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Low-temperature threshold and growth degree day (GDD) for two pistachio cultivars

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Abstract

Chilling threshold and growth degree day (GDD) of two main pistachio pistillate cultivars were determined. Layout was factorial based on a complete randomized design with three factors, two cultivars (Qazvini and Ouhedi), 5 thermal levels (+2, 0, -2, -4 and -6 °C) and three developmental stages including dormant bud, swelling bud and fully bloomed flowers for chilling studies. Critical temperature for reversible tissue colour change was determined as -4°C at bud stage, -2°C at blooming bud and +2°C at flower. Decreasing temperature down to two more degrees (*e.g.* -6 °C at bud) could shift the damage into the irreversible browning injury. For GDD measurements, three factors, including cultivar, thermal accumulation (calculation based on +4.5°C) and phenological stages were considered. Kernel filling period varied in two cultivars; Ouhedi's bigger kernel required more time to grow fully and more growth degrees day. Qazvini needed 2561.044 GDD and 138.5 days for total bearing period (flowering to harvest), and 623.363 GDD and 30 days for kernel filling period. Ouhedi needed 2917.823 GDD and 160 days for total period, and 730.61 GDD and 33.5 days for kernel filling.

Key words: Pistachio, chilling injury, growth degree day, flowering, fruit development

Introduction

Spring chilling is a major environmental stress in some years causing serious injuries to pistillate organs of pistachio. Spring chilling also adversely affects fruit set and development processes such as pollination rate and fertilization (Faust, 1997; Quamme, 1978). Temperature and flowering-fruiting phenomenon are closely related (Baskerville and Emin, 1969). Pistachio pistillates experience some significant phenological stages in which some commercially-important events including nut shell (endocarp) hardening, resuming embryo development, nut kernel filling (seed growth) happen. Determination of the incidence time of each stage can significantly help the cultural and developmental practices directly leading to quantitative and qualitative yield improvement. The tree needs a hot and dry season to develop seed (kernel) expressed partly by growth degree-day.

Amount of growth degree-day (GDD) needed for fruit ripening processes, particularly "kernel filling", accompanying with spring chilling injury threshold are regarded as two main criteria to select an area to develop pistachio cultivation.

"Ouhedi" is a globally well-known cultivar because of its market-favorable size and tasteful kernel. "Qazvini" is a small-sized nut; it is, however, famous and diversely used in confectionary industries because of its dark green and fragrant kernel.

A part of this study was carried out to determine critical temperatures for incidence of the strain in different low-temperature levels, on females of two commercial cultivars.

Materials and methods

Experiment plots were located at 35° 8' N, 49° 45' E and 1260 m altitude in a well-managed orchard.

Chilling injury: Shoots containing flower buds were collected from selected trees at different phenological stages (bud, blooming and full-bloomed inflorescence) and transferred to a low-temperature chamber. Temperature was reduced from +2°C, down to -6 at a rate of 2°C per hour. At the end of each one-hour phase, some buds and/or bloomed inflorescence samples were removed from chamber and assessed for macro- (naked-eye visible) and microscopic injuries. The critical temperatures for incidence of different injury levels were recorded and visual tissue browning was considered as the first serious (probably irreversible) injury (Quamme, 1978). Data were statistically analyzed.

Growth degree-day: Flowering and fruiting phenology of two main commercial cultivars of pistachio ("Ouhedi" and "Qazvini") were screened and the date of 50% blooming, start and finish of fast kernel filling period, and harvest were recorded. Experiment layout was based on a complete randomized block design in three replications. Each replication included three trees on which three branches in different directions were labeled for sampling.

Temperature data was received from the nearest synoptic climatology station.

GDD was calculated using the following equation considering +4.5°C (Faust, 1997) as the baseline temperature (Tb).

$$GDD = \sum n \, (T_{max} + T_{min})/2 - T_b)$$

where,

n: the number of days of mentioned period

T_{max}: maximum daily temperature

T_{min}: minimum daily temperature

Data was analyzed using Microsoft Excel® and SAS® software. Cultivars were compared statistically using Hoteling-Lawley Trace T-test.

Results and discussion

Chilling could adversely affect the reproductive structures at different morphological-anatomical levels varying with temperature; injury from higher temperatures to lower included deterioration or necrosis of stigma, style, inflorescence, current spring shoot, and whole flower buds, respectively.

