Sweeney' and 'Kohala' were the only selections having > 80% commercial size fruit.

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Inbreeding in California Canning Clingstone Peach Cultivars

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Abstract

The inbreeding coefficients of commercially important canning clingstone peach [*Prunus persica* (L). Batsch] cultivars developed in California were found to be relatively low based on pedigree analysis using the SAS INBREED procedure. However, coefficients of co-ancestry between the likely parents of future generations reveal an increasing probability of inbreeding. This increased probability is primarily the consequence of past usage of a small number of presumably unrelated parents in early crosses, and extensive use of their progeny as parents in subsequent crosses.

Introduction

Production of clingstone non-melting flesh peaches (*Prunus persica* (L.) Batsch) in the central valley of California totalled 542,455 tons in 1992. Virtually all this production is for processing where requirements include high yields of good quality, uniform fruit, an absence of red anthocyanin pigmentation in fruit flesh (due to their water solubility and oxidative browning), and dependable supply of raw fruit from mid June through August. These needs, combined with the uniform, favorable growth environments in central California, have led to extensive utilization of locally-improved germplasm for the development of new cultivars.

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Breeding progress, particularly for sequential harvest periods and crop uniformity, has been facilitated by this emphasis on elite, locally adapted genotypes, thus some inbreeding inevitably results. While Lesley (9) has reported that peach is relatively tolerant of inbreeding, greater tree vigor of his outcrossed relative to inbred lines also demonstrated some inbreeding depression. Further, advanced populations consisting of closely related individuals contain a fraction of the genetic variability compared with their ancestral base, which can lead to a decrease in the potential rate of progress for the breeding program (1, 8).

Previous studies have concluded high degrees of inbreeding for fresh-market, freestone peach cultivars grown in the Eastern United States (13) and relatively low inbreeding for the low-chill requiring, short fruit-development-period peaches released from the University of Florida (14). This paper reports the results of a pedigree analysis of California canning clingstone peach cultivars.

Materials and Methods

Production data for clingstone peach cultivars presently grown in California were obtained from the California Cling Peach Advisory Board, San Francisco, CA. Twenty-seven cultivars were selected for pedigree analysis based on a significant production (i.e greater than 100 bearing acres in 1992) or their prominence in breeding line pedigrees (Tables 1 and 2). A pedigree data file consisting of 326 breeding records was created on a VAX-8600 computer system using breeder and industry records and published pedigrees (2, 11). The SAS procedure INBREED was used to calculate the inbreeding (F) and coancestry coefficients (Ø). INBREED is included and documented briefly (12) in the main SAS program, though not supported by SAS or its author, Anthony J. Barr of North Carolina State University. The INBREED procedure requires properly sorted observations for each individual, which include individual identity (cultivar name or breeding line) as well as the male and female parents. In order to generate a comprehensive matrix of coancestry relationships, all individuals were assumed to belong to the same generation rather than the alternative of several non-overlapping generations.

The SAS procedure INBREED generated a matrix of coefficients between the individuals defined in the observations. Individual identities made up both the row and column headings of the matrix. Although SAS (12) employs the designation (P) for the inbreeding coefficient, Falconer's (3) designation of the inbreeding coefficient as (F) is used in this paper in order to avoid confusion with the parametric index (P) of Wright (17). The inbreeding coefficient (F) of an individual was reported on the diagonal of this matrix (the convergence of the individual column heading with its row heading) and the coefficients of coancestry for pairs of non-selfed individuals were reported within the remaining SAS generated matrix (off-diagonal values). Inbreeding coefficients for the selected cultivars were then transferred to Table 2 with the coefficients of coancestry for selected pairs of cultivars summarized in Table 3. The coefficient of coancestry of an individual with itself, i.e. if self-fertilized, was then calculated as:

$$\varnothing(AA)\quad (1 + F(A))/2, \qquad (16)$$

with the calculated Ø values recorded at the appropriate diagonal position on the matrix of Table 3.

The parameters generated by pedigree analysis depend heavily upon the initial levels of relatedness and inbreeding in the population. Ultimately, the coefficients of inbreeding and coancestry for the earliest ancestors are unknown and must be assumed. Two scenarios realistic for the current germplasm base were tested in this study. The first (Case-I) treated all genotypes with unknown parents as unrelated and non-inbred, whereas the second (Case-II) treated these generations as first generation selfs of unrelated parents. A tacit assumption of this method is that all grandparents of the earliest identified genotypes included here were non-inbred and unrelated. When this assumption is violated, the consequences of inbreeding for individual homozygosity and inbreeding effective population size will be underestimated (3). However, all of the genotypes included as ancestors in the peach germplasm were the product of breeding programs with intensive selection. Inbreeding in combination with selection invalidates the use of pedigree-based parameters in predicting genotypic distributions, and the assumption of unrelated grandparents permits comparison of the change in relatedness only for recent crossing or breeding cycles.

