Transpiration Response to Vapor Pressure Deficit in Field Grown Peanut

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ABSTRACT

Water deficit, i.e., rainfall amounts and distribution, is the most common abiotic stress that limits peanut production worldwide. Even though extensive research efforts have been made to improve drought tolerance in peanut, performance of genotypes largely depends upon the environment in which they grow. Based on greenhouse experiments, it has been hypothesized that stomata closure under high vapor pressure deficit (VPD) is a mechanism of soil water conservation and it has been shown that genotypic variation for the response of transpiration rate to VPD in peanut exists. The objective of this study was to determine the relationship between stomatal conductance (g_s) and VPD for field grown peanut in Virginia-Carolina (VC) rainfed environments. In 2009, thirty virginia-type peanut cultivars and advanced breeding lines were evaluated for g_s at several times before and after rain events, including a moisture stress episode. In 2010, eighteen genotypes were evaluated for g_s under soil water deficit. In 2009, VPD ranged from 1.3 to 4.2 kPa and in 2010 from 1.78 to 3.57 kPa. Under water deficit, genotype and year showed a significant effect on g_s ($P = 0.0001$), but the genotype $\times$ year interaction did not. During the water deficit episodes while recorded g_s values were relatively high, g_s was negatively related to VPD ($R^2 = 0.57$, $n = 180$ in 2009; $R^2 = 0.47$, $n = 108$ in 2010), suggesting that stomata closure is indeed a water conservation mechanism for field grown peanut. However, a wide range of slopes among genotype were observed in both years. Genotypes with significant negative relationships of g_s and VPD under water deficit in both years were Florida Fancy, Gregory, N04074FCT, NC-V11, and VA-98R. While Florida Fancy, Gregory, and NC-V11 are known to be high yielding cultivars, VA-98R and line N04074FCT are not. The benefit of stomatal closure during drought episodes in the VC environments is further discussed in this paper.

Key Words: Peanut, stomatal conductance, transpiration, vapor pressure deficit.

In the Virginia-Carolina (VC) area, peanut is an important cash crop. According to the United Nations Conference on Desertification (UNEP, 1992), this region is characterized as a moist subhumid to humid region. This classification is based on the climatic aridity index: P/ETP, where P is annual precipitation and ETP is annual potential evapotranspiration calculated by the method of Penman (Doorenbos and Pruitt, 1977). Under historically moist conditions, over 90% of the current peanut farming is rainfed in the VC area. However, increased frequency and intensity of dry spells were recently observed due to uneven precipitation distribution during the summer months with negative effects on peanut yield and quality in the VC region. To increase peanut production under rainfed cropping systems in dry years, peanut cultivars with more effective use of water need to be developed for this region.

In peanut (Devi *et al*., 2010) and soybean [*Glycine max* (L.) Merr.] (Fletcher *et al*., 2007; Sinclair *et al*., 2008; Sadok and Sinclair, 2009) it has been shown that transpiration rate linearly increased with increasing VPD at low VPD values, but it was stable at VPD over 2.5 kPa. Devi *et al*., (2010) suggested that stomata closure at midday in response to high midday VPD will limit water loss by peanut crops. Evidence by Wright *et al.* (1994) that peanut can maintain high photosynthetic activity while minimizing water loss, determined Devi *et al.* (2010) to propose midday stomata closure in response to increase VPD as a mechanism of more effective use of water. These authors' study was performed in a greenhouse and under well watered conditions, and included peanut genotypes previously identified with different transpiration efficiency.

Virginia-type is the predominant peanut market type grown in the VC region. To our knowledge, there is no information on the response of stomatal conductance (g_s) to midday VPD of the virginia-type genotypes currently grown in the VC region. Given the erratic nature of rainfall patterns, efforts are needed to enhance the effective water use of the virginia-type peanut in this region. Change of transpiration with increasing VPD it would seem to be an effective mechanism of soil moisture conservation and better water use during dry spells and later in the season during seed filling. This study was conducted to determine the relationship of g_s to midday VPD in virginia-type cultivars and advanced breeding lines under field conditions.

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Table 1. Stomatal conductance of Virginia-type peanut genotypes including commercial cultivars and advanced breeding lines in 2009 and 2010.

