Breeding of Low-chill Peach and Nectarine for Mild Winters

W.B. Sherman

Fruit Crops Department, University of Florida, Gainesville, FL 32611

J. Rodriguez-Alcazar

Centro de Fruticultura, Colegio de Postgraduados, Instituto de Ensenanza and Investigacion en Ciencias Agricolas, Chapingo, Mexico

Breeding low-chill peach and nectarine cultivars began in Florida in 1953. Objectives were to produce low-chill, early-ripening peach cultivars with fruit qualities equal to temperate-zone cultivars. Low chilling was essential for local adaptation (4). Early ripening was essential to allow production of the earliest-season peaches on the domestic market with little competition from other states and to have harvest of the crop during the relatively dry period of late April and May. Feral selections descended from Spanish seed introductions through St. Augustine, Fla., seed importations from Okinawa, and ‘Hawaiian’, a South China clone, served as the main sources of low chilling (18). These sources were hybridized with high-chilling U.S. clones having commercial fruit qualities. Resultant seedlings were selected for best adaptation and improvement in fruit qualities above that of the low-chilling parents. Chilling requirements of progeny were near midparent values; chilling requirements of the F2 seedlings ranged from equal to the low parent to equal to the high parent (14), indicating that many genes are involved in chilling. Selections were intermated, and low-chilling progeny were hybridized with other high-chilling U.S. clones, resulting in more progenies for further selection. Commercial fruit size and satisfactory horticultural qualities were obtained after six generations of crosses and backcrosses. Clonal selections made during these six generations and in subsequent generations serve as the basis for most low-chilling cultivars currently grown in Florida, southern Texas, and southern California. Selections from this program are either grown commercially or being evaluated in many tropical and tropical highland areas of the world (11, 16, 19, 24).

Fruiting nursery

The problems associated with growing progeny seedling trees for fruit evaluation became apparent soon after the Univ. of Florida low-chill peach breeding program was initiated. A major problem was availability of new land to avoid buildup of root-knot nematodes (Meloidogyne spp.). The introduction of Nemaguard and Okinawa root-knot-resistant rootstocks made testing of cultivars possible at the Univ. of Florida breeding plots, but it was not practicable to propagate every hybrid seedling on root-knot-resistant stock for initial fruit evaluation. Thus, selections and cultivars were maintained for breeding purposes on Univ. of Florida land at Gainesville, while hybrid populations were fruited primarily in grower orchards and on other state experiment station lands. The lack of available root-knot nematode-free land in grower orchards and on university farms and the need to accelerate the breeding program for hybrid seedling evaluation gave impetus to the development and use of the fruiting nursery (22) since 1975.

Progress in fruit breeding is hindered by the amount of time from seed to fruiting and the amount of land required for tree fruits. The fruiting nursery has reduced both constraints and increased efficiency in the breeding program. Operations in the fruiting nursery

700 hr <7.2°) for the mid-west at 900 to 1000 m elevation, and highly scab-resistant apple cultivars, having monogenic Vf, for elevations >1200 m. Precocious fruiting, high productivity, high fruit quality, good storage capacity, red skin, and good mildew and bitter rot resistance are other important objectives of this project. From the results already obtained, ‘Prima’, a precocious cultivar with Vf-scab resistance, high productivity, and red-skinned fruit, and ‘Princesa’, a low-chilling cultivar similar to ‘Anna’ possessing precociousness, high productivity, and good fruit flavor, crispness, firm texture, and red skin are the first two apple cultivars that were released at the end of 1986.