Critical injury temperatures are presented in Table 1. Injuries were categorized into four levels including healthy, tissue color change (reversible injury), browning (serious and probably irreversible), and complete necrosis. No significant difference was revealed between two cultivars.

Based on the results, critical temperatures for occurance of reversible (tissue color change) and irreversible (tissue browning) injuries are summarized in Table 2. Flower buds' chilling resistance was the highest among all reproductive structures. Their resistance, however, decreased as they finished their dormancy, especially just before blooming. Decrease in temperature down to about -4 ºC for about 2h could lead to their delayed bloom with some blooming and flowering abnormalities. Lower temperatures (-4 to -6 for about 6 hours) resulted in the necrosis and deterioration of very young pistils in closed buds (Fig. 1).

In the first visible injury level, the vegetative tip growth (on the inflorescence shoot) became dark green in colour. At this stage, the fertilization rate and subsequent fruit set can decrease, possibly because of negative effect of the lower temperature on the pollen tube growth and shortening of the physiologically effective pollen-reception age of the pistil. With more temperature reduction (low to about -2 for 2h), stigma, and then style showed morphological necrosis and anatomical deterioration, which resulted in pollen germination and tube growth inhibition (Fig. 2).

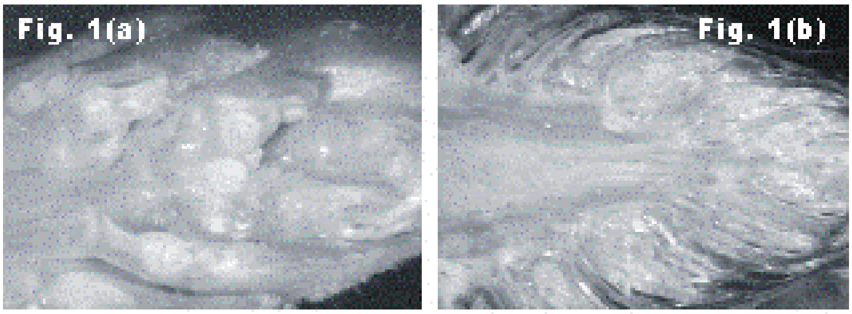
Complete necrosis of flowers, and then, inflorescence, was caused by about -4ºC for about 2h (Fig. 3).

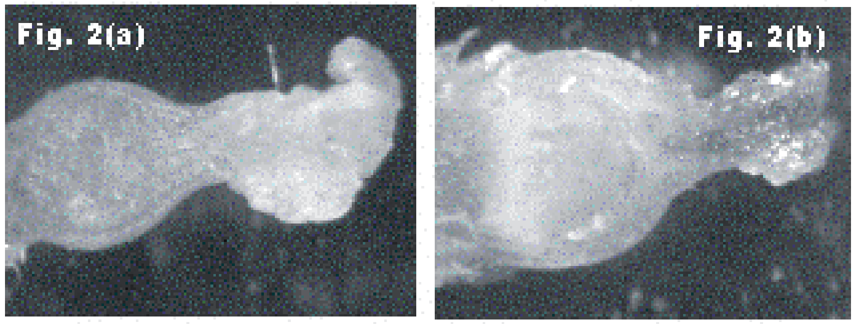
Growth degree-day: Table 3 summarizes phenology of main flowering and fruiting phenomena of two pistachio cultivars. Obviously, in Qazvin area, Ouhedi is an early-flowering and late-ripening and Qazvini a late flowering and early ripening cultivar. As apparent from the table, flowering to start of kernel filling period is the longest. It partly includes the period of fertilization, primarily embryo and mainly the full growth of endocarp.

