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Blueberry chilling model dilemmas

M.R. Warmund

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Abstract

Several chilling models have been developed to estimate the chilling requirement for specific deciduous fruit crops and to predict the time of rest completion. While the early chilling models were developed primarily for deciduous fruit trees, others were developed subsequently for several other fruit-bearing plants, including blueberries (*Vaccinium* sp.). Traditional chilling models for field-grown deciduous blueberries vary by genotype and location. However, as blueberry germplasm, cultural practices, and production systems evolve, different chilling models may be required to estimate chilling for these plants. Useful chilling models include a time of chilling inception, a temperature range where chilling is accumulated or negated with weighted values or other clearly defined calculations, and a phenological event when rest is considered completed within a specified period of time.

Many temperate-zone fruit plants require a period of low temperatures in winter before they will grow vegetatively and produce flowers uniformly in the spring. As early as 1890, S.H. Rumph recognized symptoms of insufficient chilling of peach in Georgia (Weinberger, 1950b). In the early literature, “prolonged dormancy trouble” was often used to describe insufficient chilling, which affected several deciduous fruit crops (Weinberger, 1950b). Chandler (1907) reported that various peach buds collected from different cultivars in an orchard bloomed at different times when they were brought indoors and exposed to warm temperatures in December. In 1932, Hutchins stated in an unpublished paper that 1000 h at temperatures $\leq 7°C$ were sufficient to satisfy the cold requirement of many peach cultivars grown in Georgia (Weinberger, 1950a). Weldon (1934) correlated delayed foliation of deciduous fruit trees with high average monthly winter temperatures in California. Since these early discoveries, numerous chilling models have been devised to estimate the cold requirement of many fruit crops and their cultivars (Norvell and Moore, 1982; Austin and Bondari, 1987; Linsley-Noakes and Allan, 1994; Mainland, 1985; Powell et al., 2002; Shine and Buchanan 1982; Spiers, 1976). More recently, Luedeling and Brown (2011) estimated the amount of chilling temperatures recorded during 1 Oct. to 1 May in the northern hemisphere and 1 Apr. and 1 Nov. in the southern hemisphere from 1973 to 2002. This calculation was called “safe winter chill” to compare the minimum amount of winter chilling that worldwide locations accumulated in 90% of the years studied using various models.

In warm climates, inadequate chilling of blueberry plants results in sparse foliage, erratic or delayed flowering and, in severe cases, floral bud abortion (Lyrene, 2005). The chilling requirement is commonly used to determine genotypes suited to specific growing areas. Additionally, chilling models are useful in determining the time of hydrogen cyanamide (H_2CN_2) application. This plant growth regulator induces vegetative bud break of some rabbiteye (*Vaccinium virgatum* Aiton) and southern highbush blueberry

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[1] Professor of Horticulture and Extension Fruit Specialist, Division of Plant Sciences, University of Missouri, Columbia, MO, 65211. Email: warmundm@missouri.edu.

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(*V. corymbosum* hybrids) cultivars ('Jewel', 'Emerald', and 'Star'), accelerates and concentrates fruit harvest, and enhances fruit size and yield in north-central Florida when applied after 150 or 300 chill-hours (CH) are accumulated (Williamson, 2013).

Three chilling models are the foundation for most others. The most basic model accumulates one unit of chilling for every hour in the 0° to 7°C range of temperatures during endodormancy (Chandler et al., 1937). Using this model, highbush blueberry cultivars generally require ≥ 800 CH, those of southern highbush cultivars need 150 to 800 CH, and rabbiteye cultivars require 300 to 800 CH for rest completion (Krewer and NeSmith, 2006). The Utah Model assigns weighted values to a range of temperatures with chilling inception just after the maximum negative number of chill units is accumulated in the fall (Table 1) (Richardson et al., 1974). The Dynamic Model, which was developed for hot, dry climates, also assigns values in a specific temperature range (between -2° and 13°C) and is based on the underlying assumptions that maximum chilling occurs at 7°C and one chill portion accumulates under optimal conditions during a 28 h period (Erez et al., 1988; Erez et al., 1990). Using the Dynamic Model, 'Golden Delicious' apple , 'Rainer' cherry, and 'Redhaven' and 'Flordaprince' peach require 50, 45, 75 and 8 chill portions, respectively for rest completion (Erez, 2000).

