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Forty-year investigations on apricot blooming: Evidences of climate change effects

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ABSTRACT

Current climate change negatively impacts on key seasonal biological processes of perennial plants causing erratic productions and, consequently, significant yield reductions. Being flowering time of fruit crops one of the most widely used indicators for climate change studies, the present research aimed to assess, over a long-term period (1973–2016), the climatic trend and its influence on blooming date and intensity of 40 apricot cultivars (*Prunus armeniaca* L.) grown in central Italy. Over the autumn-spring seasons, the main climatic parameters (temperature, rainfall) were acquired, and calculation of chill accumulation according to the Chilling Units model (CU) was performed. Results showed significant trends in warming of autumn-winter monthly minimum and average temperatures, particularly since the 1990s. During the critical period for overcoming of flower bud endodormancy, a dramatic loss of CUs was recorded. Most of the examined cultivars, belonging to Italian and foreign germplasm and opportunely selected for different flowering time, showed important blooming delays and blooming intensity decreases. In particular, the early-blooming cultivars showed the highest average shift of around 12 days and a loss in blooming intensity score which fell to levels of around 50% with respect to previous periods. The CUs, negatively correlated with blooming time and positively correlated with blooming intensity, seem to be crucial for apricot floral biology. The irregular autumn-winter cold rate of recent years may mean that substantial impacts can be expected in the future with possible geographic shifts of the apricot cultivation areas towards more potentially suitable areas located in the northern Italian and European regions, with considerable socioeconomic inference.

1. Introduction

Current climate change, represented by a substantial global warming, is impacting on the biological dynamics of plants showing phenological variations as a function of vulnerable environmental conditions (Walther et al., 2002; White et al., 2009). The biological processes leading to flowering are affected by ongoing climate alteration due to seasonal extreme events. In pome and stone fruit trees of temperate regions, these events may negatively influence key phases, such as bud dormancy, causing erratic budbreak and, consequently, significant plant yield reductions and financial losses (Byrne et al., 2000; Legave et al., 2013). Bud dormancy is defined as a strategy of plants for survival under unfavorable growing conditions by the insensitiveness of meristems to growth-promoting signals (Rohde and Bhalerao, 2007). In particular, endodormancy, in which growth is regulated by physiological factors inside the bud (Lang et al., 1987), is under the combined control of decreasing day-length (Caffarra et al., 2011) and chilling accumulation (Erez et al., 1971; Chuine and Cour, 1999). The genotype-specific chilling requirement has to be satisfied by cold temperatures during the autumn-winter season to ensure endodormancy release. When the chilling requirement is fulfilled, buds go into ecodormancy, an apparently quiescent state up to the exposure to warm temperatures inducing which induce the flower bud burst (Horvath et al., 2003).

A number of recent studies focusing on dormancy related traits and adaptation of genotypes to specific cultivation areas showed that, in recent years, the frequent occurrence of warmer winters in Mediterranean regions has significantly affected endodormancy release due to an unfulfilled chilling requirement. As a consequence, several fruit species may show physiological and biological disturbances producing detrimental effects on productivity (Luedeling et al., 2011; Gannouni et al., 2017; Prudencio et al., 2018). This is what has been happening for apricot (*Prunus armeniaca* L.), a fruit species strongly influenced by weather-environmental factors which impact on its floral

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biology patterns through the appearance of flower bud anomalies, drops and alterations of phenological processes (Rodrigo and Herrero, 2002; Bassi et al. 2006; Legave et al., 2006; Oukabli and Mahhou, 2007). In particular, several studies have shown that, as a consequence of short or warm winter seasons, an incomplete resumption of flower bud dormancy occurs resulting in scanty apricot blooming (Viti and Monteleone, 1995; Erez, 2000). Among apricot cultivars, substantial differences in chilling requirements have been reported (Viti et al., 2006). However, most of them need a medium chilling requirement in Mediterranean areas (Ruiz et al., 2007; Viti et al., 2013), namely 800–1200 chilling units (CUs) according to the Utah model proposed by Richardson et al. (1974). In particular, in Tuscany crop-lands of central Italy, the threshold of 1000 CUs has been considered a determinant amount for the fulfilment of chilling requirement in the majority of apricot cultivars (Viti et al., 2006; Guerriero et al., 2010). Nevertheless, the tendency of the winter climate to become progressively milder may determine substantial impacts on apricot, a species sensitive to physiological disorders such as appearance of floral anomalies and flower bud drop (Legave et al., 1982; Viti et al., 2008). Thus, studies concerning the effect of climate factors on the floral biology processes are important in planning the apricot culture for the future, focusing on resilient genotypes able to remain economically productive over the years.

Accordingly, as the flowering time of fruit crops is one of the most widely used indicators of climate change, the present research aimed to assess, over a long-term period, the climatic trend and its influence on the blooming date and intensity of a number of apricot cultivars grown in central Italy.

