Productivity of Florunner Peanut Infected with Tomato Spotted Wilt Virus

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ABSTRACT

Individual plants of peanut cultivar Florunner were evaluated over time for symptoms of tomato spotted wilt virus (TSWV) in field plots in 1988, 1989 and 1990. Time of symptom appearance was recorded for symptomatic plants. Seed yield was determined for individual symptomatic plants and apparently healthy check plants on adjacent rows. Across all times of appearance of symptoms, number of seed produced, mean weight per seed and total seed yield were lower for symptomatic plants than for healthy plants in all three years. In 1989 and 1990, linear regression indicated that both number of seed and seed yield per infected plant increased with time from planting until TSWV symptom expression. Mean seed weight also increased with time from planting until symptom expression in 1990, although this increase was small, but not in 1989. Among symptomatic plants, number of seed produced was more strongly correlated with seed yield than was average weight per individual seed.

Key Words: TSWV, yield losses, seed production, symptom expression

Spotted wilt disease, caused by the thrips vectored tomato spotted wilt virus (TSWV), is a serious limiting factor in peanut (*Arachis hypogaea* L.) producing regions of India (7,12,13), and is now established in peanut production areas of Alabama, Florida, Georgia, Mississippi, and Texas (1,2,4,5,6,8,9,17).

Symptoms of spotted wilt in peanut vary from severe stunting and distortion of peanut vines to elaborate concentric ring spots on individual leaflets, and in some cases, death of the entire plant (7,9). First symptoms usually appear a few weeks after planting, and newly symptomatic plants appear throughout most of the remainder of the season (4,5). Plants that exhibit symptoms early in the season often are severely stunted, suggesting that time of symptom expression may relate to vegetative growth of the plant. The growth stage in which the plant is systemically infected may influence pod and seed production. Reductions in both quantity and quality of yields of pods and seed are associated with TSWV infections (1,11,13). Time of symptom expression (11) and intensity (13) of symptoms have been reported to be related to yield losses in TSWV infected plants in India, but quantitative relationships between time of appearance of symptoms and productivity of infected plants have not been elucidated for cultivars used in the United States. The purpose of this study was to compare seed yields of individual peanut plants of the Florunner cultivar infected with TSWV to yields of healthy plants, and to determine the relationship between time of symptom appearance of spotted wilt and yield of infected plants.

Materials and Methods

Florunner peanut were established at the University of Georgia Attapulgus Research Station, Attapulgus, GA in 1988, 1989, and 1990. Seed were planted in single rows 0.91 m apart at 112 kg/ha seeding rate on 29 April 1988, 13 April 1989 and 14 April 1990. In all three years, areas were 24 rows, 20 m wide X 180 m long. The plots were maintained as recommended for peanut production in Georgia (10). Applications of chlorothalonil (Bravo 720 6F, ISK Biotech) 1.24 kg ai/ha, were made for control of foliar diseases.

Plants were examined for symptoms of spotted wilt on three, four and five dates in 1988, 1989 and 1990, respectively. In 1988, evaluation dates were 6 July, 13 July and 19 July which occurred during beginning seed (R5), beginning seed (R5), and full seed (R6) growth stages of the crop, respectively, as designated by Boote (3). Evaluations were made on 12 June (beginning pod = R3), 26 June (beginning seed = R5), 10 July (full seed = R6), and 24 July (beginning maturity = R7) in 1989, and on 30 May (beginning peg = R2), 14 June (beginning pod = R3), 1 July (beginning seed = R5), 15 July (full seed = R6), and 1 August (beginning maturity = R7) in 1990. On each date, plants showing initial symptoms of infection were marked with colored surveyors flags. A different color was used on each date, such that time of first symptom appearance in individual flagged plants was evident at harvest. Leaf samples were taken from each symptomatic plant in 1988 and 1989 for confirmation of the presence of the virus by use of ELISA techniques with antiserum developed by Sreenivasulu *et al.* (15). Only plants for which positive tests for the virus were obtained were used as infected plants in these experiments. In 1990, due to the large number of samples evaluated, one of every 10 symptomatic plants was assayed for diagnosis confirmation. In all years, symptoms of plants that did not test positive via ELISA were re-evaluated. If symptoms indicated that the plant had spotted wilt, samples were taken and retested via ELISA.

