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Chilling and heat requirements of sweet cherry cultivars and the relationship between altitude and the probability of satisfying the chill requirements

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Abstract

Sweet cherry cultivars have different chilling and heat requirements for breaking rest and flowering. The knowledge of these requirements may be valuable in the selection of the appropriate cultivars for producers and to avoid losses caused by an inadequate cultivar selection in a particular area. Determination of chilling and heat requirements is also important within a breeding programme, when choosing parents to obtain early flowering cultivars. Chilling requirements of seven cherry cultivars growing in south-eastern Spain were calculated using different methods (hours below 7 °C, Utah and Dynamic model), which were compared. Recording hourly average temperatures at several locations during 2 years, the Utah and Dynamic models performed better than hours below 7 °C. Different chilling requirements and slight differences in heat requirements were observed in the studied cultivars. 'Cristobalina' and 'Brooks', the earlier-flowering cultivars, were those with the lowest chilling requirements. 'Burlat', 'New Star' and 'Somerset' had medium chilling and heat requirements for flowering, and 'Marvin' showed the highest values and also the latest blooming date. All the studied cultivars may have their chilling requirements satisfied in the region of Murcia, if grown at least 650 m above sea level. Some cultivars, such as 'Cristobalina' and 'Brooks', could successfully break dormancy already when grown at an altitude above 325 m.

Keywords: Dormancy; Dynamic model; Flowering; GDH; Hours below 7°C model; *Prunus avium* L.; Utah model

1. Introduction

A specific knowledge of the influence of climatic conditions on the phenology of cultivated temperate fruits allows farmers to obtain an adequate productivity. Deciduous fruit trees and other woody perennials of temperate climates require a certain amount of winter chilling to overcome their dormancy. Once the chilling requirements have been satisfied, heat is also required to reach full bloom. The lack of chilling reduces vegetative growth and yield (Erez and Couvillon, 1987; Erez, 2000). Temperate fruits are grown in many different environmental conditions and studies concerning chilling and heat requirements of different cultivars are valuable tools to avoid incomplete breaking of dormancy or abnormal flowering.

Various models have been developed to measure the accumulation of winter chilling in deciduous fruit-growing areas: the Utah method (Richardson et al., 1974); low-requirements method (Gilreath and Buchanan, 1981); Aron method (Aron, 1983); Dynamic method (Erez et al., 1979a,b), etc. However, studies on heat requirements are fewer and the effects on flowering are not well known (Couvillon and Erez, 1985; Citadin et al., 2001; Gariglio et al., 2006).

Traditionally, hours below 7 °C or chilling hours (CH) have been used as the measure of chilling for fruit trees (Weinberger, 1950). The Utah model, proposed by Richardson et al. (1974), is used particularly in cooler areas of temperate zones (Dennis, 2003). This method quantifies the degree of accumulated chilling in chill units (CU). Positive and negative hourly values are accumulated at different rates for each temperature range. Then, net values are added to obtain a specific CU accumulation (Richardson et al., 1974). According to this method, the initial date for CU calculation begins when chilling is consistent and high temperatures are rare (Erez et al., 1979a).

The Dynamic model was proposed by Erez and Couvillon (1987) and was developed for warmer areas than the Utah model. Breakage of dormancy occurs in two steps, the first being

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reversible and the second irreversible, and chilling requirements are calculated as chilling portions (CP). As for the Utah model, temperatures have different effects on dormancy. There is also a negative influence of high temperatures, but temperature ranges differ in the two models.

Like other temperate fruits, sweet cherry has chilling and heat requirements for flowering. In recent years, many new sweet cherry cultivars have been released and grown in different environmental conditions. Some of them are early flowering, which is a desirable character in Mediterranean areas to obtain early yield. Although the south-east of Spain is an important fruit-producing area, sweet cherry is not a traditional fruit crop in the region of Murcia. However, nothing prevents this species from being cultivated in different areas of Murcia with excellent results, if appropriate varieties are chosen.

Little is known about the chilling requirements of sweet cherry. Tabuenca (1983) determined the chilling requirements of some sweet cherry cultivars growing in Zaragoza (Spain), calculated as hours below 7 °C. Mahmood et al. (2000) studied the chilling requirements of three medium-late-ripening sweet cherry cultivars, estimating the chilling needs for each one. However, as far as we know, heat requirements have not been studied in this species.

A consistent and predictable winter chilling accumulation in a particular area is more desirable than year-to-year variability. Knowledge of the chilling accumulation based on several years'

Table 1
Geographical characteristics and average chill units ± standard error, from data of 8–12 years in 42 weather stations in Murcia (south-eastern Spain)

