TITLE: Spotted Wilt Resistance Mechanisms

PERSONNEL: Mark C. Black, Texas AgriLife Extension Service, Uvalde; Michael R. Baring, Texas AgriLife Research, College Station

EXECUTIVE SUMMARY: Peanut varieties released in recent years as TSWV-resistant often do not have resistance in the classical sense (reduced or zero pathogen replication after infection). We continued to gather evidence that TSWV field resistance in runner peanut varieties involves plant canopy characteristics that affect vector thrips behavior.

Data were collected from one replicated field test in Frio County in 2009 including vegetative plant mapping of 10 entries at Phillips Farm and visual color ratings. Canopy color was evaluated visually by relative hue and saturation. Hue and saturation were analyzed separately and as sums. Hue = tint; what color is it? Similarly, Saturation = shade or how faded or rich and vibrant is the color?

In agreement with previous work in southwest Texas, field-resistant varieties tend to have less prominent mainstems (flatter canopy) and/or increased branching at mid-canopy height. In general, highly susceptible varieties have canopies that are more yellow-green (lower hue and faded (lower saturation), while varieties with some resistance are more blue-green (higher hue) and rich (higher saturation). Differences among hue and saturation are most noticeable early in the day, and become less noticeable in the bright glare of mid-day sun. Among years, early season data often agree with historical spotted wilt ratings more than mid- and late-season evaluations.

Field testing and screening breeding lines at locations with risk of spotted wilt have been a challenge in recent years because of complete use of varieties with field resistance in southwest Texas, dry winters that restrict TSWV and thrips numbers, and reduced acres of irrigated winter vegetables (hosts of thrips and virus). Work will continue on defining traits for use in field selections when disease intensity is low or absent.

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SUMMARY: We continued to gather evidence that TSWV field resistance in runner peanut varieties involves plant canopy characteristics. We hypothesize that canopy traits affect vector thrips behavior. Data were collected from one replicated field test in Frio County including vegetative plant mapping of 10 entries at Phillips Farm and visual canopy color ratings.

We are increasing our understanding of plant types that are highly vulnerable during spotted wilt epidemics and also plant types that hold up well to TSWV. This has potential for selection even in years with little spotted wilt pressure. The traits related to spotted wilt variety ratings do not indicate a simply inherited disease resistance. Canopy traits fall in the category of 'field resistance' that is apparently polygenically inherited. This type of 'field resistance' should be stable and additive with the low levels of 'true resistance' apparently available in some lines.

INTRODUCTION: The peanut disease caused by thrips-vectored *Tomato spotted wilt virus* (TSWV) has been an important factor in southwest and central TX since the early 1980s and in the Southeast and Virginia-Carolina production areas of the U.S. since the 1990s. In every test with diverse peanut breeding lines and varieties, there have been significant differences in spotted wilt disease ratings by the end of the season. Some of the variation among lines/varieties is apparently due to canopy characteristics of field grown plants, or "field resistance." Our previous work suggests that relatively less prominent mainstems (flatter canopy) and increased branching at mid-canopy often occur in field-resistant varieties grown in southwest Texas. Our data suggests in part that among varieties, thrips numbers in main stem and lateral branches vary at certain times of the season. Field resistance is usually not detected under laboratory (growth chamber) conditions. Varieties with field resistance have performed well during mid- and late-season spotted wilt epidemics, but early season epidemics can cause significant yield loss. Ideally, "field resistance" will eventually be combined with "true resistance" (detectable in growth chamber tests). In 2006, 2007, and 2008 color ratings (visual for hue, saturation) indicated that canopy color is also associated with partial field resistance (more saturated bluish-green vs. less saturated yellowish-green), but validation during a season with high disease incidence is needed.

Field screening for TSWV reactions among breeding lines is ongoing because plant breeders seek to maintain or improve multiple disease resistance and other desirable traits in future varieties. This work will lay the foundation for future crosses and selection efforts by identifying parental traits with resistance components to spotted wilt, other diseases, and stress. This work also will help explain benefits of increased seeding rate and twin-row planting patterns in managing spotted wilt because these management practices also affect canopy characteristics.

