

A New Source of Peach Germplasm Containing Semi-freestone Nonmelting Flesh Types

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Abstract. A freestone, nonmelting flesh peach would offer the opportunity to transport freestone peaches to distant markets, and so open lucrative export opportunities. Peach [*Prunus persica* (L.) Batsch.] germplasm segregating for semi-freestone and clingstone has been identified among the nonmelting flesh, open-pollinated progeny of the Univ. of Florida selection, Fla. 9-20C. The segregation approached a 1 : 1 ratio. No significant differences were detected between the two categories for titratable acidity, soluble solids concentration, or skin color. However, the semi-freestone progeny had significantly softer flesh than their clingstone siblings, although not soft enough to justify reclassification of the flesh texture. No simple genetic model can be proposed for the inheritance of this new phenotype. The semi-freestone, nonmelting germplasm represents a step towards a less perishable, freestone cultivar for the fresh market, as well as an opportunity to study the reason for the rarity of the freestone/nonmelting phenotype among peaches.

Nonmelting peaches have long been preferred for canning as they maintain their shape and texture during processing (Scorza and Okie, 1991). However, breeders are now considering the use of nonmelting flesh peaches for transport to distant markets for fresh consumption, as they are less prone to damage during handling and shipping (Berrones, 1996). This feature is of particular interest in Australia as a lucrative, out-of-season market exists in the northern hemisphere. Fresh-market preference has traditionally been toward freestone peaches. However, the combination of the freestone and nonmelting flesh traits has been reported only once (Blake, 1937) and is otherwise unknown. Consequently, the nonmelting flesh and clingstone genes were considered to be linked (Bailey and French, 1949), although the lack of a freestone/nonmelting phenotype suggests that some other factor, possibly a pleiotropic allelic series, is involved (Monet, 1989).

Besides facilitating transport, the combination of nonmelting flesh and the freestone characteristic may be advantageous to the canning and dried peach industry, since pit removal is facilitated. In addition, this material also offers the possibility for a low-chill canning and dried fruit industry to emerge. In this paper we report the discovery of nonmelting flesh peaches with a semi-freestone condition.

Materials and Methods

Plant material. Fruits studied were from a high-density planting of an open-pollinated population derived from a single tree of Fla. 9-20C, a product of the Univ. of Florida's low-chill breeding program. Fla. 9-20C is a clingstone, nonmelting flesh selection. Fruit from 58 progeny trees were evaluated in this study. Freestone, melting-flesh, low-chill peaches of three Univ. of Western Sydney, Hawkesbury selections, 95-11F, 94-75W, and B95-9, were used for comparisons of flesh adhesion and firmness. A clingstone accession, 94-60, was also used to compare flesh adhesion to the stone. All tests were conducted on harvest-ripe peaches.

Flesh adhesion. An incision was made in each peach to the depth of the stone, following the suture line of the fruit, and a knife was used to separate the two halves. The ease with which the two halves separated and the amount of flesh that adhered to the stone was used to classify adhesion according to the scheme of Blake and Edgerton (1946). An average of three fruit from each tree were assessed for adhesion.

Flesh firmness (after La Rue and Johnson, 1989). A small piece of skin (≈ 15 mm in diameter) was removed from the opposite cheeks of harvest-ripe fruit. Flesh firmness was measured in these regions using an Effegi penetrometer (Italy) fitted with an 11-mm flat tip.

Skin color (after Robertson et al., 1990). Skin color was measured using a Minolta R-200 colorimeter (Japan), calibrated to $Y = 94.1$, $x = 0.3141$, $y = 0.3217$ with the aid of a white reflective tile. Measurements of Minolta "a" and "b" values and the hue angle were recorded for each fruit. The a value records the degree of green-to-red and the b value the

blue-to-yellow pigmentation; the hue angle is a function of a and b (McGuire, 1992). All measurements were made using three randomly chosen sites on the fruit and the average value from each fruit used for statistical analysis.

Titratable acidity (TA). Peaches from each tree were homogenized using a Waring blender and the resulting pulp centrifuged at 3400 g_n for 5 min at 20 °C. A mixture of 5 mL of the supernatant and 5 mL distilled water was titrated with 0.1 M NaOH to an endpoint of pH 8.1. The TA was expressed in milli-equivalents per 100 mL of juice.

Soluble solids concentration (SSC). SSC was measured with a hand refractometer (Atago, Japan) using samples of the supernatant obtained as above.

Statistical analysis. Data for flesh firmness, skin color, TA, and SSC were subject to analyses of variance. Least significant differences (LSD) were calculated using Duncan's multiple range test. The ratio of progeny in the semi-freestone and clingstone classes was compared to a 1 : 1 ratio using a chi-square test.