Plants were inverted on 19 September, 15 September, and 14 September in 1988, 1989 and 1990 respectively. Plants were chosen that showed no symptoms of southern stem rot (*Sclerotium rolfsii* Sacc.) which also was common in the plots. In 1988, 63, 56 and 28 symptomatic plants were collected by random selection from those plants flagged at the respective evaluation dates. In 1989, 13, 12, 11 and 30 plants on which first symptoms appeared during the respective evaluation periods were harvested. In 1988 and 1989, one apparently healthy plant from an adjacent row was collected for each symptomatic plant for paired comparisons. In 1990, 107, 108, 110, 109, and 109 plants were collected from the 30 May, 14 June, 28 June, 12 July and 27 July evaluation dates respectively. One hundred twenty apparently healthy plants also were collected. Because of the larger number of plants collected in 1990, healthy plants were not paired with each symptomatic plant. Individual plants were inverted and the plants were dried in a greenhouse. Pods were removed and seed were shelled by hand. Seed were weighed and counted, and average weight per seed was determined for each plant. Plants that had no pods were not used in the analysis of weight per seed.

In 1988 and 1989, number of seed per plant, weight per seed and total seed yield per plant were compared to those of healthy checks by use of paired t tests, where the average difference between the healthy and infected plants per pair is compared to zero (14,16). Comparisons were made across all times of symptom expression and for each group of time of symptom expression. In 1990, number of seed per plant, weight per seed and total seed yield per plant of the combined symptomatic plants across all times of symptom expression and for the latest time category (after July 15) were compared to those of healthy plants by use of Student's t tests (16).

In 1989 and 1990, the relationship between time of symptom expression and number of seed, seed weight, and seed yield per plant were examined by regression of those values on time, expressed as days from planting until symptom appearance. Only symptomatic plants were used in the regression analysis. Pearson's correlation coefficients were calculated as an indication of the relationship among number of seed, seed weight and total seed yield in infected plants (16).

Results

Of plants visually diagnosed as having spotted wilt, TSWV was detected via ELISA in greater than 95% of the samples on the first test for confirmation. Plants that were retested after a second visual examination and diagnosis likewise had a high rate of agreement between visual symptom assessment and serological tests. Few plants that showed

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symptoms of TSWV for which diagnosis was not corroborated by ELISA were found in any year.

Seed yield per plant, number of seed produced per plant, mean weight per seed were lower for plants infected with TSWV than for healthy plants in all three years (Tables 1,2,3). Irrespective of time of infection, or growth stage when symptoms appeared, average seed yields of all infected plants were 31.3, 23.8, and 31.3 in 1988, 1989 and 1990 respectively (Tables 1,2,3).

Table 1. Effect of tomato spotted wilt virus infection on seed number, mean seed weight and total seed yield in individual Florunner peanut plants, 1988. Numbers in parentheses are standard deviations.

Date of Diagnosis	Number of Seed	Seed wt (g/seed)	Yield (g)
6 July (R5)[a]			
Infected	16.5 (20.5)**[b]	0.44 (0.24)**	8.1 (12.0)**
Healthy check	43.6 (26.0)	0.75 (0.16)	31.7 (18.6)
13 July (R5)			
Infected	22.3 (20.4)**	0.45 (0.19)**	10.8(11.0)**
Healthy Check	64.6 (57.9)	0.63 (0.17)	38.4 (26.7)
19 July (R6)			
Infected	30.5 (19.9)**	0.52 (01.6)**	16.3 (13.3)**
Healthy Check	44.8 (18.7)	0.71 (0.17)	31.4 (13.2)
Total			
Infected	21.4 (20.9)**	0.46 (0.21)**	10.7 (12.2)**
Healthy check	51.8 (41.5)	0.71 (0.18)	34.2 (21.4)

[a] Estimated average growth stage for the crop on the date of evaluation, based on stages reported by Boote (3).
[b] Average difference between infected and healthy yield parameters was different than zero according to paired t tests, (* P ≤ 0.05; ** P ≤ 0.01). Comparisons were made within each category of time of symptoms appearance and across categories.

