

Effect of Imazapic and 2,4-DB on Peanut Yield, Grade, and Seed Germination

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ABSTRACT

Recurrent problems with peanut seed germination and stand establishment have raised concerns about the potential effects of herbicides on peanut seed quality. Field trials were conducted in south Georgia in 2005 and 2006 to evaluate the effects of imazapic and 2,4-DB on peanut yield, grade, incidence of tomato spotted wilt virus (TSWV), and seed germination. Imazapic at 71 g ai ha⁻¹, applied at 30 and 40 days after planting (DAP), and 2,4-DB at 270 g ai ha⁻¹, applied at 75 or 90 DAP, had no effect on peanut yield, grade, incidence of TSWV, and seed germination when averaged over two locations (Dawson and Tifton) and three cultivars (Georgia Green, Georgia-01R, and C-99R). Normal cultivar yield variations were observed; however, Georgia-01R had reduced standard (25 C) and cold (15 C) germination when compared to the other cultivars.

Key Words: Peanut seed vigor; C-99R, Georgia-01R, Georgia Green.

Over the past decade, the major emphasis of peanut breeding programs in the U.S has been on the development of cultivars resistant to tomato spotted wilt virus (TSWV) (Culbreath *et al.*, 2003). Although these new varieties have outstanding resistance to TSWV and other diseases, some may have characteristics, such as reduced germination or poor seed vigor (Morton *et al.*, 2008). In recent years, the cultivars DP-1 (Gorbet and Tillman, 2008) and Georgia-01R (Branch, 2002) had great potential due to their multiple disease resistances but were not widely planted by growers due to poor seed germination and vigor issues (Beasley, 2007).

Peanut seed quality and germination are influenced by many factors including water and calcium availability during pod fill, maturity at harvest, curing and storage at the recommended moisture and temperature levels, and shelling and conditioning with minimal mechanical damage (Guerke, 2005). Because of the recent problems with the

vigor and germination of new cultivars, questions have been raised about the potential of peanut herbicides to have an influence on seed germination.

Numerous studies have been conducted on the effects of herbicides on soybean seed. Early research indicated that herbicides do not significantly alter oil content and cause only relatively small changes in fatty acid composition of soybean seed (Penner and Meggitt, 1970). Subsequent research confirmed that herbicides do not cause important alterations in soybean seed constituents (Stoller *et al.*, 1973). More recently, Bradley *et al.* (2002) found that soybean herbicides had little or no effect on seed germination, protein, and oil content. However, herbicides used as preharvest desiccants, such as glyphosate, paraquat, and sodium chlorate, applied before soybean maturity (R7) have the potential to reduce soybean seed germination (Bennett and Shaw, 2000).

Twelve herbicide active ingredients are labeled for postemergence use in peanut, but only imazapic, imazethapyr, 2,4-DB, and chlorimuron are highly systemic in the peanut plant (Senseman, 2007) and thus have potential to influence seed characteristics. Of these four herbicides, only imazapic and 2,4-DB are used over significant acreages (NASS, 2009). The 2,4-DB molecule is not readily absorbed or phytotoxic, but the secondary metabolite (2,4-D) resulting from beta oxidation is both mobile and phytotoxic (Wathana *et al.*, 1972; Wehtje *et al.*, 1992) in many species. Much research can be found that documents peanut plant injury and/or yield response to 2,4-DB and imazapic (Brecke and Stephenson, 2006; Grey and Wehtje, 2005; Grichar, 2007; Hicks *et al.*, 1998; Wehtje *et al.*, 1993; York *et al.*, 1993), however, little research has been reported on the effects that herbicides may have on seed quality. Lancaster *et al.* (2005) reported that 2,4-DB reduced seed germination of sickelpod (*Senna obtusifolia* L. Irwin and Barneby) 30 to 40% when applied just prior to flowering or during peak flowering. Ketchersid *et al.* (1978) studied the effects of 2,4-DB in peanut and noted enlarged pods with less total sound mature kernels (TSMK), but no yield reduction. Therefore, the objective of this research was to evaluate the effect of imazapic and 2,4-DB on peanut yield, grade, and subsequent seed properties (germination and vigor). TSWV incidence on peanut was also evaluated.

