J. Amer. Soc. Hort. Sci. 105(3):416–420. 1980.

Genetic and Environmental Influences on Carrot Flavor[1]

P. W. Simon[2], C. E. Peterson[2], and R. C. Lindsay[3]
University of Wisconsin, Madison, WI 53706

Additional index words. Daucus carota, sensory evaluation

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

Abstract. **Sensory analysis was performed on 4 carrot (*Daucus carota* L.) entries (inbred lines B6274 and B3615 and open-pollinated cultivars 'Imperator 58' and 'Nantes') grown in Florida, Texas, and California. Variation from entries and locations was observed for 5 sensory attributes. Significant differences were found among entries for harsh flavor (burning, turpentine-like flavor) and among locations for overall carrot flavor. Florida-grown roots elicited low sweetness and low overall carrot flavor responses, Texas-grown carrots expressed distinct differences in harsh flavor, and California-grown carrots had less harsh flavor with more sweetness and more overall carrot flavor. Significant inter-line differences were observed for different attributes at each location. Sensory analysis over all locations indicated that B3615 was more harsh, less sweet, and less preferred than the other entries. Harsh flavor and sweetness were used as independent variables in regression analyses and were found to account for much variation in overall preference and intensity of flavor differences. Harsh flavor could not be masked by dipping B3615 roots in 30% fructose. Phloem is harsher, sweeter, more flavorful, and preferred to xylem while a comparison of crown, midsection, and tip displays a significant acropetal reduction in carrot flavor.**

The improvement of vegetable quality is a complex task (9). To appraise consumer preference factors, major quality attributes must be defined and measured in representative material to gather meaningful information about consumer opinion. With this information, certain attributes may then be manipulated by altering methods of preparation, cultural practice, storage conditions, or the genetic constitution of the vegetable.

Several components of carrot culinary quality, including bitter compounds (7), sugars (3), and volatile constituents (e.g. 2) have been analyzed using laboratory procedures. These experiments provide valuable information about the quality component under scrutiny, yet they provide no estimate of the contribution of this component to carrot flavor. This report defines several parameters of raw carrot flavor and considers the responses of trained taste panelists to 4 carrot lines grown at 3 locations.

Materials and Methods

Carrots were grown in muck soil at Zellwin Farms, Zellwood, Florida; in Willacy fine sandy loam soil at the Texas A&M Experiment Station, Weslaco, Texas; and in heavy clay soil at the USDA Conservation Research Center, Brawley, California. Seed was planted at each location in early October, 1977, and roots harvested the first (FL), third (TX), and fifth (CA) weeks of February, 1978. Harvested roots were shipped by air to Wisconsin and analyzed for flavor characteristics by sensory evaluation.

Plant material used included 2 open-pollinated cultivars ('Imperator 58' and 'Nantes', Asgrow Seed Co.) and 2 inbred lines from the USDA carrot breeding program (B3615 and B6274). Roots of these 4 lines from all 3 locations were analyzed. The hybrid cultivars 'Candy Pack' and 'Spartan Bonus' grown in Texas and 'Spartan Bonus' from California were used in some experiments.

In preparation for sensory evaluation, carrots were washed and cut radially into 0.5 to 0.8 cm slices, and slices from 20 to 30 roots of each entry were mixed and served to panelists at a rate of 2 to 4 per person. In a genotype/location experiment, the middle third of roots for the 4 entries from each location was evaluated. 'Candy Pack' roots were prepared similarly except that slices from the crown and the tip portions (appropriate 1/3 of root) were also sliced and dispensed to compare the flavor variation over the length of the root. To compare xylem with phloem flavor in the center portion of roots, samples of 'Spartan Bonus' from Texas and California were employed. Roots were washed, and the crown and tip portions (1/3 root each) were discarded. After slicing, the phloem was separated from the xylem with a cork borer of appropriate size. Sample sizes were adjusted to provide the same volume used in the other experiments.

The effect of extra sweetness on harshness was determined by washing and slicing the midsection of Texas-grown roots of B3615 found to be particularly harsh by the genotype/location experiment, and dipping slices in either distilled water or 30% fructose. In the latter experiments which compare the flavors within the root (crown, midsection, and tip; xylem and phloem) and in the sugar-coating experiment, each panelist received samples from the same root rather than mixing bulk samples from several roots. The sugar-coating experiment and the xylem-phloem comparison using Texas-grown roots were done 4 to 6 weeks after harvest, respectively. All other experiments were completed 7 to 9 days after harvest.