No.	Station	County	Latitude	Longitude	Altitude (m)	Chill unit ± S.E.
1	AL31	Totana	37°43′59″N	1°30′43″W	296	1033 ± 74
2	AL41	Alhama	37°48′12″N	1°4′0″W	170	774 ± 36
3	AL51	Librilla	37°54′4″N	1°20′13″W	245	929 ± 64
4	AL62	Mazarrón	37°32′0″N	1°23′0″W	15	335 ± 48
5	CR12	Caravaca	38°2′0″N	1°75′0″W	880	1238 ± 42
6	CR32	Cehegin	38°3′0″N	1°40′0″W	624	903 ± 35
7	CR42	Moratalla	38°11′53″N	1°48′43″W	466	1158 ± 41
8	CR52	Cehegin	38°3′0″N	1°51′0″W	527	1086 ± 28
9	CA21	Murcia	37°50′13″N	1°7′41″W	120	904 ± 74
10	CA42	Fuente Alamo	37°45′0″N	1°7′41″W	90	843 ± 58
11	CA52	Cartagena	37°40′52″N	1°4′1″W	120	765 ± 74
12	CA72	Cartagena	37°37′48″N	0°54′58″W	70	794 ± 67
13	CA91	Fuente Alamo	37°41′56″N	1°14′17″W	175	794 ± 49
14	CI22	Abarán	38°14′1″N	1°18′21″W	270	867 ± 51
15	CI32	Ulea	38°11′28″N	1°15′14″W	306	995 ± 72
16	CI42	Cieza	38°16′79″N	1°27′79″W	241	889 ± 40
17	CI52	Calasparra	38°15′33″N	1°43′47″W	290	936 ± 23
18	JU12	Jumilla	38°23′40″N	1°25′30″W	360	1223 ± 34
19	JU42	Yecla	38°39′36″N	1°10′55″W	661	1323 ± 68
20	JU52	Yecla	38°33′45″N	1°6′15″W	690	1164 ± 37
21	JU61	Jumilla	38°28′0″N	1°19′0″W	525	987 ± 46
22	JU71	Jumilla	38°34′0″N	1°14′0″W	400	957 ± 34
23	JU81	Jumilla	38°20′0″N	1°19′0″W	420	989 ± 43
24	LO11	Lorca	37°36′11″N	1°37′1″W	330	1061 ± 72
25	LO21	Lorca	37°30′25″N	1°41′42″W	382	1172 ± 69
26	LO31	Aguilas	37°25′12″N	1°35′28″W	25	507 ± 57
27	LO41	Lorca	37°51′40″N	1°49′41″W	697	1298 ± 60
28	LO51	Aguilas	37°29′33″N	1°37′40″W	180	723 ± 60
29	LO61	Pto. Lumbreras	37°35′5″N	1°42′44″W	450	890 ± 32
30	MO12	Torres de Cotillas	38°0′50″N	1°17′20″W	169	830 ± 77
31	MO22	Molina Segura	38°7′2″N	1°11′57″W	150	765 ± 54
32	MO31	Molina Segura	38°4′0″N	1°14′0″W	180	791 ± 33
33	MO41	Abanilla	38°10′5″N	0°2′56″W	151	919 ± 100
34	MO51	Fortuna	38°9′58″N	1°8′53″W	240	839 ± 76
35	MO61	Ojos	38°7′41″N	1°19′52″W	195	652 ± 84
36	ML12	Yechar	38°0′0″N	1°3′0″W	320	876 ± 55
37	ML21	Mula	38°0′0″N	1°3′0″W	320	697 ± 81
38	MU21	Beniel	38°2′7″N	1°0′28″W	56	888 ± 78
39	MU31	Murcia	37°53′0″N	1°16′0″W	150	573 ± 78
40	MU52	Murcia	37°57′47″N	1°0′0″W	210	675 ± 52
41	MU62	Murcia	37°56′24″N	1°8′5″O	140	853 ± 90
42	TP81	Murcia	37°48′22″N	1°2′38″O	153	973 ± 87

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data would allow estimation of the probability of satisfying the chilling requirements of sweet cherry cultivars in a given area.

The main goals of this work were to calculate the chilling requirements for breaking the dormancy of seven sweet cherry cultivars, using different methods (the hours below 7 °C, Utah and Dynamic models), and to determine the heat requirements for flowering in south-eastern Spain. With the estimated chilling requirements and the knowledge of the chill accumulation profile in this region during the last 8–12 years, the probability of satisfying chill requirements in relation to the altitude was determined for the sweet cherry cultivars studied in this work. This information can be used to advise sweet cherry farmers about which cultivars are best suited to their area and which areas of our region are the most appropriate for sweet cherry production.

2. Materials and methods

2.1. Plant material

The sweet cherry cultivars assayed were ‘Cristobalina’ (Spain), ‘Brooks’, ‘Ruby’ and ‘Marvin’ (California, USA), ‘Burlat’ (France), ‘New Star’ (Canada) and ‘Somerset’ (New York, USA). The cultivars were chosen because they span the range of flowering time in sweet cherry. All of them were cultivated in Murcia (south-east Spain) under a Mediterranean climate. Most of the cultivars were grown in an experimental field located at Jumilla (see Table 1: station JU12 and Fig. 1), with the exception of ‘Cristobalina’, which was grown in a private orchard located at Abarán (see Table 1: station CI22 and Fig. 1). All trees were grafted on ‘SL-64’ (*Prunus mahaleb* L.) rootstock.

2.2. Determination of chilling and heat requirements

The chilling requirements necessary for breaking the dormancy of each cultivar were calculated in the field as CH (Weinberger, 1950), CU from the Utah method (Richardson et al., 1974) or CP from the Dynamic model (Erez and Couvillon, 1987).

Heat requirements were calculated as growing degree hours (GDH). GDHs are hourly average temperatures (°C) minus 4.5 °C, accumulated daily (Richardson et al., 1974). For each cultivar, heat requirements were calculated as the number of GDHs accumulated between the end of dormancy and the date when 50% of flowers were open (F^{50}). Both chilling and heat requirements were determined during two consecutive years (2004–2006).

