Heritability Estimates for Drought Resistance Related Traits in Cultivated Peanut (*Arachis hypogaea* L.)

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ABSTRACT

Drought is a major factor in reduced productivity in peanut. Cultivars that have high water-use efficiency have the potential to enhance crop yield. Studies have shown that pod yield is a function of water transpired (T), water-use efficiency (WUE), and harvest index (HI). It is logistically difficult to measure WUE (the ratio of biomass by water transpired) in a field environment, making selection of high WUE genotypes challenging in a breeding program. However, WUE is often correlated with specific leaf area (SLA) and leaf carbon isotopic composition ($\delta^{13}C$) in peanut. A good knowledge of the inheritance of SLA, $\delta^{13}C$, and HI may facilitate selection for drought resistant cultivars in peanut breeding programs. The objectives of this study were to estimate the heritability of SLA, $\delta^{13}C$, and HI traits in peanut and investigate the relationships among these traits. Fifteen genotypes were selected to measure the heritability of these traits using the variance component method based on an entry-mean basis. The genotypes were planted in a randomized complete block design with three replications in 2007 and 2008 at Headland, Alabama and Dawson, Georgia with and without irrigation. The leaf samples were taken at the 85th day after planting for measurements of SLA and $\delta^{13}C$. The HI was calculated on mature plants at 135 days after planting. Analysis of variance (ANOVA) was conducted to evaluate the effects among genotypes, locations, and year. Highly significant differences were found for year, location, genotype, and genotype x location for SLA, $\delta^{13}C$, HI, and pod yield traits (p= 0.01). The results from variance component analysis demonstrated that the overall heritability for SLA, $\delta^{13}C$, HI, and pod yield was 0.80, 0.91, 0.83, and 0.05, respectively. The $\delta^{13}C$ was negatively correlated with SLA, HI, and pod yield. Association of HI was strong with pod yield. However, under drought condition $\delta^{13}C$ had the highest correlation coefficient with pod yield. This implies that the selection for HI would result in a greater response to drought resistance and pod yield than the selection for SLA in breeding programs. The $\delta^{13}C$ can be used to discriminate the degree of drought resistance in peanut under stress condition.

INTRODUCTION

Knowledge of the inheritance of harvest index (HI) , specific leaf area (SLA), and $\delta^{13}C$ and the genetic correlations between pod yield and these traits will be an essential for planning an appropriate breeding strategy for improving peanut drought tolerance. Nigam et al. (2001) reported that the additive effects were predominant role over the dominance effects in the traits of HI and SLA based on the three peanut crosses. In addition to additive and dominance effects, epistasis was also found in the study. Songsri et al. (2008) estimated the heritability of specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR), and biomass, pod yield, harvest index (HI) for four crosses and the estimates for those traits were extreme high. The ranges for SLA, SCMR, HI and pod yield were 0.81 to 0.95, 0.89 to 0.97, 0.89 to 0.97, and 0.91 to 0.98, respectively, among the four crosses under drought stress and non-drought stress. These traits respond to drought stress and non-stressed conditions differently. However, besides the traits of SLA, SCMR, HI and pod yield, there is no report of heritability estimate on $\delta^{13}C$ in peanut. The objectives of this study were to estimate the heritability of SLA, $\delta^{13}C$, and HI traits in peanut, to investigate the relationships among these traits and how pod yield responding to SLA and $\delta^{13}C$ in peanut; and to examine the relationship between drought resistance traits under irrigated and dry-land scheme field conditions.

