Variability in Field Response of Peanut Genotypes from the U.S. and China to Tomato Spotted Wilt Virus and Leaf Spots

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ABSTRACT

Tomato spotted wilt, caused by Tomato spotted wilt virus (TSWV) and transmitted by thrips, and early leaf spot and late leaf spot are among the most important diseases of peanut in the southeastern United States. The objective of this study was to compare field susceptibility of diverse peanut lines to TSWV and leaf spot pathogens for selection of lines for mapping population development. In field trials in 2007 and 2008, 22 genotypes were evaluated for reactions to TSWV and leaf spots. Early leaf spot was the predominate pathogen in both years. There was a near-continuous range of spotted wilt from 18% to 79% for the total incidence rating with any symptoms caused by TSWV. In general, NC94022, 'Georganic', C689-6-2, 'Georgia-01R', C724-19-25, TifGP-1, C11-154-61, C12-3-114-58, and 'Tifguard' were among the most resistant genotypes to TSWV, whereas GT-C20, GT-C9 and PE-2 were the most susceptible. Final percentage of defoliation by leaf spots ranged from 10% to 97% for both years. Genotypes C689-2, Georgia-01R, C12-3-114-58, C11-154-61, Tifguard and Georganic showed resistance to leaf spots, whereas 'NC-6', 'Spancross', GT-C9, GT-C20 and PE-2 were susceptible to leaf spots. There were 3 cultivars and 3 breeding lines classified as resistant to both TSWV and leaf spots; and there were 3 genotypes from China susceptible to both TSWV and leaf spots. These phenotypic disease reaction data can be used in conjunction with genetic characterization of these genotypes for development of recombinant inbred line populations in efforts to develop markers for resistance to TSWV and leaf spots.

Key Words: *Cercospora arachidicola*, *Cercosporidium personatum*, *Arachis hypogaea*, disease resistance.

Tomato spotted wilt, caused by Tomato spotted wilt virus (genus Tospovirus; family Bunyaviridae) (TSWV) and transmitted by thrips (Thysanoptera: Thripidae), is a serious problem to southeastern U.S. peanut production. Tomato spotted wilt occurs every year with fluctuations in severity within years and locations (Culbreath *et al.*, 2003). Losses to TSWV in peanut increased steadily from the late 1980s, with annual losses as high as $40 million in Georgia alone (Bertrand, 1998). TSWV is transmitted by several species of thrips (Ullman *et al.*, 1997), but the control of thrips has not shown much promise for management of spotted wilt in peanut. The management of spotted wilt is dependent upon the use of cultivars with moderate levels of field resistance (Culbreath *et al.*, 1996), and cultural practices which reduce the incidence and severity of spotted wilt (Brown e*t al*., 1996; Culbreath *et al.*, 1999). New cultivars such as AP-3 (Gorbet, 2007), Georgia-02C (Branch, 2003) , and Tifguard (Holbrook *et al.*, 2008a) have greater levels of field resistance than Georgia Green, the moderately resistant cultivar used as a standard for genotype comparisons (Culbreath *et al*. 2008), but still can be severely affected. Higher levels of field resistance have been reported in the cultivar Georganic (Culbreath *et al.*, 1997; Culbreath *et al.*, 1999; Holbrook and Culbreath, 2008) and breeding line F NC94022-1-2-1-1-b3-B (Culbreath *et al.*, 2005; Li *et al.*, 2009), henceforth referred to as NC 94022.

Two of the most prevalent and severe foliar diseases of peanut worldwide are early leaf spot, caused by the fungus *Cercospora arachidicola* S. Hori and late leaf spot, caused by the fungus *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton (Smith and Littrell, 1980). In the U. S., most of the peanuts are grown in the southern states where environmental conditions are often favorable for leaf spot epidemics. One or both of the leaf spot diseases occur in all peanut producing states, and multiple applications of fungicides are necessary for control of the diseases.

