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Proceeding Paper

Effects of Calcium- and Seaweed-Based Biostimulants on Sweet Cherry Profitability and Quality †

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Abstract: Sweet cherry trees are one of the most important crops worldwide, producing fruits with high economic importance due to the nutritional value and bioactive properties of cherries, providing benefits to human health. Due to the currently unstable climatic conditions, cherry cracking has become a significant problem, strongly affecting the quality and yield of cherry orchards. A cracking rate of 20–25% at harvest can render cherry production unprofitable, decreasing the commercial value of the fruit, as only the cracked ones can be sold to processing industries. This study aims to assess the impact of calcium- and seaweed-based biostimulant applications on sweet cherry quality and profitability in cv. Sweetheart. Applying 300 g hL^{-1} of calcium led to a significant 52% reduction in the cracking index and a substantial 136% increase in orchard yield. Similarly, applying 150 mL hL^{-1} of seaweed resulted in a 2% increase in fruit weight and a 3% decrease in the cracking index. Therefore, our findings suggest that calcium- and seaweed-based biostimulants could serve as novel and sustainable alternatives for orchard producers, enhancing cherry profitability and marketability.

Keywords: agricultural biofortification; calcium; cracking; crop nutrition; fruit quality; productivity; seaweed; sweet cherry

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1. Introduction

Sweet cherry (*Prunus avium* L.) is a fleshy fruit highly affected by cracking, a severe physiological disorder that has strong implications on the quality and profitability of cherry orchards, decreasing the marketability of cherries [1]. Cracking is difficult to study, even under controlled conditions, since it occurs due to a combination of genetic and environmental conditions [1–3]. Several compounds have been applied in orchards to increase cherry quality and yield and decrease cracking by crop nutrition [4]. Calcium is an important nutrient for improving fruit quality [5], and it has been reported to play an important role in reducing cracking susceptibility [6,7]. Biostimulants are natural compounds obtained from fungi, bacteria, or marine algae-based seaweed extracts, and they can provide new approaches to reduce cracking [4]. These substances represent a sustainable alternative to the use of conventional chemicals, being correlated with an improved tolerance to abiotic stresses and enhanced plant growth, leading to an increase in the quality and yield of agricultural crops [8,9]. Thus, in this study, we aimed to apply calcium- and seaweed-based biostimulants (*Ascophyllum nodosum*) at the foliar level in sweet cherry trees cv. Sweetheart to increase cherry quality and profitability.

2. Material and Methods

2.1. Experimental Design

This study was carried out during 2021 in an orchard located in Santa Eulália, São Martinho de Mouros, Resende (41°04′55.3″ N 7°53′35.2″ W, altitude 615 m). In order to analyze the cherry quality and profitability by crop nutrition and try to decrease the cherry cracking, the cultivar Sweetheart was selected to perform this trial, where calcium and seaweed based biostimulant (*Ascophyllum nodosum*) were applied at foliar level. The trees were spaced 4 m × 4 m (corresponding to 625 trees/ha), being selected 12 trees to apply each treatment, namely two concentrations of calcium (Kit Plant Ca), 300 g hL^{-1} (Ca_300) and 150 g hL^{-1} (Ca_150), two concentrations of seaweed based biostimulant (Foralg), 150 mL hL^{-1} (Seaweed_150) and 75 mL hL^{-1} (Seaweed_75), a combination of 300 g hL^{-1} of calcium and 150 mL hL^{-1} of seaweed (Ca_300; Seaweed_150) and a control, where water was applied instead seaweed or calcium. From the 12 trees of each treatment, fruits were collected at the commercial ripening stage.

2.2. Biometric Parameters (Fruit Weight and Larger Diameter)

The biometric parameters were analyzed in 30 fruits randomly collected from each treatment using electronic weighing scales (EW2200-2NM, Kern, Germany) to determine the fruit weight (g) and a digital caliper (Mitutoyo, Hampshire, UK) to determine the fruit size (mm), specifically the larger diameter.

