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Nectarine Skin Speckling is Associated with Flesh Soluble Solids Content

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Abstract

The relationship between skin speckling and flesh soluble solids content (SSC) was investigated for 45 nectarine [*Prunus persica* (L.) Batsch] genotypes from the University of Florida breeding program. Skin speckling as measured on firm ripe fruit by count of speckles cm^{-2} and a 0 to 5 speckle rating was significantly correlated with SSC (r = +0.72 and +0.78 respectively). There was significant variation among genotypes for speckle number, speckle rating and SSC with broad sense heritabilities estimated as 0.67, 0.79 and 0.58 respectively. The term sugar speckles is commonly used to describe this skin speckling and accurately reflects the association between the two traits. The challenge for breeders is to increase eating quality without adversely affecting fruit appearance.

Introduction

Nectarine fruit may develop a skin speckling which some breeders consider to be related to the amount of sugar in the flesh. This skin blemishing has been referred to in the vernacular as "sugar speckles" or "sugar spots." It appears on the stylar end and cheeks of ripe fruit as a rough and raised area of spots that lack red pigment (Fig. 1). It is an important characteristic as it detracts from the clean skin finish that is highly desired on many commercial markets. The amount of speckling on fruit has been mentioned in cultivar release notices of nectarine (1, 15) and plum (2), as it relates to the appearance and attractiveness of fruit. Wen et al. (16) noted a higher level of fruit sucrose in a peach to nectarine mutant corresponded with visually greater amounts of skin surface speckling. We are not aware of any studies which report on the relationship between fruit sugar level and the amount of skin speckling, nor on the variability among nectarine genotypes for this trait. The purpose of this study was to quantify the relationship between fruit sugar level and skin speckling and to examine the variability for these traits within a nectarine breeding population.

Figure 1. Nectarine fruits with speckle ratings of 4 (15 to 40% of skin speckled) and 0 (no speckles).

Materials and Methods

Plant Material

The relationship between skin speckling and sugar level in nectarine fruits was investigated using 45 low-chill, nectarine genotypes grown at the University of Florida, Gainesville. The 45 genotypes consisted of 3 cultivars and 16 numbered selections, which were 3 to 5 years old, propagated on Flordaguard peach rootstock and planted in pairs at a spacing of 3m x 5m, and 26 seedlings randomly selected from a high density fruiting nursery (14) in its second year of fruiting.

Measurement

Two to six fruit for each of the 45 genotypes were sampled from the periphery of

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each tree at 1 to 1.5 m from the ground (170 samples in total). Fruit harvest occurred over a period of 23 days in April and May 1998. Fruit were harvested at commercial firm ripe stage of maturity. All genotypes were harvested at the same maturity stage. Genotypes with high levels of russet or with no red skin colour were not sampled because of the difficulty in rating for amount of speckle when russet was high or red skin colour was absent. Each fruit was evaluated for diameter (mm), weight (g), flesh colour (white or yellow), flesh type (melting or non-melting), amount of skin speckling and sugar level. Flesh sugar level was measured as percent soluble solids content (SSC) using a hand held refractometer with a segment of flesh cut from the stylar end and the cheeks of each fruit. A total of three measurements were made for each fruit, the two cheek measurements were averaged (cheek SSC) and analysed separately from the stylar end measurement (tip SSC)

Skin speckling was measured by two methods, a speckle number count and a 0 to 5 whole fruit speckle rating. Speckle number was counted in a 1 cm square grid on the left and right side of the fruit approximately 2 cm from the stylar end and averaged to give the speckle number. The whole fruit speckle rating was visually estimated using a scale of 0 = no speckles; 1 = less than 1%; 2 = 1 to 5%; 3 = 5 to 15%; 4 = 15 to 40%; and 5 = over 40% of fruit surface with speckles.

Data Analysis

Analysis of variance was performed using PROC GLM of SAS to test for differences among genotypes for speckle number (cm^{-2}), speckle rating, cheek SSC, tip SSC, and fruit weight (13). Correlations were performed on genotype means using PROC CORR (13). Variance components were calculated by PROC NESTED. The total variation for each trait was partitioned into, among and within-genotype components. The within-genotype variation was composed of variation among trees within a genotype, among fruit within a tree, and experimental error. Broad sense heritability was obtained by dividing the variance component for among-genotypes by the sum of the among-genotype and within-genotype variance components (7).