The development and use of resistant cultivars is one of the most desirable ways to manage both leaf spot diseases and TSWV (Culbreath *et al.*, 2003). Currently, peanut breeding programs focus on extensive field screening to look for sources of resistance and making selections of resistant lines

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once crosses have been made and breeding lines are available. Field selection for resistance to leaf spot pathogens and TSWV requires considerable space and a relatively large number of plants. Development of molecular markers for assisting in selection for resistance to TSWV and the leaf spot pathogens could increase the efficiency of breeding programs (Li *et al*., 2010; Guo *et al*., 2012). Marker assisted selection has been used in development of nematode resistant peanut cultivars COAN (Simpson and Starr, 2001) and NemaTAM (Simpson *et al*., 2003), but markers are not currently available for resistance to either of the leaf spot pathogens or TSWV. The objective of this study was to compare field susceptibility of diverse peanut genotypes, including cultivars, germplasm accessions, and advanced breeding lines to TSWV and leaf spot pathogens in order to relate to genotypic characterization of these lines in an effort to develop markers for resistance to TSWV and leaf spot pathogens (Li *et al.,* 2010) through genetic mapping (Qin *et al*., 2012).

Materials and Methods

Twenty-two genotypes were evaluated in this study, including commercial cultivars, advanced breeding lines, and germplasm accessions (Table 1). Two separate field trials were conducted at the University of Georgia, Coastal Plain Experiment Station Belflower Farm, Tifton, GA in 2007 and 2008. Soil type is Tifton loamy sand (Fine-loamy, siliceous, thermic Plinthic Kandiudult). Peanut was in an annual rotation sequence following corn (*Zea mays* L.). In each year, one experiment was planted in April to maximize potential for development of spotted wilt epidemics (Culbreath *et al*., 2003), and one was planted in May to reduce potential for spotted wilt epidemics and increase the likelihood of heavy leaf spot epidemics.

The field trials were conducted using randomized complete block designs with 4 replications. Experiment plots were 6.0 m long, separated by 2.4-m alleys. Peanut seed was planted to 91-cm-spaced twin-row plots. Planting dates were 23 April and 23 May in 2007, and 18 April and 20 May in 2008. Seeding rate was 3.3 seed/m of row. Sparse seeding rate was used to maximize pressure of Tomato spotted wilt (Culbreath *et al*., 2003) and to allow Tomato spotted wilt severity evaluation on individual plants. Only April planted trials were used for the spotted wilt evaluations, and both April and May planting trials were used for leaf spot evaluations. Fungicide applications of chlorothalonil (Bravo WeatherStik, Syngenta Crop Protection, Greensboro, N.C.) (1.26 kg a.i./ha) were made at ca. 30 days after planting with subsequent applications every 14 days until ca. 80 days after planting.

Tomato spotted wilt severity was evaluated for each plant on 25 July, 2007 and 21 July, 2008. Severity of Tomato spotted wilt was assessed using a 0 to 5 severity scale adapted from Baldessari (2008) based on visual determination of presence of symptoms and estimation of the degree of stunting (reduction in plant height, width, or both) for symptomatic plants (Table 2). Genotype comparisons were made for total incidence of Tomato spotted wilt (severity ratings of 1 or greater), as well as incidence of plants with severity ratings in classifications (2 or greater, 3 or greater, 4 or greater and 5).

Leaf spot severity was evaluated on 25 September 2007, and 26 September 2008 for each plot using the Florida 1 to 10 scale (Chiteka *et al*., 1988) where 1 = no leaf spot; 2=very few lesions on the leaves and none on upper canopy; 3 = very few lesions on upper canopy; 4 = some lesions with more on upper canopy, and 5% defoliation; 5 = noticeable lesions on upper canopy with 20% defoliation; 6 = numerous lesions on upper canopy with 50% significant defoliation; 7 = numerous lesions on upper canopy with 75% defoliation; 8 = Upper canopy covered with lesions with 90% defoliation; 9 = very few leaves covered with lesions remain and some plants completely defoliated; 10 = plants dead (Chiteka *et al*., 1988). Final percent defoliation (% defoliation) was estimated from the Florida scale rating taken just before peanut plants were inverted (Chiteka *et al*., 1988).

Final leaf spot ratings were converted to estimates of % defoliation according to the function:

$$\%defoliation = 99.7714e^{-\frac{FSR-6.0672}{0.7975}}$$

This equation was obtained by non-linear regression of defoliation level on Florida scale rating (FSR) values as reported by Chiteka *et al.* (1988).

Data were analyzed using Proc Mixed with ddfm = satterth option that performs a general Satterthwaite approximation for the denominator degrees of freedom and produces an accurate *F*-approximation (SAS v.8.3, SAS Institute, Cary, NC), unless otherwise stated. Incidence of Tomato spotted wilt and % defoliation by leaf spot estimated from Florida scale ratings were used as response variables. Genotype was considered a fixed variable, and replication and year were

Table 1. Twenty-two genotypes used for the field evaluations for reaction to Tomato spotted wilt and early leaf spot.