	Stomatal conductance			
	2009			2010
	Pre-stress	Stress	Post-stress	Stress
Genotype	*mol m^{-2} s^{-1}*			
Bailey	0.70 c[a]	0.52 a–c	0.86 a–d	0.52 a–c
CHAMPS	0.93 a–c	0.39 bc	0.91 a–d	0.57 a–c
Florida Fancy	0.92 a–c	0.44 a–c	1.10 a	0.71 a–c
Georgia 08V	0.86 bc	0.71 ab	0.84 a–d	0.58 a–c
Gregory	0.80 bc	0.51 a–c	0.93 a–d	0.80 ab
HST 02-08	1.03 a–c	0.51 a–c	1.03 ab	–
N03023EF	0.81 bc	0.50 a–c	0.73 b–d	–
N03088T	0.80 bc	0.43 a–c	0.91 a–d	–
N04074FCT	0.84 bc	0.34 c	0.62 d	0.30 c
N05006	0.90 a–c	0.31 c	0.72 b–d	0.77 ab
N05007	0.79 bc	0.46 a–c	0.82 a–d	–
N05008	0.75 bc	0.30 c	0.64 cd	0.64 a–c
N05018	1.25 a	0.43 a–c	1.01 ab	–
N05024J	1.08 ab	0.50 a–c	0.85 a–d	0.64 a–c
N05049J	0.77 bc	0.40 a–c	0.92 a–d	–
NC-V 11	0.81 bc	0.35 c	0.74 b–d	0.50 a–c
Perry	0.83 bc	0.52 a–c	0.87 a–d	0.66 a–c
Phillips	0.90 a–c	0.71 a	1.09 a	0.89 a
Sugg	1.03 a–c	0.48 a–c	0.84 a–d	0.47 a–c
VA 98R	1.00 a–c	0.40 a–c	0.98 a–c	0.53 a–c
VT003069	0.92 a–c	0.43 a–c	1.04 ab	–
VT003191	0.88 a–c	0.33 c	0.80 a–d	–
VT003192	0.78 bc	0.41 a–c	0.96 a–d	–
VT003194	0.86 bc	0.57 a–c	0.90 a–d	–
VT003200	0.75 bc	0.52 a–c	0.89 a–d	0.62 a–c
VT004152	0.88 a–c	0.40 a–c	0.84 a–d	0.67 a–c
VT023117	1.00 a–c	0.54 a–c	0.81 a–d	–
VT024024	0.80 bc	0.40 bc	1.02 ab	0.45 c
VT024051	0.82 bc	0.37 c	0.90 a–d	0.64 a–c
VT024077	0.89 a–c	0.47 a–c	0.99 ab	–
Mean	**0.88**	**0.46**	**0.89**	**0.61**

[a]Values followed by the same letter within each column are not significant based on Tukey HSD (P = 0.05).

Materials and Methods

In 2009, thirty and in 2010, eighteen peanut cultivars and advanced breeding lines were evaluated at Tidewater Agricultural Research and Extension Center near Holland, VA (36° 68′ N, 76° 77′ W, 18.9 m elevation) for midday g_s and VPD (Table 1). These genotypes represent currently grown virginia-type cultivars and advanced breeding lines with desirable agronomic characteristics tested in the Peanut Variety and Quality Evaluation (PVQE) trials. Genotypes were grown in plots of two 9.1 m rows planted on 0.9 m centers. The soil at this site is classified as Eunola (fine-loamy, siliceous, thermic Aquic Hapludults). Genotypes were planted on 20 April in 2009 and 15 April in 2010. Cultural practices were performed according to Virginia recommendations for production of high yield and quality (Faircloth and Shokes, 2008). Detailed information on the cultural practices is described by Balota (2010, 2011). Plots were replicated two times in 2009 and three times in 2010 in a randomized complete block design with genotype as the only factor. Measurements of g_s were taken with a LI-6400 IRGA portable photosynthesis system (LI-COR Biosciences Inc., Lincoln, NE). Equations used to calculate g_s were derived from von Caemmerer and Farquhar (1981) and were based on measured flow rates and water concentrations in the sample and reference IRGAs, and a pre-set leaf area of 6 cm^2. Equations were provided by the OPEN software v 5 (LI-COR Biosciences Inc., Lincoln, NE). To keep the leaf chamber at ± 0.5 C from air temperature, the block temperature feature of the

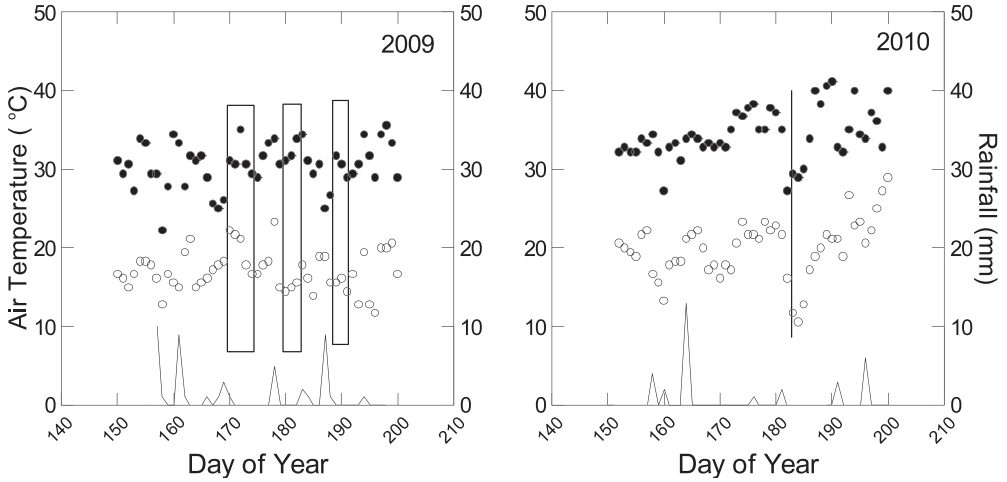

Fig. 1. Air temperature and rainfall distribution during gas exchange measurements in 2009 and 2010. Rectangles and line on the graphs mark the measuring periods each year.

equipment was used. Relative humidity (RH) inside the chamber was keep at less than 2% variation by using a high flow rate of 500 μmol s^{-1}. During measurements, PPFD was maintained constant 2000 μmol m^{-2} s^{-1} with a 6400-02B light source (LI-COR Biosciences Inc., Lincoln, NE). A 6400-01 CO_2 mixer (LI-COR Biosciences Inc., Lincoln, NE) was used to inject and maintain a constant concentration of 400 μmol CO_2 mol^{-1} air during measurements. Only fully sunlit leaves were used for the measurements. Leaves were allowed to equilibrate for 60 s before each reading of g_s. The middle leaflets of the uppermost fully developed leaf on the main stem were used.