Editing the data set to simulate a selfed origin of unknown individuals resulted in a closer agreement with coefficients determined by path analysis (3, 16) than did a redefinition of the COVINIT SAS variable. Defining COVINIT to 1.00, for example, assumes selfing occurs in undefined parents (F-calculation) as well as undefined grandparents (Ø-calculation). This greatly increased the prediction of identity by descent, because the grandparent is frequently incompletely defined in the older pedigrees tested.

Results and Discussion

The 26 cultivars studied (Table 1) represent only one-third of all cultivars presently grown, but they accounted for over 97% of the total of 30,656 bearing acres. The 10 most widely planted cultivars accounted for approximately 85% of the total bearing acreage.

Cultivars can be classified into five groups based on breeding history and time of introduction (Table 2). Group 1 included primarily older cultivars whose pedigree is unclear, although most appear to have originated as Lovell rootstock seedling selections (2, 11). 'Lovell,' a chance seedling selection, while initially planted as a drying peach, became a major rootstock for the canning peach industry. In Case I, where individuals of undefined parentage are assumed to result from cross-pollination between unrelated parents, no inbreeding is assumed. The Case II assumption of origin from self-fertilization results in an inbreeding coefficients of 0.500 if parents are assumed unrelated, and an inbreeding coefficient of up to 0.750 if

Table 1. California 1992 bearing acreage and average yield per acre for selected canning clingstone peach cultivars.

Maturity category	Cultivar	Bearing acreage	Tons/ acre[z]
Extra early	Loadel	3294	14.3
	Carson	3306	14.6
	Dee-Six	211	17.6
	Tufts	270	15.2
	Dixon	15	no data
	Fortuna	8	14.1
Early	Bowen	1474	15.5
	Paloro	93	10.23
	Andross	3465	18.7
	Jungerman	32	16.6
	Peak	293	15.0
	Klamt	987	19.5
	Andora	109	19.5
Late	Ross	2336	20.7
	Dr. Davis	1847	18.7
	Rizzi	9	20.5
	Carolyn	1597	17.3
	Monaco	488	20.6
	Halford	4365	18.7
	Everts	164	18.4
Extra late	Riegels	82	20.2
	Hesse	20	18.9
	Wiser	385	16.1
	Starn	4399	19.4
	Sullivan #4	1554	21.8
	Corona	1102	20.0

[z]State-wide average (in short tons) which does not account for differences in planting-density, tree-age, management, etc.

Table 2. Pedigree analysis of clingstone peach cultivars important to the California canning fruit industry.

Group and Cultivar	Parentage	[year of release]	Inbreeding coefficient (F)[z] Case I	Case II
Group 1				
Halford	Unkown-Lovell seedling?	[1921]	0	0.750
Lovell	Unkown	[1882]	0	0.500
Peak	Unkown	[ca. 1910]	0	0.500
Starn	Unkown-Lovell seedling?	[1950]	0	0.750
Sullivan #4	Unkown	[1940]	0	0.500
Loadel	Unkown-Lovell seedling?	[1950]	0	0.750
Monaco	Lovell mutation or seedling	[1948]	0	0.750
Group 2				
Wiser	Sims x Lovell	[1943]	0	0
Paloro	Autralian Muir x Orange Cling sdl.	[1912]	0	0
Dixon	Orange Cling sdl. x Australian Muir	[1956]	0	0
Group 3				
Andora	Lovell x Libbee	[1941]	0	0
Fortuna	Leader x (Tuscan x Paloro)	[1941]	0	0
Carolyn	Lovell x Libbee	[1942]	0	0
Carson	Leader x Maxine	[1943]	0	0
Corona	Lovell x Libbee	[1942]	0	0
Group 4				
Everts	Dix,22A-5 x Dix,5A-1	[1962]	0.047	0.070
Jungerman	Dix,22A-5 x Dixon	[1964]	0.063	0.094
Klamt	Wiser x Dixon	[1964]	0	0
Tufts	Dix,10A-4 x Everts	[1971]	0.078	0.141
Andross	Fortuna x Dix,5A-1	[1964]	0.063	0.078
Bowen	(Dixon x Halford) x Dix,22A-5	[1971]	0.031	0.047
Group 5				
Dee-Six	Dix,4A-4 x Dix,#3	[1986]	0	0
Riegels	Jungerman x Everts	[1987]	0.199	0.236
Dr. Davis	G,40-5E x D,25-9E	[1984]	0	0
Ross	D,30-3E x (Dix,22A-5 x Dix,18A-2)	[1984]	0.137	0.153
Hesse	Riegels OP	[1992]	0	0.618
Rizzi	Everts OP	[1992]	0	0.535