Entry	Genotype	Origin Source	Market type
1	Tifton 8	U.S. germplasm	Virginia
2	C724-19-25	U.S. breeding line	Runner
3	Georgia Green	U.S. cultivar	Runner
4	Georganic (C-11-2-39)	U.S. cultivar	Runner
5	Spancross	U.S. cultivar	Spanish
6	Tifguard	U.S. cultivar	Runner
7	NC-6	U.S. cultivar	Virginia
8	SunOleic 97R	U.S. cultivar	Runner
9	Tifrunner	U.S. cultivar	Runner
10	F NC94022-1-2-1-1-b3-B	U.S. breeding line	Runner
11	PE-2	Chinese breeding line	Virginia
12	PE-1	Chinese breeding line	Virginia
13	GT-C20	Chinese cultivar	Spanish
14	GT-C9	Chinese cultivar	Spanish
15	gen 04-14	U.S. breeding line	Runner
16	C 689-6-2	U.S. breeding line	Runner
17	TifGP-1	U.S. germplasm	Runner
18	Georgia-01R	U.S. cultivar	Runner
19	C-11-154-61	U.S. breeding line	Runner
20	C-12-3-114-58	U.S. breeding line	Runner
21	Georgia-02C	U.S. cultivar	Runner
22	AP-3	U.S. cultivar	Runner

treated as random effects. Main effects and interactions as well as specific treatment effects were considered significant if $P \leq 0.05$. Fisher's least significant difference (LSD) was computed using standard error and t values of adjusted degrees of freedom from ddfm = satterth option. If the interaction effect between year and genotype was not significantly different ($P > 0.05$), the data were pooled and presented averaged across years; if the interaction was significant ($P \leq 0.05$); the data were analyzed separately and are presented by year.

Genotypes were classified as susceptible, moderately susceptible, moderately resistant, and resistant, based on TSWV incidence and leaf spot intensity compared to that in Georgia Green. As an interesting note for 2007 and 2008 growing seasons, early leaf spot was the predominate disease in the field and we rated the total defoliation including both early and late leaf spots.

Results and Discussion

There was no significant interaction between year and genotype for the total incidence of Tomato spotted wilt (severity ≥ 1), but there were significant interactions for the incidence of severity categories, ≥ 2, ≥ 3, ≥ 4 and 5 (data not shown). Therefore, data were pooled across years for the analysis of incidence of severity ≥ 1, but incidence of plants in all other severity ratings categories are presented separately for each year.

For the incidence of severity ≥ 1, NC 94022 had the lowest numerical ranking for total incidence of spotted wilt, but did not differ from that of thirteen genotypes (Table 3). Only NC 94022 had total incidence of spotted wilt (severity rating ≥ 1) lower than that of Georgia Green (Table 3). For other categories of incidence of severity, NC 94022 had lower incidence of Tomato spotted wilt than

Table 2. The rating scale of severity of Tomato spotted wilt caused by TSWV.

Severity rating*	Disease severity	Plant size relative to typical healthy plants
0	No symptoms	
1	Plants with foliar symptoms, with no stunting or only slight stunting	80–100%
2	Noticeable stunting	60–79%
3	Marked stunting	40–59%
4	Very marked stunting	30–40%
5	Severe stunting	0–20%

*Adapted from Baldessari (2008).

Table 3. Reactions of different peanut genotypes to TSWV in five severity classes based on the data collected in Tifton, Georgia from 2007 and 2008.

