PEANUT SCIENCE

The Journal of the American Peanut Research and Education Society

ARTICLE

# Genetic Variability and Stability for Flavor among Runner and Virginia-Type Peanut Cultivars in Georgia

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ARTICLE INFORMATION

*Keywords:*
Arachis hypogaea L, groundnut, breeding, heritability, cold storage, roasted peanutty taste, sweet taste, combined good taste

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DOI: 10.3146/0095-3679-52.1-PS1636

ABSTRACT

Genetic stability for consistently good flavor is a very important quality characteristic sought in U.S. peanut (*Arachis hypogaea* L.) breeding programs. Maintaining good flavor quality during short-term cold storage is likewise sought as an important genetic trait. After four years (2011-14) in cold-storage at approximately 10°C and 50% relative humidity, 10 runner and five virginia-type peanut cultivars were compared for flavor. Roasted peanutty flavor was found to be significantly higher for 'Georgia-09B' and 'Georgia-14N' than 'Tifguard' and 'Florida Fancy' in the five-year average cold storage study. Likewise, Georgia-14N was found to have the highest five-year average cold-storage sweet taste flavor compared to Tifguard, Florida Fancy, and CHAMPS. In a separate study, 15 high-oleic runner and virginia-type peanut cultivars were compared for flavor when grown over three-years (2020-22) under maximum input practices with irrigation. In the most recent study, 'Georgia-22MPR' was found to have significantly higher combined good flavor (roasted peanutty plus sweet taste) compared to the three runner-type cultivars, 'Georgia-16HO', FloRun '331' and TUFRunner '297'; and three virginia-type cultivars, 'Georgia-19HP', 'Georgia-11J', and 'Sullivan'. However, Georgia-16HO and FloRun 331 were found to be statistically similar to all other runner-type cultivars; whereas Georgia-19HP was found to be statistically similar to the best-flavored virginia-type cultivars in roasted peanutty flavor, sweet taste flavor, and combined good flavor. Heritability estimates for these latter 15 high-oleic runner and virginia-type cultivars averaged over the three-years were determined to be as follows: roasted peanutty flavor H = 0.0%, sweet taste flavor H = 22.5%, and combined good flavor (roasted peanutty and sweet taste) H= 23.1%.

## INTRODUCTION

Flavor is a very important quality attribute in developing new peanut (*Arachis hypogaea* L.) cultivars.Unfortunately, previous broad sense heritability estimates for roasted peanutty flavor among peanut germplasm were found to be relatively low at about 9% (previous range 10-24%); whereas broad-sense heritability estimates for sweet taste flavor was determined to be slightly higher at 26% with previous ranges 14-37% (Pattee *et al.*, 1995). Obviously, the genetic (G) component of peanut flavor is relatively low compared to environmental (E) and the GXE interaction (Pattee *et al.*, 1994).

Many environmental effects can have an adverse effect upon flavor in any given year, i.e. maturity (digging too early or too late); lack of adequate soil nutrients (Ca and B); improper drying; storage conditions; and commingling with other

peanuts from different growing conditions (irrigated vs dryland) or different cultivars mixed together, etc. (Davis and Dean, 2016). In a nutshell, the best genetic flavor quality in a peanut cultivar is only as good as the best environment in which it is grown, harvested, dried, shelled, and stored for the best flavor possible to the consumer.

There are two-types of flavor evaluations (Davis and Dean, 2016). One is subjective individual personal preference (affective), and the other is a more objective approach by trained sensory panels to identify specific components of flavor (effective). Peanut manufacturers utilize the effective sensory panels conducted under a set of controlled conditions to determine which specific sample is best for their product to market to the aforementioned subjective individual consumers. Consequently, there are multiple peanut brands and flavors available to sell to these various individual preferences.

Equally if not more importantly, a peanut cultivar should exhibit consistent performance over years and across different environments. This GXE stability or consistent performance is perhaps one of the most important characteristics for all traits needed in a peanut cultivar for long-term utilization by growers, shellers, manufacturers, and consumers.

An example of individual personal preference versus trained peanut sensory panel was recently highlighted by Fritz *et al.,* (2022). In this study, an old landrace cultivar 'Carolina Runner #4', also known as 'Carolina African Runner', was claimed to have excellent flavor. However, based upon trained sensory roasted peanutty score, it only ranked 136 out of 205 accessions tested.

