# Chilling Unit Accumulation and Degree-Day Requirements of Four Sweet Cherry (*Prunus avium* L.) Cultivars

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**Abstract**

**Sweet cherry requires a period of low temperatures (chilling hours accumulation) to break dormancy and warm temperatures (degree-days accumulation) for bud break, tree development and fruit production. Research was carried out to establish local chilling hour and degree-day requirements for various stages of reproductive development for the main cultivars planted in the Los Antiguos valley, located in the province of Santa Cruz in Southern Patagonia, Argentina (71°38' W, 46°32' S). Three methods were used for chilling calculations over six years to obtain the number of hours at or below 7°C, and to estimate weighted chilling units (CU), determined for the period from bud differentiation stage (February 15th) until July 15th, when CU accumulation was completed to release trees from endodormancy. The average values were: 1,615 hours at or below 7°C and 1,550 CU, respectively. Simple phenological models were developed for 'Bing', 'Van', 'Lapins' and 'Sweetheart' for eight phenological stages: swollen bud, visible flower bud, white tip, first bloom, full bloom, petal fall, fruit set and harvest. Data were transformed to cumulative degree-days (CDD), calculated as mean daily air temperature (T) minus a base temperature (T0) of 4.5°C (CDD =Σ (T - T0)) after swollen bud (SB) stage. The methods compared for degree-day calculation were 1) High/low method, 2) Integration method (both calculated with a Vantage Pro2 weather station), and 3) manual calculation of temperatures obtained every half hour from data loggers located at the experimental sites. No differences were found between methods (P>0.05) and CDD average at harvest varied from 765 for 'Van' to 916 for 'Sweetheart'.**

## INTRODUCTION

Typical of tree fruit species in temperate regions, sweet cherry (*Prunus avium* L.) requires a period of low temperatures to break dormancy and a period of degree-days (heat) accumulation for tree development and fruit production. A combination of chilling and degree-days tends to provide better predictions of bud break and leaf development (Kramer, 1996), although the length of the period of low temperatures and the optimum temperatures depend on the species and cultivar.

Very little is known about the chilling requirement of sweet cherry and the optimum chilling temperature (Mahmood et al., 2000) and different methods have been used to calculate chilling hour accumulations. Bargioni (1996) mentioned that most sweet cherry cultivars need between 1,050 and 1,900 h at or below 7°C to satisfy their dormancy. Seif and Gruppe (1985) used the method proposed by Norvell and Moore (1982) to calculate chilling unit (CU) requirements of sweet cherry and inter-specific cherry hybrids. Mahmood et al. (2000) showed a curvilinear relationship between the proportion of bud break, chilling temperature and chilling duration, and they found that the optimum temperatures for satisfying chilling requirements were between 3.2 and 3.7°C, depending on the cultivar, for 'Stella', 'Summit' and 'Sunburst'. At these temperatures, between 1,081 and 1,214 h were needed to break dormancy (when 50% of the buds were at the green tip stage). In another study, bud dormancy was completed in most cultivars after 1,200 h accumulation at 6°C (Cortés and Gratacós, 2008).

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Degree-day is a unit that expresses the integral over time (days) of the difference between the air temperature (°C) and a certain threshold or base temperature (T0). T0 is the temperature from which plant development is practically proportional to the difference between air temperature (T) and T0. This base temperature is not always fixed and it can change according to different developmental stages (Goudriaan and Van Laar, 1994). In sour cherry, Eisensmith et al. (1980) found that a base temperature of 4°C was appropriate to calculate degree-days accumulation, while Iezzoni (1985) used 4.5°C to predict bloom development.

The objectives of this research were to establish local chilling hour accumulations and determine the degree-day requirements for various stages of reproductive growth, and to compare different methods of degree day calculation, for the main sweet cherry cultivars planted in the Los Antiguos valley, province of Santa Cruz in Southern Patagonia, Argentina.

## MATERIALS AND METHODS

The research was conducted during four seasons, in several commercial orchards planted with 'Bing', 'Van', 'Lapins' and 'Sweetheart' sweet cherry in Los Antiguos valley, in the Argentinean Patagonia (46°32'S, 71°38'W). Routine horticultural practices for commercial fruit production were provided, including irrigation, fertilization, wind protection, weed, pest and disease control, and winter pruning. Therefore, growing conditions were considered optimal and were not a factor considered in the experiment.

### Chilling Units

During each season, temperatures were recorded with thermometers to quantify chilling hours below 7°C (Bargioni, 1996), and for calculating chilling units (CU) using the method of Norvell and Moore (1982). CU were derived from the number of hours of exposure to a given range of effective chilling temperatures in the winter season, where one chill unit is equal to one hour of exposure between 2.5 and 9.2°C and the chilling contribution becomes less as the temperatures rise above or fall below this threshold. A factor was assigned for each range as follows: 1 to <2.5°C and 9.2 <12.5°C = 0.5; 2.5 to <9.2°C = 1.0; 12.5 to <16 = 0.0; 16 to 18°C = -0.5 and >18°C = -1.0. Chilling accumulation was considered from February 15$^{th}$ (after bud differentiation stage and at the moment from which temperatures were within the range considered effective for chill accumulation), until July 15$^{th}$, when, according to experiences carried out in other areas of south Patagonia (Cittadini et al., 2006), chilling requirements were fulfilled and temperatures fall within the range of null chill accumulation.