MATERIALS & METHODS

Fifteen genotypes were selected, including five released cultivars in the United States, 'AT-3081R', 'AT-3085RO', 'AP-3', 'Georgia Green', and 'Georgia-02C', and ten advanced breeding lines from the Peanut Breeding Program at the USDA-ARS National Peanut Research Laboratory in Dawson, Georgia. Cultivar 'Georgia Green' has a moderate degree of drought tolerance and high yield, but is susceptible to tomato spotted wilt virus (TSWV). Cultivar 'AP-3' is susceptive to drought stress. These genotypes have relatively similar maturity that is a very important character for drought tolerance because maturity involves the avoidance strategy to drought stress such as winter annuals mingle a relatively short life cycle with a high growth rate during the wet season to avoid drought altogether. The fifteen genotypes were planted in Dawson, GA (31 45' latitude, -84 30' longitude) and Headland, AL (31 22' latitude, -85 18' longitude) in 2007 and 2008 under irrigated and non-irrigated conditions, during the normal growing season from May to October (Fig. 1). The genotypes were grown in two-row plots 6.1m long and 91 cm apart at a rate of one seed per 5 cm. A randomized complete block design with three replications was applied for the tests in both years and locations. Before planting, both irrigated and non-irrigated test sites were irrigated with15 mm of water and cultivated to improve uniformity of germination. Crop management for all entries followed a standard procedure, in which fertilizers, herbicides, fungicides, and pesticides were applied accordingly during the growth season. The leaf samples were taken at the 85th day after planting for measurements of SLA, and $\delta^{13}C$. The HI was calculated on mature plants at 135 days after planting. Four undamaged leaflets on the second node from the tip of main stem were collected from four individual plants in each plot. Sampling took place between 08:00 and 10:00 and the leaflet samples were brought to the laboratory in zipped polythene bags. Before measuring SLA, leaf samples were soaked in water for two hours at room temperature (23^0C). Leaf area of each sample was measured with a LI-3000A Area Meter (LI-COR Inc., Lincoln, NE). Leaves were dried in an oven at 65 C for 72 hrs to determine dry weight. The SLA was calculated as leaf area (cm^2) over leaf dry weight (g). The leaves were ground for $\delta^{13}C$ analysis. Analysis of $\delta^{13}C$ was conducted in the Colorado Plateau Stable Isotope Laboratory at Northern Arizona University, Flagstaff, AZ. The method for $\delta^{13}C$ analysis followed the procedure and guideline described by Coplen, T.B. (1996) and Werner, R.A. and Brand, W.A. (2001). The HI was calculated on mature plants as a ratio of pod yield over above ground biomass. After digging , five plants of each plot were selected and washed. The pods and biomass were packaged in paper bags and oven dried at 65 C for at least 72 hrs.

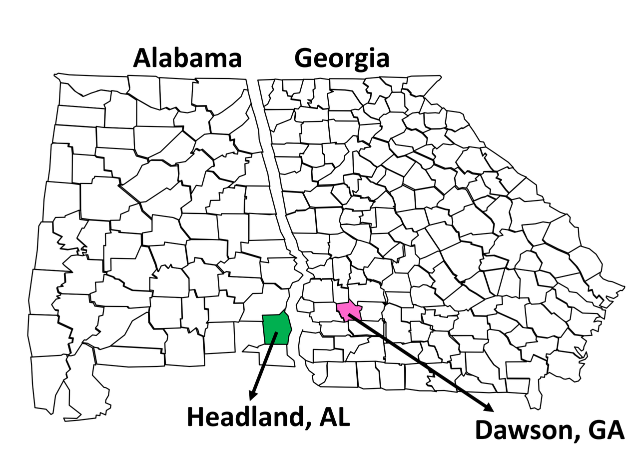

Fig.1 Locations where the test was conducted.

An analysis of variance (ANOVA) was conducted for the data collected in 2007 and 2008 using the PROC GLM procedure of SAS (SAS Institute, 2006). Genotypes were considered a fixed factor, while years, environments, and replications were considered random factors. Variance components were estimated by restricted maximum likelihood, the default method. Duncan test at 5% significance level was used to compare the differences among means for each factor. Because genotype by environment interaction was significant, irrigated and non-irrigated were analyzed separately according to a randomized complete block design for pod yield, HI, SLA, and $\delta^{13}C$. Broad-sense heritability (h^2) based on within-plot variance method was estimated as: $h^2 = \sigma_g^2 / [(\sigma_e^2/rly)+(\sigma_{gly}^2/ly)+(\sigma_{gl}^2/l)+(\sigma_{gy}^2/y)+ \sigma_g^2]$, where σ_g^2 is genotype variance, σ_e^2 is error variance, σ_{gly}^2 is genotype variance x location x year, σ_{gy}^2 is genotype variance x year, σ_{gl}^2 is genotype variance x location, *r* is number of replications, y is number of years, and *l* is number of environments. Simple correlations were calculated to determine the relationship between pod yield, HI, SLA, and $\delta^{13}C$ traits under irrigated and non-irrigated conditions to examine the relationship between drought resistance traits under irrigated and non-irrigated conditions.

Table 1. Estimates of heritability for pod yield, harvest index (HI), specific leaf area (SLA), and δ ^{13}C of 15 genotypes under irrigated and non-irrigated land in 2007 and 2008.

	SLA	HI	Yield	δ ^{13}C
Overall	0.80	0.83	0.05	0.91
Irrigated	0.78	0.78	0.35	0.93
Non-irrigated	0.54	0.75	0.23	0.88

Table 2. Means, range and correlation coefficients of pod yield, harvest index (HI), specific leaf area (SLA), and δ ^{13}C of 15 genotypes under irrigated land and non-irrigated land conditions in 2007 and 2008.