Good consistent flavor is a very desirable peanut trait, but it has relatively low heritability. So, the objective of this study was two-fold: 1). determine the relative genetic stability across several years in cold storage among different normal-oleic and high-oleic runner and virginia-type peanut cultivars and 2). access the relative genetic variability and estimated broad-sense heritability for good flavor among only high-oleic genotypes.

## MATERIALS AND METHODS

An insulated stand-alone cinder block cold storage building was used that was equipped with air conditioning and hanging heater inside for humidity control. After four-years (2011-2014) average genetic variability was determined for flavor among 15 normal-oleic and high-oleic runner and virginia- type peanut cultivars. Seed of these cultivars containing about 6% moisture were initially placed in cold storage, and these were held at an approximately total summed values equal 100 from combining F° temperature and % relative humidity, i.e. 50°F (10°C) + 50% RH = 100 (James, 1967). In a separate study, during each of three years (2020-22), 15 high-oleic runner and virginia market type peanut cultivars where also compared for roasted peanutty flavor, sweet taste flavor, and the combined good flavor of these two desirable flavors (roasted peanutty plus sweet taste).

All field tests are grown under maximum input production practices at the Gibbs Farm near the University of Georgia, Coastal Plain Experiment Station, Tifton Georgia. Each year, a randomized complete block field design with four or five replications per test was used following Georgia Extension Service's recommended input production practices of herbicides, fungicides, and insecticides and irrigation as needed throughout the growing season. These field tests were conducted on a Tifton loamy sand soil type (fine-loamy, siliceous, thermic, Plinthic Kandidult). All plots in each test consisted of two rows, 6.1m long x 1.8m wide, and six seed were planted per 30.5 cm of row length.

Each cultivar was individually dug near optimum maturity based upon the hull-scrape method from adjacent border plants (Williams and Drexler, 1981). After harvest, peanut pods from each plot were dried with forced warm air to approximately 6% seed moisture content. Pod samples were then cleaned before samples were presized and shelled on federal state inspection service (FSIS) equipment accordingly for runner and virginia-type peanut, respectively (USDA-AMS, 1998).

After shelling, seed samples were screened over a ≥7.14 by 19.05mm screen for mature sound kernels, and hand-picked for only edible seed. A 454-g sample was taken from each replication and sent to J. Leek Associates International testing laboratory at Edenton, NC for sensory flavor test evaluation. A trained 3 to 5 person flavor panel was used each year to score each sample for flavor scores on a 0 to 10 scale. A good roasted peanut score would be ≥5 flavor intensity without off flavors. Each sample was dry roasted to medium roasted peanut color (Hunter L 48 +/- 2). The roasted peanut seed were then blanched and ground into a paste.

Data from each test was statistically analyzed by analysis of variance (ANOVA) using the PROC GLM procedure in SAS version 9.4 (SAS Institute, Inc., Cary, NC). Waller-Duncan's Bayesian T-test (k-ratio = 100) was used for mean separation at P≤0.05. Fixed effect variance components (VC) were obtained by using PROC VARCOMP in SAS. The following equations were then used to estimate broad-sense heritability (H) based upon entry-means for each year and 5-replications, and for 3 years and 5-reps as a selection unit (Fehr, 1987):

$$\boldsymbol{H(1\ year, 5\ reps)} = \frac{\boldsymbol{VC_{entry}}}{\boldsymbol{VC_{entry}} + \boldsymbol{VC_{entry\ x\ year}} + \frac{\boldsymbol{VC_{error}}}{\mathbf{5}}}$$

and

$$\boldsymbol{H(3\ year, 5\ reps)} = \frac{\boldsymbol{VC_{entry}}}{\boldsymbol{VC_{entry}} + \frac{\boldsymbol{VC_{entry\ x\ year}}}{\mathbf{3}} + \frac{\boldsymbol{VC_{error}}}{\mathbf{15}}}$$

## RESULTS

High-oleic peanut cultivars have previously been known to have a long shelf-life after roasting and processing for salted peanut and peanut products (Mozingo *et al.*, 2004 and Norden *et al.*, 1987). However prior to utilization, the effect of four-years of cold storage on flavor of sound mature seed between normal-oleic and high-oleic peanut cultivars was accessed (Tables 1 and 2).