Air VPD was calculated from the saturation vapor pressure from Buck (1981) and mean RH. Air temperature, RH, and precipitation were continuously monitored next to the plots with a Watchdog weather station (Model 2475; Spectrum Technologies, Inc., Plainfield, IL) at 2 m from the ground.

In 2009, measurements were taken on 19, 20, 22, 24, 29 and 30 June, and 1, 7, 8, and 9 July (Fig. 1). On 19, 20, 22, and 24 June plants were at approximately 50% anthesis (R1) (Boote, 1982). No significant rain event was recorded for 10 d prior R1 and this time was considered a pre-stress environment. After approximately 20 d without significant rain, 29 and 30 June, and 1 July, plants were at beginning peg (R2) stage. This time was considered a stress environment as plants in all plots were showing slight leaf rolling later in the afternoon. On 5 July, 25.4 mm irrigation was applied prior to a 10 mm rainfall. Plants were at beginning pod (R3) stage. Time from 7 to 9 July was considered a post-stress environment. This strategy, i.e., sampling on consecutive days, was done in order to obtain a range of temperatures and RH to better characterize the g_s response to VPD. Data from consecutive days within each stress level/growth stage were combined for further analyses. Their combination was possible because the genotype × day of measurement interaction was not statistically significant based on the repeated measure analysis. On individual days, all genotypes were measured between 1100 and 1300 h, one leaf per plot. In 2010, measurements were taken on 1 July at R2 stage after approximately 20 d without significant rainfall and irrigation, and when plants in all plots were showing slight leaf rolling later in the afternoon (Fig. 1). The first replication was sampled from 1100 to 1200, the second from 1200 to 1300, and the third from 1300 to 1400. For each replication, one plant from all plots was measured followed by a second plant in the reverse plot order. This sampling strategy was also satisfactory for creating a range of temperatures and RH while minimizing the differences between plots due to the time of measurement.

In 2009, g_s was assessed for the interaction of genotype and sampling time (i.e., day of measurement and stress level/growth stage) using the repeated measure design by Cochran and Cox (1957) in SYSTAT. Genotype effect on g_s within each stress level/growth stage was further assessed with ANOVA from the GLM procedure of SYSTAT® 10.2 (2002, SYSTAT Software Inc, Richmond, CA). Means were separated by Tukey HSD test at $P = 0.05$. Simple linear regression equations were fitted to g_s and VPD to evaluate the effect of genotype on the transpiration response to VPD (Devi *et al.*, 2010).

Results

In 2009 during pre-stress environment, average temperature during measurements ranged from

Table 2. Results of linear regression of stomatal conductance *vs.* vapor pressure deficit of all genotypes combined at individual environments.

Stress level	n[a]	Slope ± SD	Confidence limit of X_0	Y-intercept	r	R^2
2009						
Pre-stress	240	−0.323 ± 0.07	−0.461 to −0.185	1.50	0.288	0.08
Stress	180	−0.327 ± 0.02	−0.369 to −0.285	1.33	0.760	0.57
Post-stress	180	0.076 ± 0.06	−0.196 to 0.045	1.02	0.093	0.01
2010						
Stress	108	−0.455 ± 0.05	−0.548 to −0.362	1.75	0.690	0.47

[a]n = number of data points used to draw the regression.

28.5 to 33.6 C and RH from 32 to 67%. During the stress environment, temperature ranged from 28.7 to 34.5 C and RH from 30.9 to 47.2 %. During the post-stress environment, temperature ranged from 25.2 to 29.9 C and RH from 41 to 58%. In 2010, the average RH was 39%, air temperature 27.8 C (±0.90 SD), and leaf temperature 27.4 C (±1.86 SD). In 2009, the average air temperature across all environments was 30.2 C (±2.4 SD) and leaf temperature was 32.5 C (±2.6 SD). Across all experiments in 2009, the range of VPD was from 1.29 to 4.22 kPa (±0.56 SD) and in 2010 from 1.78 to 3.57 kPa (±0.23 SD).

Genotype had a significant ($P \leq 0.002$) effect on g_s in all environments and in both years (Table 1). Phillips was among the highest and N04074FCT the lowest for g_s, consistently across environments. In 2009, the repeated measure analysis showed a significant effect of genotype ($P = 0.037$) and stress level ($P < 0.0001$) on g_s, but the genotype × stress level interaction was not significant ($P = 0.290$). When common genotypes for 2009 and 2010 were compared, genotype and year showed a significant effect on g_s ($P = 0.0001$), but the genotype × year interaction did not.

