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Selection of Alternative Genetic Sources of Large-Seed Size in Virginia-Type Peanut: Evaluation of Sensory, Composition, and Agronomic Characteristics

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Jenkins Jumbo, the ancestral source of large-seed size in the Virginia market type (*Arachis hypogaea* L.), has been shown to have a deleterious effect on flavor of peanut. The pervasiveness of Jenkins Jumbo in the ancestry of large-seeded germplasm contributes to the generally less intense roasted peanut flavor of U.S. cultivars of the Virginia market type. As a remedy to this problem, alternative sources of large-seed size were sought. Nine large-seeded selections, with NC 7 and Florunner as checks, were tested in replicated trials in North Carolina and Florida from 1996 to 1998. Pod yield, grade, weight of 100 seeds, and oil, sugar, and starch contents were measured. A descriptive sensory panel evaluated flavor attributes of a roasted sound mature kernel (SMK) sample from each plot. NC 7 scored low for sweet sensory attribute, high for bitter, and median for roasted peanut. UF714021, a multiline incorporating the Altika cultivar with several sister lines, had the best flavor profile of the large-seeded selections, but it did not have particularly large seeds relative to NC 7. The largest seeded selections were X90037 and X90053, both derived from Japan Jumbo. Flavor scores for X90037 were similar to those for NC 7 for roasted peanut (3.0 vs 2.9 flavor intensity units, fiu) and sweet (2.7 vs 2.6 fiu) but worse than NC 7 for bitter (3.3 vs 3.7 fiu) and astringent (3.5 vs 3.7 fiu). X90053 had intermediate values for roasted peanut and astringent, high value for sweet, and low for bitter. Other lines that had or were likely to have Jenkins Jumbo as a recent ancestor were generally poor in roasted flavor, supporting the hypothesis that ancestry from Jenkins Jumbo imparts poor flavor characteristics. With the exception of the unexpected relationship between astringent attribute and extra large kernel (ELK) content ($r = 0.82$, $P < 0.01$), there were no significant correlations between sensory attributes and the important agronomic traits: yield, meat, and ELK content. Among the nine large-seeded lines tested in this study, three appear to have greater potential for use as parents: 86x45B-10-1-2-2-b2-B, UF714021, and X90053.

KEYWORDS: *Arachis hypogaea* L.; roasted peanut; sweet; bitter; astringent; yield; grade; meat

INTRODUCTION

Studies of the genotypic and environmental effects on flavor quality of roasted peanut (*Arachis hypogaea* L.) have shown that large-seeded Virginia market-type genotypes are significantly lower in roasted peanut attribute intensity than runner market-type genotypes (*1*−*6*). These observations and the fact that the ancestors of cultivars in the runner and large-seeded Virginia market types are predominantly members of *A. hypogaea* ssp. *hypogaea* var. hypogaea (*7*) led to investigation of their ancestral basis (*8*, *9*). Jenkins Jumbo was the single most important ancestor exerting a negative effect on flavor. Pattee et al. (*10*) used best linear unbiased prediction procedures (BLUPs) to show that Jenkins Jumbo has a negative breeding value for the roasted peanut attribute, a neutral value for sweetness, and a positive value for bitterness. These results confirmed the observations of Isleib et al. (*8*).

Jenkins Jumbo is a selection made by Mr. R. B. Jenkins of Sumner, GA. It was first used in the Florida breeding program in the 1947 cross F359 (Jenkins Jumbo/F230-118-5-1). It was a primary parent choice in a majority of the crosses made in

