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Linkage and Correlation Analysis of Some Traits in Peach

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Abstract

Segregating F_2 peach populations in the University of Florida breeding program were analyzed to determine linkage relationships among five qualitative traits: non-showy/showy flower (*Sh*), melting/non-melting fruit flesh (*M*), white/yellow fruit flesh color (*Y*), reniform/globose/absent leaf gland (*E*), and pubescent/glabrous fruit surface (*G*). Independent segregation was confirmed between the loci for fruit flesh color and leaf gland type, pubescence and flesh color, and flower type and pubescence. Independent segregation was found between the loci for leaf gland type and fruit flesh type and between the loci for pubescence and leaf gland type in our populations. The comparisons between the last two pairs have not been documented previously and should be investigated in other breeding populations. No reliable correlation was found between fruit development period and fruit flesh type. No correlation was found between chilling requirement and fruit flesh type nor between fruit flesh color and chilling requirement.

Introduction

Generally, breeding populations in tree fruit crops are highly heterozygous which interferes with effective segregation and linkage studies. Genetic studies of morphological traits are also hampered by long juvenile periods seen in most tree fruit species (8). The diploid, self pollinated peach [*Prunus persica* (L.) Batsch), which has a relatively short juvenile period, has attracted more genetic studies than most fruit crops (13). However, even with the relatively large amount of work done on peach, only a small number of single gene traits have been identified and little information on linkage relationships exists (8). Of the approximately 40 morphological and isozyme markers identified, seven linkage groups have been identified (5, 8, 15, 16). In order to identify possible linkage relationships among five qualitative traits of peach, inheritance data from 14 hybrid populations were analyzed.

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Identification of correlations between quantitative traits such as fruit development period (FDP), chilling requirement, and/or others and qualitative traits such as fruit flesh color or type could aid in the selection of improved varieties. The selection of quantitative traits through the identification of closely linked qualitative traits greatly simplifies the selection process. Williams and Brown (21) reported a preponderance of early season white peach varieties for both flowering and maturation. They suggested that the association between these characters was more than a casual connection. FDP has an intrinsic connection to the fruit maturation season. A difference in FDP can cause a difference in maturation season when the date of full bloom is equal. Chilling requirement influences the season of flowering especially in areas such as Florida where chilling temperatures are sometimes limiting for some varieties. Varieties with a higher chilling requirement may bloom later thus being classified into a later flowering season as well as a later maturation season even though they may have varying fruit development periods. Field observations in the University of Florida peach breeding population have also indicated a possible relationship between fruit flesh type and chilling requirement and/or FDP. A longer FDP and higher chilling requirement have been associated with non-melting fleshed individuals in the population. To clarify these relationships, possible correlations between fruit flesh type and color and chilling requirement and FDP were investigated.

Materials and Methods

Selected clones in the University of Florida, Gainesville, low-chill peach breeding population were scored to determine the genotype for five morphological traits with single gene control: non-showy/showy flower (*Sh*), white/yellow fruit flesh color (*Y*), pubescent/glabrous fruit surface (*G*), reniform/globose/absent leaf gland (*E*), and melting/non-melting fruit flesh (*M*). Non-showy flowers with small petals are dominant over showy flowers which have large petals (4, 12, 20). White flesh is dominant over yellow flesh (9, 11), and the pubescent peach is dominant over the glabrous nectarine (6, 7, 17). Leaf gland type shows codominant inheritance. The homozygous recessive (ee) produces an eglandular condition, the heterozygote has globose shaped glands, and the homozygous dominant genotype (EE) has reniform shaped glands. (1, 2, 10). Melting flesh is dominant to non-melting flesh (3, 6, 7, 10).

Segregating hybrid populations in the 1991 and 1992 nurseries were identified for analysis based on the determination of the parental genotypes. In each hybrid population up to four loci were analyzed for linkage (Table 1). The phenotype of each individual in each hybrid population was recorded for the segregating loci.

Segregation of traits was analyzed in a pairwise fashion using the computer program Linkage 1 (19) with the pretabulated data setting to calculate the probability for independent segregation (Chi-square contingency tables). Five different pairwise comparisons were analyzed (Table 2) from 14 segregating progeny sets.