Descriptive profiling was performed by 25 to 30 panelists in the Sensory Evaluation Laboratory, Department of Food Science, University of Wisconsin. A panel of this size is adequate to detect a difference of 10 to 12% of full range of the hedonic scale used (1). Judges were seated in isolation booths lighted with 15 quanta fluorescent lights. Water for mouth rinsing was available. Panelists evaluated samples using an intensity of difference scale (degree of difference relative to an identified reference, 4), and quantitative descriptive analysis scales for harsh flavor, sweetness, overall carrot flavor (10), and overall preference for each entry from a single location on a single day. It is recognized that a panel of this size cannot reflect a universal opinion of preference for carrot flavor, but is was the intent of this work to attain a preliminary estimate of consumer response. Each of these attributes, except intensity of difference, was also evaluated for the root part and sugar-coating experiments. To avoid fatigue, only 4 to 6 samples were evaluated at one time. Before these experiments were begun, panelists were trained to perceive the harsh flavor with roots from 2 greenhouse-grown lines, adjudged to represent a harsh and non-harsh or mild flavor. Harshness is defined as the strong, burning, turpentine-like flavor most strongly perceived at the back of the throat during or after chewing. In the genotype/location experiment, 'Imperator 58' was used as an intensity of difference reference for the Florida-grown carrots, while the inbred line B6274 served this function for the other 2 locations.

[1]Received for publication August 30, 1979.
The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2]Geneticist and Horticulturist, USDA-SEA-AR; Department of Horticulture.
[3]Department of Food Science.

Sample means and least significant difference (LSD) values were calculated for the attributes of carrots from each location and method of preparation. Analysis of variance was performed for lines and locations. Simple and multiple regression analyses of harshness and sweetness upon overall carrot flavor, overall preference, and intensity of difference were performed (8).

Results

The mean scores of the flavor attributes demonstrate substantial variation among lines at each location (Table 1). The homogeneity of LSD values for an attribute among locations lends confidence to the reliability and repeatability of the panel, as does the observation that the line used as a reference always scored lowest in the intensity of difference ratings.

Differences among locations for each attribute were not striking. In general, California-grown carrots had lower intensity of difference scores (implying less interline difference) and milder flavor with higher scores for sweetness and overall carrot flavor relative to those grown in Florida and Texas. Texas-grown carrots expressed extremes in harshness more distinctly, while those from Florida elicited low sweetness and overall flavor responses.

Interline differences are most obvious in the consistently high level of harshness for B3615. This line also received low sweetness and preference ratings.

The coefficients of variability (CV) between panelists for the values in Table 1 are not presented here, but like the LSD values, they were highest for intensity of difference measurements (44% overall), followed by harshness (36%). The other 3 attributes averaged 29% variability. Consistent interline variation for CV was not observed and averaged 33%.

To better interpret the basis of raw carrot flavor, simple and multiple regression analyses were performed on the premise that harshness and sweetness are factors in the determination of flavor, preference, and the intensity of sample differences. Harshness and sweetness were used as independent variables singly and together over different locations, different lines, and overall to establish their contribution to overall flavor, preference, and intensity of difference.

Over different locations (Table 2), the simple regression coefficients (b) and coefficients of determination (r^2) for each location were small for the relationships between flavor and either harshness or sweetness. However, by incorporating both harshness and sweetness into a description of flavor, one-half or more of the variation for flavor could be attributed to these 2 factors ($R^2 \geqslant 0.5$). For Texas-grown carrots, harshness and sweetness accounted for 94% of the flavor variation. The relative importance of harsh and sweet flavor to overall flavor was indicated by their ratio of partial regression coefficients ($b'_{F\text{-}H}/b'_{F\text{-}S}$; 5, 8). This ratio indicates that sweetness was more important in Texas-grown carrots than those from Florida, and sweetness was even more important in the determination of flavor of California-grown carrots.

