Weed Technology. 2005. Volume 19:713–718

Deep Tillage and Glyphosate-Reduced Redvine (*Brunnichia ovata*) and Trumpetcreeper (*Campsis radicans*) Populations in Glyphosate-Resistant Soybean[1]

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Abstract: Field studies were conducted during the years 2000 to 2003 at Stoneville, MS, to determine the efficacy of fall deep tillage and glyphosate applications on redvine and trumpetcreeper populations and soybean yield in glyphosate-resistant soybean. Fall deep (≈45 cm) tillage for 1, 2, and 3 yr reduced redvine density by 95, 88, and 97%, respectively, compared with shallow (≈15 cm) tillage, but deep tillage did not reduce trumpetcreeper density. Glyphosate applied preplant reduced trumpetcreeper density (25 to 44%), but not redvine density, compared to that with no glyphosate. Glyphosate early postemergence (EPOST) either alone (45 to 67%) or followed by (fb) late postemergence (LPOST; 59 to 83%) reduced density of trumpetcreeper, but not of redvine, compared to that with no herbicide. However, dry biomass of both vines was reduced with glyphosate EPOST or LPOST compared to that with no herbicide. Soybean yields were higher with deep tillage vs. shallow tillage, glyphosate preplant application vs. no glyphosate, and glyphosate EPOST either alone or fb LPOST vs. no herbicide. Redvine did not reestablish in 2003, which was after skipping fall deep tillage for 1 yr following three consecutive years of deep tillage compared with shallow tillage. It is possible to manage redvine infestations with fall deep tillage and trumpetcreeper infestations with glyphosate preplant and postemergence (POST) in-crop applications. Integration of fall deep tillage and glyphosate POST applications could be an effective strategy to manage combined infestations of these vines in glyphosate-resistant soybean.

Nomenclature: Glyphosate; redvine, *Brunnichia ovata* (Walt.) Shinners #[3] BRVCI; trumpetcreeper, *Campsis radicans* (L.) Seem. ex Bureau # CMIRA; soybean, *Glycine max* (L.) Merr. 'DP4690 RR', 'DP 5806 RR', 'AG 4702 RR'.

Additional index words: Deep tillage, perennial vine, transgenic soybean, weed biomass, weed density.

Abbreviations: EPOST, early postemergence; fb, followed by; LPOST, late postemergence; POST, postemergence; WAP, weeks after planting soybean; WAT, weeks after late postemergence.

INTRODUCTION

Redvine and trumpetcreeper are native, perennial, fast-growing woody vines that climb on any support structure and vegetation or trail along the ground. They are found in cultivated fields, wastelands, fencerows, yards, riverbanks, swamps, and forests and are distributed extensively in the lower Mississippi Delta and throughout the southern United States. In cultivated fields, their infestations may range from spotty to severe, with infestations confined mainly to fine-textured soils (Elmore et al. 1989; Shaw and Mack 1991; Shaw et al. 1991). Redvine and trumpetcreeper are among the 10 most troublesome weeds in cotton (*Gossypium hirsutum* L.), soybean, and corn (*Zea mays* L.) in the midsouthern United States (Webster 2000, 2001). These weeds are difficult to control, because they can propagate from a deeply positioned and extensive root system (Elmore et al. 1989; Shaw and Mack 1991). Redvine (Shaw et al. 1991) and trumpetcreeper (Chachalis and Reddy 2000) also can reproduce by seed and have the potential to spread to new areas by dispersed seeds. These vines reduce crop yield and quality as well as harvest efficiency (Elmore 1984). Edwards and Oliver (2001) observed that even low densities of trumpetcreeper can interfere with soybean and that one trumpetcreeper plant per 0.5 m^2 can cause 18% loss in yield.

Contact herbicides (e.g., acifluorfen, glufosinate, lactofen, paraquat) that are active on redvine and trumpetcreeper kill only the top growth and have little or no

[1] Received for publication August 2, 2004, and in revised form January 5, 2005.

