Influence of Paraquat on Yield and Tomato Spotted Wilt Virus for Georgia-02C and Georgia-03L Peanut

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ABSTRACT

Paraquat is a common herbicide used in peanut production; however, visible injury and reduced yield have been observed in some instances. Most research regarding paraquat injury on peanut has taken place on cultivars that are no longer available and were more susceptible to tomato spotted wilt virus (TSWV) than current cultivars. Field experiments were conducted over three growing seasons to determine the effect of paraquat on yield and TSWV incidence in two moderately TSWV-resistant cultivars (Georgia-02C and Georgia-03L). Paraquat and paraquat plus bentazon were evaluated against a non-treated control at four application timings [7, 14, 21, and 28 d after ground cracking (DAGC)]. There were no yield differences among herbicide treatments or application timings for Georgia-02C peanut, but there was a treatment interaction with Georgia-03L for yield. The majority of interaction comparisons showed no yield differences, but the non-treated control had higher yields than the herbicide treatments when significance did occur. Yields were similar for the 7 DAGC timing in all comparisons. In all instances when differences occurred for both cultivars, TSWV was higher in non-treated plots than where herbicides were applied. This data supports the use of paraquat in Georgia-02C and Georgia-03L peanut since there is minimal chance of yield reduction and may also reduce TSWV incidence; however, additional studies are required.

Key Words: bentazon, herbicide application timing, herbicide tolerance, weed-free.

Paraquat is one of the most frequently used postemergence (POST) herbicides in Southeastern peanut (*Arachis hypogaea* L.) production systems. However, peanut injury can occur, reducing yield and grade characteristics (Knauft *et al.*, 1990; Wilcut and Swann, 1990). The addition of bentazon to paraquat is a common practice to reduce peanut injury, although it can be either antagonistic or synergistic in its effect on weed control depending on the weed and herbicide rate (Wehtje *et al.*, 1992) and often does not improve peanut yield despite the reduction in crop injury (Wehtje *et al.*, 1986, 1992; Wilcut *et al.*, 1989). Evaluations of cultivar response to herbicide treatments containing paraquat have been studied (Knauft *et al.*, 1990; Wehtje *et al.*, 1991b; Wilcut and Swann, 1990). However, most of the cultivars that have been evaluated are no longer grown in the U.S. With new cultivars being released each year having varying growth habits, seed size, and resistance to common peanut diseases, such as spotted wilt of peanut, caused by tomato spotted wilt *Tospovirus* (TSWV), it is important to determine whether these cultivars have tolerance to POST applications of paraquat.

The influence of peanut herbicides on the incidence of TSWV has only recently been studied. Chlorimuron has been shown to slightly increase TSWV without affecting yield (Prostko *et al.*, 2009). Other peanut herbicides, such as imazapic, 2,4-DB, and lactofen, have not had an effect on TSWV (Dotray *et al.*, 2006; Faircloth and Prostko, 2006). However, there is little information available regarding the effects of paraquat on TSWV. This is largely due to the fact that most studies related to paraquat influence on peanut occurred prior to the mid-1990s when TSWV became a significant disease problem in peanut. One study on cv. Georgia Green did show TSWV incidence to be higher with paraquat plus bentazon plus acifluorfen compared to a non-treated control in one out of two locations, but there was no effect of paraquat plus bentazon on TSWV in either location (Shaikh *et al.*, 2003). There were no yield differences for any treatment in that trial. Since there is a general lack of information regarding the effects of paraquat on TSWV incidence, especially on newer TSWV resistant cultivars (Culbreath *et al.*, 2009), our objectives were to determine the influence of paraquat on yield and TSWV incidence of two currently relevant peanut cultivars, cv. Georgia-02C (Branch, 2003) and cv. Georgia-03L (Branch, 2004).