	≥ 1[†]		≥ 2		≥ 3		≥ 4		5	
Genotypes	Pool[‡]	Rank[¶]	2007	2008	2007	2008	2007	2008	2007	2008
NC 94022	18.2[§L]	1	11.6[L]	3.5[L]	6.9[L]	2.3[L]	4.1[L]	0.0[L]	3.1[L]	0.0[L]
Georganic	18.6	2	15.4[L]	8.7[L]	11.9[L]	3.5[L]	9.6	1.6[L]	4.3	1.6[L]
C 689-6-2	20.3	3	15.1[L]	13.7[L]	11.6[L]	9.2	6.0[L]	3.0[L]	4.4	0.9[L]
Georgia-01R	21.6	4	18.6	10.6[L]	14.0	5.2[L]	7.5	1.1[L]	3.8	1.1[L]
C724-19-25	21.6	5	21.3	4.4[L]	18.7	3.6[L]	17.1	1.8[L]	9.3	1.0[L]
TifGP-1	23.1	6	15.3[L]	10.6[L]	13.1	5.4[L]	10.8	2.6[L]	6.9	1.9[L]
Tifguard	23.1	6	16.8[L]	10.1[L]	13.7	8.4	9.3	2.4[L]	7.5	1.6[L]
C 12-3-114-58	25.9	8	16.8[L]	16.4[L]	13.5	9.6	7.8	6.5	3.9	3.8
C 11-154-61	27.2	9	23.4	17.3[L]	16.1	9.8	7.2	4.2[L]	3.6	2.1[L]
Tifrunner	31.5	10	27.9	6.1[L]	15.1	2.6[L]	10.8	1.8[L]	4.4	0.0[L]
Georgia-02C	34.3	11	18.8	24.8	13.9	16.4	11.8	9.2	9.8	5.2
gen 04-14	34.7	12	19.2	20.3	13.5	14.1	8.6	10.6	2.7[L]	6.2
AP-3	34.8	13	33.7	13.9[L]	27.1	10.2	15.6	7.6	9.8	3.4
Georgia Green*	37.5	14	32.5	27.9	26.7	15.5	17.0	12.8	12.1	8.9
NC-6	46.2	15	42.7	24.5	35.4	16.4	19.8	12.1	12.5	8.5
PE-1	50.5	16	45.5	31.7	37.7	25.5[H]	32.2[H]	18.7	25.8[H]	16.9[H]
Tifton 8	54.1	17	33.4	34.4	26.6	25.8[H]	16.6	15.8	8.7	9.1
Spancross	54.2	18	43.8	32.8	30.6	20.7	19.3	14.4	14.4	10.1
SunOleic 97R	55.0	19	42.7	40.5[H]	34.3	25.8[H]	25.4	15.7	12.7	5.1
GT-C9	75.8[H]	20	79.7[H]	45.7[H]	67.7[H]	34.3[H]	58.2[H]	27.9[H]	37.8[H]	20.0[H]
PE-2	78.5[H]	21	73.3[H]	62.6[H]	66.5[H]	57.8[H]	51.3[H]	44.6[H]	37.1[H]	33.6[H]
GT-C20	78.7[H]	22	66.6[H]	53.4[H]	54.1[H]	40.3[H]	42.7[H]	28.3[H]	37.7[H]	16.1[H]
LSD ($P \leq 0.05$)	19.2		15.2	9.6	14.0	8.6	10.8	7.8	8.7	6.0

*Used as a standard for comparisons (Culbreath *et al.*, 2008).

[†]Severity classes ≥1, ≥ 2, ≥ 3, ≥ 4, and 5 represent the incidence (percentage of the total population) with: 1) no to light stunting; 2) noticeable stunting; 3) marked stunting; 4) very marked stunting; and 5) severe stunting.

[‡]This is two years average.

[§]An uppercase 'L' indicates genotype has significantly lower incidence of Tomato spotted wilt than standard comparison genotype, Georgia Green. An uppercase 'H' indicates genotype has significantly higher incidence of Tomato spotted wilt than standard comparison genotype, Georgia Green.

[¶]Numerical ranking of incidence of plants with Tomato spotted wilt severity scale ratings of 1 or higher. A difference in rank for two entries does not imply that a significant difference between the two means was detected.

Georgia Green in both years (Table 3). Several additional genotypes in addition to NC 94022 had incidence of Tomato spotted wilt that ranked lower than Georgia Green in all severity classes (Table 3). Among them, only U.S. breeding line C689-6-2 showed a lower incidence of Tomato spotted wilt than Georgia Green in all severity classes for at least one year (Table 3). Others including U.S. released cultivars Georganic, Georgia-01R, Tifguard, Tifrunner, AP-3 and breeding lines C724-19-25, TifGP-1, C 12-3-114-58, C11-154-61 showed significantly lower incidences of Tomato spotted wilt than Georgia Green in one or more severity classes in each year (Table 3).

GT-C20, which originated from China, had the highest rating in total incidence (Table 3). There were no significant differences among GT-C20, GT-C9 and PE-2, and they were all greater than Georgia Green in all severity classes in both years (Table 3). Incidence of Tomato spotted wilt in SunOleic 97R, Tifton 8, and PE-2 typically ranked higher than that of Georgia Green and was significantly higher in one or more severity classes in each year (Table 3).