For roasted peanutty flavor (Table 1), the runner-type cultivars 'Georgia-09B' (Branch, 2010) and 'Georgia-14N' (Branch and Brenneman, 2015) were found to have the highest five-year average flavor score of 5.60. However, both cultivars were significantly better than only 'Tifguard' (Holbrook *et al.*, 2008) and 'Florida Fancy'.

For sweet taste flavor (Table 2), the Georgia-14N cultivar was likewise found to have the highest five-year average score of 2.34. However, it was significantly better than only Tifguard, Florida Fancy, and 'CHAMPS' (Mozingo *et al.*, 2006). These results emphasize two important points. First, when good quality peanut seed of normal-oleic or high-oleic runner and virginia-type cultivars are placed in cold-stored at the proper

temperature and humidity, equally good roasted peanutty and sweet taste flavors after four years can result. Secondly, significant genetic variability was found for flavor quality among these specific cultivars. However, normal and high-oleic cultivars were both found to be similar in roasted peanutty flavor and sweet taste flavor under these test conditions.

**Table 1. Five-year average genetic variability in roasted peanutty flavor intensity of 10 runner-type and 5 virginia-type peanut cultivars when grown under similar maximum input production practices and irrigation at Tifton, GA and kept in cold storage for 4, 3, 2, 1, and 0 years (2011-15), respectively.**

| Peanut Cultivar | Roasted Peanutty Flavor (0-10 scale) | | | | | 5-yr Mean |
|---|---|---|---|---|---|---|
| | 2011 (4) † | 2012 (3) | 2013 (2) | 2014 (1) | 2015 (0) | |
| Runner-types: | | | | | | |
| [a]Georgia-09B | 5.7 | 6.0 | 6.0 | 5.3 | 5.0 | 5.60 a* |
| [a]Georgia-14N | 5.7 | 6.0 | 5.3 | 5.7 | 5.3 | 5.60 a |
| Georgia Greener | 6.0 | 6.0 | 5.0 | 5.3 | 5.0 | 5.46 ab |
| [a]FloRun '107' | 5.0 | 6.0 | 5.3 | 5.3 | 5.0 | 5.32 abc |
| Georgia-06G | 5.7 | 5.3 | 5.0 | 5.0 | 5.3 | 5.23 abc |
| [a]Florida-07 | 5.3 | 5.7 | 5.3 | 4.7 | 5.3 | 5.26 abc |
| [a]Georgia-13M | 5.7 | 5.3 | 5.3 | 5.3 | 4.7 | 5.26 abc |
| Georgia-07W | 5.7 | 5.0 | 5.0 | 4.7 | 5.0 | 5.08 abc |
| Georgia-12Y | 4.3 | 4.3 | 5.7 | 5.0 | 5.7 | 5.00 abc |
| Tifguard | 4.0 | 4.7 | 5.0 | 4.7 | 5.0 | 4.68 c |
| Virginia-types: | | | | | | |
| [a]Georgia-08V | 5.7 | 5.3 | 5.7 | 5.0 | 5.7 | 5.48 ab |
| CHAMPS | 5.3 | 5.3 | 4.7 | 5.3 | 5.5 | 5.22 abc |
| Bailey | 5.3 | 5.3 | 5.3 | 5.7 | 4.0 | 5.12 abc |
| [a]Georgia-11J | 4.3 | 5.7 | 5.0 | 5.3 | 4.0 | 4.86 abc |
| [a]Florida Fancy | 5.3 | 4.0 | 5.0 | 4.7 | 4.7 | 4.74 bc |

[a]High-Oleic cultivar

†( ) = No. of years in cold storage.

*Means within the last column followed by the same letter are not significantly different at P≤0.05.

During 2020-22, replicated field tests of 15 high-oleic runner and virginia market type cultivars were grown under irrigation with maximum-input production practices, harvested at optimum maturity, dried, shelled, and screened for uniform seed size to minimize environmental effects and maximize genetic differences. Significant differences were found among these 15 cultivars each year and across the three years for roasted peanutty flavor (Table 3), sweet taste flavor (Table 4), and the combined good flavor of roasted peanutty and sweet taste (Table 5).