Materials and Methods

Irrigated field trials were conducted at the Ponder Research Station located near Tifton, GA

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Table 1. Combined analysis of variance across years, herbicide treatment, and application timing for pod yield, % mature pods at harvest, and tomato spotted wilt virus (TSWV) incidence, Georgia-02C peanut.

Treatment	df[a]	Pod yield	% mature pods	% TSWV
Year	1	***	***	***
Rep (Year)	6	***	**	*
Herbicide	2	NS	NS	*
Year × Herbicide	2	NS	NS	NS
Timing	3	NS	NS	NS
Year × Timing	3	NS	NS	NS
Herbicide × Timing	6	NS	NS	NS
Year × Herbicide × Timing	6	NS	NS	NS
Error	66	-	-	-
Coefficient of variation, %		10.87	40.59	35.10

[a]df = degrees of freedom
NS, *, **, *** denote not significantly different, significantly different at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively.

from 2006 through 2008. The soil type at this location was a Tifton sand (fine-loamy, kaolinic, thermic, Plinthic Kandiudults) with 96% sand, 2% silt, 2% clay, 1.2% organic matter, and pH 6.0. Peanut seed were planted in twin rows spaced 23 cm apart (91 cm between centers of twin rows) into plots that were 1.8 m wide by 8 m long. The Georgia-02C experiment was planted 10 May 2006 and 8 May 2007, dug on 9 October 2006 and 16 October 2007, and harvested on 15 October 2006 and 29 October 2007. The Georgia-03L experiment was planted 8 May 2007 and 12 May 2008, dug on 25 September 2007 and 24 September 2008, and harvested on 8 October 2007 and 29 September 2008. The plot areas were maintained weed-free using a combination of preemergence (pendimethalin, flumioxazin, and diclosulam) and POST (imazapic, 2,4-DB) herbicides and hand-weeding. Other common production practices and Univ. of Georgia Cooperative Extension recommendations (Beasley *et al.*, 1997) were followed.

A randomized complete block design was used with a 3 by 4 factorial arrangement consisting of three herbicide treatments [non-treated control (NTC), paraquat at 0.14 kg ai/ha, and paraquat at 0.21 kg ai/ha plus bentazon at 0.28 kg ai/ha] and four application timings [7, 14, 21, and 28 d after ground cracking (DAGC)]. Peanut growth stage (Boote, 1982) at the time of application was V4 for the 7 DAGC application; V6 for the 14 DAGC application (except for Georgia-02C in 2006–V5); V7 for the 21 DAGC applications in 2007 (both experiments) and R1 in 2006 (Georgia-02C) and 2008 (Georgia-03L); and R1 for the 28 DAGC application. A nonionic surfactant (80/20, United Agri Products, Greeley, CO or LI-700, Loveland Products Inc., Greeley, CO) was included with all paraquat treatments at 0.25% v/v. The treatments were applied with a CO_2 pressurized, backpack sprayer calibrated to deliver 140 L/ha at 220 to 275 kPa (11002 DG [drift reducing] fan nozzle tips with 51 cm nozzle spacing). Treatments were replicated four times.

Incidence of spotted wilt was measured just prior to peanut digging by counting the number of disease loci per linear row in 31 cm sections and transforming the data to percentage infection based upon total row length, a method adapted from Rodriguez-Kabana *et al.* (1975) for assessing southern stem rot in peanut. Peanut yield data were obtained using commercial digging and harvesting equipment. Peanut yields were adjusted to 7% moisture. Pod maturity percentage was determined by randomly collecting 100 pods from each plot and subjecting the pods to the hull scrape method (Williams and Drexler, 1981). Pods that fell in the brown to black mesocarp color categories were considered mature. All data were subjected to analysis of variance and pooled where appropriate. Means were separated according to Fisher's protected least significant difference (LSD) test at P=0.05 (Steel and Torrie, 1980).