2.3. Cracking Index

The induced cracking index (CI) was determined as described by Christensen, 1972 [10]. For this, 3 replicates of 50 fruits without cracking from each treatment were immersed in 2 L of distilled water. After 2, 4, and 6 h, the fruits were observed to check for the presence of macroscopic cracks. In each observation session, the cracked fruits were removed, while the fruits without cracks were kept in the water. At the end of the observation period, considering the number of cracked cherries after 2, 4, and 6 h of immersion in water (corresponding to a, b, and c, respectively), the CI was determined as follows:

$$CI = ((5a + 3b + c) * 100)/250$$

2.4. Orchard Yield

At the commercial ripening stage, the production per tree was determined (kg/tree), including the amount of healthy and unhealthy cherries. Using the production of the 12 trees per treatment, the total production (kg), as well as the percentage of healthy and unhealthy cherries within each treatment was also evaluated. Lastly, based on total production per tree and number of trees per ha, the productivity (t/ha) was estimated as follows:

$$\text{Productivity} = ((\text{total production/tree}) * (\text{number of trees/ha})/1000)$$

2.5. Statistical Analyses

Our statistical analyses, which involved conducting a one-way analysis of variance (ANOVA), followed by Tukey's post hoc multiple range test ($p < 0.05$), were carried out using SPSS V.27 software (SPSS-IBM, Corp., Armonk, NY, USA).

3. Results and Discussion

3.1. Biometric Parameters (Fruit Weight and Larger Diameter)

By evaluating fruit size parameters, we observed a slight increase in fruit weight and larger diameter in cherries treated with 150 mL hL^{-1} of seaweed, while cherries treated with 300 g hL^{-1} of calcium presented lower fruit weight and larger diameter values (data not shown). The analysis of both parameters revealed significant differences among the different treatments ($p < 0.001$). Comparing fruit size with the control cherries (Figure 1), the cherries treated with 150 mL hL^{-1} of seaweed showed an increased fruit size, with increases of 1.90% in fruit weight and 0.64% in fruit larger diameter. In contrast, the other treatments caused a decrease in fruit size. The treatment involving applying 300 g hL^{-1} of calcium to the cherries presented the highest reduction in fruit size, followed by the combination of both nutrients, treatment with 150 g hL^{-1} of calcium, and treatment with 75 mL hL^{-1} of seaweed. Thus, fruit weight showed a decrease of 11.15% in Ca_300, a decrease of 9.49% when both nutrients were combined, a decrease of 6.25% in Ca_150, and a decrease of 1.82% in Seaweed_75. Concerning the fruit larger diameter, we observed a decrease of 4.23% in Ca_300, a decrease of 2.84% in combination of both nutrients, a decrease of 2.10% in Ca_150, and a decrease of 1.22% in Seaweed_75. Similar results were obtained by Correia et al. (2015), whose application of seaweed to cvs. Sweetheart and Skeena resulted in increased fruit dimensions, both in weight and diameter [11]. The application of *Ascophylum nodosum* in cv. Staccato also resulted in bigger fruits and similar weight and diameter values compared to the control cherries [12]. In cvs. Kordia and Regina, the application of a plant extract biostimulant also increased fruit diameter [13].

