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Pruning and Flower Thinning Influence the Storability of CH201/FRED® Pears

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Abstract: CH201/FRED® is a novel red-blush pear cultivar with long-term storage potential and a prolonged shelf life. However, it is prone to controlled atmosphere (CA)-related disorders, particularly cavities. This study explored the impact of the balance between vegetative growth and crop load on the development of CA-related disorders during storage. Treatments involving the removal of two-thirds of floral bouquets (Fl_Th) and the shortening of branches by two-thirds (Pr) at the bud stage (late balloon stage) promoted the growth of 1-year-old shoots, which correlated with an increased incidence of cavities and reduced calcium levels in the pears. The Fl_Th treatment resulted in larger fruits with a higher total soluble solid content, a greater force required to puncture the skin and flesh, and a higher incidence of cavities than the Pr treatment. These findings demonstrate that both crop load and the leaf area-to-crop load ratio significantly influence the susceptibility of CH201/FRED® pears to CA-related disorders during storage.

Keywords: *Pyrus communis*; controlled atmosphere; orchard management; CA-related disorders

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1. Introduction

Pear (*Pyrus communis* L.) production in Europe was relatively stable until 2020, fluctuating between 2 and 2.5 million tons yearly [1]. A slight decline has nevertheless been observed in recent years, mainly due to extreme weather conditions, such as frost and drought. Italy, Spain, Belgium, and the Netherlands are the leading pear-growing countries, accounting for approximately 70% of European production [1]. Although many pear cultivars are available, only a few dominate the market. Conference is the most important cultivar, followed by Williams BC/Bartlett, Abate Fetel, and Rocha [2]. New varieties, such as Oksana/Xenia®, Celina/Qtee®, and Cepuna/Migo®, have recently gained market shares, and their production volume is expected to rise in the upcoming years [2]. Still, new pear cultivars with a storage potential of at least six months and good and early productivity are desired.

The CH201 pear cultivar (*Pyrus communis* L.), issued from the breeding program at the Agroscope Research Center in Switzerland and recently launched under the FRED®

brand name in several European countries, is characterized by early bearing and high productivity [3,4]. The cultivar also boasts an appealing red blush, along with essential attributes, such as long-term storage potential and a prolonged shelf life. These qualities are mainly due to its texture, which offers robust resistance to mechanical damage [3]. The fruit requires 7–10 days under shelf-life conditions at 20 °C to achieve a buttery and melting texture. With just 3 days under the same conditions, its texture becomes crunchy. This flexibility minimizes fruit losses during postharvest manipulations, such as conditioning, transport, and commercialization.

The first storage experiments conducted with CH201/FRED® showed good storability when kept in a regular atmosphere (RA), comparable to Conference pears stored under controlled atmosphere (CA) conditions and harvested at similar firmness levels [3]. Under CA conditions, CH201/FRED® has shown a susceptibility to CA-related disorders, specifically the development of cavities [3,5,6]. These physiological disorders result from internal tissue breakdown and are essentially holes within the flesh, ranging from small spots to large lesions [7]. They can lead to significant economic losses throughout the postharvest supply chain, as these internal symptoms cannot be detected without cutting the fruit.

Preharvest and postharvest factors affect the development of CA-related disorders in pears, including weather conditions such as temperature and precipitation during fruit growth, orchard-specific factors, such as soil type, irrigation methods, fertilization practices, and the specific location of the fruit on the tree [8]. Such factors and their impact on pear storage are not specific to CH201/FRED®. For example, Conference trees with low crop load induced higher cavities and browning incidence in pears during storage [7]. In a study on Rocha pears, fruits affected by internal storage disorders exhibited higher K/Ca and (K + Mg)/Ca ratios, with the effect varying depending on the orchard [9]. In general, the duration of the cooling period after harvest, suboptimal oxygen (O_2) and/or carbon dioxide (CO_2) levels in the atmosphere, and the temperature and length of storage significantly influence the development of CA-related disorders in pears [7,10]. The delay between harvest and the establishment of CA conditions affects the disorders' apparition [11]. Finally, fruits harvested late in the season and oversized fruits are also more susceptible [10,12,13].

