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# Assisted pollination by means of an electrostatic system in the production and quality of sweet cherries cv. 'Regina'

***Javier Sánchez-Contreras*[1], *Miguel Palma*[2], *José Antonio Yuri*[2,*]**

[1] Departamento de Ciencias Agrarias, Facultad de Ciencias Agrarias y Forestales, Universidad Católica del Maule, Curicó 3340000, Chile

[2] Centro de Pomáceas, Facultad de Ciencias Agrarias, Universidad de Talca, Talca 3460000, Chile

## ABSTRACT

Poor pollination limits the fruit set and productivity of self-incompatible cultivars of sweet cherry (*Prunus avium* L.). This study sought to evaluate the improvement in fruit production and quality from assisted pollination using an electrostatic system in a self-incompatible sweet cherry cultivar ('Regina') grown under rain protective covering in a commercial orchard located in the central valley of Chile. For this purpose, two treatments were evaluated: (1) traditional pollination and (2) assisted pollination. The results showed that assisted pollination increased fruit set from 14% to 20% compared with traditional pollination, but not the yield. Regarding fruit quality, fruit from trees with assisted pollination presented a more advanced maturity stage, while postharvest, maturity indicators maintained minor differences between the two treatments and values very similar to those at harvest. Assisted pollination seems to be a good tool to improve fruit set in sweet cherry trees 'Regina', especially when pollen delivery is deficient, for example, with the use of plastic covers.

**Keywords:** bloom, cherry orchard, crop load, fruit set, pollinators

## INTRODUCTION

Sweet cherry (*Prunus avium* L.) production is distributed in cold temperate climate zones. Its fruit is highly demanded for its appreciated organoleptic characteristics. In terms of exported production, the principal country is Chile, with a planted area of more than 70000 ha and 414000 t exported by 2024 (CIREN-ODEPA, 2024).

Pollination, which is the process of transferring pollen from the anther to the stigma, plays a significant role in the productivity of any crop. Optimal pollination leads to high fertilisation and fruit set, favouring adequate yield and quality at harvest (Koumanov and Long, 2017). In sweet cherry trees, most cultivars require cross-fertilisation to obtain fruits, given by certain gametophytic incompatibility between them (Herrero et al., 2017), with the fruit set of self-incompatible cultivars generally lower than that of self-fertile ones (Sutyemez, 2011). In Chile, the main self-incompatible cultivar planted is 'Regina', given its good yield and fruit size, and high tolerance to cracking. It occupies a niche in late production with plantations towards the south-central area of the country.

The honeybee (*Apis mellifera* L.) is the pollinator most used in sweet cherry orchards, and recently there has been a worrying decline in its population due to diseases, adverse weather conditions and irrational use of agrochemicals (Flores et al., 2019; Vercelli et al., 2021). Sweet cherry flowering occurs early in spring,

*Corresponding author.
e-mail: ayuri@utalca.cl (José Antonio Yuri).

making it highly sensitive to extreme weather events. The use of strategies to delay flowering is effective in preventing frost damage (Xu et al., 2023; Yuri et al., 2023). Furthermore, the use of plastic covers to protect sweet cherry trees from rain and hail during flowering and before harvest has increased among producers. However, these structures also increase the canopy temperature and decrease solar radiation to trees, which can hinder bee flight and cause flower malformations, thus affecting fertilisation and fruit set (Zhang et al., 2018; Rojas et al., 2021).

Given these problems, it is crucial to have technologies and tools available to mitigate these effects for optimal fruit yield and quality. Assisted pollination is a tool used in several species and allows the efficiency of pollination to increase in the orchard (Khatawkar et al., 2021). Among the implemented methods, there are diffusers, mechanical sprayers, atomisers and electrostatic dusters (Pinillos and Cuevas, 2008; Koumanov and Long, 2017). The use of aerodynamic electrostatic systems allows direct spraying of pollen to flowers, generating an ionised electric field, which increases the probability that pollen grains reach the floral stigma (Law et al., 2000; Vaknin et al., 2000). This procedure has been shown to be beneficial for fruit set and yield in fruit species such as date, almond, pistachio and kiwifruit (Bechar et al., 1999; Gan-Mor et al., 2003). However, its effectiveness is still debated in certain crops (Pinillos and Cuevas, 2008).

This study aimed to evaluate the efficacy of assisted pollination using an electrostatic system on the production and fruit quality of 'Regina' sweet cherry trees grown under rain protective coverings in the central valley of Chile.

