Stability of the Almond Blooming Date in a Changing Climate

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Abstract

Although Global Warming is producing an increase of the medium air temperature with the progress of the years, this negative temperature trend cannot be yet appreciated in some areas, as shown by the analysis of the air temperatures observed in the Ebro Central Valley (Zaragoza, Spain) during the last 24 years, with drastic changes of temperatures during winters and spring, as well as a high variability between years. In these conditions there is an excess of chill offer and most almond cultivars satisfy their chilling requirements very early, during the first two weeks of December, when endodormancy finishes. As a consequence, blooming dates are ruled mainly by the heat requirements. Early blooming almond cultivars showed a higher variation for dates of full bloom because they are more dependent on warm temperatures during January and February, where heat accumulation is slower. Late blooming cultivars showed more stable blooming dates because have their high heat requirements are quickly satisfied by the higher temperatures during March. Cultivars with high cold and heat requirements are desirable for stable late blooming. This characteristic is essential in choosing the cultivars to be planted in a given region in relation to their climatic conditions, especially to avoid frost risks.

INTRODUCTION

Blooming date is considered dependent on the winter progression of temperatures affecting the different stages of dormancy (Lang et al., 1987). At dormancy onset, flower organogenesis is complete. During endodormancy, despite the low temperatures, bud growth is constant although hardly perceptible. After accumulating enough chilling, endodormancy concludes giving its way to ecodormancy. At this later stage, flower bud growth mostly depends on heat accumulation, so that bud growth speed increases considerably due to the usual warm temperatures (Kester and Gradziel, 1996). The end of ecodormancy is considered at full bloom (anthesis of 50% of the flowers) and referred as blooming date (Tabuenca et al, 1972).

Global Warming has produced an increase of the air temperatures during the last century, mainly in the last two decades. This temperature increase will continue and warming projections indicate that global surface temperature probably will further rise from 1.1 to 6.4°C during the twenty-first century if the measures taken for atmosphere protection are not enough to stop Global Warming (Hansen et al., 2006). Warming and related climatic changes, such as rain level and distribution, will vary from region to region around the globe, and projections for specific areas are very difficult because sharper changes are expected in the coming decades.

Climatic warming is expected to have an impact on some phenological sequences, advancing such stages as bud bursting, flowering and maturity, whereas the increase of the growing season will induce a delay of leaf fall in fruit trees. Consequently, the effect of the Global Warming raises a serious question for the evolution of dormancy in fruit trees. The variance observed among the years for the phenological sequences and for the agronomical performance of the different cultivars could provide valuable information on the adaptation ability to the new stressing conditions related to the Climatic Change.

The blooming behaviour of different almond cultivars in the Ebro Central Valley (Zaragoza, Spain) during different dormancy seasons was analysed in order to assess the influence of warm and cold winter seasons on blooming, as well as the behavior of cultivars with opposite chill and heat requirements in these seasons, mainly during the warmer seasons to consider the future scenario of Global Warming.

MATERIAL AND METHODS

Temperature trends of the last 24 years at Zaragoza (NE Spain) were assessed by linear regression of yearly averages of maximum, mean and minimum daily temperatures (T_M, T_m and T respectively). Data from years 1985 to 2008 were obtained from a meteorological station placed at the experimental station of the Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA de Aragón), located at 41º38'50” N and 0º53'07” W. Winter chill unit accumulation (Richardson et al., 1974) was assessed for every year to characterize the different dormancy seasons.

The data of blooming dates for the same years were collected for 44 almond cultivars from the Spanish National Almond Germplasm Collection managed in the same location (Espiau et al., 2002). These cultivars are from a wide geographical origin. For every cultivar, mean of blooming date and standard deviation were calculated for their linear regression analysis.

Finally, chill and heat requirements of these almond cultivars (Alonso et al, 2005) were related by linear regression with their mean blooming dates for these 24 years to establish the implication of both requirements in the determination of the blooming date.