The development of cavities is influenced by multiple factors. Storage experiments conducted with CH201/FRED® at Agroscope showed that CO_2 levels below 0.8 kPa and O_2 partial pressure above 3 kPa with a 4-week CA delay are optimal conditions to substantially reduce the proportion of affected fruit, while 1-Methylcyclopropene (1-MCP) treatment increases it [5,6,14]. Orchard-specific preharvest factors play a role in the development of cavities in CH201/FRED® pears: a 5-year study focusing on pears harvested from the same orchard and stored under consistent CA conditions revealed varying levels of cavities occurrence according to the year [5]. Furthermore, CH201/FRED® pears harvested from different orchards but stored in the same CA room exhibited distinct susceptibility to cavities [5]. Many studies indicate that crop load affects pear size and internal quality factors, including firmness and sugar content [15,16]. However, the scientific literature on how it influences CA-related disorders remains scant.

A detailed understanding of how individual orchard-related parameters, such as crop load, irrigation, mineral nutrition, and weather conditions, affect cavity development is still lacking. Such knowledge is necessary to enhance the quality and minimize the losses of this cultivar throughout its supply chain. This study assessed how crop load and tree vigor, in particular the annual shoot growth, affect CH201/FRED® tree performance, fruit quality at harvest, storability, and the occurrence of CA-related disorders.

2. Materials and Methods

2.1. Experimental Design

This study was conducted during the growing season of 2022 in an experimental orchard planted in 2017 at Agroscope (Conthey, Valais, Switzerland; latitude 46.2° N, longitude 7.3° E, elevation 520 m, annual rainfall 487 mm). The experiment was conducted on trees grafted onto quince Adams rootstock, planted with an inter-tree spacing of 1.3 m and a row spacing of 4 m. The experiment followed a randomized block design, with three replicates (blocks), each containing 18 trees, for a total of 54 trees. At the bud stage (late balloon stage, mid-April), the trees were subjected to the following treatments: (1) control (no treatment), (2) pruning (branches that were two years old or older were shortened by two-thirds, Pr), and (3) flower thinning (two-thirds of the floral bouquets were removed, Fl_Th). With the exception of treatments carried out at the bud stage, all trees were subjected to the same orchard management. A total of 12 trees in 3 blocks, selected by uniformity of vigor and size and with the same management history, were considered for each treatment. Pears were harvested at the commercial maturity stage and stored under CA conditions for 5 and 8 months at 0.5 °C, 90–95% of relative humidity, 3 kPa oxygen (O_2) and 1 kPa carbon dioxide (CO_2) with a 4-week CA delay.

2.2. Tree Performance (Crop Load, Leaf Area, Vegetative Vigor, Fruit Size)

Vegetative parameters were measured on 12 trees in 3 blocks per treatment. Crop load was calculated as the number of fruits per leaf area unit. The leaf area (m^2/tree) was determined as follows: 5% of leaves from unpruned branches within a diameter range of 5–25 mm were selected and measured with a LI-3100C area meter (LI-COR, Lincoln, NE, USA), with one leaf out of every 20 being sampled, starting from the base of the branch. A relationship between cross-sectional diameter of the branches and leaf area was then established and applied to determine the leaf area for branches that were not pruned. For the pruning treatment, the leaf area of each branch was determined by adding the respective leaf areas of elementary vegetative and generative organs (spurs and shoots visually classified into different leaf area categories).

The measurement of vegetative growth involved categorizing shoots based on five different length ranges ($\leq$20 cm, $\leq$40 cm, $\leq$60 cm, $\leq$80 cm, and >80 cm) and were expressed as cumulative growth per tree (m/tree) by adding up the values obtained for the different categories. Fruit size was measured weekly for each treatment on 15 fruits in 3 blocks per treatment from 82 days after full bloom up until harvest.

2.3. Quality Parameters

At harvest, fruit quality was determined on 20 pears per block per treatment. After storage, assessments were performed on one batch of 20 fruit per treatment (at removal from the cold room and after a simulated shelf life at 20 °C for 7 days). Skin color (background color) was measured using a CM-600d spectrophotometer (Konica Minolta, Tokyo, Japan) acquired in CIE L*a*b* color space with a D65 light. The results were expressed as hue angle (hue, tan-1(b*/a*)), a hue angle of 0° representing red, increasing to yellow (90°), and green (180°). An automated 'Pimprenelle' instrument (Setop Giraud-Technologie, Cavaillon, France) was used to determine firmness (N) and total soluble solids (TSS, %).

