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Sweet Cherry (*Prunus avium* L.) Cracking during Development on the Tree and at Harvest: The Impact of Methyl Jasmonate on Four Different Growing Seasons

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Abstract: Rainfall occurring during the developmental stages of sweet cherries on the tree can lead to significant preharvest losses, primarily due to fruit cracking. Certain cultivars exhibit a higher susceptibility to such losses, particularly when persistent rains coincide with advanced phenological stages. The current study aims to investigate the efficacy of preharvest methyl jasmonate (MeJA) applications at harvest and during distinct developmental ripening stages in mitigating sweet cherry cracking at harvest and on-tree ripening. Preharvest foliar applications of 0.5 mM MeJA were applied across various sweet cherry cultivars, including 'Prime Giant', 'Early Lory', 'Sweetheart', and 'Staccato'. By conducting this experiment over four growing seasons, we evaluated the impact of this natural elicitor on the cracking tolerance of these cultivars. The results of our analysis indicate that MeJA preharvest treatments effectively reduce fruit cracking, enhancing abiotic stress tolerance. Additionally, these treatments induce a general delay in fruit ripening on the tree across the examined cultivars. This delayed ripening effect is reflected in several quality parameters at harvest, such as the fruit firmness, external colour, total soluble solids, and total acidity. These parameters in the MeJA-treated fruit were delayed compared to the control fruit or remained unaffected for the total acidity. Conversely, the MeJA treatments delayed the accumulation of total polyphenols, exhibiting a minimal impact on reducing pedicel browning. The enhanced tolerance to cracking and delayed ripening attributed to the MeJA preharvest treatments could be helpful for plot management. Consequently, these MeJA-based preharvest treatments hold potential as valuable tools in adapting to climate change and mitigating abiotic stress in sweet cherry.

Keywords: *Prunus avium*; ripening stage; preharvest; cracking; methyl jasmonate; climate change

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1. Introduction

The increasing occurrence of extreme weather conditions associated with climate change can have a significant impact on fruit cracking. In this sense, climate change affects environmental factors, such as excessive rainfall, high humidity, and rapid changes in temperature [1]. All of these factors are involved in fruit cracking of different fruit. Thinner-skinned fruit, such as sweet cherries, tend to be more susceptible to cracking than thicker-skinned fruit, such as other stone fruit [2,3]. There are many factors involved in sweet cherry cracking, such as the fruit size and shape, growing conditions, genetic factors, and sugar content [4–6]. According to these authors, the ripening stage of the fruit is very relevant and can determine the incidence of cracking in sweet cherries [7]. In fact, Giné-Bordonada et al. [8] have observed that the different growth and ripening stages displayed differences in several parameters including the sweet cherry texture and ROS content, which are directly related to the membrane integrity, thus affecting fruit cracking, especially at the latter ripening stages. According to Yamaguchi et al. [9], the more crack-tolerant cultivars have longer periods of cell division, resulting in a larger mesocarp. Although sweet cherry cracking is a multifactorial process, some factors are decisive, such as sudden rains or high humidity, during the development on the tree, which can result in significant losses for producers [4,10].

To prevent sweet cherry cracking, several management strategies have been evaluated, including rain cover protection [11,12] and preharvest sprays based on calcium applications [4,13] and seaweed extracts [14]. Additionally, growth regulators, such as gibberellic acid [15], glycine betaine [16], and methyl jasmonate (MeJA) [17], have been applied at preharvest to reduce sweet cherry cracking. In this sense, MeJA, as an endogenous signalling molecule, plays a vital role in the growth, development, and mechanism systems in plants to effectively respond to challenging environmental conditions [18].

In Spain, there is a specific region in which sweet cherries are grown under the Protected Geographical Indication (PGI) "Cerezas de la Montaña de Alicante". The PGI emphasizes the relationship between the specific geographic region and the name of the product, where a particular quality, reputation, or other characteristic is essentially attributed to its geographical origin. These sweet cherries are produced in mountainous and steep areas and are highly appreciated by consumers for their aroma, flavour, and earlier-harvested cultivars. However, due to this topography, this crop constantly suffers losses from the incidence of rainfall year after year. In a recent study, the authors found that if the harvest time is delayed by one week more than the commercial harvest, the impact of sweet cherry cracking is increased [19]. However, as far as we know, preharvest technologies regarding sweet cherry cracking have focused on evaluating the effect of immersion or applying artificial rain on sweet cherries to evaluate the cracking impact at commercial harvest time. Therefore, this study aimed to evaluate the incidence of MeJA in reducing the cracking incidence during fruit development on the tree as well as under controlled conditions at different ripening stages in four different seasons.

2. Materials and Methods

2.1. Plant Material and Experimental Design

Experiments were performed in different field plots located at Planes and Alcoy (Alicante, Spain) with sweet cherry trees (*Prunus avium* L.) of the cultivars 'Early Lory', 'Prime Giant', 'Sweetheart', and 'Staccato' between 2019 and 2022, which were grafted onto SL-64 rootstock. The sweet cherry trees were all grown under similar agronomic practices for the different growing seasons. The MeJA treatments (Sigma-Aldrich, Madrid, Spain) were performed by applying 3 L per tree (with a manual sprayer machine) of freshly prepared MeJA solutions at 0.5 mM containing 1 mL L^{-1} Tween 20 as a surfactant. Similarly, 3 L of distilled water with 1 mL L^{-1} Tween 20 was applied to the control trees. For each treatment and cultivar, three replicates of three trees were used. Each treatment was applied two times, at pit hardening and at the beginning of colour changes. The selection of the number of preharvest applications was based on the results observed in three different tree groups studied in the 2019 season for the 'Prime Giant' and 'Early Lory' cultivars. These tree groups were treated separately with 1, 2, and 3 applications. However, the third and final application (days before harvest) did not significantly increase, in general, the preharvest and postharvest potential of the MeJA treatments in both cultivars for different parameters.