Considering variation in overall preference as a function of harshness and sweetness, these single attributes alone accounted for a greater proportion of preference than for flavor, and together they determined 92% to 97% of the variation in preference. As for overall flavor, sweetness was more important for carrots grown in Texas and California than in Florida.

The intensity of difference in carrot flavor was highly correlated with either sweetness or harshness alone, or both attributes in carrots from Texas and Florida. Much less of the differences was attributable to these factors in California-grown carrots. Unlike preference and flavor, intensity of difference

Table 1. Summary of mean scores for the descriptive panel evaluation of different carrot lines.

	Sample attributes				
Entry	Intensity of difference[z]	Harsh, biting flavor[y]	Sweetness[x]	Overall carrot flavor[w]	Preference[v]
Florida-grown					
B6274	4.04 ab[u]	3.69a	3.19a	3.29a	3.39a
B3615	4.37 a	4.52b	3.20a	3.98b	3.15a
Imperator 58 (Reference)	3.37b	3.41a	3.49a	3.36a	3.51a
Nantes	3.37b	3.11a	3.57a	3.68ab	3.83a
LSD (5%)	0.87	0.63	0.44	0.47	0.50
Texas-grown					
B6274 (Reference)	3.07a	3.05a	3.67ab	3.93a	4.23a
B3615	5.56b	4.95b	3.18a	4.10a	2.69b
Imperator 58	3.15a	2.79a	3.98b	4.02a	4.33a
Nantes	3.48a	3.06a	3.96b	4.02a	4.20a
LSD (5%)	0.76	0.60	0.49	0.54	0.50
California-grown					
B6274 (Reference)	2.68a	2.67a	4.62a	4.27a	4.66a
B3615	3.68b	3.82b	3.89b	4.02a	3.94b
Imperator 58	3.18ab	3.55b	3.29c	4.19a	3.80b
Nantes	3.74b	3.28ab	4.15ab	4.05a	4.23ab
LSD (5%)	0.81	0.67	0.53	0.59	0.55

[z]Scale: 1 = none; 7 = extreme.

[y]Scale: 1 = lacking in harshness or biting flavor; 7 = strong, burning, harsh, turpentiny, or carrot top-like.

[x]Scale: 1 = imperceptible; 7 = extremely sweet.

[w]Scale: 1 = weak carrot flavor; 7 = strong carrot flavor.

[v]Scale: 1 = dislike extremely; 7 = like extremely.

[u]Mean separation in columns by Duncan's multiple range test, 5% level.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

Table 2. Linear regression statistics for mean scores of the descriptive panel evaluations for different sample attributes of carrot lines grown in three locations.

Location	$b_{F\cdot H}$[z]	$r^2_{F\cdot H}$[y]	$b_{F\cdot S}$	$r^2_{F\cdot S}$	$b'_{F\cdot H}/b'_{F\cdot S}$[x]	$R^2_{F\cdot HS}$[w]
	Overall flavor as a function of harshness and sweetness					
Florida	0.30	.34	0.19	.01	1.36	.71
Texas	0.10	.38	−0.03	.004	0.48	.94*
California	−0.32	.21	0.32	.47	0.06	.47
All locations	0.04	.01	0.38	.27	0.70	.53
	Overall preference as a function of harshness and sweetness					
	$b_{P\cdot H}$	$r^2_{P\cdot H}$	$b_{P\cdot S}$	$r^2_{P\cdot S}$	$b'_{P\cdot H}/b'_{P\cdot S}$	$R^2_{P\cdot HS}$
Florida	−0.44	.89*	1.26	.76	−2.22	.92*
Texas	−0.71	.93**	1.88	.81*	−0.74	.97**
California	−0.87	.61	0.74	.94**	−0.33	.96**
All locations	−0.71	.76**	1.02	.74**	−1.04	.93**
	Intensity of difference as a function of harshness and sweetness					
	$b_{I\cdot H}$	$r^2_{I\cdot H}$	$b_{I\cdot S}$	$r^2_{I\cdot S}$	$b'_{I\cdot H}/b'_{I\cdot S}$	$R^2_{I\cdot HS}$
Florida	0.76	.86*	−2.41	.89*	−0.80	.98**
Texas	1.17	.98**	−2.78	.77*	3.09	.99**
California	0.86	.55	−0.45	.32	−8.50	.55
All locations	1.02	.84**	−0.93	.36*	9.45	.85*

[z]Simple regression coefficient of F as a function of H. H = harsh, irritating flavor; S = sweetness; F = overall carrot flavor; P = overall preference; I = intensity of difference.