While Georgia-14N had good flavor in the aforementioned cold storage tests, it was found to be significantly lower than 'Georgia-22MPR' (Branch and Brenneman, 2023) after roasting in 2022 and in the three-year (2020-22) average for roasted peanutty flavor (Table 3), but Georgia-14N was significantly higher than several other cultivars in sweet taste flavor (Table 4). Likewise, the combined good flavor resulted in Georgia- 22MPR having the highest three-year average, and Georgia-14N not being significantly different from Georgia-22MPR, except in 2022 (Table 5).

In this study, Georgia-22MPR was also found to be significantly higher in combined good flavor averaged across three-years than the runner cultivars, 'Georgia-16HO' (Branch, 2017), FloRun '331' (Tillman, 2021) and TUFRunner '297' (Tillman, 2018), and three virginia-type cultivars Georgia-19HP, 'Georgia-11J' (Branch, 2012) and 'Sullivan'. However, Georgia-16HO and FloRun '331' were both found to be similar to all other runner-type cultivars; whereas, Georgia-19HP was found to be similar to the best flavored virginia-type cultivars in roasted peanutty flavor, sweet taste flavor, and combined good flavor.

Table 2. Five-year average genetic variability in sweet taste flavor intensity of 10 runner-type and 5 virginia-type peanut cultivars when grown under similar maximum input production practices and irrigation at Tifton, GA and kept in cold storage for 4, 3, 2, 1, and 0 years (2011-15), respectively.

| Peanut Cultivar | Sweet Taste Flavor (0-10 scale) | | | | | 5-yr Mean |
|---|---|---|---|---|---|---|
| | 2011 (4) † | 2012 (3) | 2013 (2) | 2014 (1) | 2015 (0) | |
| Runner-types: | | | | | | |
| [a]Georgia-14N | 2.3 | 1.7 | 2.7 | 2.3 | 2.7 | 2.34 a* |
| [a]Georgia-09B | 1.3 | 3.0 | 2.3 | 2.3 | 2.3 | 2.24 ab |
| [a]FloRun '107' | 0.7 | 3.0 | 2.3 | 1.7 | 2.3 | 2.00 abc |
| Georgia Greener | 2.0 | 2.7 | 1.3 | 1.0 | 2.0 | 1.80 abc |
| [a]Georgia-13M | 1.3 | 1.3 | 3.0 | 2.3 | 0.7 | 1.72 abc |
| [a]Florida-07 | 2.0 | 1.3 | 2.0 | 1.0 | 1.8 | 1.62 abc |
| Georgia-07W | 1.3 | 2.3 | 1.3 | 1.0 | 2.0 | 1.58 abc |
| Georgia-06G | 1.3 | 2.3 | 0.7 | 0.7 | 2.3 | 1.46 abc |
| Georgia-12Y | 1.3 | 1.0 | 1.0 | 1.7 | 2.0 | 1.40 abc |
| Tifguard | 0.7 | 1.2 | 2.0 | 1.3 | 1.7 | 1.18 c |
| Virginia-types: | | | | | | |
| [a]Georgia-08V | 2.3 | 2.3 | 2.3 | 1.0 | 2.0 | 1.98 abc |
| [a]Georgia-11J | 0.7 | 2.3 | 2.3 | 2.3 | 1.0 | 1.72 abc |
| Bailey | 1.7 | 1.7 | 2.3 | 0.7 | 0.7 | 1.42 abc |
| [a]Florida Fancy | 1.3 | 0.7 | 2.3 | 0.7 | 1.2 | 1.24 bc |
| CHAMPS | 0.7 | 1.0 | 1.3 | 1.3 | 1.5 | 1.16 c |

[a]High-Oleic cultivar

†( ) = No. of years in cold storage.

*Means within the last column followed by the same letter are not significantly different at P≤0.05.