### Degree-Days

During six years, simple phenological models were developed for 'Bing', 'Van' and 'Lapins', and during two years for 'Sweetheart', considering eight phenological stages to describe the initiation of leaf growth and flowering of sweet cherry as presented by Wertheim (1976): swollen bud, visible flower bud, white tip, first bloom (visible stamen), full bloom (80% open flowers), petal fall, fruit set and harvest. Four different orchards and three trees per cultivar and per site were considered. Data were transformed to cumulative degree-days (CDD), calculated as the mean daily air temperature (T) minus a base temperature (T0) of 4.5°C (Iezzoni, 1985) (CDD =Σ (T - T0)) from swollen bud (SB) stage (for practical reasons). Three methods were compared for degree-day calculation: High/low method, Integration method (both calculated with a Vantage Pro2 weather station, of INTA) and manual data calculation of temperatures obtained every half hour from data loggers located at the experimental sites. The software for the High/low method uses the highest temperature and the lowest temperature for a given day to calculate the average temperature for that day. The difference between the average temperature and the base threshold is assumed to be the number of degree-days accumulated on that day. The software for the Integration method calculates degree-days

using the average temperature for an interval and the interval time. The number of degree-days during each interval is added together to calculate total degree-days.

ANOVA and Tukey's tests, at a significance level of 5%, were used to evaluate both parameters and to compare the methods using InfoStat/2008 (InfoStat version 2008. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina). Means and standard deviations (SD) are presented.

## RESULTS AND DISCUSSION

### Chilling Units

After analyzing the temperature conditions of the valley, it was concluded that the chilling requirements of sweet cherries were easily satisfied every year. No differences were found between the two methods compared, Chilling hours below 7°C and Chilling units (CU), (P= 0.53) or between years (P= 0.29), so average values for the four years were considered. Mean hours below 7°C temperature were 1,615 (SD: 161) and CU were 1,550 (SD: 118) (Table 1).

According to previous research, the mean chilling requirements usually varied from 733 to 1,340 h below 7°C and 1,101 to 1,482 CU for *Prunus avium* cultivars grafted onto Mazzard, with high coefficients of variation between years (11 to 30%) if using hours below 7°C (Seif and Gruppe, 1985). This annual variation in chilling requirements for cherry cultivars may be explained by interactions between genotype and weather variations, as the response to a given temperature would depend on the physiological state of the tissue and previous environmental conditions (Cortés and Gratacós, 2008). Consequently, similar temperatures may have different activities at different times during dormancy and could explain different annual bud break responses (Perry, 1971; Felker and Robitaille, 1985; Mahmood et al., 2000). In our research, coefficients of variation for chilling accumulation between years were low (7.6 to 10%) for every method considered, but chilling requirements were not determined.

### Degree-Days

No significant differences were found (Table 2), when comparing the three methods of CDD calculation, for 'Bing', 'Van', 'Lapins', and 'Sweetheart' at the various phenological reproductive development stages, from swollen bud (SB) stage. The mean CDD at harvest varied from 805 (SD=75) for 'Bing' and 765 (SD=66) for 'Van', to 852 (SD=64) for 'Lapins' and 916 (SD=88) for 'Sweetheart'.

In previous research in South Patagonia, bloom and post-bloom stages for sweet cherry coincided with the accumulation of 288 to 326 CDD and fruit maturity coincided with more than 1,000 CDD, considering accumulation after July 15$^{th}$ (Cittadini et al., 2006). Also, 175 CDD (base temperature = 4°C) were needed to start leaf area development after satisfying the chilling requirements and 1,064 CDD to reach maximum leaf area development. However, the CDD accumulation for different phenological stages was cultivar-specific (Cittadini, 2002).

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## Tables

Table 1. Mean chilling hours below 7°C (CH) and chilling units (CU) accumulated from February 15th (after bud differentiation stage) until July 15th in Los Antiguos valley, Argentina.

| Year | Method | Mean |
|---|---|---|
| 2002 | CH | 1,780 |
| | CU | 1,513 |
| 2004 | CH | 1,493 |
| | CU | 1,654 |
| 2006 | CH | 1,727 |
| | CU | 1,633 |
| 2007 | CH | 1,462 |
| | CU | 1,400 |

Table 2. Mean[1] cumulative degree-days (T0 = 4.5°C [Iezzoni, 1985]) from Swollen bud (SB) to the beginning of each phenological stage for 'Bing', 'Van', 'Lapins', and 'Sweetheart' sweet cherries, using the 3 calculation methods. Phenological stages were: first bloom (visible stamen, CB), full bloom (80% open flowers, FB), petal fall (PF), fruit set (F) and harvest (H).

| | | CB | FB | PF | F | H |
|---|---|---|---|---|---|---|
| | Method | Mean | Mean | Mean | Mean | Mean |
| 'Bing' | High/low | 108 a | 124 a | 176 a | 206 a | 826 a |
| | Integration | 105 a | 122 a | 178 a | 208 a | 853 a |
| | Manual data | 110 a | 128 a | 189 a | 216 a | 845 a |
| 'Van' | High/low | 99 a | 118 a | 170 a | 204 a | 806 a |
| | Integration | 96 a | 114 a | 172 a | 208 a | 824 a |
| | Manual data | 101 a | 120 a | 180 a | 212 a | 835 a |
| 'Lapins' | High/low | 81 a | 109 a | 169 a | 198 a | 856 a |
| | Integration | 82 a | 109 a | 174 a | 204 a | 870 a |
| | Manual data | 87 a | 116 a | 185 a | 210 a | 878 a |
| 'Sweetheart' | High/low | 101 a | 113 a | 158 a | 211 a | 888 a |
| | Integration | 112 a | 127 a | 183 a | 228 a | 900 a |
| | Manual data | 113 a | 130 a | 189 a | 235 a | 1,001 a |

[1] Averages of the observations during the season 2007.
Note: different letters within a single row indicate significant differences ($P<0.05$).