[y]Coefficient of determination of F and H.

[x]Ratio of standard partial regression coefficients for H and S, as they relate to F.

[w]Multiple correlation coefficient for the combined effect of H and S upon F.

*P < 5% due to chance.

**P < 1% due to chance.

Table 3. Linear regression statistics for mean scores of the descriptive panel evaluations for different sample attributes of four carrot lines.

Line	$b_{F\cdot H}$[z]	$r^2_{F\cdot H}$[y]	$b_{F\cdot S}$	$r^2_{F\cdot S}$	$b'_{F\cdot H}/b'_{F\cdot S}$[x]	$R^2_{F\cdot HS}$[w]
	Overall flavor as a function of harshness and sweetness					
6274	−0.96	1.00**	0.64	.87	12.11	–
3615	0.06	.30	−0.03	.05	1.18	–
'Imperator 58'	−0.17	.02	0.05	.001	1.01	–
'Nantes'	0.66	.14	0.67	.94*	−0.28	–
All lines	0.04	.01	0.38	.27	0.70	.53
	Overall preference as a function of harshness and sweetness					
	$b_{F\cdot H}$	$r^2_{F\cdot H}$	$b_{F\cdot S}$	$r^2_{F\cdot S}$	$b'_{F\cdot H}/b'_{F\cdot S}$	$R^2_{P\cdot HS}$
6274	−1.25	1.00**	0.83	.87	9.77	–
3615	−1.11	1.00**	1.47	.88	−24.25	–
'Imperator 58'	−0.89	.74	0.94	.64	1.18	–
'Nantes'	0.70	.13	0.73	.93*	−0.27	–
All lines	−0.71	.76**	1.02	.74**	−1.04	.93**
	Intensity of difference as a function of harshness and sweetness					
	$b_{F\cdot H}$	$r^2_{F\cdot H}$	$b_{F\cdot S}$	$r^2_{F\cdot S}$	$b'_{F\cdot H}/b'_{F\cdot S}$	$R^2_{I\cdot HS}$
6274	1.35	.99**	−0.88	.83	4.38	–
3615	1.60	.92*	−1.87	.63	2.11	–
'Imperator 58'	0.14	.21	−0.12	.13	1.05	–
'Nantes'	1.44	.76	0.59	.83	0.84	–
All lines	1.02	.84**	−0.93	.36*	9.45	.85*

[z]Simple regression coefficient of F as a function of H. H = harsh, irritating flavor; S = sweetness; F = overall carrot flavor; P = overall preference; I = intensity of difference.

[y]Coefficient of determination of F and H.

[x]Ratio of standard partial regression coefficients for H and S, as they relate to F.

[w]Multiple correlation coefficient for the combined effect of H and S upon F.

*P < 5% due to chance.

**P < 1% due to chance.

was influenced less by harshness than sweetness in Florida-grown carrots than those from Texas and California ($b'_{I\cdot H}/b'_{I\cdot S}$ was small for Florida and large for Texas and California).

Contrasting differences between different lines over locations demonstrated significant interline differences (Table 3). Harshness correlated almost perfectly with overall flavor, preference, and intensity of difference for line B6274. The R^2 values for individual lines were not recorded because, with only three locations, a perfect multiple correlation coefficient always results. However, this value would also be at least 0.99 for B6274 with all three dependent attributes (8). Sweetness also correlated with overall flavor, preference, and intensity of difference for B6274, but its relative importance was overshadowed by harshness, as evidenced by the large partial regression coefficient ratios.

Harshness was also important in determining lack of preference for B3615, being 24 times as important as sweetness (partial regression coefficient ratio). This relationship was also observed for intensity of difference in this line. Both B3615 and 'Imperator 58' demonstrated a weak predominance of harshness over sweetness in overall flavor, as did 'Imperator 58' for preference and intensity of difference. Neither harshness nor sweetness correlated significantly with any of the three dependent attributes for this line. Only Nantes demonstrated a significant contribution of sweetness to flavor and preference. The partial regression coefficient ratio of less than 1.0 indicated a similar interrelationship between sweetness, harsh flavor, and intensity of difference.