2.2. Sweet Cherry Cracking Evaluation

A sweet cherry cracking evaluation was performed at harvest for the 'Early Lory' and 'Staccato' cultivars. On the other hand, the impact of the MeJA treatments on sweet cherry cracking during fruit growth and development at different ripening stages on the tree for 'Prime Giant' and 'Sweetheart' was investigated. The different ripening stages selected were chosen as follows: for 'Prime Giant', coincident with the beginning of the colour changes (S1), a pink colour (S2), a bright red colour (S3), and a dark red colour (S4); for 'Sweetheart', the cultivar ripening stages in which sweet cherry cracking was evaluated were coincident with an immature green-yellow colour (S1), the beginning of colour changes (S2), a pink colour (S3), a bright red colour (S4), and dark red colour (S5). The cracking incidence on the tree was evaluated in 4 opposite labelled branches in each tree in which this disorder was evaluated in 100 fruits per tree, and the results were expressed as percentages. On the other hand, at the same time, sweet cherry cracking was evaluated in healthy fruits according to the method described by Christensen [20] in three replicates of 50 fruits for each treatment batch and expressed as the cracking index.

2.3. Fruit Quality Parameters at Harvest

Regarding the fruit quality measurements at harvest, sweet cherries were harvested at the commercial ripening stage, according to commercial practices, based on the characteristic skin colour of each cultivar. Lots for each replicate were mixed and immediately transferred to the laboratory. Then, at room temperature, 3 lots of 20 fruits that were homogenous in size and colour and without visual defects were taken at random from each field replicate and treatment and used for the following analytical measurements at harvest.

CO_2 was determined in triplicate by placing 20 fruits from each replicate in a 0.5 L plastic container that was hermetically sealed with a rubber stopper for 60 min using the static method [21]. After that, a 1 mL gas sample was taken in duplicate from the headspace, and carbon dioxide was quantified using a Shimadzu 14B (Shimadzu Europa GmbH, Duisburg, Germany) and expressed as mg of CO_2 kg^{-1} h^{-1}.

The colour was measured at harvest in each fruit individually with a Minolta colorimeter (CR-400, Konica Minolta Camera Co., Kantō, Tokyo, Japan), and three colour measurements were made for each fruit at two opposite and equidistant points at the equatorial zone and expressed as CIE $h°$ (arctg b*/a*) according to CIELab coordinates.

The firmness was determined individually using a TX-XT2i texture analyser (Stable Microsystems, Godalming, UK) equipped with a flat plate probe. The rate of descent of the disc was 20 mm min^{-1} until a deformation of 5% was reached. The fruit firmness was expressed as the ratio of the applied force to the distance travelled (N mm^{-1}).

After that, the flesh of 20 fruit of each replicate was cut in small pieces to obtain a homogeneous sample, and about 50 g was squeezed through two layers of cotton cloth and the juice was used to measure, in duplicate, the total soluble solids (TSS) and titratable acidity (TA). These two parameters were determined by duplicate in the filtered juice extracted, as previously described [22], in each replicate per batch. The TSS in the sweet cherry juice was measured using an Atago PR-101 digital refractometer (Atago Co., Ltd., Tokyo, Japan) at 20 °C and the TA was determined in each sample by automatic titration (785 DMP Titrino, Metrohm, Herisau, Switzerland). The TSS was expressed as g 100 g^{-1} and the TA was expressed as g of malic acid equivalent 100 g^{-1}.

The total phenolics were extracted by homogenizing 5 g of frozen tissue with 10 mL of water:methanol (2:8) containing 2 mM NaF (to inactivate polyphenol oxidase activity and prevent phenolic degradation) in an Ultraturrax homogeniser (T18 basic, IKA, Berlin, Germany). Then, the extracts were centrifuged at 10,000× g for 10 min at 4 °C, and the total phenolics were quantified in duplicate in the supernatant using the Folin-Ciocalteu reagent as previously described for different plant organs [23]. The results were expressed as mg gallic acid equivalent 100 g^{-1} and are the mean ± SE.

Sweet cherry fruits with visible symptoms of pedicel browning were reported in accordance with the following scale: stems with no visible symptoms (0), stems affected by browning <25% (1), 26–50% (2), 51–75% (3), and >75% of the pedicel area affected by browning (4).

2.4. Statistical Analysis

The experiments were performed using a completely randomized design. All the statistical analyses were performed with the SPSS package program, version 22 (IBM Corp., Armonk, NY, USA). The data were analysed by one-way analysis of variance and are the mean ± standard error (n = 3). (*) indicates significant differences among the MeJA-treated and control samples (Student's unpaired t-test; * $p < 0.05$, ** $p < 0.01$).

3. Results and Discussion

3.1. Effect of Exogenous MeJA on Sweet Cherry Cracking at Harvest

Cracking represents a major challenge for sweet cherry producers as it can lead to substantial economic losses. Once the fruit cracks, it becomes more susceptible to pests and diseases, which can further undermine its quality and value in the marketplace [24].