Our hypothesis for the canopy effect on spotted wilt is that thrips vectors are more dispersed throughout the canopy of field-resistant varieties and that vector efficiency increases with aggregation.

MATERIALS and METHODS: Ten peanut varieties with a range of TSWV field reactions were mapped for vegetative stem growth. The experimental design with two-row 13-ft plots was a randomized complete block with three replications. Whole plants were destructively sampled on three dates by removing a minimum of three plants in 1 row-ft from each of the two rows per plot (target was six plants per plot). The resulting gaps were measured after each sampling date to estimate stand (plants per row ft). Total number plants sampled and all branch lengths on the six largest plants were recorded (primary, secondary, tertiary, quaternary).

Canopy color was evaluated visually by relative hue and saturation. Hue and saturation were analyzed separately (data not presented) and as a sum. Hue = tint; what color is it? Similarly, Saturation = shade or how faded or rich and vibrant is the color?

RESULTS AND DISCUSSION: Spotted wilt was near zero at the test site in 2009. We attribute low disease to successive drought in the cool seasons and exclusive use of varieties in south TX with field resistance to TSWV. Early season visual evaluations of canopy color (hue and saturation) using four-category indices for hue and saturation again showed promise for identifying known spotted wilt-susceptible check varieties in a season with very low disease. Visual ratings characterized susceptible checks early in the season as being on the "yellow side" of green and a less vibrant color, and known resistant checks as being on the "blue side" of green and more vibrant color. Data presented here are a combination of hue and saturation (sum of indices). Canopy color did not explain significant variation among all 10 entries.

TSWV susceptible Tamrun88 canopy had less saturated green color than FlavorRunner458 on 10Aug, but similar canopy color on two other dates (Table 1). The most resistant cultivar, AP-3 had somewhat similar canopy color (hue + saturation indices) than both susceptible checks on all three dates, but hue alone trended towards blue green than Tamrun88 until 8Sep. TSWV-resistant cultivars from SE states had similar saturated blue green color compared to TX TSWV-resistant cultivars. However, none of the four SE TSWV-resistant cultivars had significantly more saturated and blue-green color than TSWV-susceptible FlavorRunner458. TX TSWV-resistant cultivars TamrunOL02 and TamrunOL07 maintained relatively saturated blue-green canopy color throughout the season and were significantly different from both susceptible checks on 8Sep. ANorden and AP-3 had the greatest deterioration of canopy color as the season progressed. SE breeding programs have apparently released cultivars with greater TSWV resistance but with less adaptation to stresses in Frio County compared to cultivars developed in TX.

Vegetative growth and canopy color estimates were compared to historical TSWV ratings for these 10 entries. No canopy color indices had significant correlations with historical spotted wilt ratings. Main stem length (plant height in early season) was positively correlated with spotted wilt on all three dates (Table 2A). In general, TSWV-susceptible cultivars had more small-limb (higher order secondary, tertiary) growth in July. After mid-season, varieties with actively growing branch in the upper canopy may be favored feeding sites by thrips carrying TSWV (Table 2A,B).

In early season, several parameters describing more vegetative growth and an exposed unbranched main stem were positively correlated with spotted wilt. Varieties with taller main stems vs. the first two secondary stem lengths were more susceptible based on positive correlations with disease for RMSSS1, RMSSS2, RMSSS1_2, RMSSS1_4, RMSSS, MSSS, and RMSTS.

Regression equations that explained the most spotted wilt reactions mostly agreed with previously discussed individual parameter correlations (Table 3). On 8Jul, main stem length was a positive factor, and total secondary stem length was a negative factor. On 10Aug, main stem length ratio with average of all secondary stems was a positive factor, as was total number quarternary stems. On 8Sep, total number of secondary stems was a positive factor (reflects positive correlations with higher order secondary stem lengths) and secondary stem 6 length was a negative factor.