Harsh and sweet flavors tend to be negatively correlated, but usually at an insignificant level (Table 4). Preference and intensity of difference were also significantly correlated in most comparisons. For several intra-line comparisons flavor and preference or intensity of difference were also correlated, but not for any intra-location comparisons.

Analysis of variance for the mean scores obtained from the descriptive panel indicated two significant F-values of the 5 attributes considered over lines and locations (Table 5). Interline variation was significant for harshness and interlocation variation was significant for overall flavor. Intensity of difference and sweetness demonstrated more interline variation than that for different locations, but these were not significant effects.

Descriptive panel evaluation of carrot flavor variation within the root (Table 6) indicated the least harshness and most sweetness in the mid-section of Texas-grown 'CandyPack', although the differences for these two parameters did not deviate significantly from the crown or tip. Only overall flavor varied significantly over the length of the root. Texas-grown 'Spartan Bonus' carrots stored 6 weeks provided similar results in a comparison of xylem and phloem. Xylem was in all ways less flavorful and less preferred but only overall flavor reflected

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

Table 4. Simple correlation coefficients for several sample attributes of carrots evaluated by the descriptive panel.

Location/entry	H-S[z]	F-P	F-I	P-I
Florida	−.81	−.29	.44	−.88*
Texas	−.81	−.41	.84	.99**
California	−.71	.81	−.78	−.72
6274	−.94	.99**	−1.00**	−.99**
3615	−.94	−.53	.76	−.95*
'Imperator 58'	−.99**	.63	−.95*	−.84
'Nantes'	.59	.99**	.78	.77
Overall	−.61*	.35	−.10	−.86**

[z]Simple correlation coefficient of H as a function of S. H = harsh, irritating flavor; S = sweetness; F = overall carrot flavor; P = overall preference; I = intensity of difference.

*P < 5% due to chance.

**P < 1% due to chance.

this difference significantly. California-grown 'Spartan Bonus' roots stored 1 week had the same pattern of xylem and phloem variation but for all attributes the difference was significant. This experiment did not determine whether this difference is a location effect, storage effect, or a combination of the two.

Sugar-coating harsh tasting B3615 carrots did not greatly decrease the harsh flavor but it increased sweetness significantly. The level of harshness was also substantially reduced from a score of 4.95 to 3.76 over the three week storage between initial testing (Table 1) and this experiment.

Discussion

The analysis of variance between mean scores of the descriptive panel allocated a significant proportion of variation for harshness to interline effects, i.e., genetic variation between lines tested. This was supported by consistent interline ranking for this attribute at different locations. In light of the regression statistics (high $r^2_{F\text{-}H}$ values in Table 3), it may be possible to utilize this variation in harshness to affect preference, intensity of flavor difference and, perhaps, overall flavor with certain genetic stocks. The fact that harsh flavor was a key factor in these dependent attributes for both a generally "good" carrot (B6274) and an "undesirable" line (B3615) may indicate a need to monitor harshness when genetically improving carrots; i.e. harsh flavor could be a positive characteristic to be increased in overly mild carrots and a negative component to be reduced in strongly-flavored carrots.

Sweetness was also genetically variable in the lines examined (high $r^2_{F\text{-}S}$ values in Table 3). Unlike harshness, undesirably high sweetness levels were not observed. Sweetness must be monitored if improvement of culinary quality is desired because it is important in certain lines (e.g. 'Nantes') and in certain environments as a contributor to preference and to intensity of difference and overall flavor.

Table 5. F-values from analysis of variance for the mean scores of the descriptive panel evaluation for different sample attributes of carrot lines grown in 3 locations.

Source	Sample attributes: Intensity of difference	Harsh, biting flavor	Sweetness	Overall carrot flavor	Overall preference
Entries	2.97	5.53*	2.28	0.52	2.53
Locations	0.82	0.59	0.82	7.22*	2.46

*P < 5% due to chance.

Table 6. Summary of mean scores for the descriptive panel evaluation of carrots prepared to exhibit flavor variation within the root and the effect of sugar coating.