Hourly temperatures were provided by ‘Servicio de Información Agraria de Murcia’ (S.I.A.M.; http://www.carm.es/cagr/cida/indexsiam.html). The meteorological stations were located in the experimental field (Jumilla station, code JU12, see Table 1) and very close to the private orchard (Abarán station, code CI22, see Table 1). Table 2 shows maximum and minimum monthly temperatures and rainfall during the autumn–winter season at the sampling sites.

The geographical characteristics of 42 meteorological stations distributed throughout the region of Murcia and the average CU (Utah method) for the data of 8–12 years ± standard error are shown in Table 1.

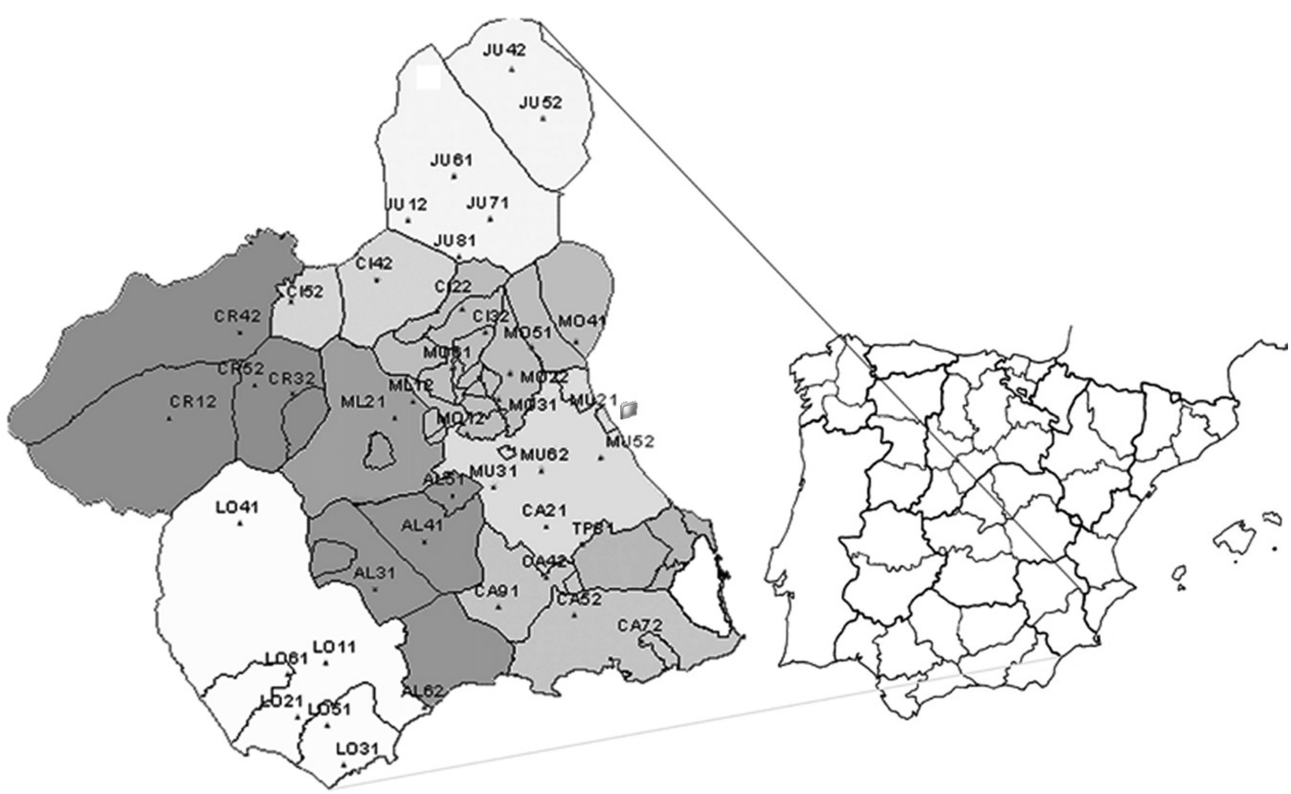

Fig. 1. The location of Murcia in Spain (latitude 38°45′ and 37°23′N; longitude 0°41′ and 2°21′W) and the meteorological stations distributed in the region.

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Table 2
Temperatures, rainfall and chilling calculated by three models at Jumilla and Abarán (Murcia)

Date	Temperature			Rainfall (mm)	Hours <7 °C	Method chill units	Portions
	Mean	Maximum	Minimum				
Jumilla							
November/2004	10.0	13.4	5.5	1.9	162	138	11
December/2004	8.7	14.3	4.5	20.7	199	441	20
January/2005	6.1	12.9	−1.9	1.4	445	386	20
February/2005	6.6	14.9	2.6	13.6	370	223	26
March/2005	11.0	17.0	1.9	7.3	188	0	14
Total					1364	1188	91
November/2005	10.0	15.8	5.2	15.9	186	152	14
December/2005	7.7	13.0	4.1	5.5	319	448	26
January/2006	6.6	10.6	−2.3	46.7	367	525	21
February/2006	8.2	12.6	4.8	12.6	251	226	12
March/2006	13.5	19.3	7.6	0.3	74	0	19
Total					1197	1351	92
Abarán							
November/2004	12.4	15.6	8.2	7.0	74	79	14
December/2004	10.5	15.8	5.8	41.8	104	373	21
January/2005	8.3	15.1	0.3	1.6	303	396	21
February/2005	8.6	18.2	3.8	20.9	262	206	19
March/2005	12.3	19.1	3.6	12.6	140	0	13
Total					883	1054	88
November/2005	12.0	18.8	7.9	26.6	79	138	14
December/2005	9.8	14.4	5.4	9.7	176	394	22
January/2006	8.3	11.8	0.7	46.0	225	496	18
February/2006	10.1	15.1	7.2	19.8	126	190	19
March/2006	15.3	20.5	8.8	0.8	26	0	11
Total					632	1218	84

Source: S.I.A.M. (http://siam.imida.es/).