Our hypothesis is that thrips vectors of TSWV respond to peanut canopy color in a way that influences spotted wilt epidemics. In general, highly susceptible varieties have canopies that are more yellow-green (lower H) and faded (lower S), while varieties with some resistance are more blue-green (higher H) and rich (higher S). Differences among H and S are most noticeable early in the day, and become less noticeable in the bright glare of mid-day sun. In recent years, early season ratings were more informative than those in mid- and late-season.

We have not identified one or two easily measured traits related to spotted wilt reaction in the seedling stage that breeders could use for early screening in the greenhouse or winter nursery. The best disease correlations with vegetative growth traits varied among years of plant mapping, but there is commonality. We continue to gain understanding of plant types that are highly vulnerable and this can be used in years with little spotted wilt pressure.

The traits related to spotted wilt variety ratings explored in this report can be described as 'field resistance' (some varieties/breeding lines have less disease in the field than would be expected based solely on laboratory tests). Fortunately, this type of 'field resistance' is stable to date, and even when epidemics occur, there should always be a similar rank of known susceptible and known resistant entries. The Georgia and Florida university breeding programs are using different sources of resistance and genetic backgrounds than Texas breeders for spotted wilt resistance, with the former apparently relying more on both dense-low spreading-highly branched canopy and some 'true resistance' to TSWV. In general SE variety canopies are more prone to southern blight, Sclerotinia blight, and heat stress. The Texas program apparently uses genetics for a less branched canopy that have advantages for field resistance to southern blight, Sclerotinia blight, and summer stress.

Field testing and screening breeding lines at locations with risk of spotted wilt have been a challenge in recent years because of complete use of varieties with field resistance in South Texas, and because of dry winters that restrict TSWV and thrips numbers. Work will continue on defining traits for use in field selections when disease intensity is low or absent.

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Table 1. Visual color ratings of peanut canopies (saturation plus hue) at Murray Phillips Farm in Frio County in 2009 in attempts to characterize entries susceptible (Tamrun 88, FlavorRunner458) to spotted wilt disease in a season with near zero spotted wilt disease (caused by *Tomato Spotted wilt virus*), with estimated historical spotted wilt reactions from TX and SE states arbitrarily assigned to entries (see entry rank for s+hSep8).

Entry	s+h Jul8		Entry	s+h Aug10		Entry	s+h Sep8		Historical spotted wilt reaction
TamrOL02	4.0	a	TamrOL02	3.7	a	TamrOL02	4.3	a	35
TamrOL07	3.7	ab	Tamrun96	3.3	ab	TamrOL07	4.3	a	25
ANorden	3.7	ab	TamrOL07	3.3	ab	Tamrun96	4.0	ab	40
Georg03L	3.7	ab	ANorden	3.0	abc	Georg02C	3.7	abc	15
Tamrun96	3.0	bc	Georg03L	3.0	abc	Georg03L	3.3	bcd	15
TamrOL01	3.0	bc	Georg02C	3.0	abc	Flrun458	3.3	bcd	50
Flrun458	3.0	bc	Flrun458	3.0	abc	TamrOL01	3.0	cd	35
Georg02C	3.0	bc	TamrOL01	2.7	bcd	ANorden	2.7	de	25
AP-3	2.7	c	AP-3	2.3	cd	Tamrun88	2.7	de	60
Tamrun88	2.3	c	Tamrun88	2.0	d	AP-3	2.0	e	10
LSD.05	0.7			0.7			0.8		
p>f	0.0024			0.006			0.0001		
CV%	13			15			14		
Average	3.2			2.9			3.3		

Table 2. Significant ($P \leq 0.05$) Pearson correlation coefficients (r)(N=30) for historical spotted wilt disease ratings with selected peanut stem characteristics from three sampling dates for ten varieties at Phillips Farm in Frio County, TX, 2009 (r^2 estimates proportion of variation in spotted wilt explained by the variable).