Results and Discussion

Nectarine genotypes differed significantly for speckle number (cm^{-2}), speckle rating, cheek SSC, tip SSC, and fruit weight (Table1). Speckle number varied from 0 to 47 speckles cm^{-2}, and the sugar speckle rating varied from 0 to 5 with an overall mean value of 19 speckles cm^{-2} and 2.7 (on our 0-5 scale), respectively (Table 2). Across all genotypes tip SSC (15.4%) was significantly greater than

Table 1. Analysis of variance for speckle number, speckle rating, cheek SSC, tip SSC and fruit weight evaluated in 1998 at Gainesville Florida.

Trait	Source of variation	df	Mean square	F value
Fruit weight	Genotype	44	2542.523	27.28***
	Error	125	93.197	
Tip SSC	Genotype	44	35.050	6.25***
	Error	125	5.609	
Cheek SSC	Genotype	44	24.484	4.56***
	Error	125	5.365	
Speckle no.	Genotype	44	587.529	8.78***
	Error	125	66.884	
Speckle rating	Genotype	44	6.636	14.87***
	Error	125	0.446	

***, Significant at $P \leq 0.001$.

Table 2. Mean and number of observations of 45 nectarine genotypes for fruit weight, tip SSC, cheek SSC, speckle number and speckle rating.

Genotype	No.	Fruit weight (g)	Tip SSC (%)	Cheek SSC (%)	Speckle no. (cm^{-2})	Speckle rating (0 to 5)
Fla 7-4N	3	86	13.4	12.7	17	3.0
Fla 90-3NW	3	69	20.0	17.4	19	3.3
Fla 90-5N	3	107	14.5	14.0	9	1.7
Fla 92-26NW	6	70	19.5	18.5	21	4.0
Fla 94-15N	6	120	10.1	9.8	12	2.3
Fla 94-19N	6	115	13.6	13.0	16	3.0
Fla 94-30CN	6	102	13.4	12.6	5	1.2
Fla 94-7N	3	88	12.3	12.3	3	0.7
Fla 95-1NW	3	64	15.5	15.0	5	1.3
Fla 95-3NW	3	83	17.0	16.1	18	3.3
Fla 95-6N	6	113	10.9	10.9	3	0.7
Fla 95-7N	6	117	10.9	10.7	8	2.0
Fla 95-9NW	5	103	14.8	14.1	15	3.2
Fla 97-3NW	3	78	10.0	10.7	2	1.0
Fla 97-55CN	4	34	19.5	17.9	45	4.0
Fla 97-57CNW	2	76	18.1	16.6	36	3.5
S1	4	50	17.2	15.4	38	3.5
S2	4	29	17.1	14.6	25	4.3
S3	4	37	9.7	9.9	0	0.3
S4	4	73	19.0	18.3	47	5.0
S5	4	37	14.3	14.2	6	1.3
S6	4	34	12.5	12.0	0	0.3
S7	4	47	12.3	11.5	19	2.3
S8	2	52	19.6	16.8	32	5.0
S9	3	41	19.6	17.8	18	3.7
S13	4	70	16.8	14.7	23	2.8
S14	3	59	19.8	17.8	28	4.0
S16	4	66	15.0	14.8	10	3.0
S17	3	73	15.6	14.8	30	3.0
S18	4	46	18.2	17.0	25	3.3
S19	3	60	16.3	14.7	31	3.3
S20	2	58	21.0	19.1	33	5.0
S21	3	72	12.7	13.2	2	0.3
S22	4	58	12.8	12.8	10	2.3
S23	3	57	14.6	14.7	0	0.0
S24	3	63	17.3	17.0	32	4.0
S25	3	54	16.9	15.9	41	4.0
S26	3	82	18.6	16.3	26	4.0
S27	3	59	12.4	12.6	9	1.7
S28	2	71	17.7	17.8	41	4.0
S29	3	51	15.4	15.1	9	1.3
S30	3	80	14.1	15.4	28	3.7
Sunhome	6	84	12.4	11.7	16	2.2
Sunred	6	65	15.7	14.5	18	2.8
SunWright	4	90	14.6	16.4	13	1.5
Mean	70	15.4	14.6	19	2.7	
SD	24	3.0	2.5	13	1.4	

cheek SSC (14.6%). Tip SSC ranged from 9.7% (for the seedling S3) to 21.0% (for the seedling S20). Eleven genotypes had fruit that received a speckle rating of 4 or greater, corresponding to over 15% of their skin covered with speckles. These consisted of nine unselected seedlings and only two numbered selections. The numbered selections (average of 13.8 speckles cm^{-2}) had significantly fewer speckles than the unselected seedlings (average of 20.7 speckles cm^{-2}) indicating there was selection pressure against seedlings with high amounts of skin speckling in these populations.