With the data from all years, the probability that chilling requirements would be satisfied was calculated as the percentage of years with enough CU in each station to satisfy the chilling requirements of every cultivar studied. This probability was correlated with the altitude of each station.

2.3. Experimental design

During the 2 years of the study, four branches of each cultivar (30 cm length and 5 mm diameter, approximately) were collected periodically from different trees. The first sample was taken on December 15th and new branches were collected when approximately 100 additional CU had accumulated. Sample collection was more frequent (approximately every 50 CU accumulated) when the accumulated chill became close to the expected value (in most cases from the third collection) until the middle of February.

In the laboratory, the bases of the branches were placed in a 5% sucrose solution, in a growth chamber under controlled conditions ($24 \pm 1\,°C$, 55 $\mu mol\, m^{-2}\, s^{-1}$, under cool white fluorescent tubes, and 70% relative humidity). After 10 days in the growth chamber, the phenological stage of the flower buds was tested using the methodology proposed by Baggiolini (1952). The date for breaking of dormancy was established when 40–50% of flower buds were at the advanced Baggiolini stage B (showing petals, Fig. 2) or at the phenological growth stage 55 according to the international BBCH scale (Meier et al., 1994).

Additionally, the weight of the flower buds was recorded after 10 days in the growth chamber. Rest was considered finished when the weight of 20 flower buds increased by at least 20% compared with the previous sampling (Guerriero et al., 2002).

2.4. Statistical analysis

Chilling and heat requirements data (CH, CU, CP and GDHs) were subjected to analysis of variance (ANOVA), with cultivar, year and model as sources of variation to estimate chilling requirements. Means were separated by LSD (0.05). R^2 and the linear regression functions were employed to determine the most suitable model for chilling accumulation and the correlation between average CU (Utah model), over 8–12 years, and the altitude of the meteorological station. All analyses were performed with the SPSS software package v. 11.0 for Windows.

3. Results

Weather data and CH, CU or CP accumulation during two consecutive years at the experimental sites are presented in

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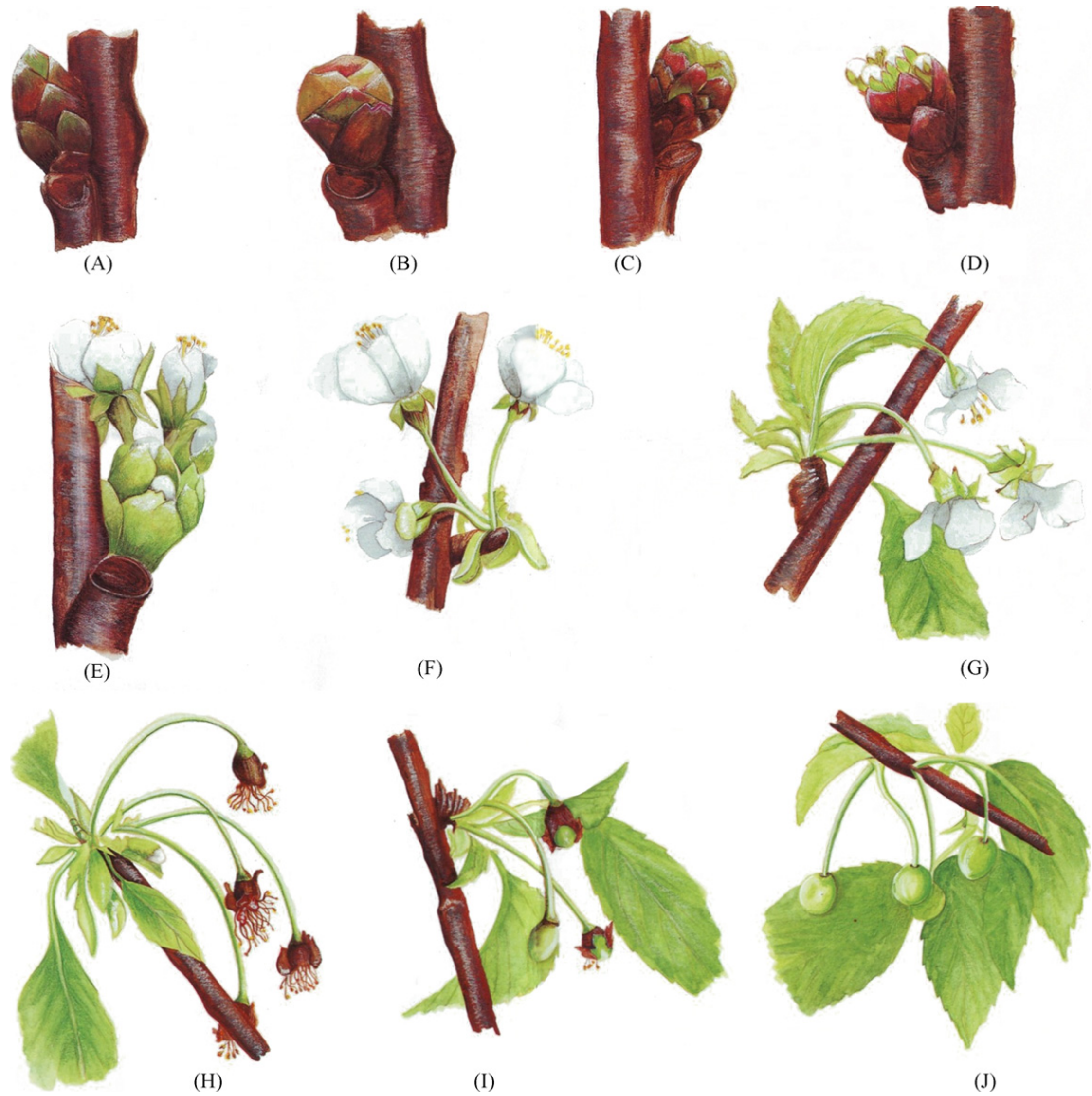