For correlation analysis, data were collected on chilling requirement and fruit development period (FDP) from segregating populations. Chilling requirements were estimated as chill units (cu) for normal foliation into four classes based on standard varieties grown at the Gainesville location: 'Okinawa' (150 cu), 'Sunred' (250 cu), 'Early Amber' (350 cu), and 'Sunlite' (450 cu) (18). Chilling requirement data were compared to the melting/non-melting flesh and the white/yellow fruit flesh color loci to identify possible correlation. Fruit development period (FDP) was determined by taking the number of days from 50% bloom to the first commercial harvest. FDP data were compared to melting/non-melting fruit flesh type.

Two hybrid populations were analyzed for possible correlations between melting/non-melting flesh and chilling requirement and/or fruit development period. Four hybrid populations were analyzed to determine if there was any correlation between chilling requirement and white/yellow fruit flesh color.

Results and Discussion

The loci for gland type (*E*) and flesh type (*M*) showed independent segregation (P = .05) (Table 1). Pubescence and leaf gland type also segregated independently (P = .05) (Table 1). These comparisons have not been documented previously.

Flesh color (*Y*) and leaf gland type (*E*) segregated independently (P = .05) (Table 1), and pubescence (*G*) and flesh color (*M*) also were determined to segregate independently (P = .05) (Table1). Finally, flower type (*Sh*) and pubescence (*G*) segregated independently in two comparisons (Table 1). These findings confirm a report by Monet and Bastard (14). Significant chi-square values were found in some populations; these did not indicate linkage but, rather, a distortion in the in-

Table 1: Hybrid populations and the parental loci combinations investigated for linkage relationships of five loci in peach: non-showy/showy flower type (*Sh*); white/yellow fruit flesh color (*Y*); presence/absence of fruit pubescence (*G*); leaf gland type (*E*); and melting/non-melting fruit flesh type (*M*).

Hybrid population	No. of trees	Genotype of parents	χ^2	P
Fla. 86-28c x Springcrest	26	*EEmm* / *EeMm*	1.96[c]	.16[c] ns
Fla. 88-25c x Fla. 88-6	12	*EEmm* / *EeMm*		
Fla. 86-28c x Fla. 88-11nw[a]	374/415[b]	*yyEE/ShshGg* / *YyEe/shshgg*	.00021[c]/1.07[bc]	.99[c] ns/.30[bc] ns
Fla. 88-26c x Fla. 88-11nw[a]	135/133[b]	*yyEE/ShshGg* / *YyEe/shshgg*		
Tropic Sweet x Fla.88-11nw	50	*yyEE* / *YyEe*		
TropicSnow x Fla.88-11nw[a]	272/267[b]	*YyEE/GgYy* / *YyEe/ggYy*	6.00/.037[bc]	.014*/.85[bc] ns
Hermosillo x Fla.88-11nw	133	*yyEe* / *YyEe*	3.02[c]	.22[c] ns
Flordagold x Fla.88-11nw	105	*yyEe* / *YyEe*		
TropicSnow x Fla. 86-28c[a]	105/105[b]	*GgYy/shshGg* / *Ggyy/ShshGg*	4.05,.001[bc]	.044*/.98[bc] ns
Fla. 83-5nw x Fla. 86-28c	51	*shshgg* / *ShshGg*		
Fla. 86-28c x Armking	127	*ShshGg* / *shshgg*		
Fla. 86-28c x Mayfire	36	*ShshGg* / *shshgg*		
Fla. 88-22c x Fla. 90-1	98	*GgEE* / *GgEe*	.15	.70 ns

[a]These hybrid populations had genotypes that allowed for multiple analyses in the same population.
[b]The first number corresponds to the loci pair listed and the second number to the second pair listed.
[c]These values were calculated using all populations with the same genotype combinations at a particular pair of loci.
*Significant at the P = .05 level.
ns Not significant at the P = .05 level.

dividual segregation of a trait from an unknown causes. Most likely this was due to vigor problems with some of the nectarines; thus full data was missing because of non-fruiting or dead trees.