At harvest, additional analyses were carried out on three batches of 10 fruit per treatment: starch [Starch Index] was determined by cutting pears in half just after harvest and dipping them in an iodine solution (40 g KI + 10 g I_2 in 1 L of distilled H_2O) for 1 min. Starch index was used as a ripening index. Acidity was measured on the juice obtained from a batch of 20 fruit with the 'Pimprenelle' instrument (Setop Giraud-Technologie, Cavaillon, France). Texture analyses were performed using a TA-XTplus Texture Analyzer

(Stable Micro Systems, Godalming, UK) equipped with a 2 mm diameter needle probe moved through the skin and flesh up to a depth of 10 mm at a speed of 10 mm s^{-1}. The influence of the treatments was assessed on the forces required to puncture the skin ($F_p{}^1$) and move the probe through the flesh up to 10 mm ($F_p{}^{max}$), which were extracted from the force-displacement curves.

2.4. Physiological Disorders

After 5 and 8 months of storage, followed by 7 days of shelf life at 20 °C, three batches of 20 pears per treatment were cut into 1.5 cm-thick slices and visually evaluated for CA-related disorders. As CA-related disorders developing on CH201/FRED® pears in this study were mainly internal cavities, results were focused on this specific disease. The percentage of affected fruits was determined for each treatment.

2.5. Ascorbic Acid

Three batches of 10 fruits per treatment were cut transversally to the equatorial region into a 3 mm-thick slice at harvest. The opposite sides of each slice were then cut into small pieces and immediately frozen in liquid nitrogen. Frozen samples were then ground to powder using a grinder with liquid nitrogen. Approximately 9 g of the sample was then mixed with a solution containing 15 mL of 3% metaphosphoric acid and vortexed for 1 min for homogenization with a Turax (IKA, Staufen, Germany). Samples were then centrifuged for 20 min at 14,000 rpm at 4 °C. The supernatant was filtered through a Nylon membrane filter with a 0.45 µm pore size (Wicom, Heppenheim, Germany). A 20 µL sample was then injected into a HPLC (LC-CaDI 22–44, Bischoff, Leonberg, Germany), equipped with a Prontosil 60–5-C18 column (5 µm, 125 × 4.0 mm). The UV-VIS detector (Lambda 1010, Bischoff, Germany) was set to 254 nm. In the mobile phase, water with 5.5% methanol and 0.5% tetrabutylammonium hydrogen sulfate at 30 °C with an isocratic flow rate of 0.8 mL min^{-1} and a run time of 3 min. Ascorbic acid was quantified using a standard.

2.6. Mineral Analyses

The macronutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) and the micronutrients iron (Fe), zinc (Zn), copper (Cu) and boron (B) were measured in this study. Three batches of 10 fruits were cut transversally to the equatorial region into a 1.5 cm-thick slice and dried at 65 °C for 24 h. 0.6 g of powder were used for mineral analyses. Consequently, 0.3 g of each sample was weighed twice into a high-pressure quartz vessel followed by microwave digestion with an Anton Paar Multiwave 7000 (Graz, Austria) with 2.5 mL HNO_3 65% and 5.5 mL UP H_2O (Millipore Milli-Q plus, MilliporeSigma, Burlington, MA, USA). The digestion was carried out for a 75 min cycle using the appropriate digestion protocol (35 min at 235 °C and 140 bar). Upon cooling to room temperature, the digested sample was transferred into a 50 mL PP volumetric flask and made up to the final volume with UP H_2O. Elemental analyses were carried out on Agilent ICP-OES 5800 (Santa Clara, CA, USA) and Thermo ICP-MS ICAPTQ (Waltham, MA, USA), according to the methods described by EN 15621:2017 and European Standard EN 17053:2018 [17,18]. The results were expressed on a dry mass basis.