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Materials and Methods

Field studies were conducted in 2005 and 2006 at the Ponder Farm near Tifton, GA and at the Bolton Research Farm near Dawson, GA. Soils were Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiodults) and Red Bay sand (fine-loamy, kaolinitic, thermic Rhodic Kandiodults) at Tifton and Dawson, respectively. Organic matter ranged from 1.0 to 1.1% with pH from 6.0 to 6.5 at Tifton and 1.0% organic matter and pH 6.2 at Dawson.

Peanut was sown in twin rows, spaced 90 cm apart at both locations on conventionally prepared seedbeds. Distance between paired twin rows was 23 cm. Experimental plot size in Tifton was two twin rows by 7.6 m in length, while Dawson plots were six twin rows by 9 m in length. Planting dates were May 9, 2005 at both Tifton and Dawson, and May 10 and May 16, 2006 for Tifton and Dawson, respectively. Rainfall was supplemented with overhead linear irrigation at Tifton, while surface drip irrigation was used at Dawson. Pendimethalin or ethalfluralin plus diclosulam was applied preemergence to the entire test area at both locations to suppress grass and broadleaf weeds. Weed-free conditions were maintained at both locations through mechanical cultivation and hand-weeding. Clethodim was applied for postemergence control of annual and perennial grasses that escaped preemergence herbicides and cultivation. Standard cultural practices for peanut production were followed using University of Georgia Extension recommendations.

The treatments were arranged in a split-plot design with four replications at each location. Peanut cultivars (main plots) were Georgia Green (Branch, 1996), Georgia-01R, and C-99R (Gorbet and Shokes, 2002). Herbicides (sub-plots) were imazapic at 71 g ai ha⁻¹ applied at 30 or 45 d after planting (DAP); 2,4-DB at 270 g ai ha⁻¹ applied at 75 or 90 DAP; and a non-treated control. All herbicides were applied with CO₂-pressurized spray equipment calibrated to deliver 140 L ha⁻¹ total spray volume and included crop oil concentrate at 1% v/v.

Prior to digging, peanut was visually rated for incidence of TSWV. The number of 31 cm sections (a single pair of twin rows) of row containing symptomatic plants was counted for each experimental plot according to Culbreath *et al.* (1997). Data were transformed into percentage based on total row length and reported as percent infection. Maturity was determined using the hull scrape method (Williams and Drexler, 1981) for each variety and plots were mechanically dug and

inverted accordingly. The cultivar Georgia Green was dug approx. 2 wk prior to either Georgia-01R or C-99R at both locations in both years. Plots were mechanically harvested using a stationary plot thresher to ensure sample integrity. Yields were transformed to kg ha⁻¹ at 10% moisture. A 500-g sample was collected randomly using a riffle divider then shelled to obtain medium-sized seed. Medium-sized seed were treated with commercial seed treatment fungicide³ and sent to the Georgia Department of Agriculture Seed Lab in Tifton, GA for germination analysis. Standard (25 C) and cold (15 C) germination tests were conducted. The cold germination test provides some indication of peanut seedling vigor (Guerke, 2005). A 1500-g sample was collected similarly and analyzed for grade, including total sound mature kernels (TSMK), sound splits, and damaged kernels⁴.

Yield, grade, TSWV incidence, standard germination and cold germination data were subjected to Mixed Models analysis of variance⁵. Year and year nested within location were used as random effects. When main effects or interactions were significant ($P \leq 0.05$), Duncan's MRT test was used for mean separation. All percentage data were arcsine transformed prior to analysis. Data transformation did not improve homogeneity of variance, thus actual percentage data are presented.