A correlation between the melting/non-melting flesh locus and fruit development period was found in one hybrid population, Fla. 86-28c x 'Springcrest' (Table 3). Non-melting flesh was correlated with longer fruit development periods (P = .05). However, no such relationship was found in the second population, (Fla. 9-20c x 'Flordaking')op (Table 3). The correlation between the melting/non-melting flesh locus and a longer FDP in one population may have been due to contamination from self pollination. The seed parent, Fla. 86-28c, is a later maturing selection and is non-melting. The non-melting selfed progeny would skew the data towards longer FDPs for the non-melters since there would be no source of genes for lower chilling requirement in these individuals.

No correlation was found between fruit flesh type and chilling requirement in two populations (Table 3). The observed relationship in the field may have been due to the original source material for the non-melting flesh trait. The original sources were varieties with higher chilling requirements which would produce a relationship between the two characters in early generations.

Table 2: Loci pairwise combinations analyzed for linkage relationship: non-showy/showy flower type (*Sh*), white/yellow fruit flesh color (*Y*), leaf gland type (*E*), presence/absence of fruit pubescence (*G*), and melting/non-melting fruit flesh type (*M*).

Loci pair analyzed	Number of populations analyzed	Status of documentation
E/e M/m	2	linkage status undocumented
Y/y E/e	6	documented independent (14)
G/g Y/y	2	documented independent (14)
Sh/sh G/g	6	documented independent (14)
G/g E/e	1	linkage status undocumented

Also, no correlation was found between the color of the fruit flesh and the amount of chilling required in the four hybrid populations investigated (Table 3). Any relationship between these traits was probably caused by the nature of the cur-

Table 3: Correlations analyzed in peach from 1993 and 1994 data between some qualitative and quantitative traits.

Population	No. of trees	Qualitative trait	Quantitative trait	r
(9-20 x Flordaking)op	22	Flesh type	Chilling requirement	–0.34[a] ns
	22		Fruit development period	0.14 ns
86-28c x Springcrest	26	Flesh type	Chilling requirement	0.16 ns
	26		Fruit development period	–0.53[a]*
83-5nw x 86-28c	50	Fruit flesh color	Chilling requirement	0.15 ns
TropicSnow x 86-28c	104	Fruit flesh color	Chilling requirement	0.17 ns
83-5nw x ArmKing	52	Fruit flesh color	Chilling requirement	–0.23[a] ns
88-26c x 88-11nw	146	Fruit flesh color	Chilling requirement	0.03 ns

[a]Negative r values correspond to comparisons to the recessive phenotype of the qualitative trait studied.
*Significant at the P = .05 level.
ns Non-significant at the P = .05 level.

rent white flesh peach market. White fleshed peaches are often early fresh market peaches due to the poor shipping quality which is not conducive to more than regional marketing.

Summary and Conclusions

Linkage analysis showed no linkage relationships for the five loci studied: non-showy/showy flower (*Sh*); melting/non-melting flesh (*M*); white/yellow flesh color (*Y*); reniform/globose/absent leaf gland (*E*); and pubescent/glabrous fruit surface (*G*). Two new independent segregation relationships were established between leaf gland type (*E*) and melting/non-melting flesh (*M*) and between the fruit surface pubescence (*G*) and gland type (*E*). The independent segregation of three pairs of loci, flesh color (*Y*) and gland type (*E*), fruit surface pubescence (*G*) and fruit flesh color (*Y*), and flower type (*Sh*) and fruit surface pubescence (*G*) was confirmed. Significant chi-square values in certain populations were most likely caused by segregation distortion at a locus due to uneven vigor of the seedlings causing omission of data from individuals in the population that did not flower and/or fruit. Though the population analyzed to determine the independence of *E* and *M* was small (38), field observations of non-melting flesh selections and varieties showing no preponderance of gland type supports the conclusion of independent segregation. Independence should be confirmed in other populations.

No reliable correlation between melting/non-melting flesh and FDP was found in two populations. Melting/non-melting flesh and chilling requirement also were not correlated in two populations. Finally, white/yellow fruit flesh color was not found to be correlated to chilling requirement in four populations.

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