2.7. Statistical Analyses

Analyses of variance (ANOVAs) calculated with R software (Version 4.3.1) were used to compare means at $p \leq 0.05$. Multiple means were compared with the Tukey HSD test and considered significantly different if $p \leq 0.05$.

3. Results

3.1. Influence of Pruning and Flower Thinning on Tree Performance

Removing two-thirds of the floral bouquets and cutting the branches by two-thirds at the bud stage led to a similarly reduced crop load at harvest (Table 1). Pruned trees exhibited greater vegetative vigor compared to the control trees. In addition to increased vegetative growth, Fl_Th enhanced leaf area and fruit weight (Table 1). Fl_Th produced larger fruit sizes as early as 82 days after full bloom compared to the Pr and control treatments, which resulted in similar fruit sizes (Figure 1).

Table 1. Influence of the pruning and flower thinning treatments on crop load, vegetative vigor, leaf area, and fruit weight at harvest *.

Treatment	Crop Load [no. Fruit/m^2]	Vegetative Vigor [m/Tree]	Leaf Area [m^2/Tree]	Fruit Weight [g]
Control	22.3 a	3.6 b	5.1 b	240.1 b
Pr	15.8 b	11.3 a	4.9 b	253.3 b
Fl_Th	12.6 b	9.5 ab	7.1 a	285.0 a

* Values are the means of triplicates of 12 trees distributed across three blocks. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

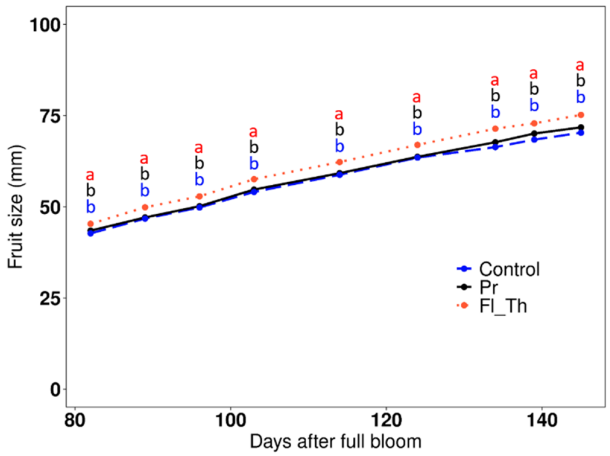

Figure 1. Influence of the pruning and flower thinning treatments on fruit size measured starting 82 days after full bloom until harvest. At each measurement day, means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

3.2. Influence of Pruning and Flower Thinning on Fruit Quality at Harvest

Firmness, starch, color, and titratable acidity (TA) values were similar for all treatments at harvest (Table 2). Fl_Th treatment resulted in a higher TSS content, and the fruit subjected to this treatment required greater force to puncture the skin ($F_p{}^1$) compared to the Pr and control treatments (Table 2). Additionally, the maximum force required to push the probe 10 mm into the flesh ($F_p{}^{max}$) was higher in the fruits from this treatment compared to the control treatment (Table 2). The textural properties of the pears harvested from trees subjected to the pruning treatment were similar to those of the control treatment.

Table 2. Influence of the pruning and flower thinning treatments on the firmness, total soluble solids (TSS), starch, color, titratable acidity (TA), and the maximal forces needed to puncture the skin (F_p^1) and the flesh (F_p^{max}) of CH201/ FRED® pears at harvest *.

Treatment	Firmness [N]	TSS [%]	Starch [Index]	Color [hue]	TA [g L^{-1}]	F_p^1 [N]	F_p^{max} [N]
Control	65.7 a	11.7 b	2.3 a	99.7 a	4.7 a	1.5 b	6.7 b
Pr	66.7 a	12.1 b	2.6 a	99.9 a	4.2 a	1.5 b	6.8 ab
Fl_Th	65.7 a	12.8 a	2.3 a	99.4 a	5.3 a	1.6 a	6.9 a

* Firmness, TSS, color and TA are the means of three samples of 20 fruits, while starch F_p^1 and F_p^{max} are the means of three samples of 10 fruits. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