The relationship between g_s and VPD when all genotypes were combined across individual environments is presented in Table 2. Negative correlations were recorded at pre- and stress environments in both years. Under these environments, average slopes of g_s and VPD ranged from −0.46 ± 0.05 to −0.11 ± 0.06 mol H_2O m^{-2} s^{-1} (Table 2). Under water stress in both years, average slopes were similar, −0.33 ± 0.02 in 2009 and −0.46 ± 0.05 mol H_2O m^{-2} s^{-1} in 2010. The relationship between g_s and VPD was strongest at stress compared with pre- and post-stress, and under stress R^2 was 0.57 (n = 180) in 2009 and 0.47 (n = 108) in 2010. When genotypes were combined, no relationship was found between post-stress g_s and VPD.

There were significant differences among genotypes for the response of g_s to VPD in all environments (Table 3 & Fig. 2–4). For example under pre-stress environment, when VPD ranged from approximately 1.4 to 2.5 kPa, 11 genotypes including Bailey (Isleib *et al.*, 2011), CHAMPS (Mozingo *et al.*, 2006), Gregory (Isleib *et al.*, 1999), HST02-08, N03032EF, N05007, N05024J, VT003192, VT003069, VT024051, and VT024077 showed no relationship between g_s and VPD. For these genotypes, the slopes of the regression ranged from −0.22 to 0.03 mol H_2O m^{-2} s^{-1} (Table 3). Thirteen genotypes showed a moderate g_s decrease with increasing VPD, and those slopes ranged from approximately −0.65 to −0.28 mol H_2O m^{-2} s^{-1}. Florida Fancy, Georgia 08V, Perry, and Phillips were among them (Table 3). For some, the regressions were significant at P = 0.1 or less, but for others the regressions were not statistically significant (Table 3). Five genotypes showed a sharp decrease of g_s with increasing VPD at pre-stress. Slopes of g_s *vs.* VPD for these genotypes ranged from −1.05 to −0.47 mol H_2O m^{-2} s^{-1}, and for all the regressions were statistically significant ($P \leq 0.1$). They were N03088T, NC-V11, Sugg, VT003200, and VT024024. Finally, genotype N05049J showed an increase of g_s with increasing VPD (Table 3). Examples of genotypic response of g_s to VPD at pre-stress are presented in Fig. 2. In 2009 under stress, VPD ranged from 2.1 to 3.6 kPa. Stomatal conductance significantly declined with increasing VPD in 25 genotypes ($P \leq 0.1$) with slopes ranging from −0.5 to −0.20 mol H_2O m^{-2} s^{-1}. Examples are presented in Fig. 3. In 2010, 6 genotypes showed a significant reduction of g_s with increasing VPD; for all others the relationship was weak. These genotypes were CHAMPS ($P = 0.029$), Florida Fancy ($P = 0.011$), Gregory ($P = 0.014$), N04074FCT ($P = 0.020$), NC-V11 ($P = 0.052$), and VA 98R ($P = 0.039$). Under post-stress environment, when VPD ranged from 1.4 to 2.5 kPa, positive relationships between g_s and VPD were recorded for Bailey, Georgia 08V, Phillips, VT003069, VT003192, VT003194, VT024024, VT004152, and VT024051. For these genotypes slopes of g_s *vs.* VPD ranged from 0.18 to 0.57 mol

Table 3. Results for the linear regression of transpiration rate *vs.* vapor pressure deficit. The genotypes are listed in the alphabetical order. The table includes slope with standard error, Y-intercept and probability values.