Among the cultivars, 'Prime Giant' exhibited the highest incidence of cracking on the tree compared to the other cultivars, such as the 'Staccato' and 'Sweetheart' cultivars, which displayed the lowest incidence of fruit cracking under ambient uncontrolled conditions (Figure 1A,B). The factors contributing to the differential tolerance among the cultivars remain unknown, but rain cracking, as a localized phenomenon, has a significant impact on fruit cracking [25,26]. In this sense, the 'Sweetheart' and 'Staccato' cultivars were not exposed to heavy rainfall since it is not common to have significant rainfalls towards the end of July, which is the typical harvesting time for these cultivars in the southeast of Spain. However, when healthy sweet cherries from all the studied cultivars were exposed right after the harvest time to controlled conditions using water immersions [20], creating an additional artificial heavy rainfall for 6 h at harvest (Figure 1C,D), the results were different. The highest incidence of sweet cherry cracking was observed in the 'Sweetheart' cultivar, with a similar incidence of cracking in the 'Prime Giant' and 'Staccato' cultivars.

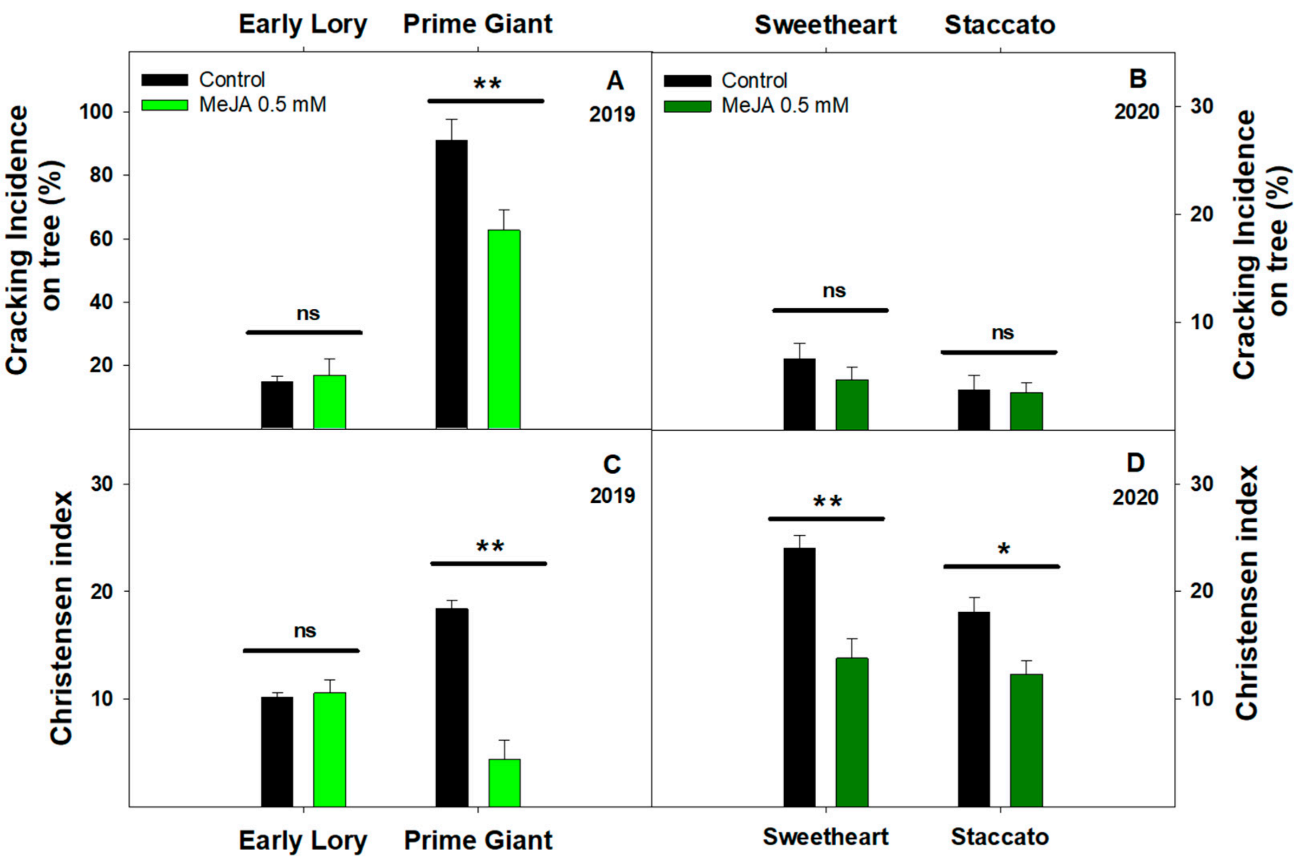

Figure 1. (**A**,**B**) Cracking incidence on tree at harvest (%) and (**C**,**D**) Christensen index at harvest (%) of four sweet cherry cultivars evaluated in 2019 (Early Lory and Prime Giant) and 2020 (Sweetheart and Staccato). Data are the mean ± standard error (n = 3). (*) indicates significant differences among MeJA-treated and control samples (Student's unpaired t-test; * $p < 0.05$, ** $p < 0.01$, ns non significant).