Table 2. Effect of tomato spotted wilt infection on seed number, mean seed weight and total seed yield in individual Florunner peanut plants, 1989. Numbers in parentheses are standard deviations.

Date of Diagnosis	Number of Seed	Seed wt (g/seed)	Yield (g)
12 June (R3)[a]			
Infected	9.4 (11.8)**[b]	0.26 (0.10)**	5.8 (8.2)**
Healthy Check	81.7 (32.9)	0.55 (0.19)	42.0 (14.5)
26 June (R5)			
Infected	11.2 (12.9)**	0.34 (0.09)**	5.7 (3.3)**
Healthy Check	92.7 (46.1)	0.46 (0.05)	31.4 (24.9)
1 July (R6)			
Infected	18.5 (14.5)**	0.34 (0.06)**	7.3 (7.1)**
Healthy Check	83.3 (32.1)	0.49 (0.03)	40.4 (14.4)
24 July (R7)			
Infected	35.2 (28.8)**	0.36 (0.11)**	17.5 (14.1)**
Healthy check	101.8 (65.3)	0.49 (0.49)	49.7 (31.0)
Total			
Infected	21.4 (23.9)**	0.35 (0.10)**	11.7 (12.0)**
Healthy check	91.9 (51.5)	0.50 (0.10)	44.8 (24.7)

[a] Estimated average growth stage for the crop on the date of evaluation, based on growth stages reported by Boote (3).
[b] Average difference between infected and healthy plant yield parameters was different than zero according to paired t tests, (*P ≤ 0.05; **P ≤ 0.01). Comparisons were made within each category of time of symptoms appearance and across categories.

Table 3. Effect of tomato spotted wilt virus infection on seed number, mean seed weight and total seed yield in individual Florunner peanut plants, 1990.

Date of Diagnosis	Number of Seed	Seed wt (g/seed)	Yield (g)
30 May (R2)[a]	13.7	0.29	3.9
14 June (R3)	26.9	0.25	7.6
1 July (R5)	35.4	0.29	10.4
15 July (R6)	38.9	0.36	14.4
1 August(R7)[b]	49.9 (39.1)*[c]	0.36 (0.09)NS	18.3 (16.1)*
Total			
Infected	33.1 (30.7)**	0.31 (0.12)*	11.0 (12.5)**
Healthy Check	85.4 (45.8)	0.42 (0.06)	35.1 (18.8)

[a] Estimated average growth stage for the crop on the date of evaluation, based on stages reported by Boote (3).
[b] Plants showing symptoms in the latest time category were compared to the healthy check using Student's t tests.
[c] Different from the healthy check according to Student's t tests, (* P < 0.05 and ** P< 0.01). Comparisons were made within each category of time of symptoms appearance and across categories.

For all time categories, number of seed per plant and total yield per plant were lower than those of their respective healthy check in all three years. (Tables 1,2,3). In 1990, mean seed weight of plants that first showed symptoms in the beginning maturity (R7) stage (after 15 July) was not different (P > 0.05) from that of the healthy check plants, but seed weights within all time categories were lower than those of the respective healthy check plants in 1988 and 1989.

Significant regression equations indicated that number of seed (Fig. 1) and total yield (Fig. 2) produced by symptomatic plants increased linearly with time until symptom expression in 1989 and 1990. In 1990, average seed weight (Fig. 3) of symptomatic plants increased linearly with time until symptom expression (Fig. 3), although the increase was small. In 1989, seed weight was similar for symptomatic plants regardless of time of symptom appearance, as indicated by a regression coefficient not different (P > 0.05) than zero

Table 4. Pearson's correlation coefficients for seed number, seed weight, and yield for Florunner peanut plants infected with TSWV.