Results and Discussion

Cultivar Georgia-02C. Variables analyzed include pod yield, % mature pods, and % TSWV (Table 1). There were no interactions among treatment effects, and all three variables showed differences between years. Yields were higher in 2007 than 2006, which is consistent with state averages (NASS, 2009), but is likely strongly correlated to pod maturity. Minimum temperatures dropped below 13 C for four consecutive nights (28 September to 1 October 2006), including below 9 C on 30 September, causing pod development to halt before reaching optimum digging maturity (normally 150 d after planting). Since there were no

Table 2. Peanut pod yield, mature pods, and tomato spotted wilt virus (TSWV) incidence as influenced by year and herbicide treatment, Georgia-02C peanut.

Variable	Pod yield	mature pods	TSWV
	kg/ha	%	%
Year[a]			
2006	3621 b	1.9 b	13.5 b
2007	4900 a	30.6 a	21.0 a
Herbicide Treatment[b]			
Non-Treated Control	4280 A	17.5 A	19.9 A
Paraquat	4290 A	16.9 A	15.3 B
Paraquat plus Bentazon	4212 A	14.4 A	16.5 B

[a]Data pooled over herbicide treatment and application timing. Means within a column followed by the same lowercase letter are not significantly different according to Fisher's protected LSD test at P=0.05.

[b]Data pooled over year and application timing. Means within a column followed by the same uppercase letter are not significantly different according to Fisher's protected LSD test at P=0.05.

significant differences in yield among the three herbicide treatments (Table 2), this data is similar to other reports that paraquat alone at the 0.14 kg/ha rate does not reduce peanut yield compared to a NTC (Wehtje *et al.*, 1991a, 1991b, 1994). Also, this data is similar to results in which paraquat plus bentazon yielded equally or better than a NTC (Teuton *et al.*, 2004; Wehtje *et al.*, 1992; Wilcut and Swann, 1990) and equal to paraquat alone (Wehtje *et al.*, 1992). Unlike results by Knauft *et al.* (1990) and Wilcut and Swann (1990) in which paraquat reduced peanut yields if applied more than 7 DAGC, there was no reduction in yield of Georgia-02C regardless of application timing. More research is needed to determine if this is a result of increased tolerance or some other mechanism.

Only herbicide treatment showed significant differences on % TSWV. Incidence of TSWV was greater in the NTC than where paraquat or paraquat plus bentazon were applied (Table 2). No differences among herbicide treatments for pod maturity indicate that plant injury from paraquat was not severe enough to cause a delay in pod development.

Cultivar Georgia-03L. There was an interaction of year by herbicide treatment by application timing for pod yield with Georgia-03L (Table 3). In 11 of the 12 comparisons across years, peanut yields in 2008 were higher than in 2007, which also correspond with state averages between the two years (NASS, 2009). When comparing the three-way interaction by herbicide treatment, there were two instances with significant differences. In both cases (21 DAGC in 2007 and 14 DAGC in 2008), the NTC had higher yields than paraquat alone. With the 21 DAGC application in 2007, the NTC also had higher yields than paraquat plus bentazon. There were no instances where there was a yield difference between paraquat alone and paraquat plus bentazon. These two occurrences support the claims that paraquat will reduce yields if applied more than 7 DAGC (Knauft *et al.*, 1990; Wilcut and Swann, 1990); however, there were twice as many instances in which there was no reduction in yield when herbicide treatments were applied later than 7 DAGC (Table 4). Further comparisons among application timings demonstrate no differences regardless of when paraquat alone was applied in either year while paraquat plus bentazon produced reduced yields at the 28 DAGC application compared to 7 or 21 DAGC in 2008 (Table 4).

