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Chilling and heat requirements of apricot cultivars for flowering

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Abstract

Chilling requirements for breaking of dormancy and heat requirements for flowering were studied for 3 successive years in 10 apricot cultivars which spanned the range of flowering times in this species. Different methods for estimating chilling requirements were evaluated and compared, and correlations between chilling requirements, heat requirements and flowering date were established. The cultivars examined showed a range of chilling requirements (chill units, CU), between 596 CU (Currot) and 1266 CU (Orange Red), though most of them showed chilling requirements between 800 and 1200 CU. The results obtained in different years by the Utah and Dynamic models were more homogeneous with respect to the hours below 7 °C model. The heat requirements for flowering ranged between 4078 and 5879 growing degree hours (GDH). The apricot cultivars showed important differences concerning flowering date, and the results indicate a high positive correlation between chilling requirements and flowering date, as well as a negative correlation between chilling requirements for breaking of dormancy and heat requirements for flowering.

Keywords: Dormancy; Environment; *Prunus armeniaca* L.; Chilling requirements; Heat requirements; Flowering date

1. Introduction

Adaptation is a concept related to how plants can survive and reproduce in a specific environment (Hill et al., 1998) and it is reflected in the synchronization between the development stages and the climate (Dietrichson, 1964). The study of the phenological behaviour of crops, as a part of a well-characterised environment, is important both to obtain satisfactory productions and to determine the most suitable agronomic techniques (Valentini et al., 2001).

Stone-fruit crops, including apricot are temperate fruits which are grown in climates with well-differentiated seasons. Mechanisms against the impact of low winter temperatures and frost damage have been developed by species growing under these conditions. Dormancy and freezing tolerance are the main mechanisms developed against these difficulties and, although they could be independent (Irving and Lamphear, 1967), freezing tolerance cannot be developed adequately without growth cessation (Fuchigami et al., 1971), which marks the onset of dormancy.

Dormancy is not a mechanism achieved suddenly by plants, but a progressive process developed during autumn, increasing its depth until reaching the so-called deep rest (Amling and Amling, 1980; Fuchigami et al., 1977; Hatch and Walker, 1969; Lang et al., 1987; Powell, 1987). Therefore, dormancy in temperate-zone, deciduous fruit trees is a phase of development that allows trees to survive unfavourable conditions during winter (Faust et al., 1991). Different models have been proposed to explain dormancy progression, from its induction to its complete release (Fuchigami and Nee, 1987; Faust et al., 1995).

Although in temperate-zone, deciduous fruit trees enter dormancy at the end of the growth stage without need of cold conditions (Coville, 1920), during the correlative inhibition stage strained in autumn, cold accelerates dormancy induction (Amling and Amling, 1980; Faust et al., 1991).

Several contributions have established models to explain the relationships between dormancy breaking and temperature, which is the most decisive climatic factor. An important advance was the establishment of the Utah model by Richardson et al. (1974), which assigned chill unit values to different temperature ranges. Subsequently, models adjusted with regard to the Utah model were developed, such as the Low-chilling model (Gilreath and Buchanan, 1981), North-Carolina model (Shaltout and Unrath, 1983) and others.

Couvillon and Erez (1985), Erez and Couvillon (1987) and Erez et al. (1979) reinforced the hypothesis that the dormancy-breaking process could be explained as a two-stage reaction. The first is reversible by high temperatures, the latter stage being

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irreversible. Fishman et al. (1987a,b) proposed the Dynamic model, which improved some difficulties of the Utah Model, especially in mild-winter climates (Erez et al., 1990).

The knowledge of the chilling requirement of a cultivar has significant practical and economic impacts on the control, maintenance and production of woody plants (Fennell, 1999), and is necessary for cultivating apricot cultivars in the most suitable areas. In this way, if a cultivar is established in an area where its chilling requirements are not satisfied adequately, the vegetative and productive behaviour of the cultivar will be affected negatively (Coville, 1920; Weldon, 1934; Black, 1952; Ruck, 1975; Samish, 1954; Samish and Lavee, 1982). On the contrary, in the case of cultivars with low chilling requirements (i.e. early-flowering cultivars) growing in cold-winter areas, blooming happens too early because chilling requirements are quickly satisfied, and low temperatures can induce an important loss of yield by frost (Scorza and Okie, 1990).