## MATERIALS AND METHODS

### *Plant material and experimental site*

The study was carried out in a commercial orchard located in San Clemente, Chile (35°32′ S, 71°27′ W, 232 m a.s.l.) during the growing season 2019/2020. Four-year-old sweet cherry trees of (*P. avium* L.) 'Regina' cultivar grafted on GiSelA-6 rootstock were evaluated. The trees were trained with a central leader system, spacing at 4.0 m × 1.8 m (1388 trees · ha$^{-1}$). The pollinator used was 'Skeena', arranged in complete rows with a 20% proportion. The location is characterised by a Mediterranean climate with hot, dry summers and rainfall concentrated between May and August. During the study year, 418 mm of rainfall and 74 chilling portions (CP) (Fishman et al., 1987) were recorded. The daily maximum temperature in September and October was 25°C and 26°C, while the daily minimum temperature was –1.6°C and –1.0°C, respectively. The climatic conditions during the periods of bloom to fruit set are resume in Figure 1.

Nutritional and phytosanitary management of the orchard was conventional and applied according to the crop needs. Drip irrigation was used, with two lines per row and four emitters per plant of 5.3 L · hr$^{-1}$ of flow.

### *Treatments*

The experimental design included two treatments: (1) traditional pollination (control), which received pollen by 10 honeybee hives · ha$^{-1}$ and (2) assisted pollination, which received pollen by 10 honeybee hives · ha$^{-1}$ plus two applications of 40 g · ha$^{-1}$ of pollen from the self-compatible cultivar 'Lapins' (Polen Chile™, Graneros, Chile), carried out with 60% and 75% of flowers open.

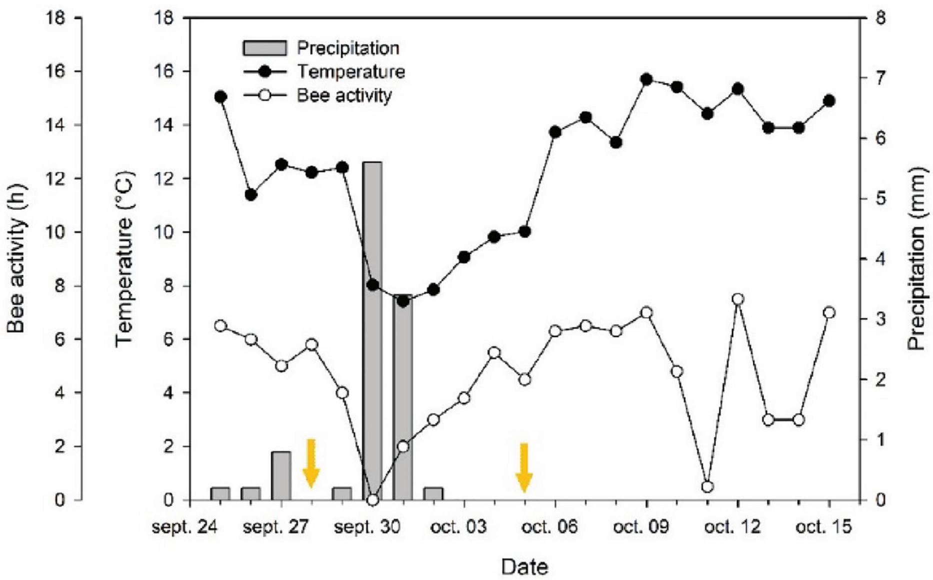


**Figure 1.** Mean daily air temperature (°C), bee activity (hours with air temperature >15°C and solar radiation >300 W · m$^{-2}$) and precipitation (mm) during the bloom periods of a fruit set of cv. 'Regina' established in San Clemente, Chile. Yellow arrow: dates of assisted pollination.

Assisted pollination was performed with a V-Trellis Orchard electrostatic sprayer (On Target Spray Systems, Mt. Angel, OR, USA) at a slow and steady rate, uniformly covering the entire trees (Figure 2A). To protect sweet cherry trees from rain during flowering, plastic covers were installed throughout the period in both treatments. All evaluations come from a 3.8 ha 'trial block' within the orchard. Both treatments were harvested at the same time.

### *Evaluations*

Fruit set and retention (%) were randomly evaluated on 30 spurs per treatment (three per tree) with at least 15 flowers per each (Figure 2B). The percentage of fruit set was determined by counting the number of fruits formed during the first 25 days after full bloom in relation to the total number of flowers per spur. The percentage of retention was determined as the number of fruits that reach harvest in relation to the number of fruits formed. Spurs were selected in the early spring before flowering. The yield (kg · tree$^{-1}$) was recorded from individual trees located in the centre of the rows, with three replicates per treatment.

