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Effects of alternating temperatures on breaking of peach (*Prunus persica* L.) seed dormancy as a function of cycle length

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مفعول درجات الحرارة المتناوبة على إيزال غفوة بذور الخوخ حسب طول الدورة

قمنا بدراسة مفعول درجات حرارة متوسطة و مرتفعة خلال التطبق على إيزال غفوة بذور الخوخ في دورات مختلفة من يوم واحد إلى 10 أ يام. أخضعنا بذورا ل 5 درجة قارة و أخرى لدرجات حرارة متناوبة بين 5 و 10 أو 13 أو 15 أو 20 أو 25 درجة خلال التطبق. إخضاع البذور ل 20 أو 25 درجة خفض الإنبات في دورة يوم واحد و قد انخفضت درجة التأثير السلبي على الانبات ل 20 و 25 درجة مع طول دورة التناوب، في حين ارتفعت مع طول المدة الزمنية لدرجات حرارة مرتفعة.

الكلمات المفتاحية : بذور الخوخ – غفوة – حرارة – الدورة

Effets des températures alternées sur la levée de dormance des graines de pêcher (*Prunus persica* L.) en fonction de la longueur du cycle

Les effets des températures élevées et modérées sur l'accumulation des unités de froid chez les graines du pêcher ont été évalués en fonction de la longueur du cycle variant de 1 à 10 jours. Les graines ont été maintenues à 5°C constante ou à 5°C alternée avec 10, 13, 15, 20, ou 25°C pendant la stratification. Les températures de 20 et 25°C ont inhibé la germination à 20°C au cycle de 1 jour. Le degré d'inhibition de ces températures a diminué avec la longueur du cycle, mais il a augmenté avec l'augmentation de la durée du séjour à température élevée.

Mots clés: Pêcher - Graines - Température - Dormance - Cycle

Effects of alternating temperatures on breaking of peach (*Prunus persica* L.) seed dormancy as a function of cycle length

The effects of high and moderate temperatures on chilling accumulation in peach seeds (effectiveness) were evaluated as a function of cycle length varying from 1 to 10 days. Seeds were held at 5°C or at 5°C alternating with 10, 13, 15, 20, or 25°C during stratification and prior to germination at 20°C. Exposure to 20 or 25°C significantly reduced subsequent germination on 1 day cycles. The degree of inhibition by 20 and 25°C decreased as cycle length increased, but increased as the proportion of time at high temperature increased.

Key words: Peach - Seeds - Temperature - Dormancy - Cycle

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INTRODUCTION

Exposure to cool, moist conditions (chilling) is required for removal of dormancy in peach seeds, and high temperature negates chilling accumulation.

Moderate temperatures enhanced chilling accumulation in buds (Erez *et al.,* 1979a), but inhibited it in seeds (Aduib & Seeley, 1985) of peach. Moderate temperatures alone can remove dormancy.

"Sharbati" peach seeds responded better to 10 than 0 or 7°C (Sharma & Singh, 1978). Ten degrees was also the optimum temperature for after-ripening of almond seeds (Kester, 1969). "Sungold" nectarine cuttings held at constant temperatures showed a faster floral bud break at 10°C than at 7°C regardless of chilling period (Gilreath & Buchanan, 1981). Exposure to temperatures of 18°C or higher can counteract the effects of previous chilling.

Peach leaf bud opening was reduced by 33% when the average temperature was raised from 10-12°C to 18°C for 15 days while 80% reduction resulted from raising the average temperature to 22.2°C for the same period (Weinberger,1954). High temperatures counteracted the effects of chilling, causing a delay in bloom and foliation and reducing fruit set of "Sullivan Elberta" peach (Weinberger, 1954).

The inhibitory effect of high temperatures is cycle length dependent. The degree of reversal of vernalization by high temperature in Petkus winter rye depends on the temperature, duration of interruption, and the amount of chilling previously accumulated (Purvis & Gregory, 1952).

Exposure to 20°C for 4 hours or less daily enhanced peach bud break in comparison with constant 4°C (Couvillon & Erez, 1985). Increasing the high temperature exposure period to 6 h resulted in chilling negation.

The effect of cycle length on chilling negation by high temperatures in leaf buds of rooted cuttings of "Redhaven" and "Redskin" peach has been evaluated (Erez *et al.,* 1979b).

Cycles of 1, 3, 6, and 9 days were used with 2/3 of the cycle length at low temperature (4°C of 1 day and 6°C for other cyles) and the remaining 1/3 at 24°C. Little or no bud break occurred in "Redskin" plants exposed to 1 and 3 day cycles, whereas 6 and 9 day cylces were just as effective, per hour at 4°C, as continuous 4°C. The chilling negation by high temperatures was dependent on cycle length.

The objective of this study was to determine the effect of cycle length on response of peach seeds to alternating temperature during stratification and its effects on subsequent germination.