On the other hand, fruit cracking was reduced significantly ($p < 0.01$) in the MeJA-treated 'Prime Giant' cultivar under ambient conditions although a non-significant effect ($p > 0.05$) was observed in general for the rest of the sweet cherry cultivars studied under uncontrolled ambient conditions at harvest time. In this sense, also no significant differences ($p > 0.05$) regarding the effect of MeJA were observed after water immersions in the 'Early

Lory' cultivar, but the effect of reducing the cracking index in the rest of the cultivars studied was clear (Figure 1C,D). According to our results, a greater effect was observed for the cultivars 'Prime Giant' and 'Sweetheart', with the highest fruit cracking reduction (76.08 and 42.05%, respectively) observed after the MeJA was applied compared with the control fruit at harvest time. In previous studies, the effect on crack reduction by MeJA has been observed at similar percentages when its action was evaluated at harvest [17–19]. In this regard, Faizy et al. [19] observed higher cracking when the commercial harvest was delayed by one week for the '0900 Ziraat' cultivar in both the MeJA-treated and control fruit. For this reason, although the MeJA effect on cracking reduction was positive for three cultivars in different growing seasons at commercial harvest in our study, the fruits' degree of ripeness and coincident abiotic stress conditions before the commercial harvest time could also affect these results. In fact, during sweet cherry development on the tree, Serrano et al. [27] described the different physiological characteristics in several parameters related to cracking, such as firmness, soluble solids content, or fruit volume [4,15,28]. On the other hand, the susceptibility to cracking in sweet cherries is dependent on the cultivar [26], and the effect of MeJA on different ripening parameters is also dependent on the species, cultivar, agronomic and environmental conditions, MeJA concentrations, and the number of applications. [29]

3.2. Effect of Exogenous MeJA on Sweet Cherry Cracking during Ripening on Tree

The ripening evolution directly affects the sweet cherry skin thickness and integrity [4,30], which can influence the cracking incidence. To elucidate the general effect of the ripening stage on the cracking incidence, this relationship was studied for the 'Prime Giant' and 'Sweetheart' cultivars during their development on the tree and when exposed to additional water immersion conditions [20] at different developmental stages with distilled water. The results demonstrated that MeJA treatment can significantly reduce cherry cracking at different ripening stages on the tree, but the effect on the cracking incidence showed a different trend among the cultivars studied. In general, during sweet cherry ripening on the tree, an increase in the cracking incidence was observed, which was effectively reduced by preharvest applications of methyl jasmonate coinciding with pit hardening (before S1) in both cultivars and with the colour change of the cherries (S1 for the 'Prime Giant' cultivar and S2 for the 'Sweetheart' cultivar), as shown in Figure 2A,B. However, this effect decreased as the fruit ripening progressed, particularly for the 'Prime Giant' cultivar, possibly because it is an earlier variety than 'Sweetheart', and more advanced ripening stages usually coincide with more intense rainfalls compared with those occurring during the ripening of the 'Sweetheart' cultivar.

Previous research [31] suggests that rain cracking in sweet cherries may not only be caused by excessive water uptake and skin phenomena. Instead, it is likely a localized phenomenon that is caused by the direct exposure of the fruit skin to liquid water. These findings indicate that rain cracking is not related to the net fruit water balance. For this reason, new rain-protection systems have demonstrated their capability to ensure good commercial yields by reducing sweet cherry cracking, even during seasons of heavy rainfall, which could result in the loss of the entire crop for unprotected orchards [11,32–34].

On the other hand, when we evaluated the susceptibility to cracking under controlled conditions, we observed that although in the 'Prime Giant' cultivar, the fruit susceptibility to cracking was similar at all the ripening stages after the colour change, the 'Sweetheart' cultivar showed a different cracking sensitivity depending on the ripening stage coinciding with high humidity or persistent rain (Figure 2C,D). In fact, in the 'Sweetheart' cultivar, the highest incidence of cracking occurred at stage 3, which coincides with the first ripening stage when the fruit acquires a homogeneous reddish coloration. Thus, both the earlier and later stages of ripening showed a lower incidence of cracking under controlled conditions (Figure 2D). In this regard, preharvest applications of MeJA were significantly effective ($p < 0.01$), especially in maturity stage 3 for both the 'Prime Giant' and 'Sweetheart' cultivars, reducing the incidence of cracking by 75.67% and 68.75%, respectively.