Literature Cited
are as follows. Hybrid seed are harvested in May, removed from the pits, and stratified at 7° to 10°C until germination in July. Germinating seed are greenhouse grown until late August, when the 10- to 30-cm-tall plants are transplanted at a spacing of 10 to 20 cm in the row and 1 m between rows in a nursery site previously fumigated with methyl bromide to kill nematodes and weed seeds. This is called the stage 1 test, and ~5000 hybrid seedlings are grown annually. The young plants either grow until defoliated by temperatures less than −6°C to −8°C (usually in January) or cease growing while retaining green leaves throughout the winter. Lateral branches are removed from March to July or until plants reach 1 m in height and are permitted to branch. Plants usually attain a height of 2 m by winter, 16 months after being set in the field. About 50% of the seedlings fruit the following spring or 24 months after seed harvest, the remainder bearing the next year. About 98% of the first fruiting seedlings are discarded based on criteria of fruit size, shape, color, and firmness, and removed from the fruiting nursery, thus leaving additional space for remaining seedlings. Between 10 and 20 seedlings are selected each year for propagation and field testing under stimulated commercial spacing and cultural operations (stage 2). Seedling selections are allowed to remain in the nursery site for the 4th year to be used as seed and pollen parents in breeding, thereby permitting use of such selections in the breeding program at least 1 year before their budded selections in the field are old enough to fruit.

The annual use in breeding since 1975 of selections made in years 2 and 3 from the fruiting nursery has probably increased gene frequency for precocity in the breeding population. This advance is shown by two seedlings that produced flower buds in Dec. 1984 from the May seed harvest.

Budded trees in stage 2 are fruited for 2 years, generally the 2nd and 3rd year, during which time fruit and tree evaluations are made. Clonal selections may be discarded at any time, but by the 4th year they generally have either been discarded or advanced into grower tests (stage 3). They may have been used in breeding for 1 year before being discarded either from the fruiting nursery, from stage 2, or from stage 3. Clones chosen by growers are propagated for commercial production, named as cultivars, and released and recommended for commercial trial by other growers.

Chilling requirement

Different amounts of winter chilling are needed to satisfy rest in peach cultivars adapted to subtropical as compared to temperate-zone climates, but the best way to calculate the chilling requirement of both groups of cultivars has been debated. The standard measurement of number of chilling hours accumulated below 7°C (25) has given way to weighted chilling hours (12) calculated as chill units (CU). Effective CU obtained in a specific area have been estimated from the average temperature for the coldest month (19), as shown in Fig. 1. Our CU estimate for a new clone is based on bloom time. When peach cultivars differing in chilling are grown at high latitudes, the bloom period generally falls within a 3- to 5-day period. All cultivars have their CU requirement fulfilled during winter and begin accumulating heat units at the same time warm spring temperatures arrive. When these same cultivars are grown at lower latitudes, the bloom period usually spreads to 2 to 5 weeks for two reasons. First, when winter temperatures fluctuate between effective temperatures for CU fulfillment and heat accumulation, clones with a low CU requirement will have their CU requirement fulfilled and begin accumulating heat units before clones with a higher CU requirement. Second, clones receiving inadequate CU show delayed budbreak (4, 5, 25). Thus, cultivars bloom in order of their chilling requirements. Four cultivars adapted to differing latitude ranges within Florida have been selected here as examples. The adapted cultivar leafs, flowers, and fruits normally in its range without showing symptoms of delayed foliation (2). Estimated CU requirements were assigned to each cultivar as follows: ‘Okinawa’ (150 CU), ‘Sunred’ (250 CU), ‘Early Amber’ (350 CU), and ‘Sunlite’ (450 CU). Thus, when all four cultivars are grown at Gainesville, where a cultivar with an assigned 350 CU requirement (Early Amber) is adapted, the lowest chilling (‘Okinawa’) blooms first, followed at about weekly intervals by the other three in order of their CU requirements. The highest chilling cultivar, ‘Sunlite’, shows typical delayed foliation symptoms after mild winters at Gainesville. The time of full bloom of new hybrid trees and selections is rated in relation to the four standard cultivars for estimating CU requirements. The CU values assigned for new hybrid seedlings and clones is not exact, but the relative order of bloom and order of CU requirements seems to correspond each year in various locations throughout the world.