3.3. Influence of Pruning and Flower Thinning on Fruit Storability and Disorders

Firmness, TSS, and color were evaluated at removal from CA storage after 5 and 8 months and after 7 days of shelf life at 20 °C to determine the influence of the treatments on the storability of the pears. Physiological disorders were evaluated after shelf life. Firmness decreased by an average of 10 N during the first five months of storage, regardless of treatment (Figure 2). Similar softening was observed during the subsequent shelf life, independent of the treatments. After eight months, fruits from the pruned trees exhibited a higher firmness value at the time of removal from CA storage, but this effect was no longer present after shelf life. TSS values showed a slight increase during the first five months of storage and then remained stable for up to eight months (Table 3). The higher TSS levels observed in pears from the Fl_Th treatment at harvest persisted throughout storage and shelf life. Furthermore, the Pr and control treatments exhibited similar TSS values over the same period. The fruits became yellower during storage and shelf life, with only a minimal influence from the treatments on this parameter (Table 3).

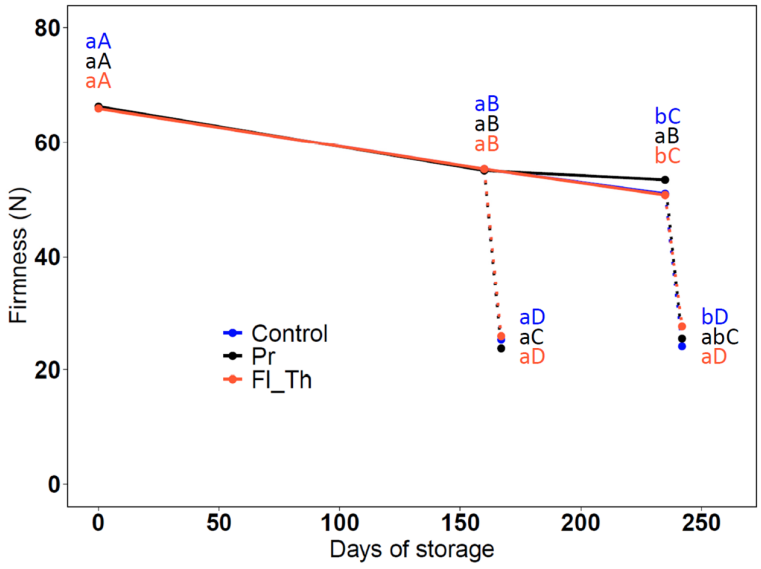

Figure 2. Influence of the pruning and flower thinning treatments on the firmness of CH201/FRED® pears stored under CA for 5 and 8 months and 7 days at 20 °C. Values are the means of 20 fruits. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test. Small letters denote significant differences between the treatments at one storage duration. Capital letters indicate significant differences in the duration of storage for the same treatment.

Table 3. Influence of the pruning and flower thinning treatments on the total soluble solids (TSS) and color of CH201/FRED® pears stored for 5 and 8 months under CA conditions followed by 7 days at 20 °C (SL) *.

	TSS [%]					Color [hue]				
Treatment	**Harvest**	**5 m CA**	**5 m CA +7 d SL**	**8 m CA**	**8 m CA +7 d SL**	**Harvest**	**5 m CA**	**5 m CA +7 d SL**	**8 m CA**	**8 m CA +7 d SL**
Control	11.7 b C	12.6 b B	13.5 a A	12.8 a B	12.9 b B	99.7 a A	95.5 a B	86.2 b D	91.5 a C	nd
Pr	12.1 b B	13.1 b A	13.3 a A	12.9 a A	12.8 b A	100.0 a A	90.1 b B	88.7 a B	90.4 a B	nd
Fl_Th	12.8 a C	13.8 a AB	14.1 a A	13.2 a BC	13.9 a A	99.4 a A	93.8 a B	85.2 b D	91.4 a C	nd

* Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test. Small letters denote significant differences between the treatments at one storage duration. Capital letters indicate significant differences in the duration of storage for the same treatment. nd: not determined.

Cavities developed in CH201/FRED® pears across all tested treatments, although to various extents (Table 4). Removing two-thirds of the floral bouquets at the bud stage (Fl_Th) led to a higher percentage of cavities after 5 months of storage compared to the Pr and control treatments. However, after 8 months, the cavity percentages were similar for both the Pr and Fl_Th treatments, while the control fruit was less affected.