Plant sample date	**8Jul**	**10Aug**	**8Sep**
A. Stem length^z --			
MSLvs			.36*
MS	.70**	.41*	.48**
S1	.42*		
S1T5Q3			.43*
S2	.52**		.37*
S2T2	-.38*		
S2T3	-.47**		
S2T4	-.39*		
S2T11			.51**
S4T2Q3			.45*

S6	-.52**		
S6T4			.38*
S6T5			.39*
S6T6			.39*
S8T1			.39*
S9			.45*
S10T1			.38*
S10T3			.37*
S11			.40*
S11T3			.39*
S12			.44*
S12T1			.41*
S13			.38*
S14			.44*
S15			.45*
S17			.63**
S18			.56**
S19			.65**
S20			.62**
S21			.56**
S22			.56**

Plant sample date	**22Jul**	**18Aug**	**25Sep**
B. Calculated variables------------------------------------			
TtNoSSt			.52**
TtNoVSt			.45*
TtVStmL			.39*
StemL	.40*		
SStemL	.38*		
SS12L	.49**		
SmMSS1_4	.43*		
MSxxS1_4	.43*		.43*
MSnodeL	.72**		
RMSSS1	.56**		
RMSSS2	.42*		
RMSSS1_2	.54**		
RMSSS1_4	.58**		
MSSS	.58**		.44*
RMSTS	.47**		
RSSTS	.40*		

[y]Asterisks (one, two) indicate significance at $P \leq 0.05$ and $P \leq 0.01$, respectively.

[z]Stem length was an average of six plants per plot. Calculated variables were based on averages of previous variables for each plot. There were three replications, N=30. MS=main stem; S, SS and SSt=secondary stem; T= and TS=tertiary stem; Q= quaternary stem; Tt=total; R=ratio (of stems described); 1_2=1 and 2; 1_4=1, 2, 3, and 4; no number indicated an average of all SS on that date.

Table 3. Regression analysis of plant mapping data (three dates, destructive sampling) for 10 varieties at Phillips Farm in Frio County, TX, 2009 and predicted spotted wilt disease intensity.

Sample date	Best regression equation[z]	Model P > F	R^2
8Jul	SW = -25.1 + 8.1MS – 0.9TtSStmL	<0.0001	.69
10Aug	SW = -60.4 + 68.2RMSSS + 2.1TtNoQSt	<0.0011	.40
8Sep	SW = -11.8 + 4.3TtNoSSt – 0.4S6	<0.0032	.35

[z]Equations were estimated by PC-SAS Proc Regression using Stepwise option, relative increase in R^2, and relative decrease in C(p) statistic as factors were added to the model. Six whole plants were collected from each plot on each date. Stem descriptions are:

SW = spotted wilt (% row ft with noteworthy symptoms)
Sm = sum
MS = average length of main (primary) stem 1 (cm)
S1 = average length of secondary stem 1 (cm)
S2 = average length of secondary stem 2 (cm)
S3 = average length of secondary stem 3 (cm)
S4 = average length of secondary stem 4 (cm)
S6 = average length of secondary stem 6 (cm)
SStmL = average total/plant secondary [arising from main(primary)] stem length (cm)
TStmL = average total/plant tertiary stem length
TtSStmL = average total/plant secondary stem lengths (cm)
TtTStmL = average total/plant tertiary (from secondary stems) stem lengths (cm)
TtQStmL = average total/plant quaternary (from tertiary stems) stem lengths (cm)
TtNoStm = average total number all stems/plant (cm)
TtNoTSt = average total number tertiary stems/plant (cm)
RMSSS12 = average ratio of main stem length to average of secondary stems 1 and 2
RMSSS1 = average ratio of main stem length to secondary stem 1 length
MSxxS1_4 = product of main stem length and the average length of secondary stems 1-4
MSSS = ratio of average main stem length/plot to average secondary stem length /plot.