Temperatures and Light Effect on Dormancy

Subjects: Plant Sciences

Contributor: Amnon Erez

Dormancy is defined as the sum of processes that create a situation wherein embryonic tissues are unable to grow, even under environmental conditions that generally favor growth and development. The effects of temperature to break dormancy, from work done on peach, can be summarized as follows: Effective temperatures are between −2 °C and 13 °C, and the most effective being 4–8 °C with reduced efficiency at higher and lower temperatures. Moderate temperatures between 13 °C and 16 °C that will not break dormancy alone, when occurring in a daily cycle after previous chilling, enhance the effect of chilling. On the other hand, temperatures higher than 18 °C in a daily cycle will nullify former chilling. This negative effect of high temperatures increases the longer the duration and the higher the temperature. However, when cycles are longer than a day, the chilling effect is final and cannot be nullified by high temperatures. Apart from the effects of temperature on dormancy, light effects on dormancy in peach trials had also been detected Clearly, the dormant vegetative buds perceive light signals and react to light during dormancy and bud breaks. On the other hand, flower buds in peach were found to be non-responsive to light. Dormancy in vegetative buds is induced by short days. During endodormancy, the limitation of light and even total darkness enhance bud breaks in spring, compared to buds receiving natural light. But darkness in spring will prevent vegetative bud break even following sufficient chilling during winter. So, there is an analogy between chilling and darkness.

Keywords: stone fruits ; chilling requirements ; chilling portions ; bud break

1. Introduction

Even before the establishment of Israel in 1948, the interest in deciduous fruit species known to the immigrants coming from Europe led to trials to cultivate them in this different climate. Research in this area, initiated by Samish [1] and continued by myself and others [2][3][4][5][6][7][8], resulted in a system by which this became possible.

The major problem for perennial plants growing in a temperate climate is how to cope with winter chilling. Contrary to animals, plants cannot change their location and need to find another solution. Deciduous fruit trees found the way through evolution: they drop susceptible parts—their leaves—and develop cold resistance in the remaining organs.

Dormancy is defined as the sum of processes that create a situation wherein embryonic tissues are unable to grow, even under environmental conditions that generally favor growth and development [9]. Only embryonic tissues above the ground go into dormancy, i.e., floral and vegetative buds, and the cambium. The dormancy of the latter is dependent on bud dormancy. There is no deep dormancy in the roots. The dormant organs perceive and react to environmental information. The dormant period is divided into three parts according to Lang et al. [9]: (i) Paradormancy is where the lateral buds are correlatively inhibited by the terminal buds. In this period, re-growth is possible by cutting the apex. (ii) Endodormancy is the true dormancy that is overcome naturally by cold. (iii) Ecodormancy is where growth is limited by unsuitable environmental conditions, mostly excessively cold temperatures. Faust et al. [10] divided endodormancy further into two periods: D-endodormancy, where dormancy is deep, and S-dormancy, a shallower dormancy where the buds may react to dormancy-breaking agents and start growing.

2. Temperatures Effect on Dormancy

The three effects of efficient dormancy breaking are a high level, uniformity and precocity of bud breaks, i.e., the need of heat accumulation for bud opening is low. This is shown in **Figure 1**.

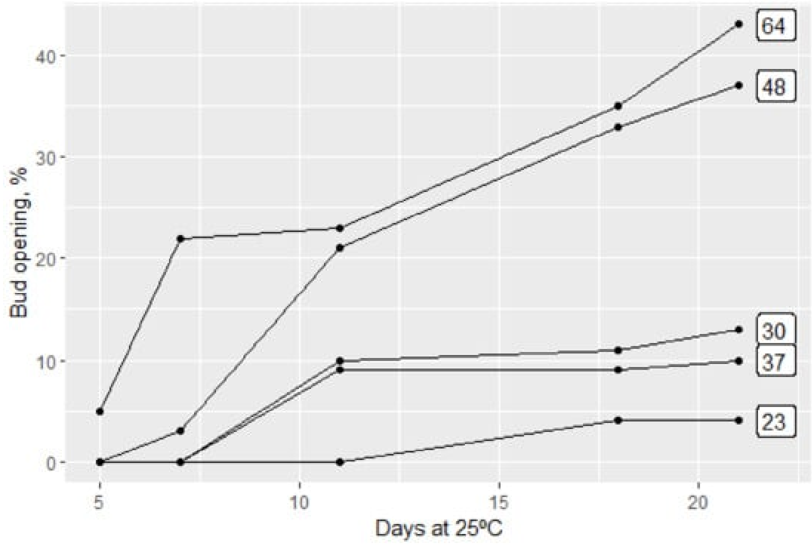

Figure 1. Breaking of vegetative buds of *Bonita* peach during forcing after different durations of exposure to days (squared on the right side) at 4 °C. (Buds on excised branches exposed to continuous chilling at 4 °C in the dark. Forcing at 25 °C in the light, bud break in %).