For TSWV incidence, only a difference between years was observed at the $P \leq 0.05$ level (Table 3), in which 2007 had higher disease pressure than 2008 (Table 5), which likely also contributed to higher yields in 2008. Yet, there was a year by herbicide treatment interaction at the $P \leq 0.10$ level, in which the NTC (37.1%) resulted in higher TSWV incidence when compared to paraquat plus bentazon (28.4%) in 2007. This is contradictory to results by Shaikh *et al.* (2003) on Georgia Green (a more TSWV susceptible cultivar), where TSWV was reported to be less in NTC plots compared to herbicide treatments with paraquat and/or bentazon. However, this data is similar to what was observed on Georgia-02C peanut (Table 2). Also similar to the Georgia-02C results, there were no differences among any herbicide treatment factors for pod maturity (Tables 3 and 5), which demonstrates that plant injury from paraquat treatments did not cause a delay in pod development.

Summary and Conclusions

These results show that there is minimal evidence of damage (beyond normal) or yield

Table 3. Combined analysis of variance across years, herbicide treatment, and application timing for pod yield, % mature pods at harvest, and tomato spotted wilt virus (TSWV) incidence, Georgia-03L peanut.

Treatment	df[a]	Pod yield	% mature pods	% TSWV
Year	1	***	NS	***
Rep (Year)	6	***	NS	*
Herbicide	2	**	NS	NS
Year × Herbicide	2	NS	NS	NS
Timing	3	NS	NS	NS
Year × Timing	3	NS	NS	NS
Herbicide × Timing	6	NS	NS	NS
Year × Herbicide × Timing	6	*	NS	NS
Error	66	-	-	-
Coefficient of variation, %		9.96	23.93	34.63

[a]df = degrees of freedom

NS, *, **, *** denote not significantly different, significantly different at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$, respectively.

Table 4. Peanut pod yield as influenced by the interaction among year by herbicide treatment by application timing, Georgia-03L peanut.

	2007			2008		
DAGC[a]	Non-Treated Control	Paraquat	Paraquat plus Bentazon	Non-Treated Control	Paraquat	Paraquat plus Bentazon
	kg/ha					
7	3913[b]	3762	3577	5119	4690	4941
14	3475	3313	3536	5064	4445	4492
21	4288	3226	3634	4476	4805	4968
28	3928	3517	3460	4786	4663	4238

[a]DAGC = days after ground cracking (application timing).

[b]LSD (0.05) = 588 for comparing means within a column, across herbicide treatments within a year, or between years within a given herbicide treatment according to Fisher's protected LSD test.

Table 5. Mature pods at harvest and incidence of tomato spotted wilt virus (TSWV) as influenced by year and herbicide treatment, Georgia-03L peanut.

Variable	mature pods	TSWV
	%	%
Year[a]		
2007	37.4 a	32.7 a
2008	40.1 a	11.8 b
Herbicide Treatment[b]		
Non-Treated Control	37.8 A	24.4 A
Paraquat	39.0 A	22.2 A
Paraquat plus Bentazon	39.4 A	20.1 A

[a]Data pooled over herbicide treatment and application timing. Means within a column followed by the same lowercase letter are not significantly different according to Fisher's protected LSD test at P=0.05.

[b]Data pooled over year and application timing. Means within a column followed by the same uppercase letter are not significantly different according to Fisher's protected LSD test at P=0.05.

reduction from paraquat on newer TSWV-resistant peanut cultivars. Crop injury data were not collected, but it was noted that injury symptoms typical of paraquat (including some stunting and leaf necrosis) were observed from all applications. The data would suggest that application of paraquat based herbicide programs at 7 DAGC might reduce the likelihood of potential yield loss compared to later applications. However, those results were not uniform and later applications up to 28 DAGC were also found to have no yield reduction, especially in Georgia-02C. Neither paraquat nor paraquat plus bentazon caused a reduction in pod maturity compared to the NTC, confirming that yield reduction by paraquat should be considered negligible in most cases, regardless of whether visible peanut injury occurs. The data also shows that paraquat based herbicide applications resulted in either equal or better control of TSWV compared to the NTC in the two cultivars evaluated. It is not understood whether this might be a result of reduced thrips feeding and subsequent infection or a synergistic effect on the genetic resistance to TSWV, or perhaps both. More research is needed to expand the knowledge of such phenomena.

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