Leaf spot epidemics were severe in both trials in both years and caused noticeable defoliation in all genotypes evaluated (Table 4). In 2008, leaf spot evaluations were not made in GT-C20 in the early planted trial because of severe stunting and mortality from Tomato spotted wilt by the time of leaf spot evaluation. A significant year by genotype interaction for percent defoliation for both early and late planted trials was observed; therefore, means of defoliation are presented by trial and year.

Defoliation for the cultivars Georganic, Georgia-01R and Tifguard, and breeding lines C12-3-114-58, C11-154-61 and C689-6-2 was significantly lower than for Georgia Green in both early and late planted trials for both 2007 and 2008; whereas, defoliation for the cultivars Tifrunner and

Table 4. Effect of peanut genotype on percent defoliation caused by leaf spots based on the data collected in Tifton, GA from 2007 and 2008.

Genotypes	April planting trial		May planting trial	
	% Defoliation		% Defoliation	
	9/25/2007	9/26/2008	9/25/2007	9/26/2008
Georganic	40 [†L]	19 [L]	29 [L]	10 [L]
NC 94022	67	41	67	79
Tifton 8	71	17 [L]	15 [L]	39 [L]
C724-19-25	71	17 [L]	19 [L]	51 [L]
Georgia Green[§]	77	54	60	87
Tifrunner	78	34 [L]	28 [L]	37 [L]
PE-2	80	95 [H]	75	66 [L]
Georgia-02C	81	39 [L]	16 [L]	72 [L]
TifGP-1	82	40 [L]	25 [L]	61 [L]
PE-1	83	60	49	74 [L]
AP-3	83	41	62	68 [L]
NC-6	85	62	75	86
gen 04-14	89	13 [L]	67	55 [L]
Tifguard	23 [L]	16 [L]	19 [L]	34 [L]
C12-3-114-58	32 [L]	13 [L]	12 [L]	18 [L]
C11-154-61	33 [L]	14 [L]	13 [L]	18 [L]
Georgia-01R	46 [L]	11 [L]	12 [L]	18 [L]
C689-6-2	54 [L]	2 [L]	6 [L]	20 [L]
GT-C20	93 [H]	‡*	98 [H]	97
Spancross	95 [H]	88 [H]	92 [H]	81
SunOleic 97R	95 [H]	20 [L]	85 [H]	81
GT-C9	95 [H]	92 [H]	90 [H]	94
LSD ($P \leq 0.05$)	15	14	21	13

[§]Used as a susceptible standard for comparisons (Culbreath *et al.*, 2008).
[†]Uppercase 'L' indicates the percent defoliation is significantly lower than susceptible standard comparison genotype, Georgia Green. Uppercase 'H' indicates the percent defoliation is significant higher than standard comparison genotype, Georgia Green.
[‡]Asterisk indicates no rating is reported because of the influence of spotted wilt.

Georgia-02C and breeding lines C724-19-25 and TifGP-1 was significantly lower than Georgia Green in late planted trials for both years and for the early planted trial in 2008 (Table 4). U.S. breeding line gen 04-14 had significantly less defoliation than Georgia Green for both trials in 2008, but not in 2007. Several additional genotypes including AP-3 and PE-1 had lower defoliation than Georgia Green for the late planted trial in 2008 (Table 4).

Defoliation for GT-C20 and SunOleic 97R was greater than for Georgia Green in both trials in 2007, and defoliation for Spancross and GT-C9 was greater than for Georgia Green for both trials in 2007 and the early planted trial in 2008. Except for GT-C20 and SunOleic 97R, there were no other genotypes that showed higher defoliation than Georgia Green for the late planted trial in 2008. In general, the late planted peanuts had lower levels of defoliation by leaf spot than early planted peanuts. However, the leaf spot evaluations for both tests were made on the same day. Therefore, the different levels of leaf spot in these two tests likely were due to longer epidemic duration in the early-planted trails than the late planted trials.

A summary of the disease responses of the genotypes in the current study, compared to previous reports of resistance to each pathogen, is listed in Table 5. The results from this study generally agreed with previous reports and comparisons of current results to previous reports indicated that the field resistances to TSWV in NC94022 (Culbreath *et al.*, 2005), Georganic (Culbreath *et al.*, 1999; Culbreath *et al.*, 2005), Tifguard (Holbrook *et al.*, 2008b), C724-19-25 (Holbrook *et al.*, 2008c), Tifrunner (Holbrook and Culbreath, 2007), and Georgia-01R (Culbreath *et al.*, 2008) were better than that in Georgia Green (Table 5). SunOleic 97R was reported as susceptible to TSWV (Culbreath *et al.*, 1999; Culbreath *et al.*, 2005). In the current study there were genotypes from China that showed higher severity of Tomato spotted wilt disease compared to that of SunOleic 97R as susceptible to TSWV. Three other U.S. cultivars, NC-6, Spancross, and Tifton8, and one Chinese breeding line PE-1 showed similar

Table 5. The field response of twenty-two peanut genotypes to Tomato spotted wilt virus and leaf spots, and the comparison to previous reports.

