and gaseous composition of the root environment on growth of corn. Agron. J. 64:674–678.
14. Sandsted, R.F. and W.L. Hymes. 1980. Naming and release of 'Midnight', a new black bean cultivar. Mimeo 239, Dept. of Veg. Crops, Cornell Univ., Ithaca, N.Y.
15. Stoffella, P.J., R.F. Sandsted, R.W. Zobel, and W.L. Hymes. 1979. Root characteristics of black beans. I. Relationship of root size to lodging and seed yield. Crop Sci. 19:823–826.
16. Stoffella, P.J., R.F. Sandsted, R.W. Zobel, and W.L. Hymes. 1979. Root characteristics of black beans. II. Morphological differences among genotypes. Crop Sci. 19:826–830.
17. Stoffella, P.J., R.F. Sandsted, R.W. Zobel, and W.L. Hymes. 1981. Root morphological characteristics of kidney beans as influenced by within-row spacing. HortScience 16(5):543–545.
18. Trought, M.C.T. and M.C. Drew. 1980. The development of waterlogging damage in wheat seedlings (*Triticum aestivum* L.). I. Shoot and root growth in relation to changes in the concentrations of dissolved gases and solutes in the soil solution. Plant and Soil 54:77–94.
19. Wample, R.L. and D.M. Reid. 1978. Control of adventitious root production and hypocotyl hypertrophy of sunflower (*Helianthus annuus*) in response to flooding. Physiol. Plant. 44:351–358.

J. AMER. SOC. HORT. SCI. 110(5):627–630. 1985.

Relationships between Parental, Seed, and Seedling Chilling Requirement in Peach and Nectarine

Jorge Rodriguez-A. and Wayne B. Sherman
Department of Fruit Crops, IFAS, University of Florida, Gainesville, FL 32611

Additional index words. *Prunus persica*, breeding, genetics

Abstract. **Attempts to select for flower bud chilling requirement (CR) at the seed stage were made in 58 families obtained from crosses and open-pollination of low chill selections and cultivars of peach and nectarine [*Prunus persica* (L.) Batsch] from the Florida breeding program. A nonsignificant correlation (r = 0.08) between midparent bud CR and family seed CR was obtained. A low significant correlation (r = 0.21**) was obtained between individual seed CR and the CR of the resultant seedling. Seed coat removal had no effect on these correlations. Narrow sense heritability for bud CR as determined by parent-offspring regression was 0.50 ± 0.06. The small range in CR of the seed and pollen parents, 300 to 450 and 200 to 400 chill units, respectively, may explain the low correlation values obtained. The data suggest that it is impractical to screen for seedling CR based on seed CR where the CR for climatic adaptability must be held within a range of less than 300 chill units.**

Breeding fruit tree species for mild winter areas often requires use of germplasm exhibiting wide variation in chilling requirement (CR). Thus, selection for CR is necessary. Most temperate zone woody deciduous species require a certain amount of chilling to break dormancy. Their seeds also require moist chilling to germinate, the amount of which has been associated with the amount of chilling required for the buds (2, 7, 11, 12, 16, 18). Mechanisms controlling CR in buds and seeds may be similar (17). Significant positive correlations have been found between the CR of the seed for germination and the bud CR of the seed parent in apple (11), peach (2), and peach x almond hybrids (8), and between the seed CR and their midparent bud CR in almonds (7). This relationships suggests that screening for CR could be done at the seed stage by monitoring germination time during stratification to separate classes from low to high chilling (18). A low correlation was found in almond between bloom date and CR of the seeds from which they originated (8).

Time of bloom has been selected efficiently on the basis of leafing time in nonflowering juvenile apple seedlings (10, 14, 15). Early selection in apple is especially useful because the time between first or 2nd year leafing and first bloom may be several years. Screening for time of bloom of peach seedlings probably could be done during the first leaf stage in the nursery.

The frequency of peach and nectarine seedlings obtained with the proper CR for the Gainesville area (300–400 units CR) are obtained is about 50% to 60% of the total number of plants screened from most crosses made in the Florida breeding program. Determination of seedling CR classes by separating germinating seed into CR classes would allow the breeder to send seedlings to proper CR areas for growing, or to eliminate these seedlings before planting. The purpose of this study was to examine the potential of selecting for seedling CR based on time of seed germination during stratification in peach and nectarine.