2. Materials and methods

2.1. Study site and plant material

From 1973 to 2016, 40 apricot cultivars characterized by different blooming and ripening time were studied. In Table 1 cultivars are shown in three groups according to the blooming time recorded under our Tuscan environmental area: i) early (before March 5th), ii) mid (between March 6th and 15th), iii) late (after March15th). For each cultivar, the ripening time as - early (E, before June 15th), - mid (M, up to June 30th), - late (L, after July 1st), and the type of fruiting habit (long shoot, L and/or spur, S) are indicated. Most of them, belonging to Italian germplasm, are still cultivated in the main apricot crop areas. Several worldwide foreign cultivars, such as, 'Bulida', 'Canino', 'Currot', 'Goldrich', 'Harcot', 'Moniqui', 'Polonais', 'Rival' and 'Rouge de Roussillon' were considered too.

Trees, grafted onto Myrabolan 29C rootstock and trained to a free palmette system (4 m × 4.5 m), were grown at the experimental site of the Department of Agriculture, Food and Environment of Pisa University located along the Tyrrhenian coastal area of Tuscany (Italy, Venturina, altitude 6 m a.s.l., lat. 43°02' N, long. 10°36' E). Over the forty-four years period, the experimental orchards have been renewed to maintain the cultivar efficiency and thus, in this work, full-bearing apricot trees (6–10 years old) were considered. The site is characterized by Mediterranean climate with warm-winters and annual average rainfall of about 600 mm; the soil in orchard is loam, moderately deep, medium texture, slightly alkaline, non-calcareous. Trees were not irrigated and routine conventional horticultural managements (pruning, thinning, fertilization, pest and disease protection) were performed. The experimental design was established in a randomized design (five single-tree replications per cultivar).

2.2. Climatic parameters

Starting in 1973, the main climatic parameters were acquired over the autumn-spring seasons. Daily measurements of hourly air temperatures were taken by thermo-hydrometers and data-loggers (Tynitag Plus®, West Sussex, UK, 2003) located inside the orchards; rainfall data were provided by the Hydrological Service of Tuscany (SIR). From 1976 onwards, minimum and maximum temperature data were converted to 'Chilling Units' (CUs), according to the Utah Model (Richardson et al., 1974). This model, the most suitable under our experimental areas (Viti et al., 2010a), assigns variable weights to differing temperature ranges, resulting in CU amount. Temperatures with a positive effect ranged between 1.5 and 12.4 °C, while temperature with a negative effect are higher than 15 °C. The start of CU accumulation is fixed when the largest value of CU is attained in autumn; in our environmental conditions the end of vegetative season (50% of leaf drop) usually occurred within the first fifteen days of November. In this work the CU accumulation is shown up to January 31st, which was considered a significant date for reaching 1000 CUs. This threshold-amount reflects the fulfilment of chilling requirement of most apricot cultivars recorded over the years in the same geographical area of this study (Viti et al., 2006; Guerriero

Table 1
Forty apricot cultivars studied over 44 year-long period (1973–2016). Cultivars have been clustered according to the blooming time: i) early (before March 5th), ii) mid (between March 6th and 15th), iii) late (after March15th). Geographical origin, ripening time (RT) as - early (E, < before June 15th), - mid (M, up to June 30th), - late (L, after July 1st), and fruit bearing habits (FH) on long-intermediate shoot (L) and/or spur (S), are shown. Blooming and ripening times are referred to the Tuscan province of Livorno (Italy).

	Early-blooming				Mid-blooming				Late-blooming			
	Cultivar	Origin	RT	FH	Cultivar	Origin	RT	FH	Cultivar	Origin	RT	FH
1	Antonio Errani	Italy	E	LS	Alessandrino	Italy	L	LS	Alessandria	Italy	L	LS
2	AmabileVecchioni	Italy	E	L	Bella d'Imola	Italy	L	LS	Canino Tardivo	Spain	L	LS
3	Boccuccia Liscia	Italy	E	LS	BoccucciaSpinosa	Italy	M	LS	Castelbrite	USA	L	LS
4	Bulida	Spain	E	S	Cafona	Italy	E	LS	Cibo del Paradiso	Italy	L	LS
5	Caldesi	Italy	E	LS	Comune	Italy	M	LS	Costasciacca	Italy	L	S
6	Canino	Spain	E	LS	Moniqui	France	E	LS	Damasquina	Spain	L	S
7	Currot	Spain	E	S	Portici	Italy	M	LS	Dasycarpa	Asia	L	LS
8	Goldrich	USA	E	LS	Rival	Canada	E	LS	Harcot	Canada	L	LS
9	New Jersey	USA	M	LS	Rouge De Roussillon	France	E	LS	Manini	Italy	L	LS
10	O'Pazzo	Italy	E	S					Molodoi	Moldova R.	M	S
11	Precoce Imola	Italy	E	LS					Nonno	Italy	L	LS
12	San Castrese	Italy	M	LS					Nugget	USA	L	LS
13	Venturina	Italy	E	LS					Orange Red	USA	M	LS
14	Vitillo	Italy	E	S					Perla	Italy	M	LS
15									Polonais	France	L	LS
16									Precoce di Monplaisir	France	L	LS
17									Reale d'Imola	Italy	M	LS