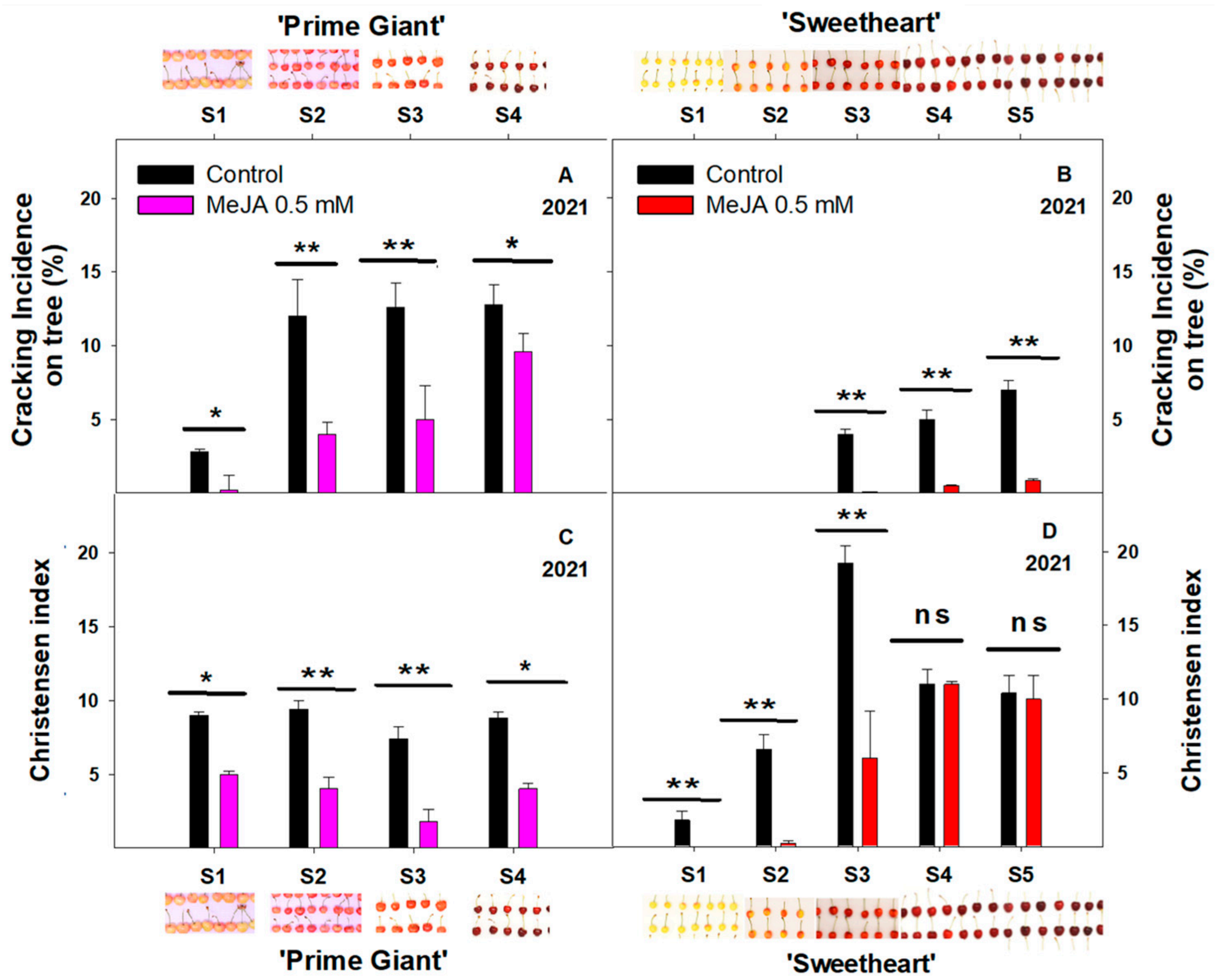

Figure 2. (**A**,**B**) Cracking incidence during development on tree (%) and (**C**,**D**) Christensen index during development on tree (%) of two sweet cherry cultivars evaluated in 2021 (Prime Giant and Sweetheart). Data are the mean ± standard error (n = 3). (*) indicates significant differences among MeJA-treated and control samples (Student's unpaired t-test; * $p < 0.05$, ** $p < 0.01$, ns non significant).

A similar pattern in the evolution of cracking under controlled conditions was observed when the experiment was repeated in both cultivars under similar conditions in the last productive cycle studied in 2022 (Figure 3A,B).

In the case of the 'Prime Giant' cultivar, the cracking showed a small increase as the fruit matured on the tree, while, again, 'Sweetheart' showed a higher incidence of cracking after full fruit coloration than that shown in the other ripening stages studied. This trend was also observed in the previous growing cycles (2021) since the 'Sweetheart' cultivar also showed lower resilience to fruit cracking under controlled conditions. Similar to previous crop cycles, MeJA significantly reduced the incidence of cracking for both the 'Prime Giant' (Figure 3A) and 'Sweetheart' cultivars (Figure 3B). The observed differences between the studied production cycles of the 'Sweetheart' cultivar could be due to a less advanced stage of maturity at the time of sampling, as shown below regarding the fruit quality parameters at harvest. In this sense, a different ethylene production on the tree [10] and the fruit firmness [17], as well as a lower soluble solid content and acidity, could reduce the susceptibility of the fruit to cracking [7]. In fact, a lower incidence of cracking is observed in sweet cherries when the epidermis, hypodermis, and parenchyma cells exhibit larger cell sizes at the latter ripening stages, highlighting the significance of the flexibility and elasticity of the epidermis to reduce this disorder [4,35]. For this reason, if the fruit evolution is delayed, the incidence of the impact of cracking on cherries subjected to different environmental stresses, especially persistent rainfalls, would also be delayed, as observed when comparing Figures 2D and 3B.