RESULTS AND DISCUSSION

The analysis of the evolution of the air temperatures registered in the Ebro Central Valley (Zaragoza, Spain) during the last 24 years does not show any clear trend in temperature increase (Fig. 1). The Mediterranean climate is characterized by a high variability between years, observing both extreme warm and cold dormancy seasons (Fig. 2). As an example, the colder period was registered in the season 2008-2009, when the turning point of the dormancy was reached on November 20 with 400 CU, whereas the warmer period was registered in the season 1989-1990, when the level of 400 CU was reached more than one month later, on December 24.

In the Ebro Central Valley, there is a surplus of chill accumulation, about 1.800 CU until the end of February (Fig. 2), resulting in an average of 13.5 CU/day. The chill and heat requirements for blooming of some almond cultivars (Alonso et al., 2005), expressed in Chill Units (CU) and Growing Degree Hours (GDHºC), are shown in Table 1. Almond chill requirements are generally low, as compared to other fruit species; as a consequence, they are completed very early, whereas heat requirements are fulfilled little by little until February, when heat accumulation increases significantly. Full blooming of most almond cultivars in Zaragoza ranges from middle February to middle March.

The linear function obtained from the regression (Fig. 3) between the mean blooming dates (BD) in Julian days from October 1st (independent variable) and the standard deviation (SD) of blooming dates observed for the different cultivars during the period of study (dependant variable), was: SD = 41.987 - 0.2148 x BD (R^2=0.7937). This function points out that in general, early blooming almond cultivars show a larger variation of full blooming dates (Fig. 3) because they are more dependent on warm temperatures during January and February, when heat accumulation is slower. Late blooming cultivars showed more stable blooming dates because they have a greater demand on heat requirements, quickly satisfied by the higher temperatures in March. According to the data of the last 24 years, the stability of the blooming date of a given cultivar increases with the progression of its blooming time. As a consequence, blooming dates of late cultivars showed lower standard deviations and higher stability in Zaragoza.

On the other hand, a very small variability on almond chill requirements had been observed, whereas the variability for heat requirements was high in the Ebro River Central Valley conditions (Alonso et al., 2005). This necessarily implies that the blooming date of any almond cultivar is strongly ruled by their heat requirements as it is corroborated by the function obtained by the linear regression between the mean blooming dates (BD) in Julian days from October 1st of the studied cultivars for the period 1985-2008 (independent variable) and its heat requirements (HR) for blooming in GDHºC (dependant variable). The function obtained in this linear regression was: HR = 133.63 x BD - 13255 (R^2=0.9583). The good fitness obtained in this linear regression (Fig. 4) could be useful in making reliable predictions of the heat requirements of a new cultivar or a breeding selection from the average date for full bloom observed under the climatic conditions of Zaragoza. The progressive increase of temperature due to the Global Warming process is causing a new climatic situation where an advancement of blooming dates has been suggested. Although the temperature analysis has not allowed any appreciation of the progressive temperature increase from 1985 to 2008 in Zaragoza, the Global Warming scenario could be compared with the warmer seasons of this period. In general, almond blooming advanced after warm periods of dormancy, but was delayed after cold ones However, the incidence of warm or cold temperatures on almond blooming is more relevant during the heat accumulation period (ecodormancy) because chill accumulation is early completed in almond under the Central Ebro Valley conditions. As a consequence, early blooming cultivars have shown higher variation on blooming dates because of a slower heat completion and more variable temperatures during February, whereas late blooming cultivars quickly satisfied their heat requirements due to the warmer and usually more stable temperatures of March. As a conclusion, almond blooming date stability is especially more consistent for cultivars with high cold and heat requirements, such as some recent releases, showing later mean blooming dates with low standard deviations. This characteristic is also essential in choosing the cultivars to be planted in a given region in relation to its climatic conditions, especially to avoid risks of spring frosts, a phenomenon with higher probability in this new climatic scenario.

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Tables

Table 1. Chill and heat requirements for blooming in some almond cultivars (Alonso et al., 2005).