Genotype	Field response to TSWV*	Previous reports to TSWV	Previous report citation	Field response to leaf spot	Previous reports leaf spot	Previous report citation
Georgia-01R	R	MR/R	Branch, 2002; Cantonwine et al., 2006	R	R	Branch, 2002 Cantonwine et al., 2006
Tifguard	R	R	Holbrook et al., 2008a	R	N/A	
C-11-154-61	R	N/A		R	N/A	
C-12-3-114-58	R	N/A		R	N/A	
C-689-6-2	R	N/A		R	N/A	
Georganic	R	R	Culbreath et al., 1999, 2005.	R	R	Cantonwine et al., 2006 and 2008
C724-19-25	R	R	Holbrook et al., 2008b	MR	N/A	
Tifrunner	MR	R	Cantonwine et al., 2006	MR	MR	Cantonwine et al., 2006; Branch and Brenneman, 2008
NC 94022	R	R	Culbreath et al., 2005	MS	N/A	
TifGP-1	R	R	Holbrook et al., 2008a	MS	N/A	
Georgia Green	MR	MR	Culbreath et al., 1999	MS	S	Monfort et al., 2004
Georgia-02C	MR	R	Branch, 2003	MS	MR	Branch, 2009
AP-3	MR	R		MS	S	Culbreath et al., 1999, 2008
gen 04-14	MR	N/A		MS	N/A	
PE-1	MS	N/A		MS	N/A	
SunOleic 97R	MS	S	Culbreath et al., 1999	MS	S	
NC-6	MS	N/A		S	MR/MS?	Green and Wynne, 1987
Spancross	MS	N/A		S	N/A	
Tifton 8	MS	N/A	N/A	MR	MR	Coffelt et al., 1985
GT-C20	S	N/A		S	N/A	
GT-C9	S	N/A		S	N/A	
PE-2	S	N/A		S	N/A	

*R = resistant, MR= moderately resistant, MS = moderately susceptible, S = susceptible.

incidence of Tomato spotted wilt in the fields as genotypes with moderate susceptibility (Table 5). Field reaction to Tomato spotted wilt had not been reported previously for most of the breeding lines including, C689-6-2, TifGP-1, C12-3-114-58, and C11-154-61, which showed promising levels of field resistance to TSWV. Genotypes PE-2, GT-C9, and GT-C20 were highly susceptible to TSWV (Table 5).

In general, there were three cultivars (Georgia-01R, Tifguard, and Georganic) and three breeding lines (C 11-154-6, C 12-3-114-58 and C 689-6-2) classified as resistant to both TSWV and leaf spots. Whereas, some Chinese lines, GT-C20, GT-C9 and PE-2 were highly susceptible to both TSWV and leaf spots. PE-1 was moderately susceptible to both TSWV and leaf spots (Table 5). There has been no report of Tomato spotted wilt in peanut in China; therefore, resistance to TSWV would not have been selected by Chinese breeders. For those genotypes from China, leaf spot evaluations in the current study were hindered by high incidence and severe symptoms of Tomato spotted wilt. However, susceptibility to leaf spots was obvious.

The results in this study were also in agreement with previous reports of field resistance to leaf spots in Georgia-01R (Culbreath *et al.*, 2008), Georganic (Culbreath *et al.*, 1999; Culbreath *et al.*, 2005) and Tifrunner (Holbrook and Culbreath, 2007) (Table 5). Tifguard and its sister line C725-19-25 showed resistance to moderate resistance to leaf spots in this study. A preliminary report from another study indicated Tifguard also had a moderate level of resistance to late leaf spot (Culbreath *et al*., 2008). Although field resistance to TSWV in NC 94022 has been reported (Culbreath *et al*., 2005), this study evaluated the reaction of NC94022 to both leaf spot pathogens and TSWV. NC 94022 proved to be moderately susceptible to early leaf spot in this study but has been observed to be resistant to late leaf spot which was the predominant leaf spot in 2010 (Culbreath and Guo, personal communication). Among the tested breeding lines, three lines, C11-154-61, C12-3-114-58 and C689-6-2, were identified as resistant genotypes showing lower percent defoliation due to leaf spot, whereas C724-19-25 and TifGP-1 were moderately resistant.