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

effect on the rootstock (Reddy and Chachalis 2004; Shaw and Mack 1991). Desiccation of foliage is only temporary and often partial, and new sprouts arise from underground rootstocks. Transgenic soybean resistant to glyphosate provides the option to use glyphosate, a non-selective herbicide to control redvine and trumpetcreeper within the crop (DeFelice and Oliver 1980; Edwards and Oliver 2001; Reddy and Chachalis 2004). Despite glyphosate translocation to rootstocks of these vines, under field conditions the amount accumulated may not be lethal because of limited translocation within the long and large rootstocks (Chachalis and Reddy 2004; Reddy 2000). Glyphosate is translocated to the rootstocks only if the rootstocks are immediately connected to the shoots that intercept the glyphosate spray. Furthermore, glyphosate movement gradually decreases from the point of attachment of treated shoot to farther along the rootstock (Chachalis and Reddy 2005). As a result, control of these vines in glyphosate-resistant soybean may be unsatisfactory with glyphosate registered-use rates (Akin and Shaw 2004; Bradley et al. 2004; Chachalis and Reddy 2004; Chachalis et al. 2001; Reddy 2000; Yonce and Skroch 1989).

Because glyphosate alone may not provide complete control of these vines, additional management tactics are needed (Reddy and Chachalis 2004). The present study examines integration of fall deep tillage and glyphosate for management of redvine and trumpetcreeper in glyphosate-resistant soybean. The specific objectives were to determine the effect of fall deep tillage and glyphosate preplant and postemergence (POST) in-crop applications on redvine and trumpetcreeper populations and on glyphosate-resistant soybean yield.

MATERIALS AND METHODS

General Conditions. Field studies were conducted on a producer farm with natural and uniform infestations of redvine and trumpetcreeper near the U.S. Department of Agriculture–Agricultural Research Service, Southern Weed Science Research Unit farm, Stoneville, MS. The soil was a Dundee silty clay loam (fine-silty, mixed, thermic Aeric Ochraqualfs) with pH 6.9 and 1.6% organic matter. Before initiation of the study, the experimental area was under conventional-tillage soybean production for at least 4 yr. The studies were conducted under a nonirrigated environment. Herbicide treatments were applied with a tractor-mounted sprayer with 8,004 standard flat spray tips[4] delivering 187 L/ha of water at 179 kPa.

[4] TeeJet standard flat spray tips. Spraying Systems Co., North Avenue and Schmale Road, Wheaton, IL 60189.

Deep Tillage and Glyphosate Study. This study was conducted during the years 2000 to 2002 to determine the effectiveness of fall deep tillage and glyphosate applied preplant and POST on redvine and trumpetcreeper populations in glyphosate-resistant soybean. The experiment was conducted in a split-split plot arrangement of treatments in a randomized complete block design with four replications. Tillage was considered as the main plot, glyphosate preplant application as the subplot, and glyphosate POST in-crop applications as the sub-subplot. Each sub-subplot consisted of four soybean rows spaced 102 cm apart and 19.8 m in length. Treatments were assigned to the same plots in all three years to assess the effect of consecutive fall deep tillage and glyphosate applications on redvine and trumpetcreeper populations.

Main plot treatments were deep and shallow tillage in the fall of the previous year. The plots were deep-tilled with a chisel plow implement having curved tines spaced 1 m apart. The plots were deep-tilled twice, both parallel and at a 45° angle to the row direction, to a depth of approximately 45 cm. After deep tillage, seedbeds were prepared with a disk harrow and/or a field cultivator. The shallow-tilled plots were disked twice with a disk harrow to approximately 15 cm of depth, followed by a field cultivator. Both shallow- and deep-tilled plots received no tillage operations during the spring before planting. Subplots were preplant application of glyphosate at 2.52 kg ae/ha at 2 wk before planting soybean and no glyphosate control. Sub-subplot treatments were glyphosate early postemergence (EPOST) at 1.26 kg/ha, glyphosate EPOST at 1.26 kg/ha followed by (fb) glyphosate late postemergence (LPOST) at 0.84 kg/ha, and a no-herbicide control (Table 1). The commercial formulation of isopropylamine salt of glyphosate[5] was used with no additional adjuvant.