Table 3. Three-year average roasted peanutty flavor among fifteen high-oleic runner and virginia peanut cultivars when grown under maximum-input production practices at Tifton, GA 2020-22.

| Peanut Cultivar | Roasted Peanutty Flavor (0-10 scale) | | | 3-yr Mean |
|---|---|---|---|---|
| | 2020 | 2021 | 2022 | |
| Runner-types: | | | | |
| Georgia-22MPR | 5.6 abc* | 5.8 ab | 6.5 a | 6.0 a |
| Georgia-16HO | 5.8 ab | 5.5 bcd | 6.4 ab | 5.9 abc |
| Georgia-09B | 5.3 abc | 6.1 a | 5.9 b-d | 5.8 abc |
| TifNV-High O/L | 5.8 abc | 5.7 bc | 5.9 cde | 5.8 a-d |
| AU-NPL 17 | 5.2 abc | 5.6 bc | 6.3 abc | 5.7 a-d |
| Georgia-20VHO | 5.7 abc | 5.3 cd | 6.1 a-e | 5.7 a-e |
| TUFRunner '297' | 5.9 a | 5.4 cd | 5.6 e | 5.6 a-e |
| FloRun '331' | 5.7 abc | 5.4 cd | 5.7 de | 5.6 b-e |
| Georgia-14N | 5.2 bc | 5.5 bcd | 6.0 b-e | 5.6 b-e |
| Virginia-types: | | | | |
| Wynne | 5.4 abc | 6.1 a | 6.3 abc | 5.9 ab |
| Georgia-19HP | 5.8 ab | 5.5 bcd | 6.1 a-e | 5.8 abc |
| TifJumbo | 5.1 c | 5.6 bc | 6.0 b-e | 5.6 b-e |
| Bailey II | 5.4 abc | 5.2 d | 6.1 a-d | 5.6 cde |
| Georgia-11J | 5.1 c | 6.1 a | 4.9 f | 5.4 de |
| Sullivan | 5.7 abc | 5.3 cd | 5.1 f | 5.3 e |
| Mean | 5.5 | 5.6 | 5.9 | 5.7 |
| % CV | 7.1 | 5.4 | 6.8 | 8.0 |

* Within columns, cultivar means followed by the same letter are not significantly different at P≤0.05.

Table 4. Three-year average sweet taste flavor among fifteen high-oleic runner and virginia peanut cultivars when grown under maximum-input production practices at Tifton, GA 2020-22.

| Peanut Cultivar | Sweet Taste Flavor (0-10 scale) | | | 3-yr Mean |
|---|---|---|---|---|
| | 2020 | 2021 | 2022 | |
| Runner-types: | | | | |
| Georgia-14N | 2.8 abc* | 3.1 a | 2.1 de | 2.6 a |
| AU-NPL 17 | 3.1 a | 2.3 ab | 2.6 abc | 2.6 a |
| Georgia-22MPR | 2.8 ab | 2.2 b | 2.8 a | 2.6 ab |
| Georgia-20VHO | 2.8 abc | 2.1 bc | 2.6 a-d | 2.5 a-d |
| Georgia-09B | 2.8 ab | 2.2 b | 2.3 a-e | 2.4 a-d |
| TifNV-High O/L | 2.4 bc | 2.3 ab | 2.2 b-e | 2.3 a-e |
| FloRun '331' | 2.3 c | 1.8 b-e | 2.5 a-d | 2.2 b-e |
| Georgia-16HO | 2.8 abc | 1.5 b-e | 2.1 cde | 2.1 def |
| TUFRunner '297' | 2.4 bc | 1.3 cde | 2.2 b-e | 2.0 ef |
| Virginia-types: | | | | |
| Bailey II | 2.7 abc | 2.3 b | 2.7 ab | 2.5 abc |
| TifJumbo | 2.8 ab | 2.1 bcd | 2.7 ab | 2.5 abc |
| Georgia-19HP | 2.3 c | 1.9 b-e | 2.5 a-d | 2.3 a-e |
| Wynne | 2.3 c | 2.3 ab | 1.9 e | 2.2 cde |
| Georgia-11J | 2.8 ab | 1.3 de | 1.3 f | 1.7 fg |
| Sullivan | 2.7 abc | 1.2 e | 0.8 g | 1.5 g |
| Mean | 2.7 | 2.0 | 2.2 | 2.3 |
| % CV | 11.0 | 29.8 | 19.5 | 23.9 |

* Within columns, cultivar means followed by the same letter are not significantly different at P≤0.05.