Treatment	Sample attributes[z]: Harsh, biting flavor	Sweetness	Overall carrot flavor	Overall preference
Texas-grown 'Candy Pack'				
Crown	4.75a	3.58a	4.56a	3.44a
Mid-section	4.24a	3.80a	4.33ab	3.68a
Tip	4.30a	3.56a	4.06b	3.40a
LSD (5%)	0.64	0.54	0.46	0.57
Texas-grown 'Spartan Bonus'				
Xylem	3.06a	4.13a	3.57a	4.15a
Phloem	3.50a	4.24a	4.34b	4.48a
LSD (5%)	0.72	0.69	0.54	0.55
California-grown 'Spartan Bonus'				
Xylem	2.71a	2.61a	2.32a	2.78a
Phloem	3.44b	3.10b	3.25b	3.39b
LSD (5%)	0.53	0.44	0.56	0.47
Texas-grown B3615				
Control	3.76a	3.50a	3.97a	3.53a
Dipped in 30% fructose	3.66a	4.39b	4.34a	4.11a
LSD (5%)	0.71	0.50	0.46	0.68

[z]Description of superscripts and scales same as for Table 1.

The combination of harsh and sweet flavor accounted for at least 83% of the variation in preference and intensity of difference over all locations and in B6274, B3615, and 'Nantes'. This explained the large genetic component of preference and intensity of difference variation in the analysis of variance.

Location also played a major part in preference. Harshness was more important in the determination of preference in Florida-grown carrots ($b'_{P\text{-}H}/b'_{P\text{-}S} < -1$) and sweetness was in California-grown carrots ($b'_{P\text{-}H}/b'_{P\text{-}S} > -1$) while both of these attributes have a large role in Texas-grown carrots. With this, it may be advisable to be aware of the relative importance of harshness and sweetness in choosing a line to be grown at a specific location (e.g. B3615 may have a suitable flavor when grown in California but not in Texas).

Overall carrot flavor varied greatly with location (Table 5). Harshness was a more important factor in determining preference in carrot roots grown in Florida, sweetness was more important in California-grown roots, and both influenced preference in Texas carrots. In the former 2 states, a genotype-environment interaction or unknown factor(s) also contributed significantly to flavor (R^2 is small). This unknown attribute may impart a positive influence on flavor because a substitution of descriptive panel scores for harshness and for sweetness into the regression formula results in predicted flavor scores lower than the observed scores.

The slight negative correlation between harshness and sweetness (Table 4) reduced orthogonality and caused an overestimation of the importance of these variables upon the dependent attributes (6). The independent conclusions drawn for these factors indicated this was a minor problem. From the standpoint of the genetic improvement of carrots, it is fortunate that these factors can be handled separately because of the dissimilar methods of managing their variation (i.e. sweetness can be increased without apparent limit of acceptability, whereas harshness has an upper and probably lower limit of acceptability).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/

Extensive conclusions concerning this correlation cannot be made without controlled genetic experiments.

A priori, it was thought that the coefficient of variability for attributes of the inbreds B6274 and B3615 would be less than those for the open-pollinated 'Imperator 58' and 'Nantes'. Perhaps this was not observed because selection for flavor had not been made in the development of these lines or it may have been masked by variation among panelists. The more often lower simple correlations between parameters of 'Imperator 58' and 'Nantes' (Table 3) may be in part due to their greater variation. Two panelists noted substantial piece-to-piece variation for Florida-grown 'Nantes' and 'Imperator 58'.

The variation of flavor within a root suggested 2 ways to improve carrot flavor: reduce the contribution of the crown and tip to the total carrot root and reduce the xylem size. Except for wasteful trimming, the former solution is not very feasible. Carrot breeders have in large part produced the latter solution by selecting for "coreless" (small xylem) types. The sugar coating experiment demonstrates that the expression of harshness and sweetness are independent so that the improvement of flavor and preference can be fully realized only by improving both attributes. The reduction in harshness upon storage suggests a need for postharvest experiments in this area.

Carrot flavor attributes were influenced by genetic and environmental variation. Harsh flavor and sweetness accounted for most variation in overall preference and intensity of carrot flavor difference but only a part of overall carrot flavor. Variation within the root also affected flavor. The objective components accounting for these attributes are discussed elsewhere (5).