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Table 1. Pedigrees of Selected Alternative Large-Seeded Genotypes and Checks

line		parentage
alternative lines	X90037[a]	Japan Jumbo//(F2-11-B-B-A6: F09), NC 7/Florigiant
	X90042[a,d]	PI 315616 (V4)/PI 315605 (Dixie Anak), PI 315631 (F_4 Sel #209 made in Israel)// (F2-11-B-B-A6: F09), NC 7/Florigiant
	X90053[a,d]	Japan Jumbo/PI 289620 (Virginia large-seeded from Israel)
	86x45B-8-1-1-b3-B[b]	UF81206/72x32B-13-1-3-b2-B
	86x45B-10-1-2-2-b2-B[b]	UF81206/72x32B-13-1-3-b2-B
	F581B-1-2-1-3-B2[b]	Pearl Early Runner (a white-seeded selection out of Early Runner)-4-2-1-1-b3-B/ F427 BV5
	F393-7-1-b4-B[b]	F334A-3-5-5-1/Jenkins Jumbo
	Dixie Giant[c]	selection from farmer stock peanuts
	Altika (UF714021)[b]	F427B-3-1-7-4-B
checks	NC 7	NC 5/F393-7-47-1-7-1
	Florunner	F334A-B-14 (Florispan component)/F230-118-B-8-1 (Early Runner component)
supplemental pedigree information	72x32B	PI 259785/Florigiant
	F230	Small White Spanish 3x-1/Dixie Giant
	F334A	GA 207-3/F230-118-2-2
	F427B	F393-7-1/GA 119-20
	UF81206 (72x94-7-1-1-2-b3-B)	PI 203396/F427B-3-1-7-4

[a] Selected from a program of selection for very large pod and seed size at North Carolina State University because they have ancestry from plant introductions. X90037, X90042, and X90053 have been renumbered N97049J, N97052J, and N97054J, respectively, within the NCSU peanut breeding program. [b] Selected from the University of Florida program as large seeded. [c] Included as a large-seeded ancestor of runner- and Virginia-type breeding populations. [d] Large-seeded Israeli germplasm is based in part upon breeding lines collected from U.S. programs and may therefore include ancestry from Jenkins Jumbo.

the Florida program through 1951, as indicated in the program's hybridization records (*11*). The two crosses of interest to the large-seeded Virginia market type are F392 (F334A-3-5-5-1/F359-1-3-14) and F393 (F334A-3-5-5-1/Jenkins Jumbo), from which Florigiant (F392) and NC 7 (NC 5/F393) were derived. Because of their commercial success, Florigiant and NC 7 pervade the ancestry of all current Virginia-type cultivars (*12*). Isleib et al. (*8*) have given a detailed summary of the pervasiveness of Jenkins Jumbo in the ancestry of the large-seeded germplasm.

A second ancestor indicated to have a negative impact on roasted peanut flavor in the large-seeded Virginia market type was Improved Spanish 2B (*8*), a Spanish-type line used to establish the breeding program in North Carolina. The BLUP analysis indicated that, among the Spanish-type ancestors of U.S. cultivars, Improved Spanish 2B was probably the worst choice from the standpoint of flavor (*10*).

Despite the generally inferior predicted effect of Virginia-type parents on flavor, Pattee et al. (*10*) showed there were a few lines with positive effects on roasted peanut and sweet attributes. AgraTech VC-1, Altika, NC Ac 18457, White's Runner, and large-seeded line X90053 all were predicted to improve flavor when used as parents. AgraTech VC-1 was selected from a breeding population more closely related to the runner than to the Virginia market type. Altika's ancestry would not lead one to expect a beneficial effect on flavor because it traces to Jenkins Jumbo as a grandparent. However, Altika also traces to GA 119-20, a line that derived its large-seed size from Dixie Giant rather than Jenkins Jumbo. Used as a parent, Dixie Giant tended to reduce bitterness while having little effect on roasted peanut and sweet intensities. White's Runner was one of the seven parents used by W. C. Gregory to establish the breeding program in North Carolina. It was a parent of NC 2, a Virginia-type cultivar that also had a weakly positive effect on roasted peanut and sweet attributes. The existence of large-seeded lines with superior effects on flavor illustrates the possibility of improving flavor in the Virginia market type without sacrificing large-seed size. The objective of this work was to evaluate sensory quality characteristics of alternative sources of large-seed size.