On the other hand, in mild areas the early ripening of temperate fruits has special economic importance, and this could be enhanced with the use of chemical breaking agents (Erez, 1987) which bring forward the date of dormancy breaking. Deep knowledge of chilling requirements and date of dormancy breaking of the cultivar is required for an optimum application date of breaking chemical agents, which should be applied when about two-thirds of the chilling requirements has been satisfied (Erez, 2000).

Chilling requirements for the breaking of dormancy of temperate fruit cultivars have to be fully satisfied for obtaining the desired vegetative growth and the best fruit-bearing capacity (Weldon, 1934; Samish, 1954; Samish and Lavee, 1982). Depth of rest, and consequently the chilling requirement, is a specific parameter of each cultivar. Therefore, important differences between cultivars have been reported (Saure, 1985; Erez and Fishman, 1998; Egea et al., 2003).

Although heat contribution to plant growth can influence the development process of the plant before the complete release of dormancy (Scalabrelli and Couvillon, 1986), heat requirements for flowering represent the thermal integral required for flowering after breaking of dormancy.

The risks related to the lack of knowledge of the heat requirements of apricot cultivars are scarce, but their knowledge will provide us with more possibilities for the management of this crop. Hence, cultivars with low chilling requirements but high heat requirement could be cultivated in relatively cold areas (Citadin et al., 2001).

It is still not clear whether cultivars have specific heat requirements for flowering (Overcash, 1965; Gianfagna and Mehlenbacher, 1985; Rom and Arrington, 1966) or whether flowering date is determined basically by chilling requirements (Brown, 1957; Swartz and Powell, 1981; Couvillon and Erez, 1985). Methods for determining the heat requirements of blooming have been developed (Richardson et al., 1974; Anderson et al., 1986). These methods essentially consist of establishing the heat accumulation, above a threshold, to which a tree is exposed from breaking of dormancy until flowering date.

Up to now, no systematic calculation of chilling requirement has been developed for apricot cultivars and new selections. Consequently, problems related to the inaccurate selection of cultivars with unsuitable chilling requirements occur, affecting the apricot production, especially in mild-winter climates. Available information is scarce, and often dissimilar, because it is frequently expressed as different measures, such as chill hours (Weinberger, 1950), chill units (Richardson et al., 1974) or portions (Fishman et al., 1987a,b), which makes difficult its utilisation.

The scarce data available for the apricot species, which is the least-studied temperate fruit with regard to chilling requirements, show that the range of chilling requirements in most apricot cultivars is from 800 to 1200 chill units, with extreme values of 500 and above 1400 (Guerriero et al., 2002; García et al., 1999; Tabuenca, 1964; Bailey et al., 1978, 1982).

The aim of this work is the calculation, in 3 successive years, of the chilling requirements for breaking of dormancy and the heat requirement for flowering of a group of apricot cultivars which cover the full range of flowering time in this species. Moreover, comparison and analysis of the different evaluation models of chilling requirements will be accomplished, as well as the study of relationships between chilling and heat requirements and flowering dates.

Hence, the information obtained will provide a better understanding of the apricot species regarding chill and heat requirements and flowering dates, which will be very useful for improving apricot cultivation.

2. Material and methods

2.1. Plant material

The plant material comprised 10 apricot cultivars spanning the range of flowering time in the apricot species. The cultivars were Currot, Búlida, Bergeron and Orange Red, which are international references and whose chilling requirements have been determined in different climatic conditions. The new cultivars Rojo Pasión, Selene, Murciana and Dorada, as well as two advanced selections (S 405/17 and Z 111/61) from the CEBAS-CSIC apricot breeding programme, were also included in this study.

2.2. Experimental design

The experiments were conducted during 2003, 2004 and 2005 in the experimental orchard of CEBAS-CSIC, in Calasparra (Murcia, South-East Spain). Hourly temperatures were collected from November to April by a thermohygrograph (Tipo 6500, Inles Richard Instruments) and an automatic data-logger (Escort Data Logging Systems).

In these field conditions, the initial date for chilling accumulation was considered to be when a consistent chilling accumulation occurred and the temperatures producing a negative effect (chilling negation) (Richardson et al., 1974; Erez et al., 1979; Guerriero et al., 2002) were scarce.

From the beginning of the chilling accumulation in the orchard, for each cultivar, three branches (with lengths of around 40 cm and diameter of 5 mm) were picked each 3–4 days from