Environments	Parameters	Mean	Std Dev	Minimum	Maximum	HI	Yield	δ ^{13}C
Overall	SLA	181.45	18.43	142.87	255.16	0.07	0.11**	- 0.37**
	HI	0.53	0.07	0.31	0.68		0.56**	- 0.38**
	Yield	6202	1809	1237	10167			- 0.33**
	δ ^{13}C	- 26.47	0.61	- 27.97	- 24.62			
Irrigated	SLA	183.23	20.34	142.87	255.16	- 0.14**	-0.28**	- 0.38**
	HI	0.56	0.06	0.3626	0.68		0.41**	- 0.24**
	Yield	7111	1107	4102	10167			- 0.21**
	δ ^{13}C	- 26.50	0.61	- 27.97	- 25.02			
Non-irrigated	SLA	179.67	16.17	144.69	246.50	0.24**	0.33**	- 0.37**
	HI	0.50	0.063	0.31	0.64		0.47**	- 0.55**
	Yield	5291	1918	1237	10083			- 0.47**
	δ ^{13}C	- 26.44	0.61	- 27.72	- 24.62			

Table 3. Duncan tests for mean values of four drought tolerant related traits of each genotype tested under irrigated land and non-irrigated land conditions in 2007 and 2008.

Genotype	SLA (cm^2/g)		HI		Yield (kg/ha)		δ ^{13}C	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Exp11-9,10	199.7 a *	189.7 a	0.62 a	0.55 a	6676 cd	5514 abc	-26.71 cde	-26.57 de
Exp13-9,10	173.7 de	178.6 cde	0.58 bcd	0.52 abc	7485 a	5517 abc	-26.60 cde	-26.84 ef
Exp14-5,6	195.1 ab	189.8 a	0.59 ab	0.52 abc	6807 bcd	5111 abc	-26.82 de	-26.73 ef
Exp14-9,10	201.8 a	184.9 bc	0.57 bcd	0.50 cd	7126 abc	5781 ab	-26.56 cd	-26.50 de
AT-3081R	190.3 abc	172.8 de	0.51827 f	0.43 e	7471 a	4918 bc	-26.46 bc	-26.07 bc
AT-3085RO	173.9 de	172.8 de	0.55 def	0.47 d	7419 ab	5400 abc	-25.93 a	-25.94 ab
Exp5-17,18	180.5 cd	174.1 cde	0.60 ab	0.52 abc	7013 abc	6102 a	-26.84 de	-26.94 f
Exp6-13,14	165.7 e	172.0 e	0.58 bc	0.55 a	6285 d	5071 bc	-26. 16 ab	-26.52 de
Exp8-1,2	175.9 de	177.6 cde	0.52 f	0.48 d	7315 ab	5789 ab	-26.40 bc	-26.13 bc
AP3	190.4 abc	187.6 ab	0.57 bcd	0.50 cd	7285 abc	4568 c	-26.92 e	-26.96 f
Exp27-1516	175.9 de	180.3 bc	0.53 ef	0.47 d	7134 abc	5254 abc	-26.19 ab	-26.12 bc
Exp31-1314	184.0 bcd	179.9 cd	0.58 bc	0.55 ab	7332 ab	5447 abc	-26.58 cde	-26.53 de
Exp31-1516	183.1 bcd	174.5 cde	0.59 b	0.52 bc	7252 abc	4981 bc	-26.58 cde	-26.35 cd
GA Green	184.9 bcd	186.8 ab	0.55 cde	0.50 cd	6907 abc	5092 abc	-26.70 cde	-26.76 ef
Georgia02C	173.6 de	173.6 cde	0.52 ef	0.43 e	7154 abc	4836 bc	-26.03 a	-25.69 a
Mean	183.2	179.7	0.56	0.5	7111	5291	-26.50	-26.44

* Means with the same letter are not significantly different.

RESULTS

Highly significant differences were found for year, location, genotype, and genotype x location for SLA, $\delta^{13}C$, HI, and pod yield traits (p= 0.01). The results from variance component analysis demonstrated that the overall heritability for SLA, $\delta^{13}C$, HI, and pod yield was 0.80, 0.91, 0.83, and 0.05, respectively (Table 1). The heritability of $\delta^{13}C$ and HI was consistently different across environments, while SLA and pod yield showed big differences in irrigated and non-irrigated conditions with 0.78 vs 0.54, and 0.35 vs 0.23, respectively. The $\delta^{13}C$ was negatively correlated with SLA, HI, and pod yield. Harvest index had a stronger association with pod yield than SLA and $\delta^{13}C$ (Table 2). For all tested genotypes, pod yield and harvest index traits were consistently high under irrigation and low when not irrigated (Table 3). This implies that the selection for HI would result in a greater response to drought resistance and pod yield than the selection for SLA in breeding programs. However, without irrigation, $\delta^{13}C$ had the highest correlation coefficient (-0.55) with pod yield, indicating that $\delta^{13}C$ can be used to determine the degree of drought resistance in peanut under drought stress.

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