Fig. 2. Phenological growth stages during flowering of sweet cherry according to Baggiolini (1952). Modified from Lichou et al. (1990).

Table 2. The chilling accumulation period in Murcia begins in November, considering the first day of this period as the one after the last negative accumulation (Richardson et al., 1974). The Abarán station is at a lower altitude and is warmer than Jumilla, with less average chill accumulation, calculated from at least 8 years data and by different methods (Table 1). In accordance with this, the location had a strong influence on the accumulated chill during 2005 and 2006 ($P < 0.001$) while the year did not have any effect. Chilling values calculated by the three methods for the whole period studied differed ($P < 0.001$) (Table 2). The interactions model–year and model–location were significant ($P < 0.01$ and $P < 0.001$, respectively). These differences are mainly due to the results from the hours below 7 °C model, which varied greatly between years and locations.

The increase in flower bud fresh weight recorded during the first year of the experiment is shown in Fig. 3. The observed increase coincided with the point when more than 50% of the flower buds were at the advanced Baggiolini B stage, after 10 days at 24 °C for all cultivars with the exception of 'Ruby'. For this cultivar, an increase of flower bud weight was observed between 700 and 800 CU; however, only after 800 CU were accumulated, had more than 50% of the flower buds reached the B stage of Baggiolini.

Considering the increase in bud fresh weight and phenological observations after 10 days in the laboratory, under controlled conditions, differences in chilling requirements were not found between years, but there were large differences among cultivars ($P < 0.001$). The model and the interaction cultivar–model were also significant ($P < 0.001$). In the climatic conditions of Murcia, the chilling requirements ranged widely (Table 3). 'Cristobalina' was the first cultivar to break dormancy followed by 'Brooks', Burlat', 'Ruby' and 'Somerset' (with similar, medium chilling requirements) whereas the highest chilling requirements were observed for 'New Star' and 'Marvin'.

Correlations between different methods were calculated with the chilling requirement data. Statistical analysis indicated that the Utah and Portions models are well related (Fig. 4A) and differences between years were minor. However, the relationship