[z]Case I assumes all genotypes with unknown parents are unrelated, while Case II assumes these genotypes are first generation selfs of unrelated parents.

the putative parent 'Lovell' was assumed to have originated from a self-pollination as well. Some selfing is considered likely in this material because most originated as chance selections from commercial plantings and because the average frequency of natural self-pollination in peach has been shown to exceed 75% under central California conditions (8, 10).

Cultivars in Group 2 resulted from organized and well characterized selection programs by early breeders, particularly M. Dixon (early 1900's-1943) of the California Canners League, W. F. Wight (early 1900's to mid 1940's) of the United States Department of Agriculture (USDA) station at Palo Alto, CA, and G. L. Philps (1920's-1952) at what was then the University of California at Berkeley Research Farm at Davis, CA. Primary selection criteria included: suitability for production in the southern San Francisco Bay area (Wight at Palo Alto) or the southern Sacramento Valley (Dixon and Philps), fruit uniformity and low red pigmentation in an otherwise yellow flesh. In addition to the utilization of 'Australian Muir,' 'Orange Cling,' 'Sims,' and 'Lovell' as parents, crosses were made with 'Michigan #1 Late' (a seedling of 'Late Crawford'), 'Lemon Free' 'Round Tuscan,' 'Goodman's Choice,' 'Alameda' and 'Transvaal Cling.' These eleven cultivars remain the basis for virtually all cultivars developed since. 'Phillips' was one of the first cultivars to achieve wide planting, and its commercial importance exceeded that of 'Tuscan' and 'Poloro.' However, 'Phillips' appears to have appears to have made no notable contribution to subsequent breeding lines.

All cultivars in Group 3 originated in the USDA program of W. F. Wight at Palo Alto, CA, with selection emphasis on tree vigor and productivity. The release of this group in the early 1940's was the consequence of the transfer of the USDA clingstone peach breeding program to the then University of California Research Farm at Davis and Winters, CA. The inbreeding coefficient (F), which is the probability that two alleles at a locus of an individual are identical by descent, (i.e. the alleles are replicates of the same allele of a common ancestor) is null for all cultivars in Case I and Case II. Three cultivars, 'Lovell,' 'Leader' and 'Libbee,' however, dominate the pedigrees of these cultivars. The coefficient of coancestry (Table 3) between selected cultivars (Ø) is the probability that they carry alleles that are identical by descent, and thus equals the inbreeding coefficient for the prospective progeny of those two cultivars. Examination of the coefficients of coancestry values for Group 2 and Group 3 cultivars shows that continued emphasis on these individuals as parents would frequently result in dramatic increases in inbreeding in their progeny (Table 3).

Breeding of clingstone peach continued under L. D. Davis, after the establishment of the U.C campus at Davis, CA in the 1950's. This work led to the development of a number of new cultivars which make up the Group 4 group. These cultivars resulted from controlled crosses between parents selected for high flavor with low frequency of split-pits and pit-fragments, in addition to fruit uniformity and tree productivity. This period is also notable for the introduction of important new germplasm, and the use of multiple generations of interbreeding between established cultivars and breeding lines, particularly lines Dix,22A-5 and Dix,5A-l, before release of new cultivars.

The most important new germplasm brought into the program at this time was from a cross between 'Elberta' and the high flavor nectarine plant introduction ss292557. Earlier cultivars and breeding lines, particularly those selected by Wight and Dixon, were also utilized extensively during this stage. Crosses between Group 4 cultivars have low consanguinity (Table 3), though this conclusion is based on the assumption that Wight's and Dixon's material originated from different sources. An inbreeding coefficient of 0.063 would result from first-cousin matings of otherwise unrelated diploids; 0.125 from half-sib matings, 0.250 from full-sibs, and 0.500 from selfing. The higher coefficients of coancestry between many of these individuals, however, again predict a higher expected inbreeding coefficient for progeny resulting from the continued intermating of this germplasm.

Following L. D. Davis' retirement in 1964, the clingstone peach cultivar selection and evaluation program continued intermittently, first under C. O. Hesse (1970-1979) and later under A.

Table 3. Coefficients of coancestry (∅) of selected cultivar combinations (all values have been multiplied by 100).