Results and Discussion

Herbicide Effects. The interaction of herbicide, year, location, and cultivar was not significant. Therefore, data for herbicides are discussed pooled across year, location, and cultivar. Neither imazapic applied at 30 or 45 DAP nor 2,4-DB applied at 75 or 95 DAP effected peanut yield, seed quality, or TSWV incidence (Table 1). Peanut yield ranged from 3930 to 4170 kg ha⁻¹, and light to moderate TSWV incidence (24%) was observed. Peanut seed quality was not affected by herbicide with an average grade of 72 and germination rates of 76% and 72% for standard and cold germination, respectively. These results are similar to Ketchersid *et al.* (1978) who reported that 2,4-DB applied at rates up to 0.45 kg ha⁻¹ did not adversely affect Spanish-type peanut yield or seed quality. The rates used by Ketchersid *et al.* (1978) are approximately twice the current recommended rate for use in

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⁵Statistical Analysis Software 9.1, SAS Institute Inc., Cary NC 27512.

Table 1. The influence of imazapic and 2,4-DB on peanut yield, grade, TSWV incidence, and seed germination in Georgia^a.

Herbicide ^c	Rate <i>g ailha</i>	Application <i>DAP</i>	Yield <i>kg ha⁻¹</i>	TSMK ^b	TSWV	Germination	
						25 C	15 C
Nontreated	—	—	4110 a	72 a	23 a	71 a	77 a
Imazapic	71	30	4030 a	72 a	23 a	71 a	77 a
		45	4030 a	72 a	24 a	74 a	77 a
2,4-DB	270	75	3930 a	72 a	23 a	72 a	74 a
		95	4170 a	72 a	25 a	70 a	75 a

^aData pooled across two years (2005, 2006), two locations (Dawson, Tifton) and three peanut cultivars (Georgia Green, Georgia-01R, C-99R). Means within a column followed by the same letter are not statistically different according to Duncan's MRT ($P = 0.05$).

^bAbbreviations: DAP, days after planting; TSMK, total sound mature kernels.

^cIncluded crop oil concentrate at 1% v/v.

peanut. The current study utilized modern runner-type cultivars and also is distinctive in that 2,4-DB was applied much later in the growing season. Several studies have reported no effect of imazapic on peanut yield and grade despite visual observations of plant injury (Dotray *et al.*, 2001; Grichar, 1997; Webster *et al.*, 1997). However, these earlier studies did not consider seed germination, vigor, or interactions with TSWV.

The interactions of factors other than herbicide including cultivar \times year, cultivar \times location, and year \times cultivar \times location were significant for all five response variables (data not shown). Accordingly, data for cultivar effects were separated by location and/or year and will be presented by location.

Dawson. The interaction of year \times location \times cultivar was significant for both peanut yield and grade. Georgia Green was the highest yielding cultivar in 2005, but was the lowest yielding cultivar in 2006 (Table 2). Similarly, Georgia Green

Table 2. Peanut yield and grade response by year and cultivar, Dawson^{ab}.

Location	Cultivar	Yield	Grade
		<i>kg ha⁻¹</i>	<i>% TSMK</i>
2005	C-99R	4230 c	74 b
	Georgia-01R	4730 b	76 a
	Georgia Green	5210 a	77 a
2006	C-99R	3700 a	71 b
	Georgia-01R	3360 b	73 a
	Georgia Green	2960 c	69 c

^aData presented by year and location due to significant interaction and is pooled across herbicides (imazapic and 2,4-DB). Means within a column and year followed by the same letter are not statistically different according to Duncan's MRT ($P = 0.05$).

^bAbbreviations: TSMK, total sound mature kernels.

had the highest in grade in 2005, but the lowest grade in 2006. Yields in 2005 were 40% greater for all three cultivars versus 2006. The experimental field utilized in 2005 was previously in unimproved bahiagrass (*Paspalum notatum* Fluegge) pasture with no peanut grown in recent history. The portion of the field planted in 2006 had been in continuous peanut rotation since 2004. Thus, the high yields observed in 2005 were expected and likely due to decreased incidence of many common fungal diseases (Katsvairo *et al.*, 2007; Norden *et al.*, 1977). Georgia Green performed well in 2005 in the absence of disease pressure; however, in 2006 when incidence of leafspot (caused by both *Cercospora* spp. and *Cercosporidium* spp.) and white mold (caused by *Sclerotium rolfsii* Sacc.) increased, Georgia Green performance decreased. Conversely, Georgia-01R and C-99R produced high yields in 2005 and were superior to Georgia Green in 2006. Several studies have described the increased tolerance of Georgia-01R and C-99R cultivars to common diseases found in Southeastern U.S. peanut production (Cantonwine *et al.*, 2006; Gorbet and Shokes, 2002). Although disease pressure increased in 2006 at this location, TSWV incidence was low with a maximum rating of 9% (Table 3). Accordingly, no significant response to TSWV was demonstrated.