	2009									2010		
	Pre-stress[a]			Stress			Post-stress			Stress		
Genotype	Slope ± SE	Y-intercept	P	Slope ± SE	Y-intercept	P	Slope ± SE	Y-intercept	P	Slope ± SE	Y-intercept	P
Bailey	−0.14±0.4	0.97	*0.752*	−0.38±0.06	1.51	***0.002***	0.18±0.40	0.52	*0.670*	−0.39±0.39	1.58	*0.368*
CHAMPS	−0.18±0.4	1.27	*0.663*	−0.19±0.14	0.90	*0.264*	−0.27±0.29	1.42	*0.402*	−0.50±0.15	1.89	***0.029***
Fl. Fancy	−0.54±0.3	1.98	***0.124***	−1.46±0.19	1.70	***0.068***	−0.36±0.41	1.77	*0.434*	−0.59±0.13	2.09	***0.011***
GA 08V	−0.41±03	1.67	*0.223*	−0.21±0.25	1.22	***0.045***	0.57±0.25	−0.25	***0.082***	−0.45±0.39	1.65	*0.310*
Gregory	−0.23±0.5	1.23	*0.632*	−0.50±0.09	1.83	***0.006***	0.03±0.24	0.87	*0.909*	−0.71±0.17	2.34	***0.014***
HST02-08	0.14±0.5	0.75	*0.802*	−0.22±0.23	1.08	*0.400*	0.04±0.09	0.94	*0.639*			
N03032EF	−0.11±0.3	1.03	*0.720*	−0.32±0.13	1.35	***0.064***	−0.17±0.44	1.05	*0.723*			
N03088T	−1.05±0.5	2.83	***0.070***	−0.40±0.10	1.48	***0.017***	0.01±0.26	0.90	*0.989*			
N04074FCT	−0.28±0.2	1.39	*0.158*	−0.27±.10	1.11	***0.063***	−0.58±0.27	1.64	***0.097***	−0.53±0.14	1.93	***0.020***
N05006	−0.59±0.3	2.04	***0.103***	−0.23±0.08	0.97	***0.047***	−0.34±0.29	1.35	*0.319*	−0.46±0.32	1.85	*0.229*
N05007	−0.08±0.4	0.95	*0.833*	−0.24±0.15	1.09	*0.189*	−0.32±0.24	1.42	*0.260*			
N05008	−0.37±0.6	1.44	*0.577*	−0.20±0.04	0.89	***0.006***	−0.07±0.33	0.77	*0.848*	0.17±.20	1.08	*0.445*
N05018	−0.31±0.5	1.84	*0.570*	−0.27±0.08	1.18	***0.025***	0.22±0.49	1.43	*0.673*			
N05024J	−0.22±0.7	1.51	*0.758*	0.33±0.11	1.36	***0.037***	−0.07±0.56	1.06	*0.902*	0.03±0.67	0.58	*0.968*
N05049J	0.28±0.2	0.24	***0.136***	−0.43±0.17	1.62	***0.062***	−0.57±0.16	1.92	***0.023***			
NC-V11	−1.01±0.2	2.77	***0.001***	−0.17±0.06	0.82	***0.053***	−0.06±0.23	0.85	*0.811*	−0.36±0.13	1.49	***0.052***
Perry	−0.51±0.3	1.83	*0.150*	−0.46±0.25	1.70	***0.140***	−0.35±0.23	1.75	*0.202*	0.35±0.29	1.53	*0.296*
Phillips	−0.65±0.4	2.15	*0.188*	−0.41±0.29	1.70	*0.229*	0.30±0.65	0.32	*0.680*	−0.19±0.3	1.31	*0.555*
Sugg	−0.52±0.2	2.04	***0.023***	−0.38±0.09	1.48	***0.013***	0.30±0.48	1.39	*0.573*	−0.34±0.27	1.40	*0.269*
VA-98R	−0.40±0.6	1.71	*0.524*	−0.35±0.06	1.36	***0.008***	−0.48±0.1	1.81	***0.007***	−0.67±0.22	2.24	***0.039***
VT003069	−0.05±0.2	1.00	*0.855*	−0.43±0.07	1.61	***0.004***	0.57±0.17	−0.03	***0.028***			
VT003191	−0.34±0.5	1.53	*0.482*	−0.04±0.12	0.45	*0.734*	−0.5±0.36	0.90	*0.894*			
VT003192	0.03±0.4	0.74	*0.952*	−0.24±0.10	1.04	***0.078***	0.22±0.55	0.55	*0.715*			
VT003194	−0.52±0.4	1.85	*0.223*	−0.20±0.2	1.08	*0.367*	0.34±0.15	0.24	***0.078***			
VT003200	−0.61±0.2	1.93	***0.045***	−0.36±0.15	1.46	***0.080***	−0.43±0.20	1.63	***0.098***	−0.22±1.03	0.10	*0.842*
VT004152	−0.29±0.4	1.44	*0.477*	−0.21±0.12	0.98	***0.141***	0.18±0.39	0.59	*0.645*	−0.54±0.32	2.00	*0.166*
VT023117	−0.52±0.5	1.98	*0.347*	−0.31±0.11	1.31	***0.055***	−0.29±0.17	1.30	*0.172*			
VT024024	−0.47±0.2	1.71	***0.061***	−0.34±0.06	1.34	***0.006***	0.49±0.09	0.13	***0.005***	−0.14±0.14	0.84	*0.372*
VT024051	−0.02±0.3	0.85	*0.957*	−0.25±0.13	1.08	***0.116***	0.44±0.16	0.07	***0.049***	−0.06±0.42	0.77	*0.900*
VT024077	−009±0.6	1.06	*0.880*	0.05±0.14	0.33	*0.714*	−0.26±0.19	1.48	*0.238*			

[a]Number of the data points used to draw individual linear regressions was eight at pre-stress and six for all other environments.