Breeding strategy

Early ripening is one of the most important goals of the Florida peach breeding program because ripening must be completed before the summer rains begin in early June. Thus, the harvest season is extended by breeding increasingly early cultivars. Early ripening results from early bloom and a short fruit development period (FDP). Earliness of bloom is limited by frost risk and use of short FDP in breeding programs is limited by failure of immature embryos to germinate. Feral populations of peach reproduce by seed germinating from pits and exhibit a 130- to 150-day FDP, but this has been reduced by one-half through breeding. Seed germination becomes more difficult as the FDP decreases (8). Embryos from fruit with 90- to 110-day FDP can be germinated by cracking the pit fresh from the tree, removing the kernel, and stratifying immediately. About half of our annual progeny, 2000 seedlings, are produced in this manner and have a short (60- to 80-day) FDP pollen parent. Seed from fruit ripening before an 80-day FDP must be cultured in vitro. Early ripening clones are used as females in hybridizations with pollen parents also ripening < 80 days to increase the frequency of short FDP individuals in the progeny. Seeds are either embryo cultured (65- to 80-day FDP) or ovule cultured (50- to 65-day FDP). In addition to pit cracking and in vitro embryo rescue, increases up to 50% germination were obtained with butanedioic acid mono(2,2-diethylhydrazide) (diaminozide), maleic hydrazide, and thiourea applied to trees 4 weeks prior to harvest (3). However, this procedure is not considered practicable because of apparent phytotoxicity, resulting in severe tree decline.

The average bloom period at Gainesville from the earliest (< 100 CU) to latest (= 550 CU) clone is = 5 weeks, making it necessary to store pollen (freezing method) if low-chill males are to be used on high-chill seed parents. Bloom occurs at Gainesville earlier than at most other U.S. locations, and pollen obtained from these locations is frozen for use the following spring at Gainesville. Usually three to five pollen parents are chosen for hybridizations, with 20 to 30 seed parents permitting about 50 combinations. Daily, flowers are hand-emasculated and immediately pollinated because a given tree may bloom over a period of 3 to 10 days. Remaining flowers are rubbed off after the desired number of pollinations are made.

Fig. 1. Average January temperatures and estimated chill units (CU) in Florida.
About 60,000 hand-pollinations are made, and ~25% set fruit. About 50% germination is obtained, but only about 2000 hybrid seedlings will be obtained due to loss of weak seedlings, disease, and other factors. Another 1000 to 3000 seedlings are reduced from F₂ clones obtained from open-pollination, since peach is 90% to 95% self-pollinated (6). Some of these F₂ seedlings are obtained directly from the fruiting nursery as this method accelerates the breeding program. About 50 hybrid seedlings per cross and up to 200 F₂ seedlings per open-pollinated seed parent are desired.

Breeding goals

A major goal of the Univ. of Florida breeding program is to develop commercially acceptable peach and nectarine cultivars ripening in sequence from late April until early June for the 100- to 350- and 400- to 600-CU zones (Fig. 1). The early season is limited by spring frosts on early bloom and the ability to breed large (5 cm in diameter) fruit cultivars in the 50- to 70-day FDP range. The late season is fixed as the rainy season begins in early June. The 100- to 350-CU zone represents central Florida and the subtropics (1, 11, 15, 19). The 400- to 600-CU zone represents northern Florida and some low-chill areas in the world’s temperate zones, such as southern Spain and northern Argentina.

A new goal of the breeding program is the production of a series of low-chill, early ripening, nonmelting flesh cultivars (21). The firm, nonmelting flesh character is inherited as a single recessive gene. Both the early ripening genetic freestone, melting flesh, and the genetic clingstone, nonmelting flesh types, are clingstones, so they may not be distinguishable by the consumer. The early-ripening, genetic freestones behave physiologically as clingstones, since the fruit are not on the tree long enough for the pit (endocarp) and (mesocarp) to separate. There are several advantages to the genetic clingstone which have nonmelting flesh. It would enable the grower to harvest fruit physiologically more mature with high tree-ripe flavor and without soft overripe fruit to discard. The breeder would not have to discard a high percentage of hybrid seedlings because of fruit softness and the fruit would have a prolonged shelf life, which would be especially helpful in U-pick and roadside markets and in subtropical areas where refrigeration is not readily available.

The U.S. markets are based on yellow-fleshed peaches, but many countries prefer white-fleshed fruit (a single dominant gene). In addition, the deep yellow to light orange flesh (inheritance unknown) is attractive in fresh fruit. Efforts have been made in the breeding program to produce clones of these flesh types because they offer potentials as novel fruit types. Frost hardiness in blossoms, fruit characteristics such as size, flavor, shape, and color, resistance to bacterial leaf spot, consistent fruiting, and a short juvenile period are some additional characters receiving attention in the breeding program (21).