Materials and Methods

Crosses and open-pollinated (OP) families from 16 selections and cultivars from the Univ. of Florida breeding program were used for this study. Two pollen parents, 'EarliGrande' (200 CR units) and clone Fla. 7-3 (400 CR units), were crossed to 16 seed parents ranging from 300 to 450 chilling units (Table 1). Crosses were made during February and March of 1982. Fruit from crosses and OP families were picked when ripe, and seed were removed and stratified at 5° to 6°C using standard procedures. Open-pollinated peaches are about 95% self-pollinated (6). An additional group of 10 families, including crosses and OP families, was included in this study, but their testae were removed. Previous reports indicate that germination inhibitors present in the testa lengthen the CR of the embryo (1, 2, 3, 4,

Received for publication 21 Dec. 1984. Florida Agr. Expt. Sta. J. Ser. No. 6095. This research was supported by a grant from the United States-Israel (Binational) Agr. Res. and Dev. Fund (BARD). The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 1. Florida low chill selections and cultivars used as seed parents.

Seed parent	Chilling requirements (units)
Fla. 3-4	375
Fla. 9-18	375
Fla. 5-20	325
Fla. 9-9	350
Fla. 7-11	375
Fla. 5-15	350
Fla. 9-16	325
Fla. 9-12	300
Fla. 5-14	350
Fla. 9-13	350
Fla. 8-6	350
Fla. 8-14	350
Flordagold	300
Sunripe	350
Sunlite	450
Fla. KE15	400

9). Seed were examined every 5 days once germination started. Individual seed were removed from stratification when the radicle reached a length of 2–2.5 cm, and the number of hours in stratification was recorded. One hour in the refrigerator was counted as a chilling unit. Germinating seed then were grown in a greenhouse until they reached a height of 25–30 cm.

The seedlings were planted in the field in late September of 1982 at 1 m between rows and 0.2 m within rows in a high density fruiting nursery (HDN) which was managed as reported previously (13). Seedlings were classified for their chilling requirement based on time of flower bud break in February and March of 1984. Cultivars of known chilling requirement were used as a reference. Chill unit requirements of parents had been estimated relative to each other based on time of flower bud break. Time of bloom under north central Florida conditions is mainly dependent on CR completion, rather than on differences among seedlings for heat unit accumulation; therefore, the data when more than 75% of the flower buds were open was considered a reliable index to seedling CR.

The Statistical Analysis System (SAS, Institute Cary, N.C.), provided computational procedures to run correlations, regressions, and contrast tests. The General Linear Models (GLM) procedure was used to obtain weighted regression analysis when a mid parent-offspring relationship was analyzed and the number of offspring was not the same in all families (5). Midparent-offspring regression was based on the relationship of midparent CR value and number of chill units necessary to obtain 80% germination of progeny based on those seed that germinated.

Results and Discussion

Relationship between midparent flower bud CR, Seed CR, and progeny mean CR. A low nonsignificant correlation (r = 0.08) was found between midparent flower bud CR and progeny CR in seed with testa intact (Table 2). The narrow range in midparent CR may explain the lack of significant correlation between midparent flower bud CR and progeny seed CR, a correlation found significant by other researchers (2, 11, 18). The mean chill unit requirement for germination in the 10 families was 2160 units and 2510 units for seed without and with the testa, respectively. Testa removal did not improve (r = −0.14) the relationship between midparent and progeny CR (Table 2). However, removal of the testa slightly reduced the time necessary to stratify. When 'Redhaven', a high chilling cultivar (950 chill units) was included in the analysis, the range in CR in the experiment was expanded, and a significant positive linear correlation between midparent flower bud CR and seed CR (family) was obtained (r = 0.43**). This finding sub-

Table 2. Relationship between midparent bud chilling requirement (CR) and amount of chilling for 80% germination in seed with and without testa in several Florida low chill peach and nectarine families.