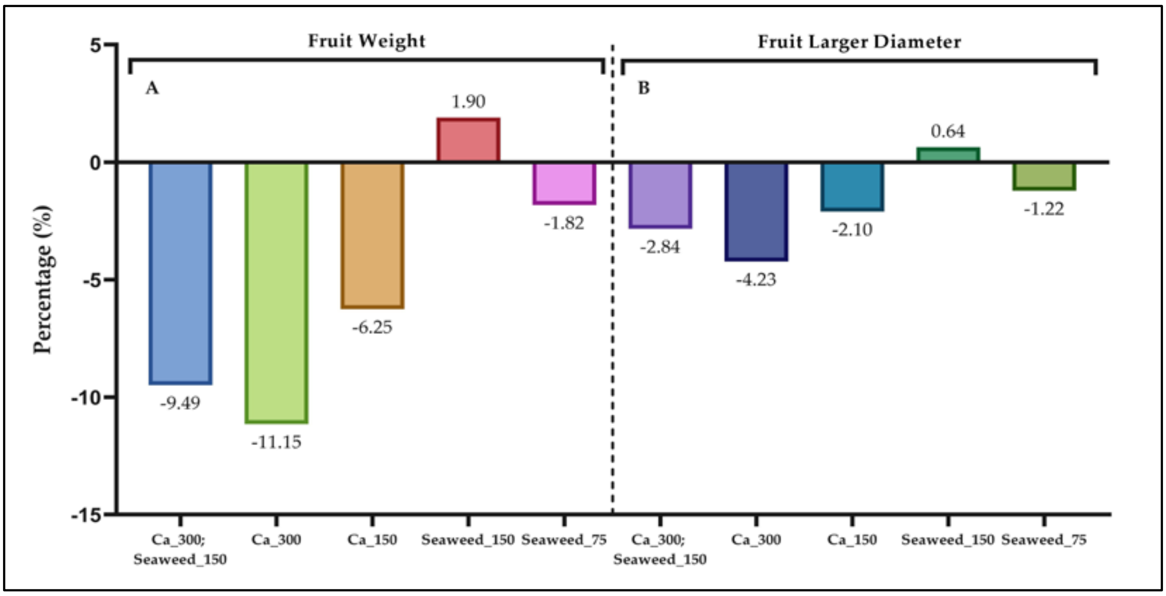

Figure 1. Fruit weight (**A**) and fruit larger diameter (**B**) relative to the control treatment. In each treatment, the value corresponds to the percentage (%) increase or decrease in fruit growth compared to the control treatment.

3.2. Cracking Index

Our analysis of the CI data showed significant differences among the different treatments ($p < 0.001$), as the cherries treated with 300 g hL^{-1} Ca presented the lowest CI, while the combination of both nutrients presented the highest CI (data not shown). Thus, after comparing the CI with the control (Figure 2), we observed an increase of 27.47% when both nutrients were applied and decreases of 3.14%, 14.86%, 44.59%, and 51.79% for Seaweed_150, Seaweed_75, Ca_150, and Ca_300, respectively. A previous work reported a decrease in the CI of around 50% when calcium was applied in cv. Sweetheart [6]. Calcium treatments also reduced the CI in cv. Ferrovia in [7]. Likewise, the application of *Ascophyllum nodosum* also decreased the CI in cvs. Sweetheart and Skeena [11].

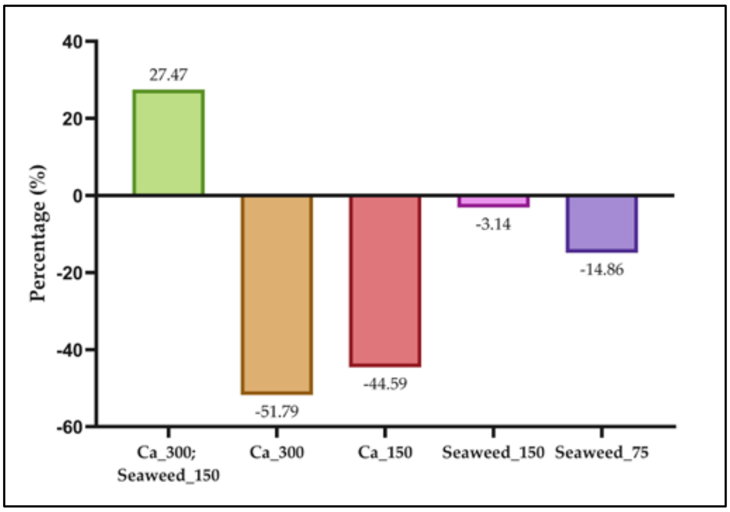

Figure 2. The cracking indices of treated cherries compared with control cherries. In each treatment, the value corresponds to the percentage (%) increase or decrease in the cracking index compared to the control treatment.

3.3. Orchard Yield

3.3.1. Production Per Tree

The total production per tree as well as the amount of healthy and unhealthy cherries per tree (Figure 3) were higher in the cherries treated with 300 g hL^{-1} of calcium (42.98 ± 18.24, 36.47 ± 16.06, and 6.51 ± 2.87 kg/tree, respectively) and lower in the cherries treated with 150 mL hL^{-1} of seaweed (9.17 ± 4.87, 7.47 ± 4.10, and 1.70 ± 0.94 kg/tree, respectively). Our analysis of these parameters revealed significant differences among the treatments ($p < 0.001$).