Table 4. Influence of the pruning and flower thinning treatments on percentage of CH201/FRED® pears affected by cavities and stored for 5 and 8 months under CA conditions followed by 7 days at 20 °C (SL) *.

Treatment	**5 m CA +7 d SL**	**8 m CA +7 d SL**
Control	15.0 b	16.0 b
Pr	23.3 b	43.7 ab
Fl_Th	50.0 a	67.3 a

* Values are means of three batches of 20 fruits. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

3.4. Influence of Pruning and Flower Thinning on Ascorbic Acid and Mineral Content

Pears issued from the control treatment exhibited lower acid ascorbic levels at harvest compared to Pr and Fl_Th (Table 5). The N, P, and K content was similar in all treatments (Table 6). Ca was higher in the control condition, while Mg was lower in the Fl_Th treatment. The K-to-Ca ratio was higher in Fl_Th, while pruning treatment led to a K-to-Ca ratio between the control and Fl_Th levels. Fe, Zn, and Cu were not affected by the treatments, while a higher B level was measured in the Pr condition.

Table 5. Influence of the pruning and flower thinning treatments on the ascorbic acid content of CH201/FRED® pears at harvest *.

Treatment	**Ascorbic Acid [mg/100 FW]**
Control	3.85 b
Pr	4.97 a
Fl_Th	4.88 a

* Values are means of three batches of 10 fruits. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

Table 6. Influence of the pruning and flower thinning treatments on the mineral composition and K/Ca ratio of CH201/FRED® pears after 8 months of storage under CA conditions *.

Treatment	Mineral Concentration [mg kg^{-1}]									
	N	P	K	Ca	Mg	Fe	Zn	Cu	B	K/Ca
Control	3158 a	539 a	7254 a	957 a	0.52 a	11.23 a	6.55 a	3.02 a	12.47 b	7.58 b
Pr	3128 a	635 a	7717 a	802 b	0.52 a	10.93 a	6.58 a	3.23 a	13.86 a	9.62 ab
Fl_Th	3163 a	564 a	7321 a	728 b	0.47 b	9.59 a	5.72 a	2.68 a	12.92 ab	10.06 a

* Values are means of three batches of 10 fruits. Means with the same letters do not differ significantly at $p \leq 0.05$ in the Tukey HSD test.

4. Discussion

This study showed that decreasing the number of pear flowers by removing two-thirds of the floral bouquets or cutting the branches by two-thirds at the bud stage not only affected the yield and fruit quality at harvest but also increased the fruit's susceptibility to CA-related disorders during storage. Fl_Th treatment, nevertheless, had a greater impact than Pr.

Thinning is recommended in pear production to maximize fruit quality and yields by targeting a balance between vegetative growth and fruiting over the years [15]. Different methods can be applied to reduce the levels of fruit set, such as hand and mechanical thinning, application of plant bioregulators, pruning, and shading of the trees [15]. Thinning early in the season, before cell division is completed, has the advantage of preventing the waste of carbohydrates and significantly affecting fruit size [19]. This effect was observed in this study, as the Fl_Th treatment led to larger fruits than the control treatment. Removing floral bouquets before knowing which flowers will set fruit is nevertheless risky, as it can lead to a sub-optimal crop load and oversize fruit, which may be more susceptible to browning disorders during storage [8,10]. This was corroborated in the present study, as pears from the Fl_Th treatment were particularly affected by cavities during storage.

Pruning in pear production aims to optimize tree structure, control tree size and crop load, and improve light distribution within the canopy to enhance fruit quality and yield [20,21]. In the present study, branches were shortened by two-thirds at the bud stage to promote the growth of 1-year-old shoots and to evaluate their impact on the development of CA-related disorders during storage. This pruning method effectively enhanced vegetative growth compared to the control treatment. Interestingly, pruning fostered the growth of annual shoots to a similar extent to flower thinning. Furthermore, both treatments resulted in a comparable reduction in crop load relative to the control. Since fruit and leaf development depends on carbohydrates, nutrients, and water [22,23], competition arises between the tree's reproductive and vegetative organs for these shared resources [24]. Competition for essential minerals, such as calcium, may affect the susceptibility of pears to CA-related disorders, as this element plays a crucial role in maintaining cell wall integrity in fruit [25]. An adequate calcium level in pears is essential under CA conditions with low oxygen and high carbon dioxide levels; as such, a storage condition heightens the risk of reactive oxygen species accumulation, which is particularly damaging to fruit cells [8]. Indeed, a low calcium level is associated with internal flesh browning in apples [26–29]. However, there is limited information about the impact of calcium on storage disorders in pears.