Family	Midparent chilling units	Seed chilling units	
		With testa	Without testa
Fla. 5-20 x EG[z]	262	2448	2184
Fla. 9-9 x EG	275	2496	2280
Fla. KE 15 x EG	300	2496	2184
Fla. 9-12 OP	300	2400	---
Flordagold OP	300	2424	---
Fla. 5-15 OP	325	2712	2160
Fla. 9-16 OP	325	2448	---
Sunripe OP	350	2232	1872
Fla. 9-9 OP	350	2592	---
Fla. 3-4 OP	350	2664	---
Fla. 5-14 OP	350	2568	1944
Fla. 9-18 OP	375	2112	---
Sunlite OP	400	2784	2328
Fla. KE15 OP	400	2592	2136
Fla. KE15 x Fla. 7-3	400	2496	2472
Sunlite x Fla. 7-3	425	2496	1824
Redhaven OP[y]	950	3840	---
Correlation (r) with midparent CR		0.08[x] NS	0.14[w] NS

[z]EG = 'EarliGrande'.
[y]Not included in correlation analysis for the value shown.
[x]Correlation value for n = 16.
[w]Correlation value for n = 10.

Table 3. Midparent value of the flower bud chilling units of parental clones and progeny in some Florida low chill peach and nectarine families.

Cross	Midparent	Progeny mean	SD	Progeny range
Fla. 3-4 x EG[z]	275	310	86.7	175–475
Fla. 3-4 x Fla. 7-3[y]	375	402	42.5	300–475
Fla. 3-4 OP	350	360	65.2	150–475
Fla. 9-18 x EG	287	353	9.3	175–475
Fla. 9-18 x Fla. 7-3	387	423	45.8	350–475
Fla. 9-18 OP	375	398	62.7	275–475
Fla. 5-20 x EG	262	372	16.0	350–400
Fla. 5-20 x Fla. 7-3	362	355	48.8	250–450
Fla. 5-20 OP	325	355	30.8	300–400
Fla. 9-9 x EG	275	322	69.0	175–450
Fla. 9-9 x Fla. 7-3	375	403	43.5	275–475
Fla. 9-9 OP	350	363	22.9	250–450
Fla. 7-11 x EG	287	317	53.2	250–375
Fla. 7-11 x Fla. 7-3	387	354	84.2	175–475
Fla. 7-11 OP	375	348	93.5	100–450
Sunripe x EG	275	321	58.3	250–400
Sunripe x Fla. 7-3	375	368	51.3	275–475
Sunripe OP	350	380	25.5	350–450
Fla. 5-15 x EG	262	340	95.9	175–450
Fla. 5-15 x Fla. 7-3	362	359	76.3	175–450
Fla. 5-15 OP	325	375	97.0	175–475
Fla. 9-16 x EG	262	297	54.7	175–375
Fla. 9-16 x Fla. 7-3	362	395	51.3	250–475
Fla. 9-16 OP	325	384	33.7	350–450
Fla. KE15 x EG	300	391	70.6	175–475
Fla. KE15 × Fla. 7-3	400	390	95.3	175–475
Fla. KE15 OP	400	366	100.8	150–475
Sunlite x EG	325	359	57.3	250–475
Sunlite x Fla. 7-3	425	428	42.2	350–450
Sunlite OP	450	364	47.1	250–450
Fla. 9-12 x EG	250	304	89.1	100–450
Fla. 9-12 x Fla. 7-3	350	388	56.4	275–475
Fla. 9-12 OP	300	346	31.7	275–400
Correlation (r) with midparent		0.56***[x]		

[z]EG = 'EarliGrande' chilling req. = 200 units.
[y]Fla. 7-3 Chilling req. = 400 units.
[x]Correlation value for n = 33.

Table 4. Effect of pollen parent on seed chilling requirement (CR) for germination and resulting seedling CR in peach and nectarine.