Results

Two distinct classes of flesh-to-stone adhesion were discovered among 58 open-pollinated progeny of Fla. 9-20C. The first conformed with Blake and Edgerton's (1946) description of nonmelting, clingstone fruit (class 5), the flesh remaining attached to the stone. These fruit were also compared to those from 94-60, a known clingstone type, and showed the same flesh adherence phenotype as this latter line. The other class of progeny fell between Blake and Edgerton's freestone class and their semi-clingstone class. The firm flesh of these peaches separated easily from the stone as in a freestone; however, unlike the clean pit of a true freestone, a thin, covering layer of soft pulp remained attached. All the progeny were red around the pit cavity. In the semi-freestones, the pulpy adhering membrane made up part of this red tissue. The fruit from each tree could be unambiguously assigned to one of the two classes and all fruit from one tree were of one class. Of the 58 progeny trees tested, 30 were classified as producing semi-freestone and 28 as producing clingstone fruit. This segregation fits a 1 : 1 ratio with a chi-square value of 0.017. All of these progeny have nonmelting flesh.

Fruit from the clingstone and semi-freestone categories did not vary significantly for TA, SSC, or skin color (Table 1). Clingstone fruit were firmer than semi-freestone fruit (46 vs. 42 N; $n = 28$ and 30 respectively; $P \leq 0.001$). In addition, the resistance to penetration of the nonmelting flesh of these two fruit types was nearly twice that of freestone/melting flesh fruit (28 N; $n = 3$).

Discussion

The germplasm used in this study was developed from the Florida selection, Fla. 9-20C, and contains individuals with nonmelting flesh and a semi-freestone adhesion. Classes

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Table 1. Mean values for fruit characteristics of the sibling clingstone and semi-freestone peaches segregating in an open-pollinated population derived from Fla. 9-20C.

Characteristic	Flesh adhesion phenotype ²	
	Clingstone	Semi-freestone
SSC (%)	8.6 (1.20)	7.7 (1.80)
TA (meq/100 mL)	10.3 (2.10)	9.8 (1.80)
Minolta "a"	16.1 (0.64)	16.4 (0.80)
Minolta "b"	41.4 (1.06)	41.6 (0.79)
Hue angle	67.4 (1.66)	68.0 (1.03)

²(standard error of the means); n = at least 20 progeny.

of flesh adhesion and texture have previously been defined by Blake and Edgerton (1946). Our nonmelting, semi-freestone fruit are not found in their classification. This new germplasm offers the opportunity for several new developments with nonmelting types that would be suitable for the domestic and export markets.

The inheritance of the melting/nonmelting flesh and freestone/clingstone characteristics is not fully understood. Bailey and French (1933) suggested that these characteristics are controlled by two linked genes. They proposed that a gene with two alleles, *M* and *m*, controls the development of melting and nonmelting flesh respectively. The clingstone and freestone phenotypes are controlled by alleles, *f* and *F*, of a second gene: *M* and *F* are completely dominant over their associated alleles. When an *F*₂ progeny was made from freestone/melting flesh and clingstone/nonmelting flesh parents, these authors observed only three phenotypic classes: individuals with the freestone/nonmelting flesh combination were absent. The absence of one class of recombinant individuals does not fit with the authors' proposed mode of inheritance and they suggested that flesh firmness may be controlled by more than one gene.

A second hypothesis proposed by Monet (1989) suggested that one pleiotropic gene is responsible for both characteristics. He suggested that there were at least three alleles at this locus; *F*, *f* and *fl*, with *F* being dominant to *f* and *fl*, and *f* being dominant to *fl*. Individuals with the genotype *F*, - have freestone/melting flesh; *f*, *f* or *f*, *fl* are clingstone/melting flesh; and *fl*, *fl* homozygotes are clingstone/nonmelting flesh. This genetic model fits the observed phenotypes more closely than that of Bailey and French (1933). Further, Bailey and French noted the occurrence of individuals with a semi-clingstone phenotype. This observation does not fit with the two traits being controlled by two linked, dominant/recessive gene pairs. A possible third gene, *St*, has also been proposed to influence flesh firmness (Bailey and French, 1941). They suggested that this gene influences the degree of flesh

firmness within the nonmelting and melting categories. However, the existence of this gene has been questioned by other researchers (Monet, 1989; W. Sherman, pers. comm.).

Weinberger (1944) suggested that flesh adhesion can be modified by the environment, making the flesh of freestone peaches adhere to some degree during certain seasons. However, in this trial, three separate cultivars (Univ. of Western Sydney, Hawkesbury, selections 95-11F, 94-75W, and B95-9) in the same row of the orchard as the progeny, exhibited an indisputable, true, freestone nature, thus arguing against a pronounced environmental effect. Furthermore, this classification problem tends to be associated with early season peaches. The progeny in our study were midseason types with the harvest being from late November to early December. These freestone cultivars were also low-chill types and had a similar fruit development period (\approx 112 days for Fla. 9-20C and from 85 to 120 d for the progeny) to that of the progeny, so differences due to length of the fruit development period can also be ruled out.