Standard germination and cold germination were significant for cultivar \times location, but not year. The cultivar Georgia-01R showed reduced germination at both temperatures compared to C-99R or Georgia Green (Table 3). Morton *et al.* (2008) have documented the reduced seed germination and vigor of several late-maturing peanut cultivars. Georgia-01R is considered a late-maturing peanut (Branch, 2002) and has shown tendencies towards reduced germination and vigor in on-farm demonstration. However, yields indicate that despite slow or inconsistent germination, the less

Table 3. Peanut TSWV incidence and germination response by location and cultivar^{ab}.

Location	Cultivar	TSWV	Germination	
			25 C	15 C
		%	%	%
Dawson	C-99R	8 a	79 a	74 a
	Georgia-01R	5 a	71 b	64 b
	Georgia Green	9 a	82 a	76 a
Tifton	C-99R	33 b	74 b	71 a
	Georgia-01R	32 b	66 c	62 b
	Georgia Green	43 a	85 a	74 a

^aData presented by location due to significant interaction and is pooled across herbicides (imazapic and 2,4-DB). Means within a column and location followed by the same letter are not statistically different according to Duncan's MRT (P = 0.05).

^bAbbreviations: TSWV, tomato spotted wilt virus.

determinant growth habit of this later-maturing peanut often compensates for less than optimal stand establishment (Tables 2 and 4).

Tifton. The interaction of year \times location \times cultivar was significant for both peanut yield and grade. Georgia-01R showed highest yield at Tifton for 2005, but no differences were detected between cultivars for 2006 (Table 4). All cultivars had high grades in 2005, with Georgia-01R exceeding both C-99R and Georgia Green (Table 4). Peanut grades were decreased overall during 2006, with both C-99R and Georgia-01R producing a higher percentage of sound mature kernels than Georgia Green. Generally, 2006 was a hotter and drier year when compared to 2005. This may have contributed to the reduced peanut yield and grades in 2006.

Incidence of TSWV and peanut germination data were significant for the interaction of location \times cultivar, but not year. TSWV incidence was greater at Tifton both years when compared to Dawson, exhibiting a 3 to 4 fold increase in incidence (Table 3). As expected, the cultivar Georgia Green showed highest incidence of TSWV compared to either C-99R or Georgia-01R. Continuing a trend shown at the Dawson location, Georgia Green had highest germination response at both temperatures (25 and 15 C), while Georgia-01R consistently performed poorly in germination and vigor response.

Summary and Conclusions

Despite notable differences in cultivar response to growing conditions, neither imazapic nor 2,4-DB influenced peanut performance. Cultivar differenc-

Table 4. Peanut yield and grade response by year and cultivar, Tifton^{ab}.

Location	Cultivar	Yield	Grade
		kg ha ⁻¹	% TSMK
2005	C-99R	4810 b	75 b
	Georgia-01R	5380 a	77 a
	Georgia Green	3790 c	73 c
2006	C-99R	3530 a	69 a
	Georgia-01R	3530 a	69 a
	Georgia Green	3470 a	65 b

^aData presented by year and location due to significant interaction and is pooled across herbicides (imazapic and 2,4-DB). Means within a column and year followed by the same letter are not statistically different according to Duncan's MRT (P = 0.05).

^bAbbreviations: TSMK, total sound mature kernels.

es were the dominant effect in this series of studies as opposed to herbicides. As peanut germination and stand establishment concerns remain high, producers and researchers should focus on other production practices or post-harvest mechanisms that may be decreasing peanut performance rather than the negligible impacts of herbicides. Georgia-01R had reduced seed germination when compared to the other cultivars in this study. This would help explain the establishment problems that have been observed when this cultivar is planted.

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