MATERIALS AND METHODS

Genotype Resources. Nine large-seeded genotypes (**Table 1**) were tested with NC 7 and Florunner as checks. Eight lines were selected from the North Carolina and Florida breeding programs because of their large-seed size and exotic ancestry. Dixie Giant was included as a large-seeded ancestor of Runner- and Virginia-type breeding populations. Plants were grown in replicated trials in 1996, 1997, and 1998 at two locations in North Carolina and one in northern Florida. Plants were grown and harvested under standard recommended procedures for the specific location.

Agronomic Characteristics. Peanut yield is expressed in terms of unshelled pods prior to removal of foreign material. A pod sample from each plot was graded according to USDA, AMS standards (*13*). Critical characteristics of large-seeded Virginia-type peanuts were analyzed for purposes of this study. They include (a) extra large kernels (ELK), the fraction of shelled seed that rides an 8.33 × 25.4 mm slotted screen, (b) sound mature kernels (SMK), the fraction of shelled seed that rides a 5.95 × 25.4 mm slotted screen for Virginia and a 6.35 × 19.05 mm slotted screen for Runner type, (c) meat content, the sum of SMK and sound splits (undamaged split seed which fell through the SMK screen), and (d) seed weight, the weight of 100 randomly selected SMK. Grade factors ELK, SMK, and meat content are expressed as a percentage of a 500 g cleaned unshelled pod sample.

Sample Preparation and Roasting. Each year an SMK fraction from each replicate of each location entry was shipped to Raleigh, NC, in February following harvest and placed in controlled storage at 5 °C and 60% RH until roasted. The peanut samples were roasted between May and June using a Blue M "Power-O-Matic 60" laboratory oven, ground into a paste, and stored in glass jars at −20 °C until evaluated. The roasting, grinding, and color measurement protocols were as described by Pattee and Giesbrecht (*1*).

Seed Composition. Composition was measured for a subsample of the SMK sample for each field plot. Oil was extracted as described by Oupadissakoon et al. (*14*); the supernatant was decanted into aluminum pans and evaporated, and the oil residue was measured gravimetrically. Following removal of the oil the sugar and starch were extracted from the residue and measured using the protocol of Pattee et al. (*15*).

Sensory Evaluation. A long-standing (5−13 years experience), six- to eight-member trained roasted peanut descriptive profile panel in the Food Science Department, North Carolina State University, Raleigh, NC, evaluated all peanut-paste samples using a 14-point universal flavor intensity unit (fiu) scale. Panel orientation and reference control were as described by Pattee and Giesbrecht (*1*) and Pattee et al. (*2*). Two

Table 2. Adjusted Means for Sensory Attributes and Seed Composition and Agronomic Traits of 10 Large-Seeded Peanut Cultivars and Lines and Florunner Evaluated over 3 Years in Irrigated Plots in North Carolina and Florida[a]