A trial of exposing cut peach branches (12 per treatment), taken in autumn 1971, to increasing periods of chilling at 4 °C followed by forcing at 25 °C is shown.

The response of dormant small peach trees to different temperatures under controlled temperature conditions have been examined [11][12][13][14]. On the basis of these studies, the effects of temperature can be summarized as follows:

- Effective temperatures to break dormancy in the peach are between −2 °C and 13 °C, and the most effective being 4–8 °C with reduced efficiency at higher and lower temperatures.
- Moderate temperatures between 13 °C and 16 °C that will not break dormancy alone, when occurring in a daily cycle after previous chilling, enhance the effect of chilling. On the other hand, temperatures higher than 18 °C in a daily cycle will nullify former chilling.
- This negative effect of high temperatures increases the longer the duration and the higher the temperature. However, when cycles are longer than a day, the chilling effect is final and cannot be nullified by high temperatures.

Several models were suggested to quantify the amount of chilling based on measuring air temperatures. The most common are the chilling hours model [15], the Utah model that measures chilling units [16] and the dynamic model measuring chilling portions that was developed based on the results and concepts presented above [17][18]. **Figure 2** presents a scheme of the dynamic model. The dynamic model explains and summarizes all the effects of temperatures on dormancy. It is based on two reactions in the dormant buds: The first creates a temporary product (named “intermediate” in **Figure 2**) due to the chilling effect; this reaction can be negated by high temperatures that will decrease the temporary product. The second reaction changes the temporary product to the final one. For the temporary product to transform to the final one, it has to reach a specific critical level. Once this level has been attained and the required portion of the final product has been produced, the temporary product level diminishes to zero, but starts accumulating again with further exposure to chilling. As a guideline, one chilling portion is obtained after exposure to 6 °C for about 28 h. With different temperature combinations, this period will be different. These portions were named “chilling portions” and represent the accumulated chill to be compared with the chilling requirements, which are specific to each cultivar, to elucidate the moment of the endodormancy release.

The Dynamic Model

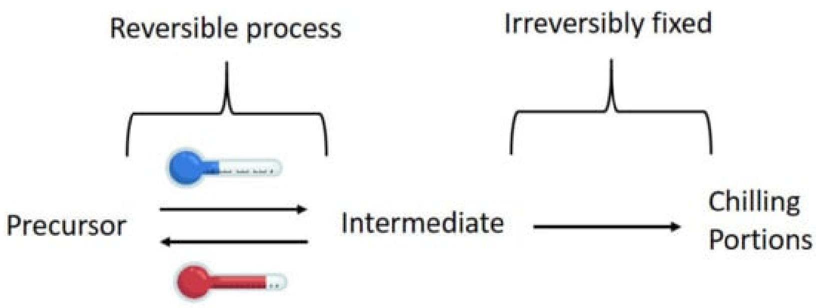

Figure 2. Scheme of the dynamic model.

When running the model with meteorological temperature data, one has to take into consideration that the provided temperatures are measured in the shade. On bright days, direct solar irradiation increases bud and bark temperatures above that in the shade. This difference appears to increase with the rise in day temperature. Differences of 3–5 °C have been recorded [19]. With global warming, this difference increases, leading to greater discrepancy. Thus, a correction of the measurements is required. Using thermistor needles inserted in representative buds or exposed but covered with material having a similar response to that of buds will give more reliable data. This model has been accepted as the best so far to describe the chilling requirements of *Prunus* dormant buds [20][21].

3. Light Effects on Dormancy

Apart from the effects of temperature on dormancy, light effects in peach trials had also been detected [22][23]. Clearly, the dormant vegetative buds perceive light signals and react to light during dormancy and bud breaks. On the other hand, flower buds in peach were found to be non-responsive to light [22]. Dormancy in vegetative buds is induced by short days. During endodormancy, the limitation of light and even total darkness enhance bud breaks in spring, compared to buds receiving natural light. But darkness in spring will prevent vegetative bud breaks even following sufficient chilling during winter [23]. So, there is an analogy between chilling and darkness.