The quality and condition parameters of the fruit were evaluated at harvest (20 December 2019) in a sample of 60 fruits per treatment. Individual fruit weight (g) was measured using an analytical balance (Precisa, Wedderburn Scientific Scales, Switzerland) and diameter (mm) was measured using a digital vernier calliper in the equatorial zone of the fruit (CALDI-6MP, Truper, Mexico). The colour was visually determined using a scale (light red = 1, red = 2, mahogany red = 3, dark mahogany = 4 and black = 5). Firmness (g · mm$^{-1}$) was estimated using a FirmTech II (BioWorks, Inc., Wamego, KS, USA). Subsequently, 6 replicates of 10 fruits were taken to determine the soluble solid content (SSC;°Brix) with a digital handheld refractometer (PAL-1, Atago, Tokyo, Japan).

Furthermore, a 5 kg sample of fruit per treatment was packed in modified atmosphere packaging (MAP, Packlife Containers, Santiago, Chile) and stored in regular air chambers (0 ± 1°C/85%–90% relative humidity (RH)) for 30 days to determine weight, diameter, colour, firmness and SSC as described above.

### *Statistical analysis*

Data were subjected to an one-way analysis of variance. Means between treatments were compared with the Tukey test ($p \leq 0.05$). Statistical analysis was performed with Statgraphics version 18-X64 (Warrenton, VA, USA).

## RESULTS AND DISCUSSION

Pollen availability, synchrony and proximity of the pollinator to the cultivar gain special relevance for fruit set in sweet cherry cultivars with some degree of self-incompatibility (Sagredo et al., 2017). A study in cv. 'Regina' sweet cherry trees showed a decrease of up to 50% in fruit production when trees were within 10 m of the pollinator relative to those immediately adjacent to the pollinator within the row (Núñez-Elisea et al., 2008). The implementation of electrostatic pollination increased pollen deposition on the flower stigma (Law et al., 2000). However, the effectiveness of this technique on fruit set depends on the species and the climatic conditions (Broussard et al., 2023).

Fruit set in sweet cherry trees is generally low compared to other crops, and it depends on both the cultivar and the rootstock. Dwarfing rootstocks not only promote greater flower production per spur than vigorous ones, but also favour earlier flowering (Dziedzic et al., 2019). The level of the fruit set obtained in traditional pollination (14%) was considered a medium level according to Chilean producers (low 8%–10%; medium 15%–20%; high 34%–40%) (C. Tapia, personal communication). Assisted pollination increased fruit set by 40% compared with traditional pollination (Table 1). Also, fruit retention increased by 3%, although no statistical differences between treatments. Fruit set increase with assisted pollination resulted in a higher fruit weight per tree, which translated into an average yield increase of 3 t · ha$^{-1}$, without significant differences with traditional pollination. However, it should be considered that 3 t would be equivalent to the total management cost per hectare, considering the current returns received by local producers (US$ 6 · kg$^{-1}$).

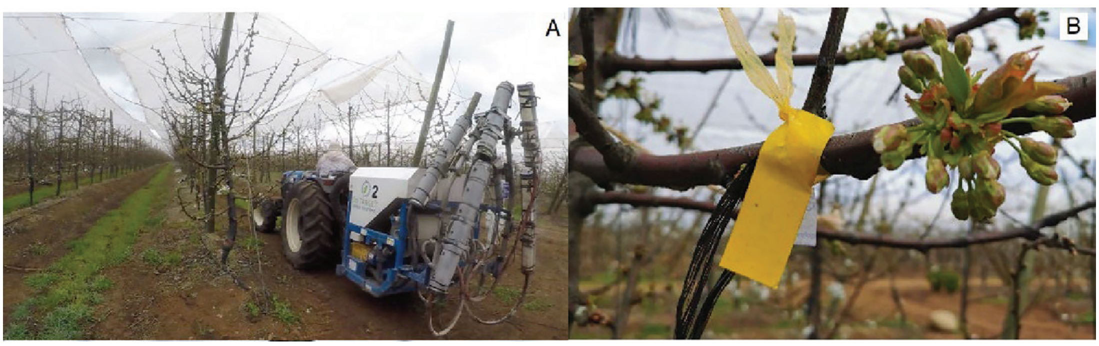


**Figure 2.** (A) Assisted pollination during blooming in an orchard of 'Regina' sweet cherry trees under plastic cover. (B) Experimental unit of plant material.

**Table 1.** Fruit set, retention and yield in 'Regina' sweet cherries.

| Treatment | Total flowers | Fruit set (%) | Fruit retention (%) | Yield | |
|---|---|---|---|---|---|
| | | | | (kg · tree$^{-1}$) | (kg · ha$^{-1}$) |
| Traditional pollination | 567 | 14.1 ± 5.9 b | 50.9 ± 29.6 a | 11.1 ± 4.9 a | 15424 ± 3229 a |
| Assisted pollination | 455 | 19.9 ± 6.0 a | 52.6 ± 24.8 a | 13.3 ± 2.3 a | 18479 ± 6830 a |

Means ± standard deviation in a column followed by the same letter do not differ statistically according to the Tukey test ($p \leq 0.05$), ($n = 20$).