Summary

The results in this study indicated a wide range of field reactions to TSWV and leaf spots among the tested lines. This information should be useful for formulating disease management strategies by using different peanut cultivars or breeding lines. In addition, these trials included fourteen of a panel of sixteen genotypes for which genetic diversity was characterized using simple sequence repeat (SSR) markers (Li *et al*., 2010) and four of these genotypes, NC94022, SunOleic 97R , Tifrunner, and GT-C20, have been used to develop two recombinant inbred line (RIL) populations (Qin *et al*., 2012). Based on the results of these field trials, the parents, NC 94022 and SunOleic 97R differ markedly in their field resistance to TSWV, while the other pair of parents Tifrunner and GT-C20 differs greatly in field resistance to both TSWV and leaf spots. Information from the combination of the field and genetic characterization of these genotypes could be useful in development of mapping populations and construction of genetic linkage map for quantitative trait loci (QTLs) studies (Qin *et al*., 2012).

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Literature Cited

Baldessari, J.J. 2008. Genetics of Tomato spotted wilt virus resistance in peanut (*Arachis hypogaea* L.). University of Florida, Gainesville, FL. 113 pp.

Bertrand, P.F. 1998. 1997 Georgia plant disease loss estimates. University of Georgia Coop. Ext. Serv. Pub. Path 98-007, Athens, GA.

Branch, W.D. 2002. Registration of 'Georgia-01R' peanut. Crop Sci. 42:1750-1751.

Branch, W.D. 2003. Registration of 'Georgia-02C' peanut. Crop Sci. 43:1883-1884.

Branch, W.D. and T.B. Brenneman. 2008. Field evaluation for the combination of white mod and Tomato spotted wilt disease resistance among peanut genotypes. Crop Prot. 28:595-598.

Brown, S.L., J.W. Todd, and A.K. Culbreath. 1996. Effect of selected cultural practices to Tomato spotted wilt virus and populations of thrips vectors in peanuts. Acta. Hortic. 431:491-498.

Cantonwine, E.G., A.K. Culbreath, C.C. Holbrook, and D.W. Gorbet. 2008. Disease progress of early leaf spot and components of resistance to *Cercospora arachidicola* and *Cercosporidium personatum* in runner-type peanut cultivars. Peanut Sci. 35:1-10.

Cantonwine, E.G., A.K. Culbreath, K.L. Stevenson, R.C. Kemerait, T.B. Brenneman, N.B. Smith, and B.G. Mullinix. 2006. Integrated disease management of leaf spot and spotted wilt of peanut. Plant Dis. 90:493-500.

Chiteka, Z.A., D.W. Gorbet, F.M. Shokes, T.A. Kucharek, and D.A. Knauft. 1988. Components of resistance to late leaf spot in peanut. I. Levels and variability – implications for selection. Peanut Sci. 15:25-30.

Coffelt, T.A., R.O. Hammons, W.D. Branch, R.W. Mozingo, P.M. Phipps, J.C. Smith, R.E. Lynch, C.S. Kvien, D.L. Ketring, D.M. Porter, and A.C. Mixon. 1985. Registration of Tifton-8 peanut germplasm. Crop Sci. 25:203-203.

Culbreath, A.K., D.W. Gorbet, N. Martinez-Ochoa, C.C. Holbrook, J.W. Todd, T.G. Isleib, and B.L. Tillman. 2005. High levels of field resistance to *Tomato spotted wilt virus* in peanut breeding lines derived from *hypogaea* and *hirsuta* botanical varieties. Peanut Sci. 32:20-24.

Culbreath, A.K., B.L. Tillman, D.W. Gorbet, C.C. Holbrook, and C. Nischwitz. 2008. Response of new field resistant peanut cultivars to twin row pattern or in-furrow applications of phorate insecticide for management of spotted wilt. Plant Dis. 92:1307-1312.

Culbreath, A.K., J.W. Todd, and S.L. Brown. 2003. Epidemiology and management of Tomato spotted wilt in peanut. Annu. Rev. Phytopathol. 41:53-75.