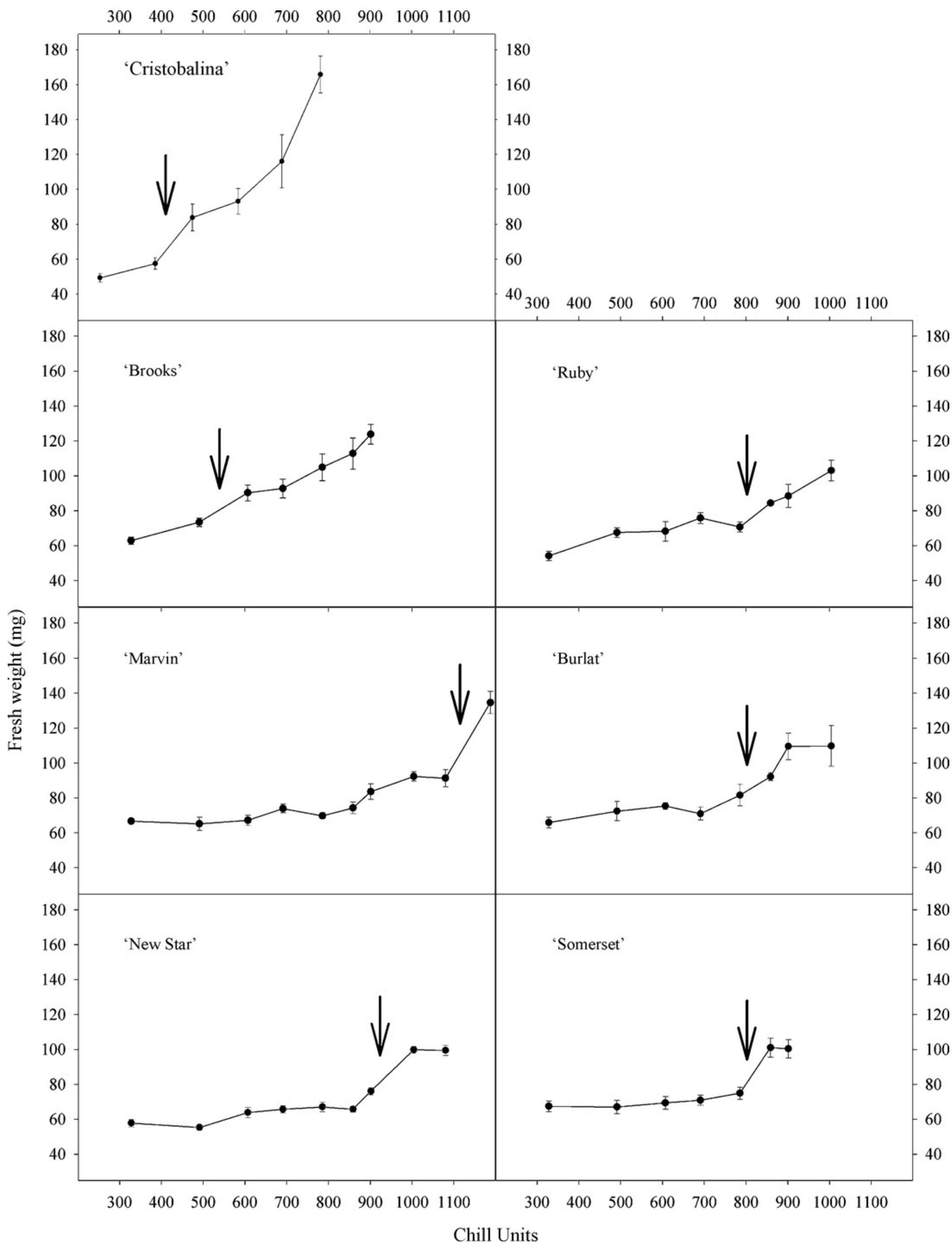

Fig. 3. Fresh weight evolution of flower buds of the sweet cherry cultivars 'Cristobalina', 'Brooks', 'Ruby', 'Marvin', 'Burlat', 'New Star' and 'Somerset', as a function of chilling accumulation (Utah model). Arrows indicate the break of dormancy. Bars represent the standard error.

between chilling requirements calculated as hours below 7 °C and the Utah or Portions models depended on the year (Fig. 4B and C).

Heat accumulation did not differ between years and a great similarity was observed among cultivars, with values in a range between 7326 and 9450 GDH (Table 3). Only 'Ruby' and 'Marvin', with low and high heat requirements, respectively, differed significantly from one another. Differences between years were observed for some cultivars, such as 'Cristobalina'.

There was a good correlation ($R^2 = 0.629$, linear regression function: $y = 700.29 + 0.71x$) between CU, accumulated at the 42 stations within the region of Murcia, during several years, and altitude for each station (Table 1).

Using the data for each cultivar, percentage of years with enough CU to break rest was plotted against altitude of the stations (Fig. 5). The graphs were then divided vertically into 3 zones, I, II and III, representing a high, medium and low variability of the probability to fulfil chilling requirements, respectively.

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Table 3
Blooming dates, chilling and heat requirements of seven sweet cherry cultivars, calculated at Abarán (Murcia) for 'Cristobalina' and at Jumilla (Murcia) for the rest of the cultivars

Cultivar	H < 7 °C	Chill units	Portions	GDH	Blooming date
Cristobalina	176.0 a	397.0 a	30.4 a	9195.0 ab	March 14th
Brooks	411.5 b	556.0 b	36.7 b	7863.2 ab	March 27th
Ruby	618.0 c	806.0 c	48.0 c	7326.2 a	March 29th
Somerset	618.0 c	806.0 c	48.0 c	8625.2 ab	April 3rd
Burlat	618.0 c	806.0 c	48.0 c	8750.2 ab	April 4th
New Star	709.5 cd	909.3 d	53.5 d	8257.0 ab	April 4th
Marvin	788.0 d	1001.5 e	57.6 e	9449.7 b	April 9th

Separation of cultivar means (lower-case letters) by the LSD test ($P \leq 0.05$). Data are averages of two consecutive years.

Table 4
Land area as a function of altitude in Murcia

Altitude (m)	Area (ha)	Percentage	Accumulated percentage
0–200	169,200	15	15
201–600	485,000	43	58
601–1000	364,100	32	90
1001–2000	113,000	10	100
>2000	0	0	100
	Total: 1131,300		

Source: Anuario Estadístico (http://www.carm.es/econet/publica/anuario/).

'Cristobalina' could be cultivated in almost every area of the region with the exception of those close to the sea, because the percentage of years in which its chilling requirements would be satisfied is 100% at more than 175 m above sea level (Fig. 5). With a very high probability, 'Brooks' would not have problems regarding the satisfaction of its chilling requirements above 325 m altitude. In our region, stations located above 450 m would be appropriate for 'Ruby', 'Somerset' and 'Burlat'. For 'New Star' and 'Marvin', the limiting altitudes are 550 and 650 m, respectively. The distribution of areas in Murcia according to altitude is recorded in Table 4. All cultivars studied here could be grown between 600 and 1000 m above sea level, where fulfilment of their chilling requirements would be guaranteed. This represents 32% of the total area of the region. Additionally, most cultivars could be grown at much lower altitudes (up to 200 m), representing 75% of the total area (Table 4).