Relationship of characters

The fruiting nursery concept has been used since 1975 in the Florida low-chilling peach and nectarine breeding program. It appears from visual observations and selection records that evaluations in the fruiting nursery of young trees with few fruit effectively reflect the evaluations in mature trees under orchard conditions. This relationship must be close enough for high genetic progress to be made in advancing potential commercial selections. Recent studies have shown that expression of traits in the fruiting nursery, such as chilling requirement, fruit development period, fruit size, and flower bud set is highly correlated with expression in mature clones of the same selections in simulated commercial plantings (15). Chilling requirement was slightly higher and fruit size slightly lower in young seedlings selections in the fruiting nursery than in mature trees of the same selections in simulated commercial plantings. Although seed chilling requirement was shown not to predict seedling chilling requirement accurately (13), time of autumn growth cessation was generally related to chilling requirement of clones (10). The highest chilling requirement clones ceased growth first in the presence of shortening days. A correlation matrix among chilling requirement, length of fruit development period, crop load, fruit color, fruit size, fruit shape, and fruit firmness showed a low few, but significant relationships (15). None of the correlations were high enough to be of use in seedling selection.

Genetic studies

A major goal has been to breed early ripening peach and nectarine cultivars. Seedling marker genes for early ripening have been described in peach, and evidence has been presented for major genes controlling time of ripening (23). Genetic progress in reducing days from bloom to maturity and increasing fruit size was obtained among selections (15). The increase in fruit size and short fruit development period were obtained while maintaining high ratings in the same selections for fruit color, firmness, and shape. In other genetic studies, the degree of parental flower bud set was shown to predict the degree of early flower bud set in 18-month-old offspring (7, 14). Seedling vigor was found to be reduced for red-leaf progeny in populations segregating for the red-leaf allele, and variable susceptibility to freeze injury was shown to exist among 8-month-old hybrid seedling progenies (9).

Clonal testing

Many countries in the subtropics and tropical highlands have few crops capable of producing a high value per unit area, but contain large areas of land suitable for low-chilling peach and nectarine culture. Some countries currently grow low-chilling seedling “creole” peaches for local consumption, but these fruit lack the qualities necessary to compete in markets with expensive imported fruit of cultivars grown in more temperate climatic zones of the world.

Summary

Breeding work and clonal testing in low-chilling peach and nectarine has been reviewed and details have been given on what has been accomplished (2, 17, 20) and potential goals to be reached (21). The Florida cultivar improvement program is unique in the world for its development of low-chilling peach and nectarine germplasm. Cultivars and selected clones are currently being tested in more than 60 countries with warm winter areas. Significant commercial production in Florida low-chilling cultivars occurs in 10 countries. These low-chilling cultivars and their adaptation have been evaluated at various latitudes, altitudes, and microclimatic conditions (1, 4, 11, 16, 19).

Literature Cited

estimating and completion of rest for 'Redhaven' and 'Elberta' peach
parental, seed, and seedling chilling requirements in peach and nectarine,
rental flower bud set and seedling precociousness in peach and nectarine,
Prunus persica (L.) Batsch. Fruit Var. J. 40:8–12.
density nursery system for breeding peach and nectarine: a 10-year
low chilling peach and nectarine cultivars in the Bolivian highlands.
Fruit Var. J. 35:122–125.
18. Sharpe, R.H. and J.S. Shoemaker. 1958. Development of temperate-
19. Sherman, W.B., R.J. Knight, and T.E. Crocker. 1978. Peach and
nectarine breeding and testing in warm parts of the world. Proc. Trop.
(In press.)
(In press.)
22. Sherman, W.B., R.H. Sharpe, and J. Janick. 1973. The fruiting nur-
sery; Ultra high density for evaluation of blueberry and peach seed-
characters associated with early ripening in peaches. HortScience 7:502–
503.
Florida peaches and nectarines in the tropics and subtropics. Fruit Var.
J. 31:75–78.