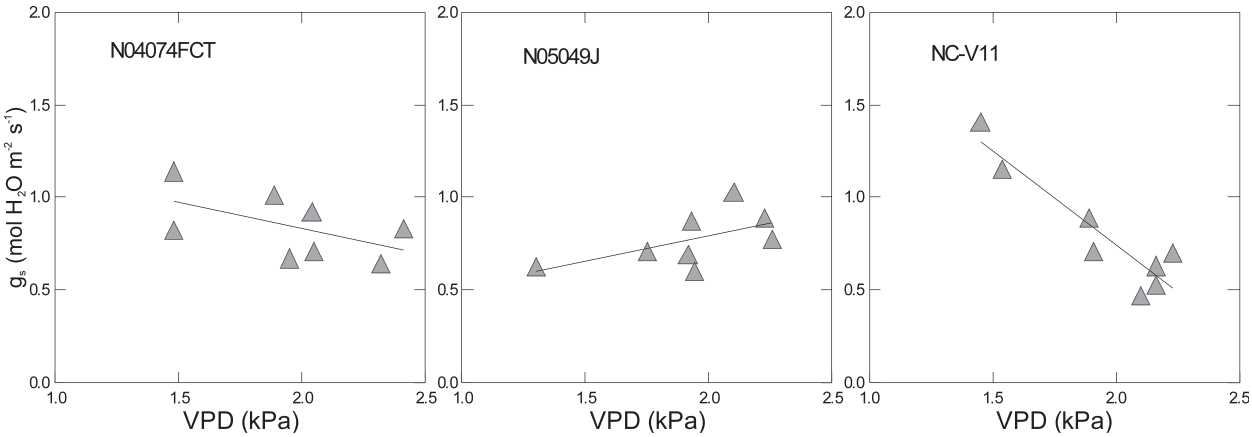

Fig. 2. Examples of response of stomatal conductance (g_s) to vapor pressure deficit (VPD) at midday and pre-stress in 2009. For equations of the regressions of g_s to VPD, slopes, Y-intercept, and P values are presented in Table 3.

H_2O m^{-2} s^{-1} (Table 3). For some, regression was significant at P = 0.1 or less, but for others regression was not statistically significant (Table 3). Examples of increase of g_s with increasing VPD after rain and irrigation events are presented in Fig. 4. N04074FCT, N05006, N05007, N05049J, Perry, VA 98R, VT003200, VT023117, and VT024077 continued to show a significant decline in g_s with increasing VPD post-stress and slopes ranged from -0.26 to -0.57 mol H_2O m^{-2} s^{-1} (Table 3); examples are presented in Fig. 4. For the remaining genotypes no relationship was observed between post-stress g_s and VPD.

Discussion

Data were collected under rainfed field conditions typical for Eastern Virginia in June and July. During these months plants can experience water stress due to scarce precipitation. Based on relatively high g_s values in Table 1, the peanut genotypes were not under severe water stress at any sampling time, even though at certain times they appeared to be stressed. Under severe water deficit, peanut can close stomata and reduce its conductance to nearly zero (Kottapalli *et al.,* 2009), but in our study, a genotype's average g_s was no less than 0.46 mol m^{-2} s^{-1}. Under mild rather than severe water stress, closing stomata in response to increased VPD would seem to be a useful mechanism of conserving water. In our experiment, genotypes, stress level/growth stage, and year showed significant effects on g_s, but their interaction did not. This denotes a strong genotypic effect on g_s. Genotypes N04074FCT and NC-V11 had consistently lower g_s values compared with the other genotypes at all sampling times in 2009 and 2010 (Table 1). Phillips, Gregory, Georgia 08V, and Florida Fancy had higher g_s values across sampling times and years, and almost 30% higher than N04074FCT and NC-V11. In part, this can be explained by a different number of stomata per leaf but other factors are involved as well (Balota, unpublished data). When all genotypes were combined under water stress, i.e., average g_s was 0.46 in 2009 and 0.61 mol m^{-2} s^{-1} in 2010, g_s was negatively related to VPD (R^2 = 0.57, n = 180 in 2009; R^2 = 0.47, n = 108 in 2010), but the relationship was not significant when average g_s exceeded 0.88 mol m^{-2} s^{-1} (Table 2). However, a wide range of slopes among genotypes were observed in all environments and years (Table 3). In this respect, our field data are in agreement with the green house observations by Devi *et al*., (2010) that genotypic differences for the response of transpiration to VPD in peanut exist. Genotypes with significant negative relationships of g_s and VPD under water stress in both years were Florida Fancy, Gregory, N04074FCT, NC-V11, and VA-98R. While Florida Fancy, Gregory, and NC-V11 are known to be high yielding cultivars, VA-98R and line N04074FCT are not (Wynne *et al*., 1991; Isleib *et al*., 1999; Balota, 2010).

Three groups of genotypes were distinct for the response of g_s to VPD in our tests. The first group showed decrease or no response at pre-stress, decrease at stress, and no response of g_s with increasing VPD at post-stress. Genotypes in this group are high yielding cultivars and breeding lines such as NC-V11, Florida Fancy, Sugg, Gregory, and N05018, but also documented low yielding lines in PVQE tests in VC region, N03023EF, and HST 02-08 (Wynne *et al*., 1991; Isleib *et al*., 1999; Balota, 2010). The second group showed slow decreases at pre-stress, decreases under stress, and significant increases of g_s with increasing VPD at post-stress. Genotypes included in this group were Georgia 08V, VT003069, VT024051, VT024024,