Cultivar	CU	GDHºC	Cultivar	CU	GDHºC
Aï	454	8082	Miagkoskorlupij	468	7521
Alzina	468	6779	Moncayo	468	8760
Ayles	487	7951	Nec Plus Ultra	468	6414
Bertina	468	8587	Nonpareil	403	7918
Blanquerna	468	6949	Picantilli	428	7481
Cambra	468	7863	Ponç	428	6400
Chellastone	468	6278	Pou de Felanitx	403	5427
Xine	403	5931	Primorskij	428	8468
Constantini	454	5460	Rachele	383	8308
Cristomorto	428	8152	Ramillete	454	5998
Desmayo Largueta	428	5545	Rof	468	6596
Desmayo Rojo	468	6596	Tardive de la Verdière	365	8862
Felisia	428	9363	Texas	368	7863
Ferragnès	454	8082	Thompson	468	7863
Filipo Ceo	468	7685	Titan	454	8463
Fournat deBrézenaud	416	7390	Tokyo	468	7863
Guara	468	8001	Totsol	428	7068
Jordi	428	6567	Tuono	468	8001
Lauranne	428	8671	Verdereta	416	6719
Legrand	428	8152	Vivot	428	6703
Marcona	428	6703	Yaltinskij	468	8587
Masbovera	468	7863	Zahaf	402	5692

Figures

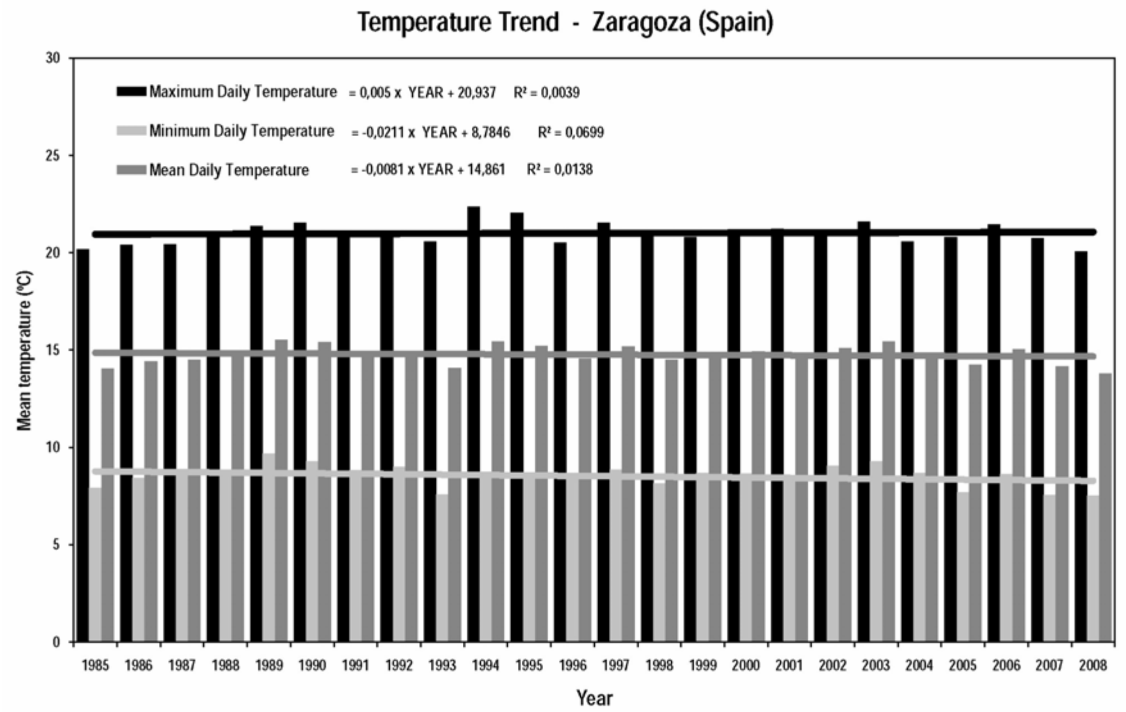

Figure 1. Temperature trends in Zaragoza (Spain) and linear expressions of maximum, minimum and mean daily temperature for the period 1985 to 2008.