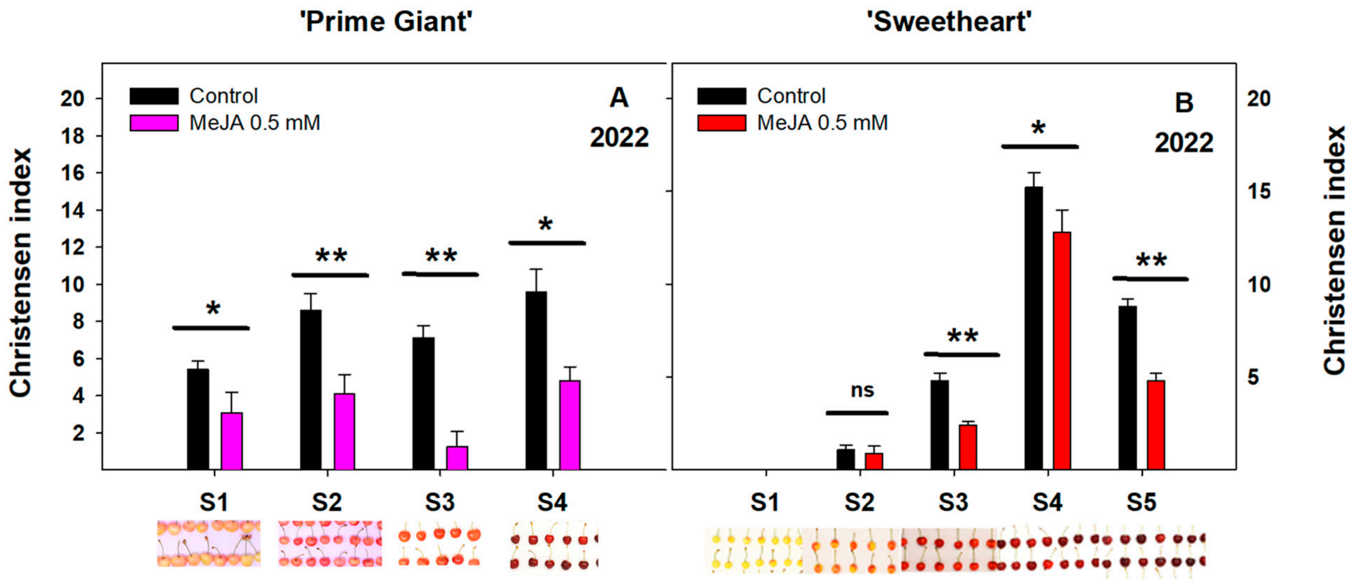

Figure 3. (**A**,**B**) Cracking incidence (Christensen index) during development on tree (%) of two sweet cherry cultivars evaluated in 2022 (Prime Giant and Sweetheart). Data are the mean ± standard error (n = 3). (*) indicates significant differences among MeJA-treated and control samples (Student's unpaired t-test; * $p < 0.05$, ** $p < 0.01$, ns non significant).

3.3. *Effect of Exogenous MeJA Preharvest Treatments on Quality Parameters at Harvest*

Sweet cherries that are harvested at the right stage of maturity, with the appropriate firmness, colour, and sweetness, have a longer shelf life and can reach a higher price in the market [36]. MeJA preharvest treatments resulted in higher fruit firmness values at harvest for all the evaluated cultivars, including 'Early Lory', 'Prime Giant', and 'Sweetheart', across multiple growing cycles (Table 1). However, the 'Staccato' cultivar, as well as 'Prime Giant' and 'Sweetheart', during the 2022 and 2020 growing cycles, respectively, did not exhibit significant differences ($p > 0.05$) in the fruit firmness following the preharvest treatments with MeJA. A similar positive effect, displaying a higher fruit firmness after preharvest MeJA treatments, was reported [17,37] in most of the sweet cherry cultivars evaluated, including 'Sweetheart', while in other cultivars, such as '0900 Ziraat', the fruit firmness was unaffected or showed lower values in MeJA-treated fruit at harvest after different preharvest MeJA applications [19]. In this study, it appears that an increase in firmness is correlated with a reduction in the susceptibility to cracking in most of the evaluated cultivars. This relationship has also been reported by Erogul [38] and Yildirim et al. [39], who investigated the impact of preharvest treatments involving calcium or gibberellins, respectively, on cracking susceptibility. However, it is worth noting that this association may be influenced by specific cultivars and species, as suggested by Balbotin et al. [17] and Erogul [38].

Colour is one of the most important characteristics that buyers and consumers use to determine the maturity and ripeness of fruit [40]. Sweet cherry cultivars differ in their optimal colour at harvest, but, in general, sweet cherries with a deep red colour are preferred because they are associated with sweetness, flavour, and a high nutritional value [41]. In general, preharvest treatments with MeJA delayed the colour evolution in most of the cultivars studied in this research at harvest time (Table 1). Different sweet cherry cultivars, such as 'Prime Giant', 'Sweetheart', and 'Staccato', showed a significant delay ($p < 0.05$) in the evolution of CIE $h°$ compared to the control fruit. However, similar values were observed in the 'Early Lory' cultivar treated with MeJA compared to the control batches at harvest. On the other hand, it is important to highlight that the cultivar 'Sweetheart' was harvested in 2020 and 2022 with a very similar colour, indicating a similar effect of reducing the cracking incidence in both growing seasons (Figures 1D and 3B). Supporting these results, it is easy to see in Figure 3B that the highest cracking was observed at ripening stage S4 (2022), while in 2021, sweet cherries harvested at that stage (S4) already showed increased cracking resilience (Figure 2D). This was probably because a later stage of ripening could induce cracking tolerance in different cultivars, as has already been described in this study and which is in agreement with other preharvest sweet cherry studies, which indicated that a later ripening stage shows lower turgor pressure after stage III, inducing resilience to rainfall cracking [42]. In this sense, the TSS in the 'Sweetheart' cultivar were also higher in the control fruit in 2021 compared to the 2022 harvest. This indicates that the 'Sweetheart' cherries in 2021 had advanced maturity compared with that observed in 2022 at a similar colour stage, which is in consonance with the lower TA level found in 2021 compared to 2022 (Table 1).