	sensory attributes (fiu)[b]				seed composition traits (g kg^{-1})			agronomic traits			
cultivar or line	roasted peanut	sweet	bitter	astringent	oil	sugar	starch	yield (kg ha^{-1})	meat (%)	ELK[c] (%)	seed wt [g (100 seeds)$^{-1}$]
Dixie Giant	2.76^{d}	3.03^{bc}	3.14^{de}	3.57^{abcd}	450^{d}	50^{c}	38^{cd}	3354^{bc}	61.5^{d}	40.4^{c}	98.3^{e}
86x45B-8-1-1-b3-B	2.98^{abcd}	2.83^{cde}	3.56^{ab}	3.61^{abc}	452^{d}	53^{ab}	45^{b}	4037^{a}	65.6^{c}	45.6^{bc}	99.7^{c}
86x45B-10-1-2-2-b2-B	3.08^{ab}	2.74^{def}	3.50^{abc}	3.44^{cde}	481^{a}	45^{d}	39^{cd}	4069^{a}	68.8^{b}	30.6^{d}	78.4^{e}
F393-7-1-b4-B	2.93^{bcd}	2.66^{ef}	3.40^{bc}	3.46^{bcde}	466^{bc}	40^{e}	43^{b}	3364^{bc}	65.9^{c}	34.3^{d}	87.7^{d}
F581B-1-2-1-3-B2	2.79^{cd}	3.06^{bc}	3.12^{de}	3.36^{e}	458^{cd}	47^{cd}	38^{de}	1896^{d}	65.6^{c}	32.8^{d}	83.8^{de}
UF714021	3.05^{abc}	3.33^{a}	2.94^{e}	3.43^{de}	450^{d}	50^{bc}	42^{bc}	3067^{c}	66.9^{bc}	33.6^{d}	82.8^{de}
X90037	2.96^{abcd}	2.66^{ef}	3.31^{cd}	3.48^{bcde}	448^{d}	46^{d}	37^{de}	3646^{ab}	66.0^{c}	49.8^{ab}	127.8^{a}
X90042	2.72^{d}	2.36^{g}	3.71^{a}	3.63^{ab}	466^{bc}	42^{e}	36^{de}	3080^{c}	65.3^{c}	49.7^{ab}	116.1^{b}
X90053	2.87^{bcd}	3.10^{ab}	3.16^{de}	3.55^{abcde}	418^{e}	53^{a}	52^{a}	3562^{abc}	65.9^{c}	48.7^{b}	125.0^{a}
NC 7	2.95^{abcd}	2.55^{fg}	3.67^{a}	3.66^{a}	471^{ab}	40^{e}	34^{ef}	4022^{a}	71.9^{a}	54.6^{a}	104.8^{c}
Florunner	3.20^{a}	2.97^{bcd}	3.17^{de}	3.41^{de}	465^{bc}	46^{d}	33^{f}	3635^{ab}	74.1^{a}	18.1^{e}	62.6^{f}

[a] Means followed by the same letter are not significantly different at the 5% level of probability by *t*-test. [b] fiu = flavor intensity units. [c] Extra large kernel content.

Table 3. Correlations among Sensory Attributes and Seed Composition and Agronomic Traits of 10 Large-Seeded Peanut Cultivars and Lines

	roasted peanut (fiu)[a]	sweet (fiu)	bitter (fiu)	astringent (fiu)	oil (g kg^{-1})	sugar (g kg^{-1})	starch (g kg^{-1})	yield (kg ha^{-1})	meat (%)	ELK[b] (%)	100-seed wt [g (100 seeds)$^{-1}$]
roasted peanut	1.000	0.161	–0.017	–0.239	0.201	0.064	0.148	0.547	0.588	–0.255	–0.335
sweet	0.161	1.000	–0.909[d]	–0.493	–0.557	0.757[c]	0.526	–0.348	–0.298	–0.479	–0.331
bitter	–0.017	–0.909[d]	1.000	0.640[c]	0.560	–0.587	–0.385	0.509	0.426	0.485	0.212
astringent	–0.239	–0.493	0.640[c]	1.000	–0.039	–0.112	–0.097	0.555	0.117	0.816[d]	0.529
oil	0.201	–0.557	0.560	–0.039	1.000	–0.758[c]	–0.725[c]	0.106	0.431	–0.287	–0.556
sugar	0.064	0.757[c]	–0.587	–0.112	–0.758[c]	1.000	0.672[c]	–0.035	–0.463	–0.084	0.106
starch	0.148	0.526	–0.385	–0.097	–0.725[c]	0.672[c]	1.000	0.104	–0.243	–0.103	0.120
yield	0.547	–0.348	0.509	0.555	0.106	–0.035	0.104	1.000	0.383	0.393	0.236
meat	0.588	–0.298	0.426	0.117	0.431	–0.463	–0.243	0.383	1.000	0.183	–0.117
ELK	–0.255	–0.479	0.485	0.816[d]	–0.287	–0.084	–0.103	0.393	0.183	1.000	0.862[d]
100-seed wt	–0.335	–0.331	0.212	0.529	–0.556	0.106	0.120	0.236	–0.117	0.862[d]	1.000