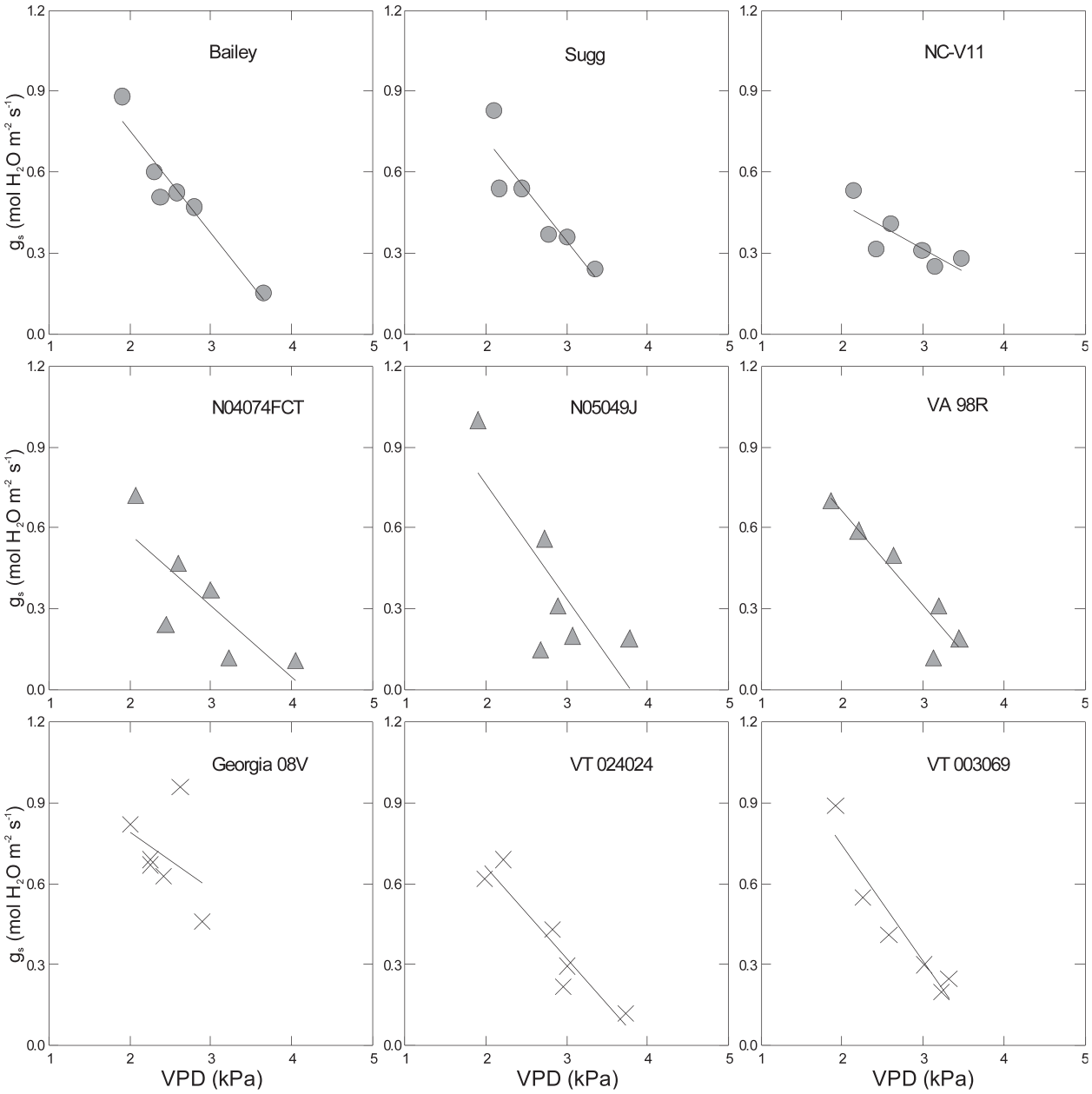

Fig. 3. Examples of response of stomatal conductance (g_s) to vapor pressure deficit (VPD) at midday and stress in 2009. Equations of the regressions of g_s to VPD, slopes, Y-intercept, and P values are presented in Table 3.

and VT003194. Bailey and Phillips also showed small increases of g_s with increasing VPD post-stress, but the relationships were not statistically significant. All these genotypes are high yielding cultivars presently grown for high production in the VC area (Branch, 2009; Isleib *at al.*, 2006, 2011; Mozingo *et al.*, 2006) and advanced breeding lines that were tested for potential release in PVQE tests in Virginia, North Carolina and South Carolina (Balota, 2010, 2011). An important characteristic for these genotypes was their ability to resume transpiration after rain and irrigation, and to fit into the well watered plant model of transpiration increasing linearly with increasing VPD (Sinclair and Bennett, 1998). This suggests that these genotypes recovered well from water stress. Crop production is proportional to its transpiration (de Wit, 1958); therefore, the ability to resume high rates of transpiration after drought episodes and when water becomes available seems to be an important drought tolerance characteristic for the Virginia-type peanut grown in the VC environments. Finally, the third group showed significant decreases of g_s with increasing VPD under all environments, with the exception of N05049J, which showed a positive response of g_s to VPD at pre-stress and negative at stress and post-stress. None the less all genotypes in this group continued