		No. of seed	Yield
1988			
	No of seed	-	0.91**[a]
	Seed wt.	NS[b]	NS
1989			
	No of seed	-	0.94
	Seed wt.	0.34**	0.59
1990			
	No of seed	-	0.93**
	Seed wt.	0.20**	0.41**

[a] ** indicates a significant correlation, P ≤ 0.01.
[b] NS indicates that the correlation was not significant, P > 0.05.

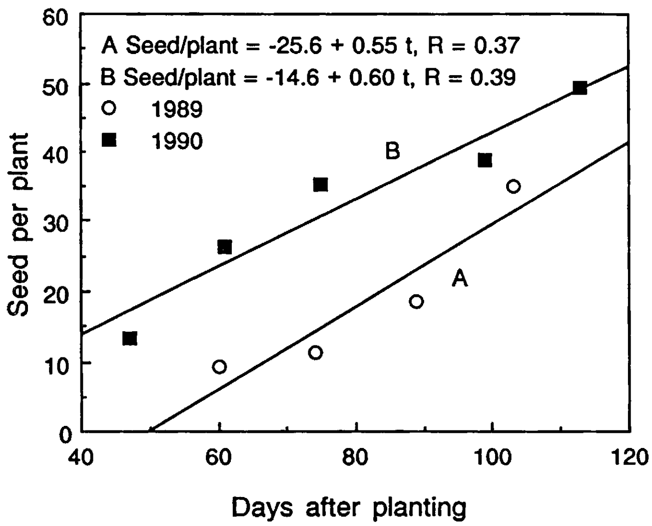

Fig. 1. Linear regression of number of seed produced per plant vs. time (t) in days after planting that spotted wilt symptoms appeared, 1989 (A) and 1990 (B).

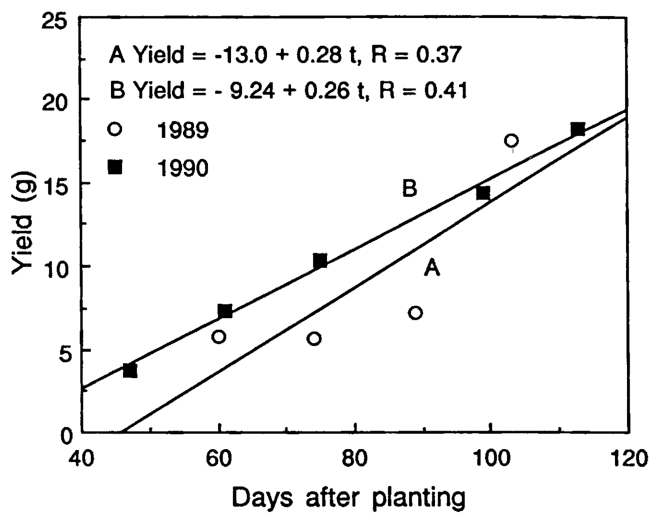

Fig. 2. Linear regression of yield per plant vs. time (t) in days after planting that spotted wilt symptoms appeared, 1989 (A) and 1990 (B).

(Fig. 3). Variation was great in both years as indicated by coefficients of determination (Figs. 1, 2, and 3).

Number of seed produced per plant was positively correlated ($P \leq 0.01$) with total yield per plant in all three years (Table 4). Average weight per seed produced was correlated ($P \leq 0.01$) with yield per plant in 1989 and 1990, but not in 1988 (Table 4). In 1989 and 1990, correlation coefficients were larger for number of seed and yield per plant than for seed weight and yield. In 1989 and 1990, number of seed per plant and average seed per plant were positively correlated ($P \leq 0.01$) (Table 4).

Discussion

Infection with TSWV dramatically reduced seed yield in individual Florunner peanut plants. Reduction in yield per plant was due to fewer seed produced as well as lower average weight of the individual seed. Reduction of the number of seed produced appears to be the more important of these two components. The degree to which yield of individual plants are affected is related to the time at which symptoms occur, with most severe yield reductions occurring with early appearance of symptoms, however, reductions occurred at all sampling periods. Yield reductions associated with our earliest evaluations may be related to effects of infection on early stages of the reproductive phase of the plants. Initial evaluations in 1989 and 1990 were made during periods of intense blooming and pegging in the crop. Narendrappa (11) reported that peanut plants infected after the plants were 95 days old suffered no loss in yield. In 1990, even plants in which symptoms appeared after beginning maturity had lower yields than those of healthy plants.

