
	SPRAY	CTRL
26	18.9%	26.6%
28	44.3%	29.5%
30	35.3%	42.4%
>30	1.5%	1.5%

3.3. Cracking incidence

In cherry production, rain-induced cracking stands out as the principal factor responsible for yields reduction. In our study, CTRL cherries exhibited a statistically significant increase in the occurrence of cracking (Table 5). This result is consistent with previous findings (Erogul, 2014; Michailidis and Tanou, 2022), which also demonstrated that the application of Ca oxide has a beneficial impact on reducing the occurrence of induced-cracking in sweet cherries.

To explain this phenomenon, two hypothetical mechanisms for the reduction of cracking due to calcium have been proposed. As reported by Winkler and Knoche (2019), the first mechanism suggests that Ca promotes cross-linking among the cellular components of the cell wall, thus modifying the mechanical properties of both the fruit skin and the flesh, making them more rigid. The second proposed mechanism suggests that the decrease in the incidence of cracking is a consequence of the reduction in water uptake. This reduction occurs because the application of Ca and K salts results in a more negative osmotic potential of external water. The more negative osmotic potential on the fruit surface, compared to the internal one, reduces water uptake, finally leading to a decrease in cracking. This inevitably slows down water uptake rate, contributing to the observed reduction in cracking incidence (Wójcik et al., 2013). It is plausible, as delineated by Knoche et al. (2022) and further supported by Christensen (1972), that the water absorption rate in sweet cherry fruit is governed by the potential gradient between solutions present on the fruit skin and within the exocarp cells. Even though this may be the case of also our study, further investigations regarding the content of Ca and K of the fruit tissue, as well as the fruit osmotic potential, are required.

According to our results, the decrease in the occurrence of cracking, after foliar applications, can be attributed to the second hypothesis. The evaluation of the cracking index was conducted according to the CI protocol (Christensen, 1972), which quantifies the susceptibility of cherries to cracking as a consequence of their ability to assimilate water. This trend effectively replicates the incidence of cracking resulting from elevated environmental moisture levels, a common challenge in modern orchards shielded by anti-rain netting, including the orchard used for the present study. In these plots, the cherries are protected from mechanical cracks caused by rainfall. However, they remain susceptible to hygroscopic cracking, a condition wherein they absorb significant amounts of water, ultimately leading to fissuring. Moreover, cherries subjected to salt treatments showed a decrease in fruit texture (Table 2), thereby failing to demonstrate the expected improvement in mechanical properties as assumed in the first hypothesis.

Table 5. Effect of calcium and potassium application (SPRAY) on cracking incidence (CI) of 'Regina' sweet cherries. CTRL represents the control treatment. Results are the mean ± SD of three replicates each composed of 50 fruits. Different letters indicate statistical differences among the treatments at $p<0.05$ according to the Tukey test.

Treatment	CI (%)
SPRAY	2.53 ± 0.83 b
CTRL	5.73 ± 1.08 a

4. Conclusions

In the present study, significant effects of foliar applications of commercial products (rich in Ca and K) were observed on shoot growth and on the SPAD index. In particular, there was a significant increase in shoot growth in sprayed plants compared to control plants. The SPAD index, which reflects chlorophyll levels, also showed higher values in sprayed plants especially in June. Regarding fruit quality, foliar salt application significantly decreased firmness, affected color parameters providing lower saturation and hue angle, and increased TSS content. Furthermore, the analysis of bioactive compounds revealed that the commercial product applications significantly enhanced total anthocyanin content and antioxidant activity in cherries. In terms of fruit size, sprayed cherries were predominantly in the 28 mm caliber category, while the control treatment were in the 30 mm category. Despite that, the 28 mm category seems to be associated with higher commercial success and consumer preference. Finally, regarding the cracking effect, the application of the three commercial products, demonstrated a remarkable reduction in cracking incidence compared to the control treatment. These preliminar findings highlight potential effects associated with the applications of commercial foliar salts in sweet cherry production by improving fruit quality and reducing fruit post-harvest cracking incidence.

Funding: This research received no external funding.

Acknowledgments: We thank OP Rivoira for their technical support assistance and for provision of their orchard facilities.

Conflicts of Interest: The authors declare no conflict of interest.

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