MATERIAL AND METHODS

"Siberian C" peach seeds were used. Dry pits were obtained from Hilltop Nurseries, Hartford, Michigan, and were held at 5°C until used. Seeds were removed from the pits and soaked in a fungicide solution (0.03% "Captan" = N-[(trichloromethyl) thio]-4-cyclohexene-1,2-dicarboximide) for 24 h, then placed in petri dishes containing 2 layers of filter paper moistened with Captan solution. Four dishes (10 seeds per dish) were used per treatment. After stratification, germination capacity was evaluated by holding seeds for 10 days at 20°C in the dark. The final germination (%) represents total germination during stratification plus 10 days at 20°C.

1. Experiment 1

The ratios of days at 5°C to days at higher temperatures (10°, 15°, 20°, and 25°) used were 1/1, 2/1, 3/1, 2/2, 4/1, 5/1, 3/3, 4/2, 6/1, 4/4, 6/3, and 5/5. All cycles were repeated until the seeds accumulated 1344 h (8 weeks) at 5°C.

2. Experiment 2

"Siberian C" peach seeds were subjected to the same treatments but the time of exposure to 5°C was limited to 1008 h (6 weeks). In addition to long cycles a diurnal cycle (16/8 h) was included. The percentage germination data of both experiments were transformed to arcsin square root of percentage germination, then analyzed as a 2 factors (temperature regime x cycle time) factorial. For convenience in statistical analysis, treatments were stratified to allow analysis of a) total cycle time with constant ratio of times at low vs. high temperature, or b) total cycle duration with time of exposure to high temperature constant. In each analysis the control treatment (constant 5°C) was included for comparison.

RESULTS AND DISCUSSION

1. Experiment 1

- **Cycles in which days at 5°C/days at higher temperature =1/1**

Temperature significantly affected response, but cycle length did not, and interaction was non-significant (Table 1).

Table 1. Effect of stratification temperature and cycle length (ratio of days at 5°C/days at higher temperatures= 1) on germination (%) (during stratification plus 10 days at 20°C) of "Siberian C" peach seeds following a total time of 1344 h at 5°C

	Stratification temperature (°C)			
Cycle (days)	5/10	5/15	5/20	5/25
1/1	88ab	84ab	40cde	10f
2/2	88ab	80b	48cd	26e
3/3	90ab	98a	40cde	26e
4/4	88ab	90ab	34de	30e
5/5	86ab	82ab	52c	24ef
Control	(continuous 5°C)----------92ab----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

The treatments of 5/20 and 5/25°C significantly reduced germination regardless of cycle length, whereas 5/10 and 5/15°C had neither a promotive nor an inhibitory effect.

Probably germination response was saturated following chilling for 1344 h. Promotion or inhibition by temperatures of 10 or 15°C would have required shorter stratification periods.

- **Cycles in which days at 5°C/days at higher temperature=2/1**

At this ratio the main effects of both temperature and cycle length, as well as their interaction, were significant (Table 2).

Only 20 and 25°C significantly inhibited germination. The degree of inhibition by 20, but not 25°C, decreased as the cycle length increased from 6 to 9 days. No promotion was apparent at any temperature or cycle length, probably because the seeds held at continuous 5°C were approaching maximum percentage germination after 1344 h.

Table 2. Effect of stratification temperature and cycle length (ratio of days at 5C/days at higher temperatures = 2) on germination (%) (during stratification plus 10 days at 20°C) of "Siberian C" peach seeds following a total time of 1344 h at 5°C

	Stratification temperature (°C)			
Cycle(days)	5/10	5/15	5/20	5/25
2/1	86abc	80bc	48d	42d
4/2	96a	88abc	46d	34d
6/3	96a	96a	74c	44d
Control	(continuous 5°C)----------92ab----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

- **Cycles of a single day at high temperatures and increasing times at 5°C**

Main effects of both temperature, cycle length and their interaction were significant (Table 3).

Table 3. Effect of stratification temperature and cycle length (with a single day at high temperature and increasing time at 5°C) on germination (%) (during stratification plus 10 days at 20°C) of "Siberian C" peach seeds following a total time of 1344 h at 5°C

	Stratification temperature (°C)			
Cycle (days)	5/10	5/15	5/20	5/25
1/1	88ab	84ab	40d	10e
2/1	86ab	80b	48cd	42cd
3/1	98a	88ab	56c	48cd
4/1	96ab	88ab	88ab	82ab
5/1	92ab	86ab	86ab	86ab
6/1	92ab	98a	88ab	84ab
Control	(continuous 5°C)----------92ab----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

Moderate temperatures (10 and 15°C) did not significantly reduce germination at any cycle length. However, 20 and 25°C partially negated chilling on short cycles but not on those longer than 4 days.

Thus, the inhibitory effect of high temperature declines as the proportion of time at low

temperature increases. The threshold cycle for inhibition by both 20 and 25°C appeared to be 4 days. Any cycle shorter than this threshold significantly inhibited chilling accumulation.

However, no beneficial effect of moderate temperatures (10° or 15°C) was evident since the stratification period was too long (1344 h at 5°C) and germination percentage was saturated.