SSC measured from cheek and stylar tip fruit segments were positively and significantly correlated with sugar speckling, as measured by counts of speckles per unit area and visual estimation of speckle density (Table 3). The highest correlation of $r = 0.78$ was between tip SSC and speckle rating, indicating that ca. 61% of the variation in the amount of sugar speckling can be explained by sugar level. A high positive phenotypic correlation indicates there is an associated increase in both traits. This association may be due to shared genetic effects, a common response of independent genes to shared environments, or a combination of both factors. The association between SSC and skin speckling may be due to the same genes controlling both traits and/or both SSC and skin speckling responding similarly to environmental changes such as temperature, exposure to light or stage of ripeness. This relationship provides a quandary for breeders who wish on the one hand to increase sugar levels in the fruit, but on the other to produce fruits that have no skin blemish.

A linear regression is not justified as a result of a high correlation unless a cause and effect relationship exists. We believe this is the case, based on our experience. The linear regression equation relating speckle rating and tip SSC shows that for a sugar speckle rating of 1 (less than 1% of fruit surface with speckles) fruit would average 10.6% SSC (Fig. 2). A speckle rating of 2, corresponding to between 1% and 5% of fruit surface with speckles is considered the upper acceptable level of blemish on first grade fruit in Australian markets, and this corresponds to an average of 13.4% SSC. Arguably consumers could be educated to accept nectarines with higher levels of skin speckling and be taught that these will generally be the sweeter fruits. However, it seems a better marketing approach to produce fruit consumers require rather than educate them to accept what we have available. It would be desirable to increase sugar levels above 13% SSC without increasing skin speckling, and there are some outlying genotypes that have a higher level of sugar than expected for the amount of speckling observed (Fig. 2). Selections such as Fla 95-1NW had a tip SSC of 15.5% but with a skin speckle rating of only 1.3 (Table 2). It could be that this selection has high levels of some optically active compounds other than sugars that provide a high SSC reading without providing the sugars to cause skin speckling. It would be of interest to study such outliers to see why they have relatively low amounts of skin speckling.

In the current study we have considered SSC to be a measure of sugar level. Wills et al. (17) measured constituent sugar composition and SSC for 12 peach and nec-

Table 3. Phenotypic correlations and broad-sense heritability estimates for 45 nectarine genotypes for the traits tip SSC, cheek SSC, speckle number, speckle rating and fruit weight.

	Tip SSC	Cheek SSC	Speckle no.	Speckle rating	Fruit weigh
Tip SSC		0.96**	0.72**	0.78**	–0.38*
Cheek SSC			0.70**	0.72**	–0.34*
Speckle no.				0.88**	-0.23^{NS}
Speckle rating					-0.14^{NS}
Broad-sense heritability	0.58	0.49	0.67	0.79	0.87

NS, *, ** Nonsignificant or significant at $P < 0.05$ and 0.01 respectively.

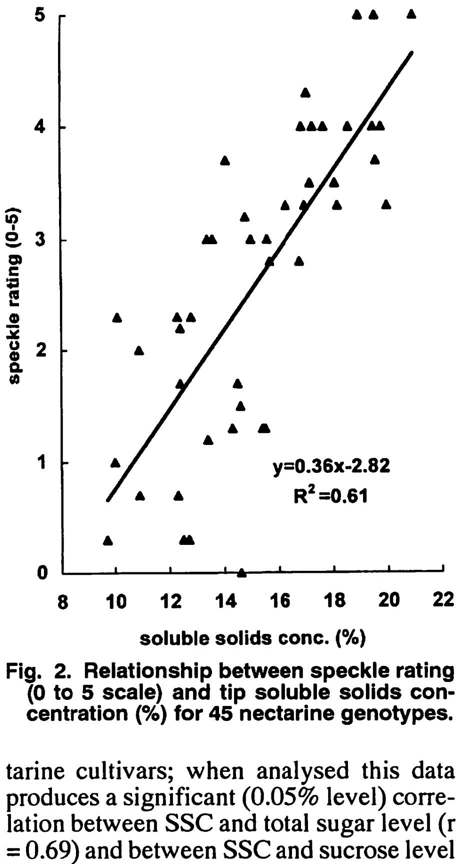

Fig. 2. Relationship between speckle rating (0 to 5 scale) and tip soluble solids concentration (%) for 45 nectarine genotypes.