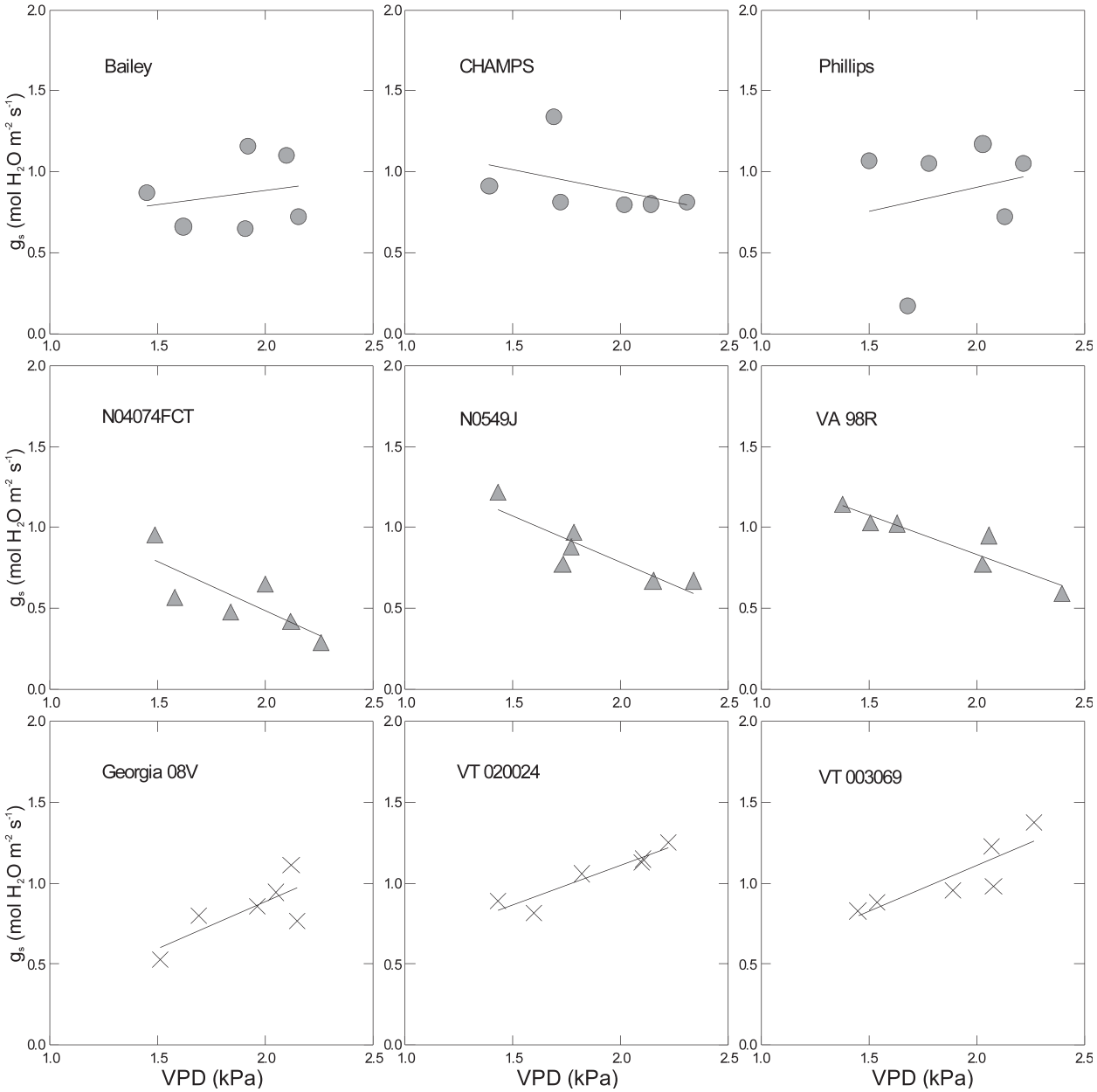

Fig. 4. Examples of response of stomatal conductance (g_s) to vapor pressure deficit (VPD) at midday and post-stress in 2009. For equations of the regressions of g_s to VPD, slopes, Y-intercept, and P values are presented in Table 3.

to show declines of g_s to VPD increases after rain and irrigation. Based on this experiment, we cannot conclude if the relationship between g_s and VPD was typical for moist conditions or somehow stress affected the post-stress relationship for these genotypes. Examples of genotypes in this group are N04074FCT, N05049J, Perry, and VA 98R. Indeed, based on PVQE tests these genotypes appear to have low yields, in particular under sub-optimal growing conditions. For example, N04074FCT was the lowest yielding genotype in PVQE tests at six locations in Virginia, North Carolina, and South Carolina, in 2009 and 2010 (Balota, 2011). In 2010, a record year for sustained drought throughout the VC peanut growing region, Perry and VA 98R had the lowest yields at all PVQE locations among commercial cultivars. Finally, N05049J was the second lowest for pod yield after N04074FCT in PVQE tests in 2008 and 2009 (Balota, 2010). Our data clearly show that genetic differences among tested genotypes existed for g_s and the relationship of g_s with VPD. Also, based on results from water stress in both years, it appears that not only high but also low yielding genotypes consistently expressed reduced g_s with increasing VPD, therefore questioning the importance of this drought tolerance mechanism under our environments. From only 2009 data, there is

indication that the relationship of g_s and VPD after rather than during water stress could be more important and better associated with yield in dry years for the VC region, but more research is needed to confirm this hypothesis and to elucidate how stomata closure in response to VPD can increase drought tolerance and yield in the VC region.

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