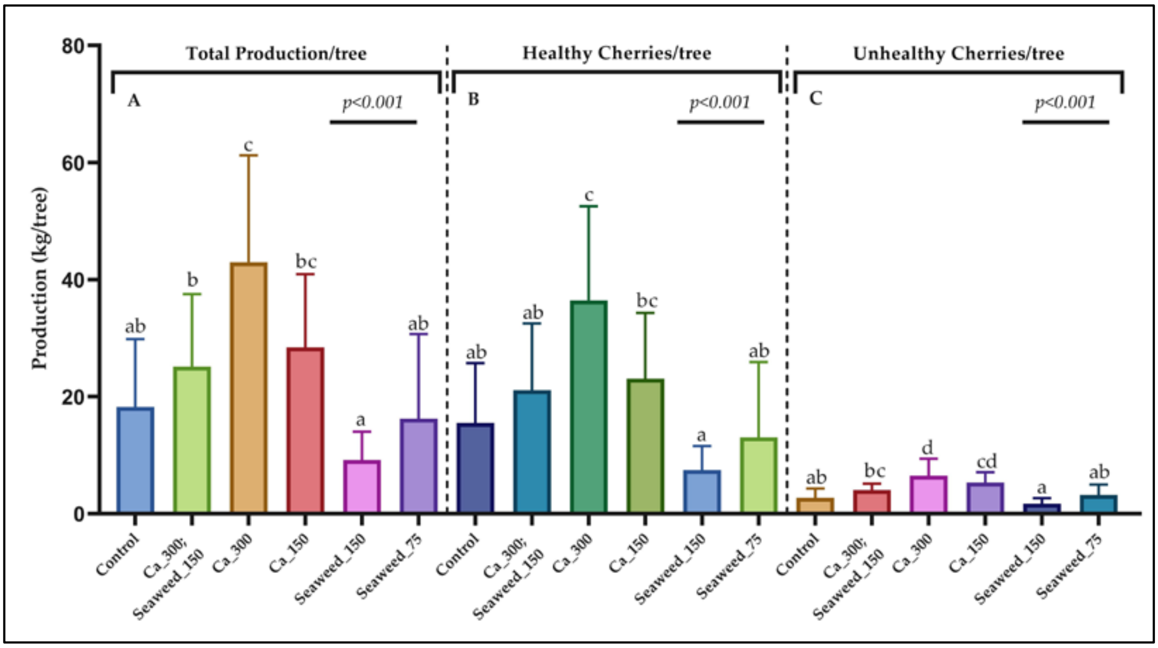

Figure 3. Total cherry production per tree (**A**), amount of healthy cherries per tree (**B**), and amount of unhealthy cherries per tree (**C**) in each treatment. Each column shows the mean ± SE (n = 12). Different letters indicate significant statistical differences ($p < 0.001$), determined according to Tukey's test.

3.3.2. Total Production

Considering the production of the 12 trees of each treatment, the total production was determined, as well as the amount of healthy and unhealthy cherries. The cherries treated with 300 g hL^{-1} of calcium had a higher total production value (515.71 kg), corresponding to 437.64 kg of healthy cherries and 78.06 kg of unhealthy cherries (Figure 4). In contrast, the treatment involving the foliar application of 150 mL hL^{-1} of seaweed resulted in the lowest total production value (110.00 kg), corresponding to 89.64 kg and 20.35 kg of healthy and unhealthy cherries, respectively. Additionally, the amount of healthy cherries in Ca_300 corresponded to 84.86% of the total production, while in Seaweed_150, the amount of healthy cherries corresponded to 81.50% of the total production (Figure 5).