Producing Temperate-zone Fruit At Low Latitudes: Avoiding Rest
and the Chilling Requirement

Gordon R. Edwards
Department of Plant Physiology,
Waite Agricultural Research Institute, Glen Osmond, South Australia 5064

TEMPERATURE REGIMES FAVORABLE FOR
YEAR-ROUND GROWTH

Commercial production of temperate-zone fruits is well es-
blished in localized areas in the tropics. This paper considers mete-
orological and cultural conditions necessary for success.

Many components of climate influence plant growth; for tem-
perate-zone fruits at low latitudes, temperature, particularly mini-
mum temperature, is considered the determining factor. Many factors
influence the temperature regime of a particular location; in the
present context, latitude and altitude are major determinants (Table
1).

Latitude

Seasonal variation in temperature declines with decreasing lati-
tude; uniformity throughout the year is approached at the equator.
Minimum temperature is influenced more in the colder than in the
warmer months (Fig. 1A), whereas maximum temperatures are less
affected.

The lower three curves in Fig. 1A exemplify temperature regimes
of the temperate zone. Growth and fruit production occur in the
warmer months and rest occurs in the cooler months and adequate
chilling is received to break it. Such environments occur mainly
between lat.50° and lat.30°.

The middle three curves in Fig. 1A are typical of areas in which
winter temperatures are too low for growth; rest occurs, but chilling
is inadequate for most cultivars. These areas occur mainly between
lat.30° and lat.15° and include subtropical regions as well as many
desert environments.

The upper three curves in Fig. 1A are representative of areas with
relatively uniform temperatures year-round where little to no chilling
occurs according to any currently used method of assessment.
Such areas are usually in the wet or dry tropics between lat. 15°
and lat.0°.

In areas of inadequate winter chilling, successful culture of tem-
perate-zone fruit is dependent on cultivars with a low chilling re-
quirement; desiccation and/or chemicals to terminate growth and
assist defoliation; and appropriate rootstocks, irrigation, and/or
chemicals to hasten and synchronize bud burst in the next growth
cycle (6, 7, 13, 16). In equatorial regions where winter chilling is
rare, the effect of altitude on temperature (Fig. 1B) is exploited.

Altitude

At low elevations in equatorial regions, vegetative growth is ex-
cessively vigorous and may continue unabated all year. There is no
synchronous periodicity of growth and no chilling to break rest after
growth eventually ceases. Historically, most attempts to grow tem-
perate-zone tree fruits in the tropics have been confined to high
elevations in order to satisfy the chilling requirement. Some ex-
amples of such areas are Pueblo Hondo, Venezuela (2510 m); Molo,
Kenya (2477 m); and Holetta, Ethiopia (2390 m). Although the
chilling requirement may be satisfied on current methods of as-
essment, the uniformly suboptimum temperatures year-round pre-
clude satisfactory tree growth and fruit development. Delayed
foliation, erratic bud burst, asynchronous shoot and fruit growth,
and prolonged defoliation still occur. To my knowledge no large-
scale culture of temperate fruits exists under these conditions.

The only large-scale commercial culture of temperate-zone tree
fruits in the tropics occurs at intermediate altitudes. Apples are
grown commercially at Batur, E. Java, Indonesia (lat.8°S, 800–1200
m alt.) (17, 21, 24). The mean annual maximum is 26.7°C, the
mean annual minimum is 18.4°C. Apples were successfully grown
experimentally in the Philippines at Baguio (lat.16°N, alt. =1500
m, mean max 23.3°, mean min 15.1°) and Spencer farm, near
General Santos, Mindanao (lat.6°N, alt. 520 m, mean max 29.7°,
mean min 20.1°) (9) (Fig. 2A). In Venezuela, peaches are grown
commercially at altitudes from 1200 to 1700 m in valleys lower,
and thus warmer, than Colonia Tovar (lat.10°N, alt. 1790 m, mean
max 21.4°, mean min 12.1°) (22, 25). Low-chill peaches were
successfully grown experimentally at Baguio, but not at lowland
sites in the Philippines (9) (Fig. 2B).

1Present address: 4/4 Frick Ave., Firle 5070, South Australia.