[a] fiu = flavor intensity units. [b] Extra large kernel content. [c] Denotes correlations different from zero at the 5% level of probability. [d] Denotes correlations different from zero at the 1% level of probability.

sessions were conducted each week on nonconsecutive days. Panelists evaluated four samples per session. A commercial creamy Jif reference was available during each panel session. The fiu of the reference was 4. Sensory evaluation commenced in June or July of each year and continued until all samples were evaluated. The individual panelists' scores were averaged together for each sensory attribute and used in all analyses.

Statistical Analysis. Sensory data were unbalanced due to unequal replication of treatments at different locations and to roasting of duplicates for samples whose roast color fell outside the specified range. PROC MIXED in SAS (*16*) was used for analysis of the unbalanced data set to estimate adjusted genotype means. Genotype means were compared by *t*-test using a uniquely calculated standard error of the difference for each comparison. Covariates fruity and roast color were used, as needed, on the basis of the findings of Pattee et al. (*5*, *17*) and Pattee and Giesbrecht (*18*).

RESULTS AND DISCUSSION

When used as a parent in the 1950s to develop Virginia-type cultivars in the Florida peanut breeding program, Jenkins Jumbo contributed retrogressive roasted peanut characteristics to descendent cultivars (*8*, *10*). The negative combining ability of Jenkins Jumbo was not foreseen at that time because there was no formal collection of sensory data on breeding lines. In the same period in the Virginia–Carolina area, NC 2 was the predominant cultivar. Florigiant replaced NC 2 in the mid-1960s and was in turn replaced by NC 7 in the early 1980s (*7*). Had NC 2, a line with positive predicted combining ability for roasted peanut attribute (*10*), been as widely used as a parent as were Florigiant and NC 7, two descendents of Jenkins Jumbo, then the average roasted peanut attribute of modern Virginia-type cultivars might not be below the average of Runner-type cultivars. Now that sensory characteristics have been analyzed to determine their heritabilities (*6*), it is possible to include them as criteria in the selection of parents for cultivar development.

To be a useful parent, a line should combine relatively high values for the sensory attributes roasted peanut and sweet and low values for the attributes bitter and astringent, and it must have very large seed size and acceptable yield and meat content. The lines tested in this study included an array of large-seeded germplasm from the Florida and North Carolina programs. Because of the pervasiveness of Jenkins Jumbo ancestry in large-seeded cultivars and breeding populations, it was not possible to obtain germplasm completely unrelated to Jenkins Jumbo except for Dixie Giant. Among the plant introductions ancestral to the lines tested, large-seeded Israeli germplasm is based in part upon breeding lines collected from U.S. programs and may therefore include ancestry from Jenkins Jumbo. Florunner, the industry standard for sensory characteristics, was included to provide a benchmark for identifying large-seeded germplasm with superior sensory quality. There was significant ($P < 0.05$) variation among large-seeded lines for each of the sensory characteristics, seed composition traits, and agronomic traits including seed size (**Table 2**). NC 7, the standard large-seeded Virginia cultivar, scored low for sweet sensory attribute, high for bitter and astringent, and median for roasted peanut. UF714021, a multiline incorporating the Altika cultivar along with several selections out of Altika, had the best flavor profile of the large-seeded selections, but it did not have particularly large seed relative to NC 7 [82.8 vs 104.8 g (100 seed)$^{-1}$, $P < 0.05$]. The largest-seeded selections were X90037 and X90053 [127.8 and 125.0 g (100 seed)$^{-1}$, respectively], both derived from Japan Jumbo. Flavor scores for X90037 were similar to those for NC 7 for roasted peanut [2.96 vs 2.95 flavor intensity units (fiu), ns] and sweet (2.66 vs 2.55 fiu, ns) but higher than NC 7 for bitter (3.31 vs 3.67 fiu, $P < 0.05$) and astringent (3.48 vs 3.66 fiu, $P < 0.05$). X90053 had intermediate values for roasted peanut (2.87 fiu) and astringent (3.55 fiu), high value for sweet (3.10 fiu), and low for bitter (3.16 fiu). Other lines that had or were likely to have had Jenkins Jumbo as a recent ancestor were generally poor in roasted flavor, supporting the hypothesis that ancestry from Jenkins Jumbo imparts poor flavor characteristics.