Table 5. Three-year average combined good flavor among fifteen high-oleic runner and virginia peanut cultivars when grown under maximum-input production practices at Tifton, GA 2020-22.†

| Peanut Cultivar | Combined Good Flavor (0-10 scale) | | | 3-yr Mean |
|---|---|---|---|---|
| | 2020 | 2021 | 2022 | |
| Runner-types: | | | | |
| Georgia-22MPR | 8.4 a* | 8.0 a-d | 9.3 a | 8.6 a |
| AU-NPL 17 | 8.3 a | 7.9 a-d | 8.9 ab | 8.4 ab |
| Georgia-09B | 8.2 a | 8.4 abc | 8.2 b-e | 8.3 ab |
| Georgia-14N | 8.0 a | 8.6 a | 8.1 de | 8.2 ab |
| Georgia-20VHO | 8.4 a | 7.4 b-f | 8.6 bcd | 8.1 abc |
| TifNV-High O/L | 8.2 a | 8.0 a-d | 8.1 de | 8.1 abc |
| Georgia-16HO | 8.6 a | 7.0 def | 8.5 bcd | 8.0 bc |
| FloRun '331' | 8.0 a | 7.2 def | 8.3 b-e | 7.8 bc |
| TUFRunner '297' | 8.4 a | 6.7 ef | 7.8 e | 7.6 cd |
| Virginia-types: | | | | |
| Wynne | 7.7 a | 8.4 ab | 8.2 cde | 8.2 ab |
| Bailey II | 8.1 a | 7.4 b-f | 8.8 abc | 8.1 abc |
| TifJumbo | 7.9 a | 7.7 a-e | 8.7 a-d | 8.1 abc |
| Georgia-19HP | 8.1 a | 7.4 c-f | 8.6 bcd | 8.0 bc |
| Georgia-11J | 7.9 a | 7.4 c-f | 6.2 f | 7.1 de |
| Sullivan | 8.4 a | 6.5 f | 5.8 f | 6.8 e |
| Mean | 8.2 | 7.6 | 8.1 | 8.0 |
| % CV | 5.5 | 9.9 | 7.3 | 9.7 |

† Combined good flavor = roasted peanutty flavor + sweet taste flavor.

* Within columns, cultivar means followed by the same letter are not significantly different at P≤0.05.

## DISCUSSION

It is interesting to note that 'Georgia-09B' resulted from a single backcross to 'Georgia Green' (Branch, 1996) and was found to have good roasted peanutty flavor (Tables 1 and 3), and good sweet taste flavor (Tables 2 and 4) in this study. Previously, Georgia Green was found to have among the highest Best Linear Unbiased Prediction (BLUP) breeding values for roasted peanut and sweet attributes in a large multilocation five-year (1996-2000) study, involving 'Florunner', 'Southern Runner', and 'Sunbelt Runner' (Pattee *et al*., 2003).

The results from this current study also shows that the high-oleic cultivar Georgia-22MPR had consistently good combined flavor during each year and across the three-years (2020-22). The cross between Georgia Green x 'C-99R' (Gorbet and Shokes, 2002) resulted in both'Georgia-06G' (Branch, 2007a) and 'Georgia Greener' (Branch, 2007b). Likewise, Georgia- 22MPR was selected from a cross between Georgia Greener and the advanced Georgia breeding line, GA 082524. Thus, the high BLUP breeding value and general combining ability (GCA) of the female parent Georgia Green (Isleib and Pattee, 2007) can also be found in the pedigree of Georgia-22MPR.

Broad-sense heritability (H) based on selection across 3-years and 5-rep locations for roasted peanutty flavor = 0.0%, sweet taste flavor = 22.5%, and combined good flavor = 23.1% in this study. The H = 0 for roasted peanutty flavor were found to result from much larger expect mean squares in variance component X entry interaction analyses for year than entry. Entry H was based on 5-replications also determined by individual years for roasted peanutty flavor equaled 53.2% in 2020; 80.6% in 2021; and 84.6% in 2022. Likewise, H estimates found for sweet taste = 63.5% in 2020; 72.6% in 2021; and 87.8% for 2022, whereas, H estimates found for CG = 15.5% in 2020; 71.5% in 2021; and 92.2% in 2022. In conclusion, these results clearly illustrate the importance of good consistent flavor over environments similar to that found with several runner and virginia-type peanut cultivars.

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