The effect of the preharvest MeJA treatments, in general, had a greater impact on delaying sugar accumulation than affecting the TA parameter compared to the control fruits. In fact, with respect to the TA, no significant differences were found in most of the cultivars and growing seasons studied (Table 1). However, a significant effect was observed in most of the MeJA-treated batches studied during the four growing seasons, delaying the TSS accumulation compared to the control fruit. Balbotín et al. [17] and Saracoglu et al. [37] conducted studies on the 'Regina', 'Sweetheart', '0900 Ziraat', and 'Bing' sweet cherry cultivars and found that MeJA-treated fruit exhibited lower levels of total soluble solids (TSS) compared to the control group. However, there were no significant differences in terms of the titratable acidity (TA) content in the MeJA-treated fruit. These observations were in consonance with the results obtained from our analysis in the present study. On the other hand, Faizy et al. [19] observed a distinct pattern in the '0900 Ziraat' cultivar, where the application of MeJA not only delayed the accumulation of TSS but also postponed the accumulation of TA at two different harvest times. We observed the same effect in 2021, but only for the 'Sweetheart' cultivar, where a significant delay ($p < 0.05$) in the TA was recorded. It is important to note that preharvest treatments with MeJA have been demonstrated to impact the expression of multiple genes associated with fruit ripening, resulting in a delayed ripening process in peaches, as demonstrated by [43]. In contrast, Shafiq et al. [44] found that the preharvest MeJA treatment did not have a significant effect on the TSS and TA in apples. Conversely, various authors have reported an increase in the TSS content following the application of MeJA in peaches, blackberries, and raspberries [45–47]. Therefore, the effect on the TSS and TA in MeJA-treated fruit may vary depending on the ripening stage at which the fruit is evaluated and the species being tested.

Polyphenol accumulation is related to a decrease in the CIE $h°$, as reported by different authors [41,48]. The CIE $h°$ values of the MeJA-treated sweet cherries from all four cultivars were higher compared to the control fruit (Table 1). These findings suggest that the MeJA treatments generally delayed the fruit skin colour development in all the cultivars, although the observed impact on polyphenols was not statistically significant ($p > 0.05$). However, some specific cultivars in some of the growing cycles studied also showed a significant delay in total polyphenol accumulation (Table 2). Balbotín et al. [17] reported that the application of 0.4 mM MeJA on sweet cherries resulted in a decrease in the CIE $h°$ after preharvest treatments, while Faizy et al. [19] observed redder sweet cherries after treatments with 2 mM MeJA on the '0900 Ziraat' cultivar. However, our data showed the opposite effect with a 0.5 mM MeJA treatment on the total polyphenols. Several other authors did not observe an increase in polyphenols with different MeJA concentrations or a decrease in the CIE $h°$ [38,49,50].

Table 1. Effects of preharvest methyl jasmonate treatments at a 0.5 mM concentration on fruit colour, total polyphenols, firmness, total soluble solids, and titratable acidity at harvest time.

Fruit Firmness (N mm^{-1})			
Cultivar	**Year**	**Control**	**MeJA 0.5 mM**
'Early Lory'	2019	1.10 ± 0.04	1.25 ± 0.04 *
'Prime Giant'	2019	1.77 ± 0.07	1.91 ± 0.08 *
'Prime Giant'	2021	1.31 ± 0.04	1.51 ± 0.07 *
'Prime Giant'	2022	1.19 ± 0.05	1.21 ± 0.05 ^{ns}
'Staccato'	2020	2.84 ± 0.11	2.88 ± 0.12 ^{ns}
'Sweetheart'	2020	1.94 ± 0.07	1.99 ± 0.07 ^{ns}
'Sweetheart'	2021	1.78 ± 0.09	2.08 ± 0.08 *
'Sweetheart'	2022	1.73 ± 0.08	2.17 ± 0.09 **
Fruit Colour (CIE $h°$)			
Cultivar	**Year**	**Control**	**MeJA 0.5 mM**
'Early Lory'	2019	22.50 ± 0.40	21.93 ± 0.8 ^{ns}
'Prime Giant'	2019	15.65 ± 0.65	18.61 ± 0.49 *
'Prime Giant'	2021	13.37 ± 0.31	14.32 ± 0.43 **
'Prime Giant'	2022	21.50 ± 0.52	23.92 ± 0.59 *
'Staccato'	2020	16.24 ± 0.55	18.73 ± 0.72 *
'Sweetheart'	2020	16.58 ± 0.58	18.19 ± 0.70 *
'Sweetheart'	2021	20.64 ± 0.20	22.48 ± 0.32 *
'Sweetheart'	2022	17.49 ± 0.34	19.67 ± 0.25 **
Total Soluble Solids (g 100 g^{-1})			
Cultivar	**Year**	**Control**	**MeJA 0.5 mM**
'Early Lory'	2019	13.05 ± 0.19	11.88 ± 0.04 *
'Prime Giant'	2019	22.96 ± 0.59	18.50 ± 0.45 **
'Prime Giant'	2021	17.56 ± 0.18	17.83 ± 0.11 ^{ns}
'Prime Giant'	2022	22.75 ± 0.41	22.06 ± 0.45 ^{ns}
'Staccato'	2020	21.05 ± 0.05	20.17 ± 0.26 *
'Sweetheart'	2020	22.42 ± 0.07	22.37 ± 0.10 ^{ns}
'Sweetheart'	2021	19.61 ± 0.35	18.90 ± 0.16 *
'Sweetheart'	2022	19.03 ± 0.18	18.21 ± 0.18 *
Titratable Acidity (g 100 g^{-1})			
Cultivar	**Year**	**Control**	**MeJA 0.5 mM**
'Early Lory'	2019	1.12 ± 0.01	1.07 ± 0.01 ^{ns}
'Prime Giant'	2019	1.20 ± 0.05	1.31 ± 0.03 ^{ns}
'Prime Giant'	2021	1.09 ± 0.01	1.11 ± 0.01 ^{ns}
'Prime Giant'	2022	1.52 ± 0.01	1.53 ± 0.02 ^{ns}
'Staccato'	2020	1.21 ± 0.01	1.28 ± 0.01 *
'Sweetheart'	2020	1.23 ± 0.02	1.24 ± 0.01 ^{ns}
'Sweetheart'	2021	1.33 ± 0.02	1.24 ± 0.03 *
'Sweetheart'	2022	1.44 ± 0.03	$1.48 \pm 6.12 \times 10^{-3}$ ^{ns}

Data are the mean ± standard error (n = 3). (*) indicate significant differences among MeJA-treated and control samples (Student's unpaired t-test; * $p < 0.05$, ** $p < 0.01$, ^{ns} non significant).