Group			1	1	1	1	1	1	1	2	2	2	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5
		Cultivar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
													Case I																
1	1	Halford	50	25	.	13	.	13	25	13	.	.	13	.	13	.	13	.	.	6	.	.	13	.	.	.	.	.	.
1	2	Lovell		50	.	25	.	25	50	25	.	.	25	.	25	.	25	.	.	13	.	.	6	.	.	.	.	.	.
1	3	Peak			50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	4	Starn				50	.	13	25	13	.	.	13	.	13	.	13	.	.	6	.	.	3	.	.	.	.	.	.
1	5	Sullivan #4					50	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	6	Loadel						50	25	13	.	.	13	.	38	.	38	.	.	19	.	.	19	.	.	.	.	.	.
1	7	Monaco							75	25	.	.	25	.	25	.	25	.	.	13	.	.	6	.	.	.	.	.	.
2	8	Wiser								50	.	.	13	.	19	.	19	.	.	25	.	.	9	.	.	.	.	.	.
2	9	Paloro									50	30	.	13	.	.	.	16	16	13	14	19	9	.	16	2	8	8	8
2	10	Dixon										50	.	6	.	.	.	13	28	25	19	13	16	.	20	16	5	10	6
3	11	Andora											50	.	25	.	25	.	.	6	.	.	3	.	.	.	.	.	.
3	12	Fortuna												50	.	13	.	4	4	3	4	28	2	.	4	0	2	2	2
3	13	Carolyn													50	.	25	.	.	6	.	.	3	.	.	.	.	.	.
3	14	Carson														50	.	.	.	.	.	6	.	.	.	.	.	.	.
3	15	Corona															50	.	.	6	.	.	3	.	.	.	.	.	.
4	16	Everts																53	20	6	30	17	17	.	36	7	12	18	26
4	17	Jungerman																	53	14	18	8	21	.	37	7	10	18	10
4	18	Klamt																		50	9	6	9	.	10	1	2	5	3
4	19	Tufts																			54	12	13	.	24	4	8	12	15
4	20	Andross																				53	5	.	19	1	5	6	9
4	21	Bowen																					52	.	.	7	9	9	8
5	22	Dee-Six																						50	.	.	.	.	.
5	23	Riegels																							57	7	11	30	18
5	24	Dr. Davis																								50	7	3	3
5	25	Ross																									57	5	6
5	26	Hesse																										50	9
5	27	Rizzi																											50
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Table 3. (Continued).

Group		Cultivar	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3	4	4	4	4	4	4	5	5	5	5	5	5
			1	2	3	4	5	7	9	6	8	11	10	14	19	20	21	12	13	23	25	17	18	15	16	22	24	26	27
													Case II																
1	1	Halford	88	75	.	75	.	75	75	38	.	.	38	.	38	.	38	.	.	19	.	.	22	.	.	.	.	.	.
1	2	Lovell		75	.	75	.	75	75	38	.	.	38	.	38	.	38	.	.	19	.	.	19	.	.	.	.	.	.
1	3	Peak			75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	4	Starn				88	.	75	75	38	.	.	38	.	38	.	38	.	.	19	.	.	19	.	.	.	.	.	.
1	5	Sullivan #4					75	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1	6	Loadel						88	75	38	.	.	38	.	38	.	38	.	.	19	.	.	19	.	.	.	.	.	.
1	7	Monaco							88	38	.	.	38	.	38	.	38	.	.	19	.	.	19	.	.	.	.	.	.
2	8	Wiser								50	.	.	19	.	19	.	19	.	.	25	.	.	9	.	.	.	.	.	.
2	9	Paloro									50	38	.	13	.	.	.	20	23	19	20	22	14	.	22	2	9	22	20
2	10	Dixon										50	.	9	.	.	.	19	30	25	22	19	17	.	24	2	7	24	19
3	11	Andora											50	.	38	.	38	.	.	9	.	.	9	.	.	.	.	.	.
3	12	Fortuna												50	.	19	.	5	6	5	5	29	4	.	5	1	2	5	5
3	13	Carolyn													50	.	38	.	.	9	.	.	9	.	.	.	.	.	.
3	14	Carson														50	.	.	.	.	.	9	.	.	.	.	.	.	.
3	15	Corona															50	.	.	9	.	.	9	.	.	.	.	.	.
4	16	Everts																54	24	9	34	19	19	.	39	7	13	39	54
4	17	Jungerman																	55	15	22	12	22	.	39	7	12	39	24
4	18	Klamt																		50	11	9	13	.	12	1	4	12	9
4	19	Tufts																			57	14	16	.	28	5	12	28	34
4	20	Andross																				54	7	.	15	1	6	15	19
4	21	Bowen																					53	.	21	7	9	21	19
5	22	Dee-Six																						50	.	.	.	.	.
5	23	Riegels																							62	7	12	62	39
5	24	Dr. Davis																								50	7	7	7
5	25	Ross																									57	12	13
5	26	Hesse																										81	39
5	27	Rizzi																											77
			1	2	3	4	5	7	9	6	8	11	10	14	19	20	21	12	13	23	25	17	18	15	16	22	24	26	27