The flesh of the clingstone peaches was significantly firmer than that of the semi-freestones and, hence, there are differences in flesh adherence and flesh texture. As mutations are rare events, it is unlikely that they would occur simultaneously in two separate genes. Lester et al. (1996) have shown by Southern analysis that Fla. 9-20C is homozygous for a deletion that spans the region containing the polygalacturonase gene. The absence of this gene would explain the nonmelting nature of Fla. 9-20C. This deletion alone cannot account for the ability of Fla. 9-20C to segregate for semi-freestone and clingstone types nor for the difference in flesh texture shown between these types in this study. Fla. 9-20C may be either hetero- or hemizygous for further deleted regions flanking the polygalacturonase gene and that these regions have become homozygous in the progeny. Hesse (1975) suggested that interactions between the *M* and *F* loci might suppress the expression of a freestone, nonmelting flesh phenotype. These possible deletions in Fla. 9-20C may interfere with this interaction, giving rise to the semi-freestone phenotype.

The progeny assessed in this study were derived from an open pollination of a single tree of Fla. 9-20C. Peaches are highly self-fertile, with around 95% self-pollination. Therefore, if adhesion phenotypes observed in this study were due only to a single gene, then an approximate ratio of 3 : 1 between the two categories would be expected: the observed ratio, however, closely approximated 1:1 for the two categories. This result suggests that either the trait is not inherited in this simple Mendelian fashion or there may be an ef-

fect due to cross pollinations. Up to 22% out-crossing has been reported in peaches (Fogle, 1977); however, even this level of cross-pollination cannot account for the deviation in the observed ratio from that expected.

Whatever the cause of this new phenotype, this germplasm offers an opportunity to study the inheritance of the melting/nonmelting and clingstone/freestone characteristics. Further molecular analysis of the chromosomal regions flanking the polygalacturonase gene from clingstone, freestone, and semi-freestone types should allow the mode of inheritance of these traits to be determined. This, in time, will permit directed breeding programs to be developed, allowing fully freestone, nonmelting peaches to be produced.

Literature Cited

- Bailey, J.S. and A.P. French. 1933. The inheritance of certain characters in the peach. Proc. Amer. Soc. Hort. Sci. 29:127-130.
- Bailey, J.S. and A.P. French. 1941. The genetic composition of peaches. Mass. Agr. Expt. Sta. Bul. 378 (Annu. Rpt. 1940):91. Cited in Hesse, 1975.
- Bailey, J.S. and A.P. French. 1949. The inheritance of certain fruit and foliage characteristics in the peach. Mass. Agr. Expt. Sta. Bul. 452.
- Berrones, M.L. 1996. Zaiger Genetics field trip: A lesson in creation. Fruit Gardener 28:4-5 & 11.
- Blake, M.A. 1937. Progress in peach breeding. Proc. Amer. Soc. Hort. Sci. 35:49-53.
- Blake, M.A. and L.J. Edgerton. 1946. Standards for classifying peach characters. N.J. Agr. Expt. Sta. Bul. 728.
- Fogle, H.W. 1977. Self pollination and its implications in peach improvement. Fruit Var. J. 31:74-75.
- 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.
- La Rue, J.H. and R.S. Johnson. 1989. Peaches, plums and nectarines. Coop. Ext., Univ. of California, Div. of Agr. and Natural Resources, Oakland Ca.
- Lester, D.R., W.B. Sherman, and B.J. Atwell. 1996. Endopolygalacturonase and the melting flesh (*M*) locus in peach. J. Amer. Soc. Hort. Sci. 121:231-235.
- McGuire, R.G. 1992. Reporting of objective color measurements. HortScience 27:1254-1255.
- Monet, R. 1989. Peach genetics: Past, present and future. Acta Hort. 254:49-53.
- Robertson, J.A., R.J. Horvat, B.G. Lyon, F.I. Meredith, S.D. Senter, and W.R. Okie. 1990. Comparison of quality characteristics of selected yellow- and white-fleshed peach cultivars. J. Food Sci. 55:1308-1311.
- Scorza, R. and W.R. Okie. 1991. Peaches (*Prunus*), p. 177-231. In: Genetic resources of temperate fruit and nut crops. Intl. Soc. for Hort. Sci., Wageningen, The Netherlands.
- Weinberger, J.H. 1944. Characteristics of the progeny of certain peach varieties. Proc. Amer. Soc. Hort. Sci. 45:233-238.