Several chilling experiments have been conducted to estimate the chilling requirement for blueberry and various models have been developed to predict rest completion, with modifications for genotypes and climatic conditions (Table 1) (Austin et al., 1982; Austin and Bondari, 1987; Fraiss and Whidden, 2010; Gilreath and Buchanan, 1981; Spiers, 1976; Spiers and Draper, 1974). Norvell and Moore (1982) determined that the Utah model estimated the chilling requirement for 'Bluecrop' and 'Coville' northern highbush blueberry (*V. corymbosum* L.) when the Utah model was applied, but assigned 0.5 chill units for each hour < 1.5°C. Also, rest was considered complete when four buds on a stem had 1 cm of growth. Another model used in North Carolina assigns positive weighted values below 12.8°C; -0.25 CU from 12.9 to 18.3°C; -1 CU > 18°C; and no

Table 1: Utah chilling model and various other modified models used to estimate the chilling requirement of blueberry.

	Model				
Chill Units	Utah[z]	Arkansas[y]	Low chilling[x]	'Woodard'[w]	'Aliceblue'[w]
0	<1.4	---	<1.8	<-2.5	---
0.5	1.5 to 2.4	< 2.4	1.8 to -7.9	-2.5 to 0.9	<2.5
1.0	2.5 to 9.1	2.5 to 9.1	8.0 to 14.0	1.0 to 9.7	2.5 to 9.9
0.5	9.2 to 12.4	9.2 to 12.4	14.1 to 17.0	9.8 to 13.7	10.0 to 15.9
0.0	12.5 to 15.9	12.5 to 15.9	17.1 to 19.5	13.8 to 16.4	16.0 to 20.4
-0.5	16.0 to 18.0	16.0 to 18.0	19.6 to 21.5	16.5 to 20.0	20.5 to 24.0
-1.0	>18.0	>18.0	>21.5	>20.0	>24.0

[z] Utah model (Richardson et al., 1974).
[y] Arkansas model (Norvell and Moore, 1982)
[x] Low chilling model (Fraissee and Whidden, 2010)
[w] 'Woodard' and 'Aliceblue' model (Shine and Buchanan, 1982).

longer accumulates CU after Feb. 28 (Mainland, 1985).

Several blueberry chilling models have been developed for warm climates where chilling temperatures are limited. However, the chilling requirements listed for similar cultivars are often conflicting. Such discrepancies may be attributed to the methods used to estimate chilling. For example, Spiers et al. (2006) reported that 'Tifblue' rabbiteye blueberry required 400 CH for rest completion. In this study, CH accumulated at temperatures ≤ 7°C and rest was considered complete when the terminal two buds on a forced cutting in the greenhouse reached stage 3 (bud scales separated, apices of flower petals visible) within a three week period. In contrast, Krewer and NeSmith (2006) reported that 'Tifblue' had a chilling requirement of 600 to 700 h when the number of hours ≤ 7°C were summed and 90% of the buds or blooms grew within a two week exposure to warm temperatures. Shine and Buchanan (1982) devised two different modified Utah models for 'Aliceblue' and 'Woodard' rabbiteye blueberries, and defined rest completion as the time between green tip (i.e., foliar margins evident) and tight flower cluster bud stages. More recently, Fraiss and Whidden (2010) developed a web-based tool that calculates positive chill units for 'Aliceblue' rabbiteye blueberry between -2.5 and 15°C and also for 'Tifblue' between -1.2 and 12.9°C, but negative units are not accumulated at any temperature. For southern highbush blueberry, the number of hours below ≤ 7°C has been used in Florida to determine the chilling requirement for cultivars (J. Olmstead, personal communication).