MeJA-induced anthocyanin accumulation has been demonstrated in many species, such as strawberries [51], apples [52], loquat [53,54], mango [55], and pomegranate arils [56]. However, all the studies regarding sweet cherries have a different number of applications and different key moments of application. Therefore, the difference observed by the different authors could be due to different moments of application during sweet cherry development on the tree and a cultivar-dependent effect. However, it could also be due to the different concentrations of MeJA applied. In this sense, our research team already demonstrated that a higher concentration of MeJA could delay and even stop table grape colour evolution, while lower concentrations of MeJA were capable of increasing the anthocyanin content, reducing the CIE $h°$ [57].

The pedicel, which attaches the cherry to the tree, serves as a vital connection point for nutrient uptake and water transport, influencing fruit development [58]. Pedicel browning in sweet cherries has been linked to fruit ripening and dehydration, as reported by [59]. Additionally, environmental factors, such as the use of plastic cover trees, have been suggested to affect the condition of sweet cherry pedicels, as indicated by [33]. These authors compared fruit obtained from uncovered trees and those from covered trees. Consistently, the fruit from the uncovered trees exhibited higher levels of pedicel browning, which serves as an indicator of condition defects. These findings highlight the importance of providing adequate protection to minimize stress on the pedicels and maintain their freshness. The MeJA-treated fruits generally displayed lower values of pedicel browning at harvest, as shown in (Table 2). However, no significant differences ($p > 0.05$) were observed among all the studied cultivars, except for 'Prime Giant' in the 2019 season. The overall incidence of pedicel browning was not high at harvest, as this condition typically develops during the postharvest storage of sweet cherries [59]. However, a recent review described the effect of MeJA in maintaining the chlorophyll content and reducing the oxidation of this molecule, thus preserving the greenness of the tissues [60]. In this sense, several authors of studies on different horticulture products also described that preharvest [61] and postharvest [62] MeJA treatments positively impacted plant tolerance by modifying the antioxidant defence mechanism and reducing chlorophyll loss.

Table 2. Effects of preharvest methyl jasmonate treatments at a 0.5 mM concentration on fruit total polyphenols and stem quality at harvest time.

Total Polyphenols (mg 100 g^{-1})			
Cultivar	**Year**	**Control**	**Meja 0.5 mM**
'Early Lory'	2019	99.48 ± 3.91	90.75 ± 2.77 *
'Prime Giant'	2019	87.15 ± 4.16	78.42 ± 7.65 *
'Prime Giant'	2021	98.39 ± 6.10	102.57 ± 2.55 ^{ns}
'Prime Giant'	2022	91.45 ± 5.67	84.56 ± 3.45 ^{ns}
'Staccato'	2020	81.66 ± 2.98	73.46 ± 1.44 *
'Sweetheart'	2020	75.07 ± 2.98	73.60 ± 3.44 ^{ns}
'Sweetheart'	2021	109.73 ± 9.74	100.64 ± 9.77 ^{ns}
'Sweetheart'	2022	85.97 ± 3.21	83.56 ± 2.97 ^{ns}
Pedicel Browning (Scale 0–4)			
Cultivar	**Year**	**Control**	**Meja 0.5 mM**
'Early Lory'	2019	0.75 ± 0.20	0.72 ± 0.12 ^{ns}
'Prime Giant'	2019	0.81 ± 0.17	0.39 ± 0.16 **
'Prime Giant'	2021	0.83 ± 0.09	0.70 ± 0.10 ^{ns}
'Prime Giant'	2022	0.07 ± 0.02	0.06 ± 0.02 ^{ns}
'Staccato'	2020	0.20 ± 0.03	0.16 ± 0.02 ^{ns}
'Sweetheart'	2020	0.18 ± 0.01	0.19 ± 0.01 ^{ns}
'Sweetheart'	2021	0.62 ± 0.09	0.66 ± 0.07 ^{ns}
'Sweetheart'	2022	0.06 ± 0.02	0.05 ± 0.02 ^{ns}

Data are the mean ± standard error ($n = 3$). (*) indicate significant differences among MeJA-treated and control samples (Student's unpaired *t*-test; * $p < 0.05$, ** $p < 0.01$, ^{ns} non significant).

4. Conclusions

MeJA could effectively reduce sweet cherry cracking during ripening on the tree and at harvest time. Medium and advanced ripening stages before harvest time were more susceptible to fruit cracking. MeJA preharvest treatments delayed fruit ripening, increasing the fruit firmness and delaying the colour, soluble solids, and total acidity evolution compared to the control fruit at harvest. For this reason, MeJA, as a preharvest treatment, could be an efficient tool to reduce abiotic stress and delay ripening during fruit development on the tree, improving the fruit quality at harvest.

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