2. Experiment 2

• Cycles in which days at 5°C/days at higher temperature =1/1

Temperature was alternated between 5°C and 10°, 13°, 15° or 20°C for 16/8 h, or for 1/1, 2/2, or 3/3 days. The 5/10°C treatment promoted germination in comparison with constant 5°, but the difference was significant only on the 6 day (3/3) cycle (Table 4).

The effects of 13° were non-significant, but 15°C significantly inhibited chilling accumulation in the 1 and the 2 day cycles. In contrast 20°C had an inhibitory effect regardless of cycle length. These effects were not significant when seeds were exposed to 5°C for longer periods (1344 h in Exp. 1).

Table 4. Effect of stratification temperature and cycle length (diurnal vs cycles in which days at 5°C/days at higher temperature = 1) on germination (%) (during stratification plus 10 days at 20°C) of "Siberian C" peach seeds following a total time of1008 h at 5°C.

	Stratification temperature (°C)			
Cycle	5/10	5/13	5/15	5/20
16/8h	83abc	78abc	33efg	18g
1/1day	83abc	63cd	30efg	18g
2/2day	83abc	88ab	45def	25fg
3/3day	93a	88ab	53de	18g
Control	(continuous 5°C)----------68cd----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

• Cycles in which days at 5°C/days at higher temperature= 2/1

The cycles used were 16/8 h, 2/1, 4/2, and 6/3 days. High temperatures of 10° and 13°C slightly promoted germination (not significant at 5% level) in comparison with continuous 5°, while 15°C inhibited it on diurnal and 3 day cycles but not on longer ones (Table 5).

On the other hand, 20°C was inhibitory, regardless of cycle length. Thus the inhibitory effect of 15°C was cycle length dependent.

Table 5. Effect of stratification temperature and cycle length (days at 5C/days at higher temperatures = 2) on germination (%) (during stratification plus 10 days at 20°C) of "Siberian C" peach seeds following a total time of 1008 h at 5°C

	Stratification temperature (C)			
Cycle	5/10	5/13	5/15	5/20
16/8h	83a	78a	33b	17b
2/1day	75a	65a	38b	22b
4/2day	80a	70a	75a	25b
6/3day	80a	83a	65a	22b
Continuous 5°C	----------68a----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

• Cycles with a single day at high temperatures and increasing time at 5°C

Increasing cycle length again showed that the inhibition of germination by 15° and 20°C depends on relative time of exposure to high vs low temperature (Table 6).

Table 6. Effect of stratification temperature and cycle length (cycles with a single day at high temperature and increasing time at 5°C) on germination (%)(during stratification plus 10 days at 20°C) of "Sib C" peach seeds following a total time of 1008 h at 5°C

	Stratification temperature (°C)			
Cycle	5/10	5/13	5/15	5/20
16/8h	83abc	78abc	32gh	17h
1/1day	83abc	63cde	30gh	17h
2/1day	75abcd	65cde	37fgh	20h
3/1day	88ab	80abc	65cde	47efg
4/1day	93a	75abcd	80abc	55def
Continuous 5°C	----------68bcde----------			

Mean separation among treatment combinations by Duncan's Multiple Range Test at the 5% level

A high temperature of 15°C inhibited germination on cycles of 16/8 h, 1/1, and 2/1 days, but not when the cycle length was increased to 4 and 5 days.

The inhibitory effect of 20°C also declined as cycle length increased, but was still evident on the 5 day cycle. The threshold cycle was similar to that in experiment 1, but inhibition by 20°C was much greater in seeds chilled for 1008 h (expt. 2) than in those chilled for 1344 h (Expt. 1).

In these studies it appeared that the inhibitory effect of a given exposure to high temperature on subsequent germination of peach seeds decreased as the cycle length increased.

Moderate temperatures were not effective in stimulating gerniantion because germination of the controls was saturated.

Cycles of a single day at high temperatures and increasing time at 5°C showed that the inhibitory effect of 20° and 25°C decreased with cycle length and disappeared on cycles longer than 4 days.

Interruption of long periods (5-7 days) by high temperature (11-12 days) did not negate chilling accumualtion (Erez & Lavee 1971). However, temperatures of 21°C or higher for 8 h daily completely negated chilling accumulation (Erez *et al.*, 1979a).

Temperatures of 15°C or higher for 8 h a day inhibited subsequent germination of peach seeds (Mahhou & Dennis, 1993). Similarly 20°C for 12 h a day prevented vernalization of Petkus winter rye from occurring.

The exposure of rye to 3, 4, or 7 days at 4°C followed by 1 day at 20°C revealed that the degree of high temperature-induced devernalization decreased as time of exposure to 4°C increased (Purvis & Gregory, 1952). The authors concluded that vernalization goes through a fixation process and is time dependent.

CONCLUSION

The effective temperature range in breaking peach seed dormancy lies between 0° and 10°C. High temperature interspersed during stratification negates chilling accumulation, while moderate temperature promotes it.

The effect of high temperature on chilling negation is cycle length dependent (depends on the duration of low temperature). The chilling becomes more stable and less susceptible to reversal as chilling proceeds.

This suggests that after-ripening goes through a fixation process the degree of which depends upon time of exposure to low temperature.

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