Kernel filling period varied in two cultivars; Ouhedi's bigger

Table 2. Critical temperatures for chilling injury incidence at two levels in three developmental stages

Stage	Color change	Browning
Bud	-4 ºC	-6
Blooming bud	-2	-4
Bloomed inflorescence	+2	0





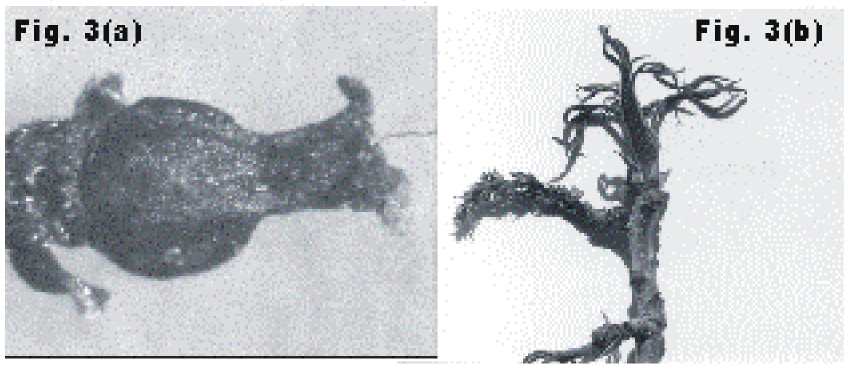


Fig. 1. Healthy (a) and browned (b) bud
Fig. 2. Healthy (a) and necrotic (b) stigma and style
Fig. 3. Complete flower (a) inflorescence (b) necrosis

Table 1. Mean comparison for different injury levels in five temperatures through Duncan method (*P*<0.01). In each column, bold letters are presenting critical injury incidence for two important levels (tissue color change and browning)*

Temperature (ºC)	Bud				Blooming bud				Bloomed inflorescence			
	Healthy	Color change	Browning	Necrosis	Healthy	Color change	Browning	Necrosis	Healthy	Color change	Browning	Necrosis
+2	*20.0a	0.0b	0.0c	0.0b	16.6a	3.33b	0.0d	0.0c	2.16b	**11.0**a	6.3b	0.5b
0	19.6a	0.33b	0.0c	0.0b	15.8a	4.16b	0.0d	0.0c	0.0b	1.83b	14.0a	4.16c
-2	18.6a	1.33b	0.0c	0.0b	2.83b	**13.5**a	3.3b	0.0c	0.0b	0.16b	6.83b	13.0b
-4	0.16b	**11.5**a	7.16b	1.6b	0.33b	1.8b	**14.5**a	3.6b	0.0b	0.0b	1.0c	19.0a
-6	0.0b	1.5b	**15.8**a	2.6a	0.0b	0.0b	1.66c	17.8a	0.0b	0.0b	0.0c	20.0a

*Numbers are based on 20 samples each including 5 buds

Table 3. Phenology of important events of flowering and fruiting of two pistachio cultivars

Cultivar	Stage			
	Flowering	Kernel filling start	Kernel filling finish	Harvest
Ouhedi	16-26 April	13-18 July	15-29 Aug.	20-26 Sept.
Qazvini	20-27 April	3-9 July	4-30 Aug.	1-6 Sept.

Table 4. Length of period and GDD required for each important periods of pistachio cultivars flowering and fruiting in Qazvin area

Cultivar		Periods			
		Flowering to start of kernel filling	Kernel filling	Finish of kernel filling to harvest	Total (flowering to harvest)
Ouhedi	Length (day)	87.0	33.5	39.5	160.0
	GDD (degree)	1406.4	730.6	780.8	2917.8
Qazvini	Length (day)	74.5	30.0	34.0	138.5
	GDD (degree)	1178.7	632.4	750.0	2561.1

kernel took more time to grow fully and needed more growth degree days. The period is horticulturally important as the yield (total kernel weight) and market value (based on split and full nut percent) of the crop depends highly on the proper growth of kernel. It lasts about one month; some cultural practices (hormonal and chemical treatments) are aimed to help the embryo growth in that period (Gholipour, 2005). GDD requirements for various growth and development process of Ouhedi were higher than Qazvini (Table 4). Proper GDD accumulation during the kernel-filling period is one of main criteria when evaluating a new area for pistachio cultivation.

The study revealed that chilling threshold and growth degree day requirements of the two main pistachio pistillate cultivars are different. Critical temperature for reversible tissue colour change was -4^{o}C at bud, -2^{o}C at blooming bud and +2^{o}C at flower stage. Decreasing temperature down to two more degrees could shift the damage into the irreversible injury. Cultivar, Ouhedi's with bigger kernel required more GDD for fully developed kernel.

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