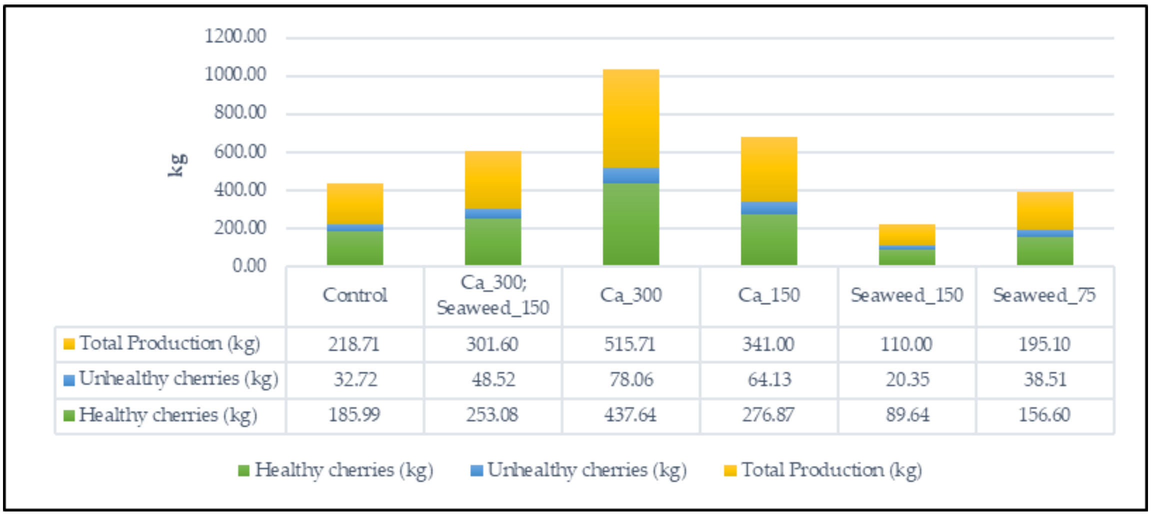

Figure 4. Total production values and the amounts of healthy and unhealthy cherries (kg) obtained from the 12 trees of each treatment.

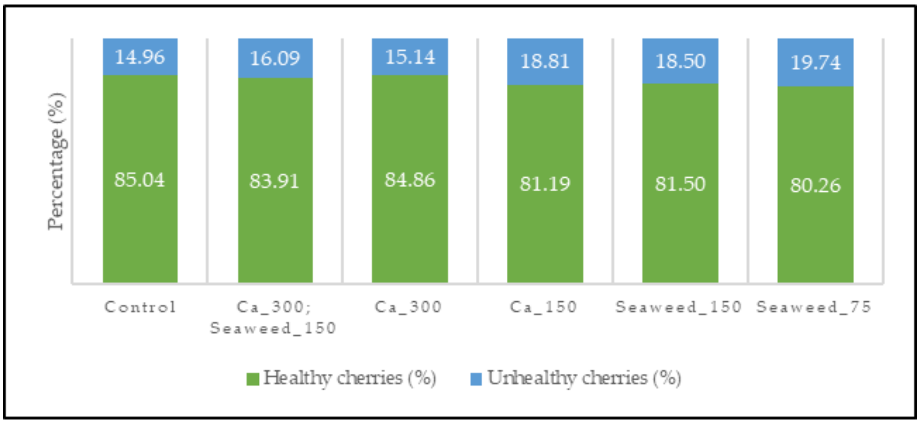

Figure 5. Percentage (%) of healthy and unhealthy cherries obtained from the 12 trees of each treatment.

Comparing the total production in each treatment with the control (Figure 6), the Ca_300 treatment presented the highest increase in total production (135.80%), followed by the Ca_150 treatment (55.91%) and the combination of both nutrients (37.90%). On the other hand, the treatments involving seaweed led to a decrease in total production (49.71% for Seaweed_150 and 10.80% for Seaweed_75).

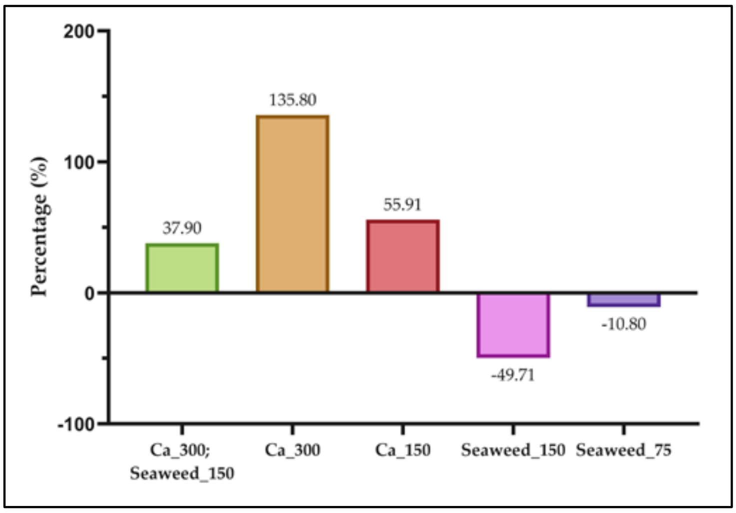

Figure 6. Total production relative to the control treatment. In each treatment, the value corresponds to the percentage (%) increase or decrease in total production compared to the control treatment.