4. Discussion

The Utah model has been used successfully in cool climates, whereas the Dynamic model seems to better indicate the response of some fruit trees to chilling in warmer and/or subtropical areas (Dennis, 2003). In this study, differences were not found between these two models when estimating the chilling requirements for seven sweet cherry cultivars in north-western Murcia. They were used to calculate approximate flowering dates, taking into account the cultivars' heat requirements. Mean temperatures during winter are moderate and negative chilling values, generated with the Utah model, are not important, which would explain the similarity to the results obtained with the

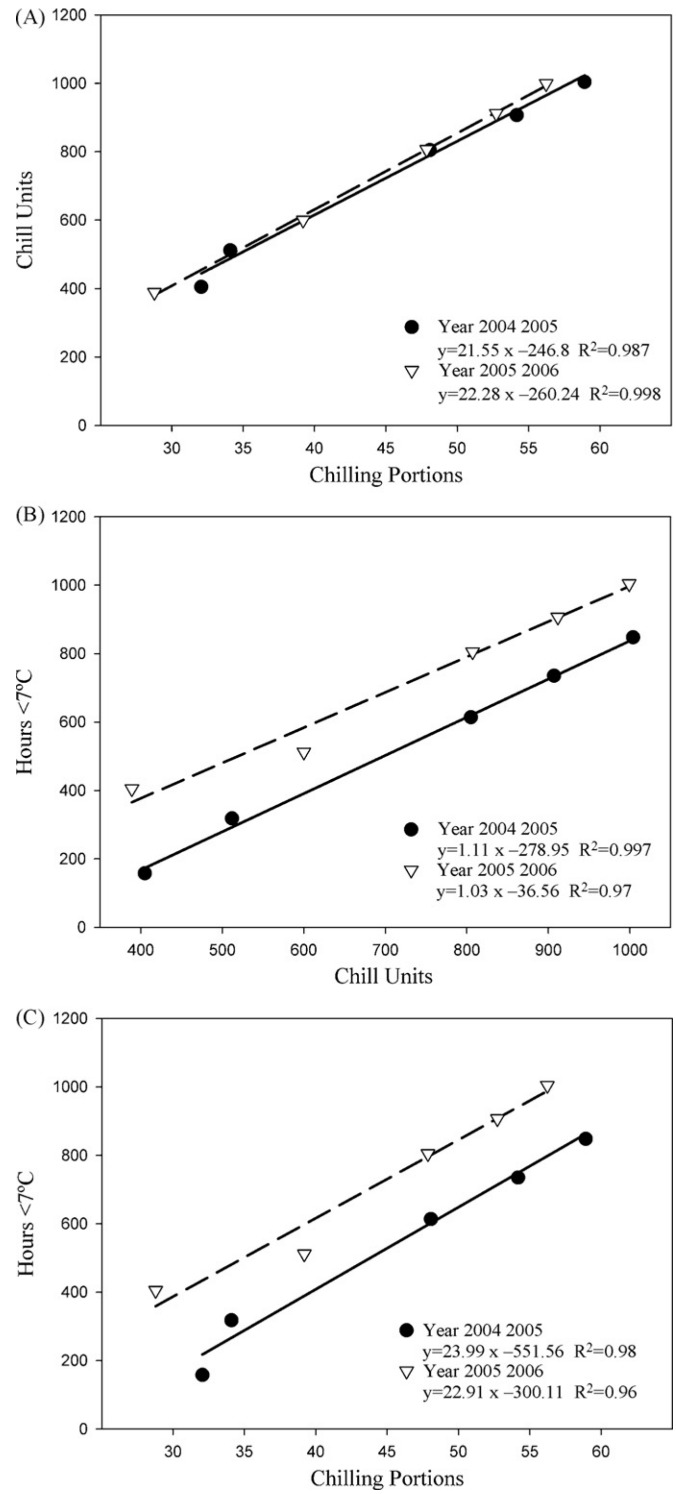

Fig. 4. Correlation between the chilling requirements of seven sweet cherry cultivars, calculated as chill units (Utah model), CP and hours below 7 °C.

Dynamic model. However, the results obtained with the hours below 7 °C model were not correlated with either the Dynamic or the Utah model, suggesting that this model is not appropriate for calculation of sweet cherry chilling requirements in our Mediterranean climatic conditions.

Most work on the determination of chilling requirements in sweet cherry has used the number of hours below 7 °C. It is

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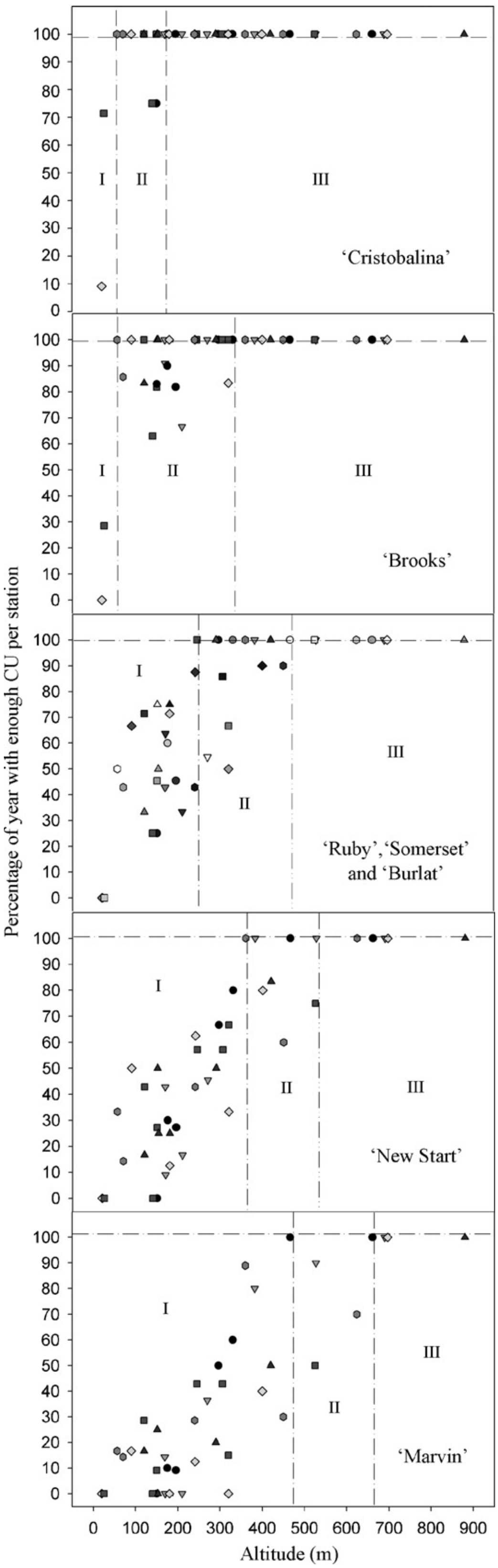