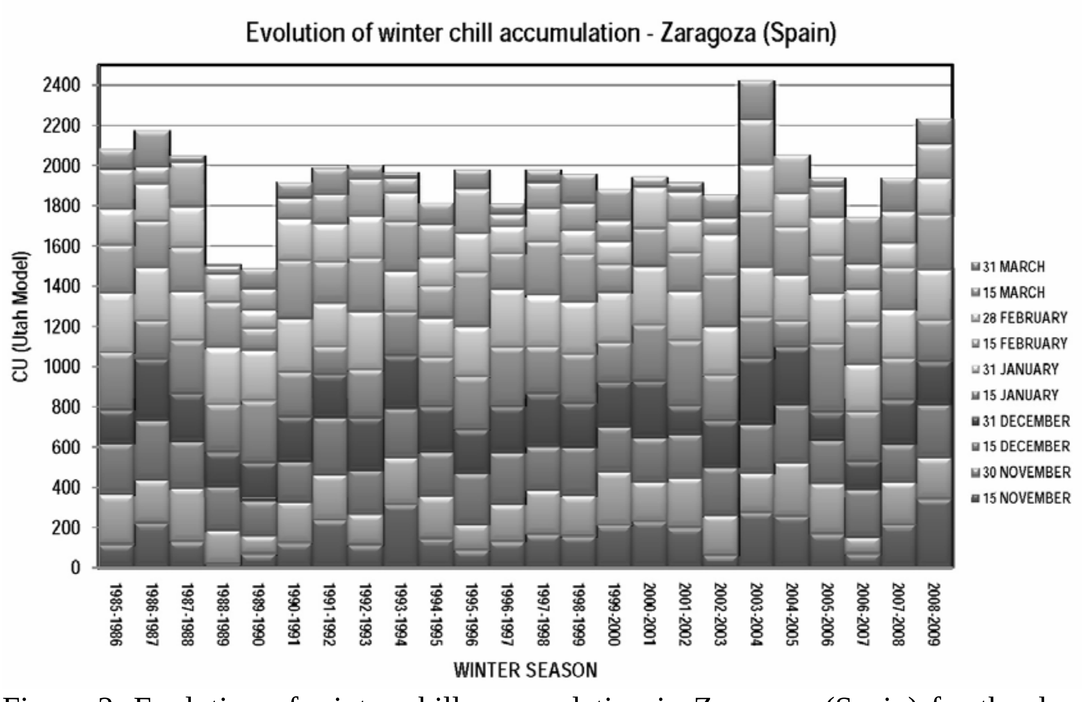

Figure 2. Evolution of winter chill accumulation in Zaragoza (Spain) for the dormancy seasons from 1985 to 2008.