Calcium is transported throughout the plant via the transpiration stream in the xylem vessels [30]. This element is then primarily delivered to organs with the highest water demand, predominantly the leaves, with newly developing leaves acting as the strongest calcium sinks due to their high transpiration rates [31]. This was confirmed in this study, given that the higher vegetative growth observed in both Fl_Th and Pr treatments led to fruit with a lower calcium level compared to the control. These treatments also induced

a higher incidence of CA-related disorders during storage. Enhancing vegetative growth through pruning or flower thinning at the bud stage creates competition for calcium between young leaves and fruit, negatively affecting the storability of pears by increasing the incidence of CA-related disorders.

Larger fruits have often been associated with higher internal browning [10,32]. In our study, Fl_Th-treated fruits were larger and more affected by CA-related disorders than the fruit from the Pr treatment. A greater leaf area in the Fl_Th treatment than Pr (where cutting back the branches by two-thirds reduced the number of leaves per tree) was likely the reason. A higher leaf-to-fruit ratio increases photosynthates (carbohydrates) production by the leaves relative to the fruit demand [33], which leads to larger pears with increased TSS content and greater flesh firmness, as indicated by the higher force required for puncturing the skin ($F_p{}^1$) and flesh ($F_p{}^{max}$). These findings suggest that CH201/FRED® pears from Fl_Th treatment exhibited higher flesh density and reduced gas diffusivity, including CO_2, through the skin and tissues. This likely resulted in greater CO_2 accumulation within the fruit, contributing to a higher incidence of CA-related disorders.

High ascorbic acid content limits CO_2-induced internal browning disorders in apples [34,35] and pears [36,37]. Ascorbic acid is an antioxidant that neutralizes reactive oxygen species (ROS), which are generated at higher partial pressures under CO_2-enriched storage conditions [36]. It also inhibits the oxidation of phenolic compounds to quinones, which leads to fruit browning by blocking polyphenol oxidase activity [38]. These findings were not observed by our study, as CH201/FRED® pears with the lowest CA-related disorders showed the lowest ascorbic acid content. The lower crop load achieved in the Fl_Th and Pr treatments might have enhanced ascorbic acid levels in the pears due to better resource allocation and improved light availability [39]. These findings suggest that ascorbic acid is one of several factors related to the development of CA-related disorders in CH201/FRED® pears. Similar results were reported on Braeburn apples, in which a negative correlation was found between ascorbic acid content and internal browning [40]. Further research is therefore needed to understand the underlying mechanisms better, identify the influencing factors, and understand the fruit's defense strategies against this disorder in CH201/FRED® pears during storage.

5. Conclusions

This study showed that reducing two-thirds of floral bouquets and shortening branches by two-thirds at the bud stage stimulated one-year-old shoot growth, which was linked to a higher incidence of cavities and lower calcium levels in CH201/FRED® pears. The Fl_Th treatment produced larger fruits with increased total soluble solid content, greater skin and flesh firmness requiring more force to puncture, and a higher occurrence of cavities compared to the Pr treatment. The higher leaf area-to-crop load ratio was positively correlated with the disorders. These findings demonstrate the importance of appropriate orchard pruning and flower and fruit thinning strategies to ensure consistent yields and high-quality CH201/FRED® pears meeting market and consumer expectations.

By evaluating the impact of fruit thinning on calcium allocation and cavity development during storage, future research could refine orchard management practices to enhance the storability and marketability of CH201/FRED® pears. Specifically, the influence of commonly used fruit thinning strategies on CH201/FRED® postharvest performance would warrant explorations, as such methods may influence fruit quality, nutrient distribution, and storability.

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M.R., F.B. and D.N.; supervision, S.G.R. All authors have read and agreed to the published version of the manuscript.

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