Culbreath, A.K., J.W. Todd, D.W. Gorbet, W.D. Branch, R.K. Sprenkel, F.M. Shokes, and J.W. Demski. 1996. Disease progress of Tomato spotted wilt virus in selected peanut cultivars and advanced breeding lines. Plant Dis. 80:70-73.

Culbreath, A.K., J.W. Todd, D.W. Gorbet, S.L. Brown, J.A. Baldwin, H.R. Pappu, C.C. Holbrook, and F.M. Shokes. 1999. Response of early, medium, and late maturing peanut breeding lines to field epidemics of Tomato spotted wilt. Peanut Sci. 26:100-106.

Culbreath, A.K., J.W. Todd, D.W. Gorbet, F.M. Shokes, and H.R. Pappu, H.R.. 1997. Field response of new peanut cultivar UF 91108 to Tomato spotted wilt virus. Plant Dis. 81:1410-1415.

Gorbet, D.W. 2007. Registration of 'AP-3' peanut. J. Plant Registr. 1:126-127.

Green, C.C. and J.C. Wynne. 1987. Genetic-variability and heritability for resistance to early leafspot in 4 crosses of virginia-type peanut. Crop Sci. 27:18-21.

Guo, B.Z., C.Y. Chen, Y. Chu, C.C. Holbrook, P. Ozias-Akins, and H.T. Stalker. 2012. Advances in genetics and genomics for sustainable peanut production. *In* N. Benkeblia (ed.). Sustainable Agriculture and New Biotechnologies. CRC Press, Boca Raton, FL. pp. 341-368.

Holbrook, C.C. and A.K. Culbreath. 2007. Registration of 'Tifrunner' peanut. J. Plant Registr. 1:124.

Holbrook, C.C. and A.K. Culbreath. 2008. Registration of 'Georganic' peanut. J. Plant Registr. 2:17.

Holbrook, C.C., P. Timper, and A.K. Culbreath. 2008a. Registration of peanut germplasm line TifGP-1 with resistance to the root-knot nematode and Tomato spotted wilt virus. J. Plant Registr. 2:57.

Holbrook, C.C., P. Timper, A.K. Culbreath, and C.K. Kvien. 2008b. Registration of 'Tifguard' peanut. J. Plant Registr. 2:92-94.

Holbrook, C.C., P. Timper, W.B. Dong, C.K. Kvien, and A.K. Culbreath. 2008c. Development of near-isogenic peanut lines with and without resistance to the peanut root-knot nematode. Crop Sci. 48:194-198.

Li, Y., A.K. Culbreath, B.Z. Guo, S.J. Knapp, and C.C. Holbrook. 2009. Tomato spotted wilt and early leaf spot reactions in peanut genotypes from the U.S. and China. Phytopathology 99:S73.

Li, Y., C.Y. Chen, S.J. Knapp, A.K. Culbreath, C.C. Holbrook, and B.Z. Guo. 2010. Characterization of simple sequence repeat (SSR) markers and genetic relationships within cultivated peanut (*Arachis hypogaea* L.). Peanut Sci. 38:1-10.

Monfort, W.S., A.K. Culbreath, K.L. Stevenson, T.B. Brenneman, D.W. Gorbet, and S.C. Phatak. 2004. Effects of reduced tillage, resistant cultivars, and reduced fungicide inputs on progress of early leaf spot of peanut (*Arachis hypogaea*). Plant Dis. 88:858-864.

Qin, H., S. Feng, C. Chen, Y. Guo, S. Knapp, A. Culbreath, G. He, M.L. Wang, X. Zhang, C.C. Holbrook, P. Ozias-Akins, and B.Z. Guo. 2012. An Integrated genetic linkage map of cultivated peanut (*Arachis hypogaea* L.) constructed from two RIL populations. Theoretic and Applied Genetics 124:653-664.

Simpson, C.E. and J.L. Starr. 2001. Registration of 'COAN' peanut. Crop Sci. 41:918-918.

Simpson, C.E., J.L. Starr, G.T. Church, M.D. Burow, and A.H. Paterson. 2003. Registration of 'NemaTAM' peanut. Crop Sci. 43:1561.

Smith, D.H. and R.H. Littrell. 1980. Management of peanut foliar diseases. Plant Dis. 64:356-361.

Ullman, D.E., J.L. Sherwood, and T.L. German. 1997. Thrips as vectors of plant pathogens. In: Thrips as Crop Pests, T. Lewis (ed.), CAB International, Wallingford, UK. pp. 539-564.