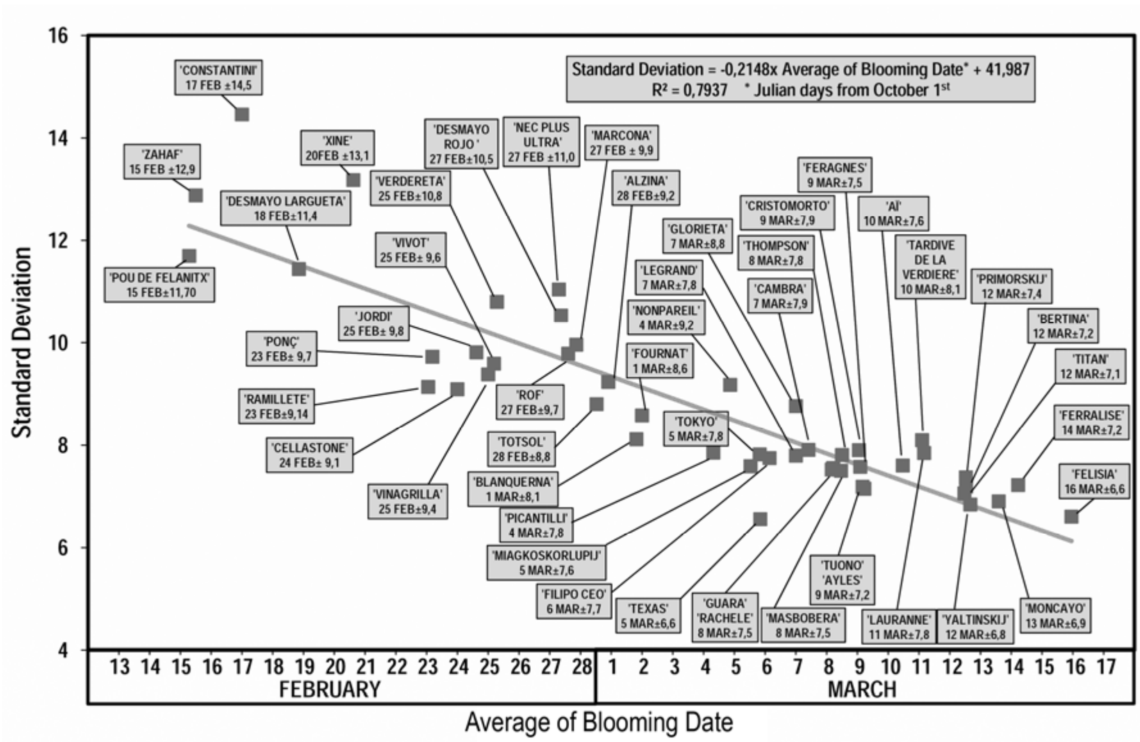

Figure 3. Relationship between the average of blooming date of some almond cultivars and its standard deviation for the 1985-2008 period in Zaragoza (Spain).

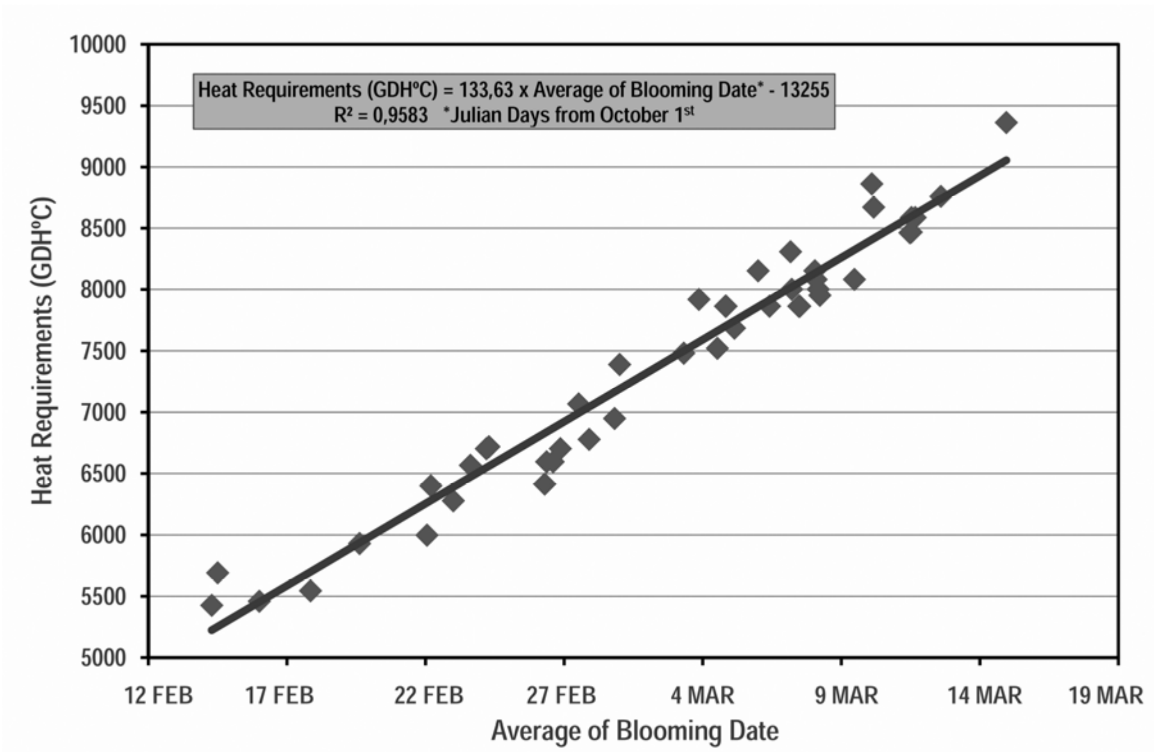

Figure 4. Relationship between the average of blooming dates of some almond cultivars and their heat requirements for blooming in Zaragoza (Spain).