H. Kuniyuki (1979-1984) and J. Beutel (1979-1987). New cultivars were developed from continued intermating of L. D. Davis's material, with a consequent rise in the inbreeding coefficients (Group 5).

'Ross,' while being one of the more inbred (though only moderately so by peach standards), lines released to date, is the present standard of quality and productivity for the industry. 'Dr. Davis,' which is nearly as highly regarded as 'Ross,' shows no inbreeding. This results from the use of the 'Elberta' x ss292557 as a great-grandparent of 'Dr. Davis,' thus avoiding intermating with established parental lines. Progeny analysis has shown 'Dr. Davis' to be heterozygous for the peach/nectarine gene and this cultivar has a history of throwing nectarine sports in production orchards. 'Rizzi' and 'Hesse' are similar high quality and high productivity cultivars released in 1992 (5, 6).

Most of Wight's and L. D. Davis' breeding lines were lost during a program reduction in the 1970's and 1980's. This has led to an even greater dependence on the small number of cultivars developed from this material, particularly 'Ross,' 'Dr. Davis' 'Everts' and 'Riegels.' Although this selection substantially alters the composition of the breeding population, it neither inherently nor substantially reduces the opportunity for obtaining additional short-term selection response, as demonstrated by Shaw (15) for strawberry.

Falconer (3) has shown that inbreeding with selection is a very efficient method for fixing desirable genes. Pedigree inbreeding coefficients, while providing information on the rate of change of (F), are of limited value in developing breeding strategies unless the relationship between (F) and the trait(s) of interest is accurately determined. Other potentially detrimental consequences of inbreeding, such as low genetic diversity and limits to long-term selection response are difficult to test empirically (15).

Current germplasm, though limited, continues to satisfy breeder needs for traditionally important traits, as well as for new and largely unanticipated traits, including potential for extended cold-storage (5), greater orange pigmentation of the fruit flesh (6, 7), and a tree architecture and bearing habit more suitable to high-density plantings (4, 5). Important traits not found in this germplasm include resistance to brown rot caused by *Monilinia fructicola* (Wint.) Honey (7) and further extension of the harvest season. New material has been incorporated into the breeding program to provide genetic variability to alleviate these deficiencies as well as providing alternatives to the established germplasm. Current germplasm should continue to provide a robust gene pool for continued and efficient breeding progress when employing selection based on performance history (breeding value) and coancestry relationships.

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Evaluation of Some New York Sweet Cherry Selections in Romania

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Abstract

Six sweet cherry cultivars and 16 numbered selections from the New York State Agricultural Experiment Station were evaluated for bloom and maturity dates, tree yield and trunk circumference in an orchard planted in 1977 at The Fruit Research Institute in Piteşti-Mărăcineni, Romania. The latest blooming selections were NY 9801 and 'Vogue.' Harvest maturity spanned approximately 11 days. 'Van' was the highest yielding cultivar and only 'Vogue,' 'Kristin,' NY 7690 and NY 6476 had mean average yields similar to 'Van.' NY 7690 was the only high yielding New York selection with a comparably small trunk circumference to be considered as a potential commercial cultivar in Romania.

Introduction

The Fruit Research Institute in Piteşti-Mărăcineni, Romania, is responsible for testing new sweet cherry varieties which have the potential to diversify and improve the sweet cherry assortment (1, 2, 3). New selections are tested for their adaptation to the agroecological conditions and their potential commercial value. In March 1977, a comparative trial orchard was planted in Piteşti with 16 number selections and one cultivar from the New York State Agricultural Experiment Station, Geneva, New York, and 5 cultivars of commercial importance in Romania. The objective of this article is to present the results of this experiment.

Materials and Methods

The field trial included 22 individuals (16 numbered selections and 6 cultivars). 'Kristin' was formerly NY 1599. The selections were randomized in 4 complete blocks with 4 trees in each replication. The trees, propagated on mahaleb rootstock, were planted at 4.5 m in the row and 5 m between rows and trained to a modified central leader system. The space under the trees was disced while orchard grass

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