Pollen sources contrasted	Estimated seed CR (units)[z]	F value	Estimated tree CR (units)[z]	F value
'EarliGrande'[y] vs. Fla. 7-3[x]	2172 vs. 2278	(2.91 NS)	355 vs. 377	(9.91**)
'EarliGrande' vs. OP	2172 vs. 2304	(1.86 NS)	335 vs. 366	(18.11**)
Fla. 7-3 vs. OP	2278 vs. 2304	(0.35 NS)	377 vs. 366	(9.59**)

[z]Average of 12 families per cross or OP.
[y]'EarliGrande' chilling requirement = 400 units.
[x]Fla. 7-3 chilling requirement = 200 units.
NS,**Nonsignificant (NS) and significant at $P = 0.01$ (**).

stantiates another study on peach (2) which indicated that it is difficult to separate clones that differ in less than 300 units of CR by observing the germination behavior of seed produced by the clones.

Table 5. Correlation between chilling requirement (CR) of seed and bud break in seedling and seed families in the Florida low chill peach and nectarine population.

Comparison	n	Correlation coefficient (*r*)
Mean seed CR (family) vs. family bud CR	36[z]	0.01 NS
Individual seed CR vs. individual seedling CR (with seed coat)	943[y]	0.21**
Individual seed CR vs. individual seedling CR (no seed coat)	226[y]	−0.08 NS

[z]Number of families.
[y]Number of seedlings.
NS,**Nonsignificant (NS) significant at $P = 0.01$ (**).

The range of midparent values for flower buds CR was between 262 and 450 chilling units (Table 3). There was a significant correlation ($r = 0.56$**) between midparent flower bud CR and the resulting seedling progeny, based on time of bloom in the field, suggesting that monitoring time of bloom of seedlings is more effective than monitoring seed germination behavior in attempting to predict flower bud chilling requirement.

Effects of CR of pollen parent on seed and resulting seedling bud CR. Because 2 pollen parents differing in chilling requirement (200 vs. 400 CR) were used in this study, it was possible to test whether the pollen parent flower bud CR was related to either the CR of the resulting seed or to the flower bud CR of the resulting seedling. The effect of pollen parent flower bud CR and the resulting seed CR was not significant, statistically, as compared to the significant pollen parent effect on seedling flower bud CR (Table 4). This lack of significance suggests that either our method for determining completion of rest in seed was ineffective or that seed and seedling bud chilling requirements have different genetic bases.

The regression of offspring on midparent means for flower bud chilling requirement provides an indication of additive gene action ($h^2 = 0.50 \pm 0.06$) controlling expression of this trait (Fig. 1). This value is conservative considering the range in CR of the material used. The inclusion of 'Redhaven' in the regression analysis inflated the h^2 to 0.75. Thus, parental flower bud CR is a good indicator of seedling progeny flower bud CR, but not of seed progeny CR. Seed CR and flower bud CR apparently are not as closely related as suggested previously (17).

Relationship between individual seed CR and corresponding seedling flower bud CR. When individual seed CR was compared to its corresponding seedling flower bud CR, a low significant correlation ($r = 0.21$**) was obtained (Table 5). Removal of the testa did not increase the correlation, although some increase was expected by removing the maternal influence of the seed coat. Indications that the role of the testa in germination is more of a physical nature than a chemical one can be drawn from data presented by several authors (1, 2, 7).

The low correlation values obtained in this study between seed CR and corresponding seedling flower bud CR agree with those obtained (8) in almond progenies. Thus, it appears that early selection among peach and nectarine seedlings for CR on the basis of CR for seed germination is not practical where the range in CR is less than 300 chill units.