References

1. Samish, R.M. The use of dinitrocresol-mineral oil sprays for the control of prolonged rest in apple orchards. J. Pomol. Hortic. Sci. 1945, 21, 164–179.
2. Samish, R.M.; Lavee, S. The chilling requirement of fruit trees. Proc. XVI Int. Hort. Cong. 1962, 5, 372–388.
3. Erez, A. Means to compensate for insufficient chilling to improve bloom and leafing. Acta Hortic. 1995, 395, 81–96.
4. Erez, A.; Lavee, S. Breaking the dormancy of deciduous fruit trees in subtropical climates. Proc. XIX Inter. Hort. Cong. 1974, 3, 69–78.
5. Erez, A.; Zur, A. Breaking the rest of apple buds by narrow-distillation-range oil and dinitro-o-cresol. Sci. Hortic. 1981, 14, 47–54.
6. Erez, A.; Yablowitz, Z. Effect of dormancy agents with armobreak in the peach. Acta Hort. 1997, 441, 183–190.
7. Erez, A.; Yablowitz, Z.; Aronovitz, A.; Hadar, A. Dormancy breaking chemicals: Efficiency with reduced phytotoxicity. Acta Hort. 2008, 772, 105–112.
8. Crane, O.; Sar Shalom, A.; Erez, A. Coping with global warming effects on reduced winter chilling for deciduous fruit trees. Acta Hort. 2022, 1346, 91–100.
9. Lang, G.A.; Early, J.D.; Martin, G.C.; Darnell, R.L. Endo-, para-, and ecodormancy: Physiological terminology and classification for dormancy research. HortScience 1987, 22, 371–377.
10. Faust, M.; Erez, A.; Rowland, L.J.; Wang, S.Y.; Norman, H.A. Bud dormancy in perennial fruit trees; Physiological basis for dormancy induction maintenance and release. HortScience 1997, 32, 623–629.
11. Erez, A.; Couvillon, G.A.; Hendershott, C.H. Quantitative chilling enhancement and negation in peach buds by high temperatures in a daily cycle1. J. Am. Soc. Hortic. Sci. 1979, 104, 536–540.
12. Erez, A.; Couvillon, G.A.; Hendershott, C.H. The effect of cycle length on chilling negation by high temperatures in dormant peach leaf buds1. J. Am. Soc. Hortic. Sci. 1979, 104, 573–576.

13. Erez, A.; Couvillon, G.A. Characterization of the influence of moderate temperatures on rest completion in peach. J. Am. Soc. Hort. Sci. 1987, 112, 677–680.
14. Couvillon, G.A.; Erez, A. Effect of level and duration of high temperatures on rest in the peach. J. Am. Soc. Hortic. Sci. 1985, 110, 579–581.
15. Weinberdger, J.H. Chilling requirements of peach varieties. Proc. Amer. Soc. Hort. Sci. 1950, 56, 122–128.
16. Richardson, E.A.; Seeley, S.D.; Walker, D.R. A model for estimating the completion of rest for Redhaven and Elberta peach trees. Hortscience 1974, 9, 331–332.
17. Fishman, S.; Erez, A.; Couvillon, G.A. The temperature dependence of dormancy breaking in plants: Mathematical analysis of a two-step model involving a cooperative transition. J. Theor. Biol. 1987, 124, 473–483.
18. Fishman, S.; Erez, A.; Couvillon, G.A. The temperature dependence of dormancy breaking in plants: Simulation of processes studied under controlled temperatures. J. Theor. Biol. 1987, 126, 309–322.
19. Erez, A.; Couvillon, G.A. Evaporative cooling to improve rest breaking of nectarine buds by counteracting high daytime temperatures. HortScience 1983, 18, 480–481.
20. Luedeling, E.; Zhang, M.; McGranahn, G.; Leslie, C. Validation of winter chill models using historic records of walnut phenology. Agric. Forest Meteor. 2009, 149, 1854–1864.
21. Luedeling, E. Climate change impacts on winter chill for temperate fruit and nut production: A review. Sci. Hortic. 2012, 144, 218–229.
22. Erez, A.; Samish, R.M.; Lavee, S. The role of light in leaf and flower bud break of the peach (Prunus persica). Physiol. Plant. 1966, 19, 650–659.
23. Erez, A.; Lavee, S.; Samish, R.M. The Effect of limitation in light during the rest period on leaf bud break of the peach (Prunus persica). Physiol. Plant. 1968, 21, 759–764.