In areas where blueberries are grown in traditional deciduous production systems, there are three important components of a chilling model. The first component is the time and temperature for chilling inception, which is often a specific time or event when the model begins accumulating chill hours, units, or portions. In northern climates, chill models often begin after a freezing event at a specified temperature at or below 0°C or after the maximum negative accumulation of chill hours (Richardson et al., 1974; Warmund and Krumme, 2005). The second part of a chilling model includes the range of temperatures where chill hours, units, or portions are accumulated or subtracted with their weighted values. The third component of a chill model is the phenological event when rest is considered satisfied within a specified period of time. For example, the time when bud scales separate and leaf margins are first visible, when stem growth occurs, when floral apices are observed, etc. (Norvell and Moore, 1982; Spiers and Draper, 1974; Warmund and Krumme, 2005). Varying these three components is relatively easy when developing a chilling model for blueberries grown in temperate climates where plants naturally defoliate, cool temperatures occur during a dormant season, with a distinct period of subsequent flowering and foliation.

In contrast to chill models used for conventionally-grown plants, different models may be developed for blueberry plants grown under shade structures or in high tunnels due to the modified light and temperature conditions. Optimum flower bud initiation for several highbush and rabbiteye genotypes generally occurs following 6 to 8 weeks of photoperiods < 12 h, although some rabbiteye genotypes require a shorter daylength (< 10 h) (Darnell, 1991). For evergreen production of blueberries, whereby plants avoid dormancy, different models that calculate the accumulation of warm temperatures or growing degree hours may be devised to predict flowering and fruiting periods. Such models may vary due to genotype, timing of nitrogen application, and pruning and disease management practices.

Recent findings by Song et al. (2013) may eventually eliminate the need to develop chilling models for blueberry. Transgenic tissue-cultured 'Aurora' highbush blueberry, which overexpressed a flowering activator gene, 35S:VcFT, produced small plants with a single flower from either an apical or auxiliary bud without exposure to chilling temperatures. In contrast, nontransgenic 'Aurora' plants required a year in culture and 800 CH to produce flowers. Not only did VcFT reverse the photoperiodic and chilling requirement of 'Aurora' plants and promote precocity, it also induced continuous flowering. Thus, VcFT or VcFT-like genes may be used to manipulate flowering in genetically engineered plants, eliminating the need to estimate rest completion with chilling models in the future.

In the meantime, accurate chilling models that are specific to the genotype, climate, and production system are needed especially for low-chilling regions. Useful chilling models identify a time of chilling inception, a range of temperatures where chilling is accumulated or negated with weighted values or other clearly defined calculations, and a phenological event when rest is considered completed within a specified period of time.

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Changes in vineyard establishment and canopy management urged by earlier climate-related grape ripening: A review

Abstract

One of the main objectives of wine grape growers in several viticultural areas throughout history has been the achievement of full ripening, i.e. maximum soluble solids concentration in the absence of apparent berry shrinkage. Recently, this target is somewhat losing its appeal since an increasing number of consumers from both domestic and foreign markets prefer lighter wines characterized by moderate alcohol content. The above scenario needs to be added of another actor, i.e. the global warming and its effects on vine growth and berry composition which can be summarized as it follows: (i) onset of flowering and veraison phenological stages occurs earlier; (ii) grape ripening is generally accelerated as per increment of sugar accumulation into the berries which, in turn, leads to higher alcohol content in the wine; (iii) faster depletion of organic acids in the juice and more rapid increase of pH values which, as a consequence, triggers high microbiological instability of the must during pre-fermentation; (iv) due to excessive heat summations and poor thermal excursion the overall aroma profile can result untypical shifting towards overripe; (v) uncoupling of technological (more accelerated) and phenolic (more delayed) ripening with negative effects on grape and wine aroma and flavor, especially in red grape varieties; (vi) higher frequency of berry withering up to sun burn damage. In the medium-to-long term these factors likely will affect the geographical distribution of viticulture and will require new breeding programs for selecting more adapted roostocks and scions, whereas in the short term, new management techniques able to mitigate these negative impacts are urgently needed. In this review, several tools including varietal and clonal choice, possible diversification of wines produced, suitable training system and rootstocks, traditional and innovative management techniques able to regulate a too much accelerated and/or unbalanced grape ripening process, will be presented and discussed.

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