Fig. 5. Percentage of years that chilling requirement for sweet cherry cultivars were satisfied in relation to the altitude where each meteorological station is located, within the region of Murcia. The vertical, discontinuous lines separate three different zones, I, II and III, representing a high, medium and low variability of the probability to fulfil chilling requirements, respectively.

difficult to compare results obtained by different authors since many factors need to be considered, such as the choice of plant material, the criteria used to determine when rest is completed or the environmental conditions during the previous growing season (Dennis, 2003).

Tabuenca (1983) determined that the chilling requirements of the early flowering cultivar 'Cristobalina' were 500–550 h below 7 °C, whereas in this study a value of only 176 h was found for the same cultivar. Some authors have indicated that the Californian cultivars 'Brooks', 'Marvin' and 'Ruby' have low chilling requirements: 200–250 h below 7 °C (Marsall, 1990; Herraiz, 1992; Ballester, 1992). Accordingly, we have found that 'Brooks' had a low chilling requirement, estimated as CH, CU or CP. However, we found different results for 'Ruby' and 'Marvin', which required medium and high chilling accumulation, respectively, to break dormancy. Also, the requirements of the cultivars 'Ruby' and 'Marvin', among others, were estimated by the Utah method (Tersoglio et al., 2006) and the results are in agreement with our findings for these two cultivars. 'Ruby', with less than 950 CU, reached a normal budbreak and 'Marvin' needed more than 1000 CU. Erez (2000) reported that 'Burlat' had CP similar to those that we have estimated in our climatic conditions.

In general, the heat requirements for flowering of the cherry cultivars studied here were high (Table 3) compared with those calculated in other *Prunus* species such as almond (Egea et al., 2003; Alonso et al., 2005). In these studies, some almond cultivars had less than 6000 GDHs ('Desmayo Largueta', 'Constantini' or 'Pou de Felanitx'). A recent work estimated that heat requirements for ten apricot cultivars were under 5900 GDHs (Ruiz et al., 2007). Our data show a narrow range of heat requirements, with a slight increase in the case of the late-flowering cultivar 'Marvin'. Spiegel-Roy and Alston (1979) suggested that the chilling and heat requirements of pear (*Pyrus communis* L.) are closely related to the time of bloom. Chill and heat requirements were found to be interdependent processes (Couvillon and Erez, 1985) and an inverse relationship between the effects of chilling and heat accumulation on the blooming time of peach cultivars was found (Citadin et al., 2001). Greater chilling exposures lead to a reduction of heat requirements. In almond, heat requirements were found to be more important for regulation of blooming time than were chilling requirements in the cold climatic conditions of Zaragoza (north-east Spain), due to the early completion of chilling (Alonso et al., 2005). However, in south-east Spain, the flowering time of some almond cultivars was influenced more by chilling than by heat requirements (Egea et al., 2003). In agreement with this, our results suggest that differences in chilling requirements have a stronger influence on the blooming date than do heat requirements of sweet cherry cultivars, in our climatic conditions, and that the average blooming date of both years was earlier for cultivars with lower chilling requirements but not for those with lower heat requirements, whereas the latest-blooming cultivar needed the highest chill and heat accumulations to flower.

The results show a wide range of chilling requirements for breakage of rest for the cultivars studied, which could be grown successfully in specific areas of the region. This is sup-

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ported by the fact that yields per hectare of sweet cherry in the region of Murcia are well above average yields in other regions of Spain (M.A.P.A., 2003, http://www.mapa.es/es/estadistica/infoestad.html). Of great interest in Murcia are those cultivars with low or medium chilling requirements, which produce early harvests and fruits of high quality without the cracking problems, that are frequent in areas with abundant rains (Caprio and Quamme, 2006).

Accumulated chilling is affected by the local geography, especially the altitude in tropical and subtropical regions (Ou and Chen, 2000). Accordingly, we have found a positive relationship between chilling accumulation and altitude of different areas in our region. The probability of satisfying the chilling requirements at different altitudes has been determined using climatic information from several years. 'Cristobalina', 'Brooks', 'Ruby', 'Burlat' and 'Somerset' can be grown with a high probability of chilling requirement satisfaction in wide areas of our region. 'New Star' and, particularly, 'Marvin' should be grown only in the highest areas of our region, to avoid problems related to lack of chilling. This is confirmed by the fact that all cultivars growing in the experimental station, at 360 m above sea level, flower without problems, with the exception of 'Marvin' which frequently shows irregular blooming and yield. Knowledge of the relationship between altitude and chill accumulation in different areas of our region, or at other locations, is of great interest when deciding which sweet cherry cultivars to plant. Further work could involve estimation of the chill and heat requirements of more sweet cherry cultivars, to complete our knowledge of the adaptability of this species to areas where its culture has not been traditional.

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