3.3.3. Productivity (t/ha)

Significant differences among the different treatments ($p < 0.001$) were found in productivity (Figure 7). The highest yield values were found for the cherries treated with 300 g hL^{-1} Ca (26.86 ± 11.40 t/ha), followed by the cherries treated with 150 g hL^{-1} Ca (17.76 ± 7.82 t/ha), those treated with both nutrients (15.71 ± 7.72 t/ha), and the control cherries (11.39 ± 7.26 t/ha). The application of seaweed resulted in lower productivity (10.16 ± 9.02 t/ha for seaweed at 75 mL hL^{-1} and 5.73 ± 3.04 t/ha for seaweed at 150 mL hL^{-1}).

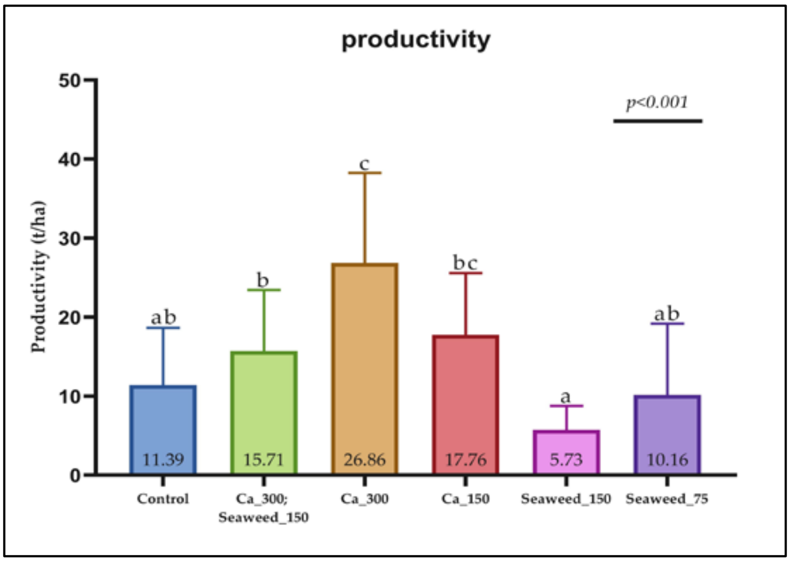

Figure 7. Cherry productivity (t/ha) in each treatment. Each column shows the mean ± SE. Different letters indicate significant statistical differences ($p < 0.001$), determined according to Tukey's test.

The use of biostimulants has been associated with increases in plant growth and yield in several crops [14]. As reported by Correia et al. (2020), the application of *Ascophyllum nodosum* led to an increase in the yield of sweet cherry trees of cv. Skeena [15]. In cvs. Kordia and Regina, the foliar application of a plant extract biostimulant also led to an increase in fruit yield [13]. In our study, the application of a seaweed-based biostimulant resulted in lower fruit yield, contrasting with the results described in the literature. However, in this study, we used another cultivar, Sweetheart, which was less responsive to the treatments involving seaweed. On the other hand, calcium has been reported as an essential nutrient in several plants, especially in fruits [7]. Our results showed an improvement in yield when seaweed and calcium were applied in combination and also when calcium was applied individually, consistent with the results reported by Correia et al. (2020) in their study on cv. Skeena [15].

4. Conclusions

Consumers prefer fruits of a good size and without defects, meaning that fruit size and the cracking index are important quality parameters that have a large influence on the marketability of fruits. In our study, the pre-harvest application of calcium- and seaweed-based biostimulants had a positive effect on cherry quality and yield. Both nutrients played a significant role in decreasing the cracking index, especially in the cherries treated with calcium. On the one hand, the use of *Ascophyllum nodosum* produced fruits that were bigger, but the orchard yield was lower. On the other hand, calcium application generated smaller fruits but highly increased the orchard yield in addition to significantly decreasing the cracking index. Although new studies and strategies are needed, these findings suggest that the nutrients studied herein could represent new and sustainable alternatives that could be used by producers in their orchards to improve cherry profitability and marketability.

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