Literature Cited

1. Basker, D. 1977. The number of assessors required for taste panels. *Chem. Senses Flavor* 2:493-496.
2. Buttery, R. G., R. M. Seifert, D. G. Guadagni, D. R. Black, and L. C. Ling. 1968. Characterization of some volatile constituents of carrots. *J. Agr. Food Chem.* 16:1009-1015.
3. Carlton, B. C. and C. E. Peterson. 1963. Breeding carrots for sugar and dry matter content. *Proc. Amer. Soc. Hort. Sci.* 82:332-340.
4. Mahoney, C. H., H. L. Stier, and E. A. Crosby. 1957. Evaluating flavor differences in canned foods. I. Genesis of the simplified procedure for making flavor difference tests. *Food Technol.* 11:29-36.
5. Simon, P. W., C. E. Peterson, and R. C. Lindsay. 1980. *J. Agr. Food Chem.* (in press).
6. Snedecor, G. W. and W. G. Cochran. 1967. Statistical methods, 6th ed. Iowa State Univ. Press, Ames.
7. Sondheimer, E. 1957. Bitter flavor in carrots. III. The isolation of a compound with spectral characteristics similar to hydrocarbon extracts of bitter carrots. *Food Res.* 22:296-299.
8. Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York.
9. Stevens, M. A. 1974. Quality of fresh and processed vegetables. 19th Intern. Hort. Congress p. 437-446.
10. Stone, H., J. Sidel, S. Oliver, A. Woolsey, and R. C. Singleton. 1974. Sensory evaluation by quantitative descriptive analysis. *Food Technol.* 28:24-34.

J. Amer. Soc. Hort. Sci. 105(3):420–423. 1980.

Influence of Environment and Flower Maturity on Hybrid Seed Production of Exserted Stigma Tomatoes Crossed without Emasculation[1]

J. W. Scott[2] and William L. George, Jr.[3]
Department of Horticulture, The Ohio Agricultural Research and Development Center, Wooster, OH 44691

Additional index words. *Lycopersicon esculentum,* heterostyly, positional sterility, anthesis

Abstract. **Two inbreds of tomato (*Lycopersicon esculentum* Mill.) with exserted stigmas, one without and the other with positional sterility *(ps),* were crossed without emasculation, at 3 stages of maturity under 3 environmental conditions. Seed production was maximal when flowers at anthesis were pollinated during cloudy weather with relative humidities (RH) of about 70% and temperatures about 24°C. Seed production was poor when flowers were pollinated 3 days before anthesis during hot (32°C), clear, dry weather (RH - 48%). The *ps* inbred had less than 1% selfing at all stages of flower development and environments. Selfing contamination for the ps^+ inbred was less than 4% per line except in some cases when flowers were crossed before anthesis. Selfing of 35% occurred when flowers were crossed 3 days before anthesis during favorable pollinating weather.**

The self-pollinating nature of cultivated tomato has made production of hybrid seed difficult and expensive since manual operations are required for both emasculation and pollen transfer. Several reports indicated considerable time savings for hybrid seed production by using seed parents with stamenless *(sl)* (9), positional sterile *(ps)* (2, 12, 15) or *ps* plus exserted stigmas (15) to eliminate emasculation. Seed parents with either exserted stigmas (4, 19) or male sterility *(ms)* (17) would likely result in similar time savings. The use of non-emasculating schemes have other drawbacks such as maintenance of parental seed *(sl, ps, ms)* or stigma exertion of F_1 plants (19). Consequently commercial development of non-emasculating schemes or natural crossing schemes (16, 22), which eliminate manual pollen transfer as well as emasculation, has been limited. However, some of these labor-saving methods may become more commercially feasible in the future if the benefits can be shown to outweigh the disadvantages.

[1]Received for publication August 27, 1979. Approved for publication as Journal Article No. 142-79 of the Ohio Agricultural Research and Development Center.

The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked *advertisement* solely to indicate this fact.

[2]Assistant Professor. Mailing address: Department of Horticulture, 2001 Fyffe Court, The Ohio State University, Columbus, OH 43210.

[3]Professor. Mailing address: Department of Horticulture, University of Illinois, 125 Mumford Hall, Urbana, IL 61801.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-09-01 via Open Access. This is an open access article distributed under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0/). https://creativecommons.org/licenses/by-nc-nd/4.0/