tarine cultivars; when analysed this data produces a significant (0.05% level) correlation between SSC and total sugar level (r = 0.69) and between SSC and sucrose level (r = 0.69). Similarly, Robertson et al. (12) present SSC and sucrose levels for 11 ripe peach cultivars which gives a significant (0.05% level) correlation of r = 0.91. We were able to discriminate SSC with reasonable accuracy based solely on taste, indicating SSC is related to sugar level and sweetness in the Florida germplasm.

Genotypic difference in fructose, glucose, sucrose and sorbitol have been reported for peach and nectarine (3, 4, 17) and it may be that some constituent sugars increase sensory sweetness without increasing skin speckling. However, within the sugars found in the University of Florida nectarine germplasm (16), it seems that as fruit sugar level of a genotype increases so does the amount of speckling. Breeders therefore need to consider how eating quality may be improved in ways other than increasing sugar levels. This may be achieved by increasing the perceived sweetness through a decrease in flesh acidity or by increasing the aroma component of the fruit. Potential to improve flavour through both these routes exists in current germplasm and is a major aim in breeding.

Fruit weight was significantly negatively correlated with sugar level (r = –0.38), which agrees closely with the results of Hesse (10) of r = –0.32 between soluble solids and fruit length in peach. This correlation, while significant, is relatively small and indicates that it will be moderately difficult, but not impossible to increase both fruit size and sugar level.

There was no significant difference in degree of speckling or sugar level of white versus yellow flesh, nor between melting and non-melting flesh (data not presented). Neither fruit weight nor sugar level were significantly correlated with ripe date or fruit development period (data not presented) and was probably due to the relatively small period (23 days) during which the 45 genotypes were sampled.

Broad sense heritability for SSC, skin speckling and fruit weight were all moderate to high (Table 3). Skin speckling heritability was high (0.67 and 0.79) however, these estimates are based on a sample of nectarine genotypes that were chosen to include both high and low skin speckling and so provide an upper level estimate of heritability. Our heritability estimates for tip SSC and cheek SSC agree closely with the repeatability of SSC of 0.52 reported by de Souza et al. (6) for peach. The broad-sense heritability of 0.77 for SSC reported by Brooks et al. (3) for canning peach is higher than our estimate. This may have been due to different germplasm, or to underestimation of environmental variance they had noted would occur when only one tree of each genotype was available for sampling. Variability for sugar content from fruit to fruit within a peach genotype has been suggested as a possible reason for low narrow sense heritability obtained for SSC in peach (9). In Hanscheís study, SSC was obtained by one measurement from one fruit per genotype. In a later study Hansche (8) measured 5 fruits per genotype and reported the SSC narrow sense heritability for dwarf peach as 0.17 and for dwarf nectarine as 0.35. There are numerous reports of variation in fruit sugar content due to environmental factors. Dann and Jerie (5) have shown that in fruit of peach, sugar levels increase with distance from the roots and this is reasonable since these fruit are closer to the leaves where the sugars are assembled. Peiris et al. (11) reported SSC varied from 11.9% to 15.4% for tissue samples taken from different locations on a medium size peach. There will also be variation in sugar level due to differences in fruit maturity stage at harvest. Despite these sources of variation, which can increase the within genotype component of variance in our analysis, we have still found a high broad sense heritability. This provides evidence that with a systematic method of measurement there is potential for genetic improvement of sugar level.

We made no microscopic study on the morphological origin of skin speckling associated with increasing SSC, but we did observe both in the field and with the aid of a dissecting scope the progression of speckling on fruit as they ripened on individual trees. Each speckle appears to originate at a lenticel.

Based on the highly significant, positive correlation between skin speckling and tip and cheek SSC of nectarines reported in this study, we propose the use of the term "sugar speckles" to describe this type of skin speckling. This speckling blemish provides a challenge to breeders who wish to increase perceived sweetness while keeping the skin uniformly red and attractive.

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