Since symptomatic plants were flagged only three times in 1988, and these represented a much shorter time interval than those in subsequent years, relative responses among the three years could lead to erroneous conclusions. However, similar trends between seed number and yield were observed in all three years. In addition, different environmental conditions as well as temporal aspects of symptoms expression after planting could have contributed to plant response to virus infection.

Time of appearance of symptoms within the time categories addressed here also could influence yield. Although this factor was not examined in this study, the authors realize that appearance of symptoms in the field may occur in a continuous fashion, and that grouping symptomatic plants based upon arbitrary discreet periods of time of appearance of first symptoms could contribute to other differential responses. The low yields associated with early appearance of symptoms, however are evident even with large time interval categories, although specific thresholds may exist within each of those time periods. Severity of effects of TSWV on individual plants within time categories was not considered in this study. Although severity of symptoms on a plant may be correlated with time of symptom expression, relationship between severity of symptoms and yield per plant has been reported (13). Variation in severity of effects of infection combined with differences in time of symptom expression within specific time categories used in our study may have contributed to the high variation around the regression lines for the yield components.

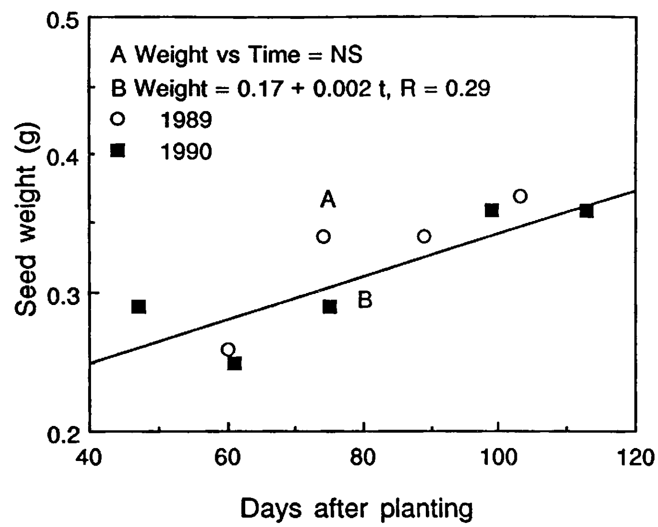

Fig. 3. Linear regression of seed weight vs. time in days after planting that spotted wilt symptoms appeared, 1989 (A) and 1990 (B).

Incubation periods for TSWV may vary, and symptom expression may depend on periods of stress or other environmental factors, such as temperature, more than on actual time of inoculation or infection. Our study suggests that regardless of time of infection, time of appearance of symptoms can serve as an index of the net effects of the interaction of TSWV infection of the host plant with TSWV and the environment on yield for a particular plant. Because of high populations (nine to fifteen plants per m of row) of peanut plants in production fields, and the ability of individual peanut plants to compensate for losses in stand or yield of adjacent plants, a linear relationship between incidence of spotted wilt and yield on a per field basis probably does not exist. Extrapolation of the effects of TSWV infection on peanut yields in individual plants to entire fields would require consideration of compensatory capabilities of the crop and the dispersal patterns of infected plants in the field. Our study indicates that yield losses would be less in plants showing symptoms late in the season than in plants in which symptoms appear early. Based upon our results, time of appearance of symptoms must be considered in developing models relating disease incidence and progression to peanut yields. This study provides a quantitative description of the relationship between time of symptom expression and yield in individual plants that will serve as an initial step in subsequent description of yield losses to TSWV as pertaining to disease progress and dispersal patterns in plant populations on a whole field basis. Investigations to determine the relationships among time of appearance of spotted wilt symptoms, cumulative disease incidence and yield in populations are in progress.

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