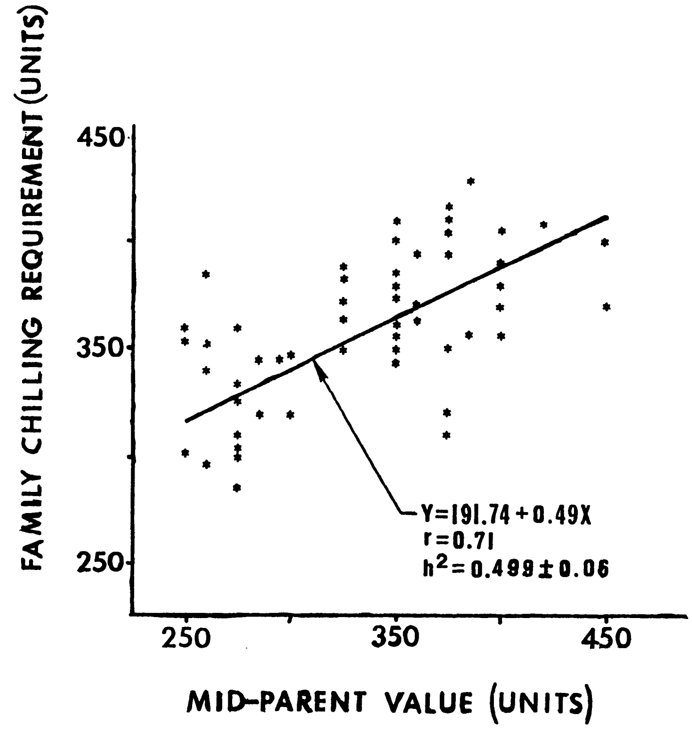

Fig. 1. Regression of offspring on mid-parent value for bud chilling requirement in some low chill peach and nectarine Florida selections.

Literature Cited

1. Bonamy, P.A. and F.G. Dennis, Jr. 1977. Abscicic acid levels in seeds of peach. II. Effects of stratification temperature. J. Amer. Soc. Hort. Sci. 102(1):26–28.
2. Chang, S. and D.J. Werner. 1984. Relationship of seed germination and respiration during stratification with cultivar chilling requirement in peach. J. Amer. Soc. Hort. Sci. 109(1):42–45.
3. Diaz, D.H. and G.C. Martin. 1972. Peach seed dormancy in relation to endogenous inhibitors and applied growth substances. J. Amer. Soc. Hort. Sci. 97(5):651–654.
4. Du Toit, H.J., G. Jacobs, and D.K. Stydom. 1979. Role of the various seed in peach and dormancy and initial seedling growth. J. Amer. Soc. Hort. Sci. 104(4):490–492.
5. Freund, R.J. and R.C. Littell. 1981. SAS for linear models. Cary, North Carolina: SAS Institute, Inc.
6. Hesse, C.O. 1975. Peaches, p. 285–335. In: J. Janick and J.N. Moore (eds.). Advances in fruit breeding. Purdue Univ. Press. West Lafayette, Ind.
7. Kester, D.E. 1969. Pollen effects on chilling requirement of almond-peach hybrids seeds. J. Amer. Soc. Hort. Sci. 94(3):318–321.
8. Kester, D.E., P. Raddi, and R. Asay. 1977. Correlation of chilling requirements for germination, blooming, and leafing within and among seedling populations of almond. J. Amer. Soc. Hort. Sci. 102:145–148.
9. Lipe, W.N. and J.C. Crane. 1966. Dormancy regulation in peach seeds. Science. 153:541–542.
10. Oppenheimer, C.H. and E. Slor. 1968. Breeding apples for a subtropical climate. Theor. Appl. Genet. 38:97–102.
11. Pasternark, G. and L.E. Powell. 1980. Chilling requirements of apple seeds from cultivars having low and high chilling requirements for shoot growth. HortScience 15(3):408. (Abst.)
12. Sanada, T., Y. Yoshida, and T. Hanniuda. 1982. Methods of seed storage in apple breeding 3. Differences in storage using early to late maturing cultivars and wild species. Bio. Abstr. 73.
13. Sherman, W.B., R.H. Sharpe, and J. Janick. 1973. The fruiting nursery: ultrahigh density for evaluation of blueberry and peach seedlings. HortScience. 8(3):170–172.
14. Tydeman, H.M. 1958. The breeding of late flowering apple varieties. Rpt. E. Malling Res. Sta. 1957.
15. Tydeman, H.M. 1964. The relation between time of leaf break and of flowering in apple seedlings. Rpt. E. Malling Res. Sta. 1963. p. 70–72.
16. Vegis, A. 1963. Climatic control of germination, bud break, and dormancy, p. 273. In: L.T. Evans (ed.). In environmental control of plant growth. Academic Press, New York.
17. Westwood, M.N. 1978. Temperate-zone pomology. W.H. Freeman and Co., San Francisco, Calif.
18. Westwood, M.N. and H.O. Bjornstad. 1968. Chilling requirements of dormant seeds of 14 pear species as related to their climatic adaptation. Proc. Amer. Soc. Hort. Sci. 92:141–149.