Relationships among sensory attributes and seed composition and agronomic traits can be discerned through their statistical correlations across genotypes. Florunner was excluded from the correlations because it is not a large-seeded cultivar and its inclusion would have distorted the correlations. Of the 55 pairs of traits, only 3 were correlated at the 1% level of probability and 5 at the 5% level (Table 3). Of the three highly significant correlations, one is trivial in that it occurred between the percentage of extra large kernels (ELK) and the weight of 100 seeds. The second strong correlation was between sweet and bitter sensory attributes ($r = -0.90$, $P < 0.01$), a correlation that has been reported previously (*6*). However, unlike the previous study, there was no significant correlation between sweet and roasted peanut ($r = -0.16$, ns) or bitter and roasted peanut ($r = -0.02$, ns). The previous studies incorporated a broad range of Virginia-type germplasm while this study included only a small subset of large-seeded Virginia-type germplasm, most of it closely related to Jenkins Jumbo through F393 (**Table 1**). The third strong correlation was between astringent and ELK ($r = 0.82$, $P < 0.01$). The basis for this correlation is not immediately evident. In contrast, the correlation between astringent and weight of 100 seeds was not significant.

Other significant but weaker correlations include that between sweet attribute and total sugar content ($r = 0.74$, $P < 0.05$). Previous work with a broader group of Virginia-type germplasm indicated that sensory perception of sweetness was weakly correlated with sugar content in the Virginia and Runner market types (*19*). Other anticipated correlations were also observed. Specifically, bitter and astringent attributes were positively correlated ($r = 0.64$, $P < 0.05$), and seed composition traits were interrelated with sugar and starch contents being negatively correlated with oil content ($r = -0.76$ and $r = -0.72$, $P < 0.05$) while sugar and starch contents were positively correlated ($r = 0.67$, $P < 0.05$).

With the exception of the unexpected relationship between astringent attribute and ELK content, there were no significant correlations between sensory attributes and the important agronomic traits: yield, meat, and ELK content. This suggests that breeders should be able to identify parents that would improve the flavor profile of Virginia-type peanuts without negatively influencing yield, meat, or ELK content. Among the nine large-seeded lines tested in this study, three appear to have potential for use as parents: 86x45B-10-1-2-2-b2-B, 86x45B-8-1-1-b3-B, and X90053 (**Table 2**). Of these, the first two combine the best flavor profiles with yield and meat content, but they are not particularly large seeded in comparison with the three very large-seeded North Carolina lines (X90037, X90042, and X90053). For crosses within the Virginia market type, the Florida lines 86x45B-10-1-2-2-b2-B and 86x45B-8-1-1-b3-B would be useful parents because one would be using another large-seeded line as the other parent in the cross. For crosses to Runner-, Spanish-, or Valencia-type lines, one needs to use a Virginia-type parent with very large seeds in order to recover progeny of the Virginia type [80−100 g (100 seeds)$^{-1}$]. Of the very large-seeded North Carolina lines, X90053 has the best overall flavor profile and acceptable yield. All three North Carolina lines were very similar for meat and ELK content.

With sensory and agronomic data in hand, it is possible to identify sources of large-seed size that, used as parents, will maintain the desirable agronomic characteristics while improving the overall flavor profile of Virginia-type breeding populations. Furthermore, the data presented illustrate the need for systematic monitoring of sensory quality to identify lines combining superior flavor and agronomic characteristics.

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