**Table 2.** Fruit quality in sweet cherries 'Regina' at harvest and after 30 days of cold storage (0 ± 1°C/85%–90% RH).

| Period | Treatment | Weight (g) | Diameter (mm) | Colour (1–5) | Firmness (g · mm$^{-1}$) | SSC (Brix) |
|---|---|---|---|---|---|---|
| Harvest | Traditional pollination | 12.4 ± 1.5 a | 28.1 ± 1.3 a | 4.0 ± 0.0 b | 285 ± 38 a | 19.1 ± 0.6 b |
| | Assisted pollination | 11.7 ± 1.5 b | 28.2 ± 1.4 a | 4.4 ± 0.5 a | 262 ± 36 b | 20.4 ± 0.7 a |
| 30 days MAP | Traditional pollination | 11.8 ± 1.3 a | 28.4 ± 1.2 a | 4.1 ± 0.4 a | 322 ± 63 b | 19.1 ± 0.6 a |
| | Assisted pollination | 11.7 ± 1.3 a | 28.0 ± 1.2 a | 4.1 ± 0.4 a | 355 ± 46 a | 20.5 ± 0.9 a |

Means ± standard deviation in a column followed by the same letter do not differ statistically according to the Tukey test ($p \leq 0.05$), ($n = 120$).
MAP, modified atmosphere packaging; SSC, soluble solid content.

Electrostatically assisted pollination has proven to be favourable in the yields of almonds (*Prunus dulcis* Mill.) and pistachios (*Pistacia vera* L.), with an increase of 13% and 11%, respectively, compared with traditional pollination (Vaknin et al., 2001a, 2001b). Castro et al. (2021) reported a little difference between traditional and assisted pollinations for kiwifruits (*Actinidia deliciosa*), the latter being only relevant in areas where pollinators are limiting, as in large orchards in New Zealand. In apples (*Malus domestica* Borkh.), the assisted pollination showed an increase in fruit set of between 56% and 76% compared with natural pollination, while in sweet cherries the increase was 15% (Hansen, 2015; Whiting et al., 2022).

Optimal cold accumulation during dormancy promotes adequate bud break and abundant and concentrated flowering in sweet cherry trees. The accumulation of CP during the study season was 74, nearly to the level requirement for 'Regina' (82 CP) (Campoy et al., 2019). The weather conditions during flowering were favourable for both bee flight and fruit set, with only 1 day without bee activity due to rainfall (Figure 1). In sweet cherry trees, temperature strongly affects pistil viability and fruit set. The stigmas are vulnerable to high temperatures, resulting in a short period of stigmatic receptivity; it can last 5 days at 10°C, while at 20°C it is reduced to 2 days. Furthermore, a slight increase in temperature during the pollination to fertilisation phase can result in a higher proportion of flowers with both degenerate ovules, decreasing the fruit set (Hedhly et al., 2007; Herrero et al., 2017; Zhang et al., 2018).

Studies in apple trees showed that when the climatic conditions were unfavourable for blooming, electrostatic pollination did not increase the fruit set. Instead, when climatic conditions were favourable, assisted pollination increased fruit set by up to 25% compared with traditional pollination (Williams and Legge, 1979). The use of plastic covers on sweet cherry trees has shown a negative effect on the flight of honeybees due to a decrease in UVB radiation, which disorients them (Blanke et al., 2017). In this study, assisted pollination may have compensated for the reduced flight of bees under plastic covers, which was reflected in increased fruit set (Table 1).

Regarding fruit quality at harvest, in this study, sweet cherries showed a slight maturity advance in assisted pollination treatment, maintaining a higher SSC after 30 days of cold storage (Table 2). Regarding the size of the fruit, there were no significant differences in the diameter of the fruit with treatment, but there was a significant difference in the weight of the fruit at harvest, although to a magnitude that was not commercially relevant. Although assisted pollination could increase fruit size in certain crops, due to a better fertilisation of the ovules (Pinillos and Cuevas, 2008), there are no studies that show such improvement in sweet cherry trees.

## CONCLUSIONS

Assisted pollination in sweet cherry cv. 'Regina' grown under rain protective covering showed higher fruit set, although without statistical differences in yield compared with traditional pollination. Maturity indicators showed a slight advance in the treatment with assisted pollination, and during postharvest, continued to show minimal differences between treatments, with values very similar to those at harvest.

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## AUTHOR CONTRIBUTIONS

J.A.Y. designed experiments and performed analytical measurements. J.S-C. and M.P. equally contributed to the manuscript writing.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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