Glyphosate-resistant soybean cultivars and planting dates were ‘DP5806 RR’ on May 16, 2000; ‘DP4690RR’ on May 9, 2001; and ‘AG4702RR’ on May 9, 2002. Cultivars were selected based on regional use patterns by producers and seed availability. Soybean was planted in 102-cm-wide rows using a planter[6] at 325,000 seeds/ha. Pendimethalin at 0.84 kg ai/ha plus imazaquin at 0.14 kg ai/ha plus paraquat at 1.12 kg ai/ha in 2000 and metolachlor at 2.30 kg ai/ha plus flumetsulam at 0.07 kg ai/ha plus paraquat at 1.12 kg ai/ha in 2001 and 2002 were applied to the entire experimental area immediately

[5] Roundup Ultra® and Roundup UltraMax®, isopropylamine salt of glyphosate. Monsanto Agricultural Company, 800 North Lindbergh Boulevard, St. Louis, MO 63167.

[6] MaxEmerge 2 planter. Deere and Co., 501 River Drive, Moline, IL 61265.

Table 1. Redvine density and dry biomass at 4 WAT as affected by tillage and glyphosate preplant and postemergence applications in glyphosate-resistant soybean at Stoneville, MS, in 2000 to 2002.[a,b]

Main effect	Glyphosate application		Redvine density			Redvine dry biomass		
	Rate	Timing	2000	2001	2002	2000	2001	2002
	kg ae/ha		stems/m²			g/m²		
Tillage								
Shallow	—	—	27.6 a	41.8 a	45.5 a	63.0 a	88.6 a	95.2 a
Deep	—	—	1.4 b	5.0 b	1.5 b	7.6 b	21.6 b	4.6 b
Preplant								
No glyphosate	—	—	16.4 a	23.7 a	23.6 a	38.0 a	61.9 a	62.8 a
Glyphosate	2.52	Preplant	12.5 a	23.1 a	23.3 a	32.5 a	48.3 a	37.1 a
In-crop postemergence								
No herbicide	—	—	15.5 a	29.3 a	30.2 a	62.3 a	90.1 a	73.3 a
Glyphosate	1.26	EPOST	15.8 a	20.3 a	21.4 a	24.9 b	55.8 ab	41.2 b
Glyphosate fb glyphosate	1.26 0.84	EPOST LPOST	12.1 a	20.6 a	18.8 a	18.5 b	19.3 b	35.2 b

[a] Abbreviations: EPOST, early postemergence; fb, followed by; LPOST, late postemergence; WAT, wk after LPOST.

[b] Means within a column for each main effect followed by same letter are not significantly different at the 5% level as determined by Fisher's least-significant-difference test.

after planting. Residual herbicides were applied to control all other weeds. Because of the difficulty in soybean stand establishment, existing vegetation in no-glyphosate plots and new sprouts and/or partially killed redvine and trumpetcreeper plants in glyphosate preplant-applied plots were desiccated with paraquat at planting. Both EPOST and LPOST treatments were applied 4 and 6 wk after planting (WAP) soybean, respectively. Fluazifop-P at 0.28 kg ai/ha was applied POST during midseason as needed to control grass weeds.

Redvine and trumpetcreeper plants were counted, and aboveground biomass was harvested and dry weights recorded from two randomly selected, 1-m² areas between the center two rows of each plot at 4 wk after LPOST (WAT). Soybean was harvested from each entire plot using a combine, and grain yield was adjusted to 13% moisture in 2001 and 2002. The soybean crop failed in 2000 because of late-summer drought, and grain yields in that year were too low to justify harvesting. The data were subjected to analysis of variance using Proc Mixed, and the least-square means were calculated (Statistical Analysis Systems 2001). Treatment means were separated at the 5% level of significance using Fisher's protected least-significant-difference test.

Redvine and Trumpetcreeper Reestablishment. This study was conducted in 2003 to determine the reestablishment potential of redvine and trumpetcreeper following three consecutive years of deep tillage and preplant application of glyphosate. The same experimental design as described in the above study was used without imposing deep tillage and preplant application of glyphosate. After the harvest of soybean in the above study, the entire experimental area was left undisturbed in the fall of 2002. In the spring of 2003, both shallow- and deep-tilled plots were prepared for planting using a disk harrow and a field cultivator.

Glyphosate-resistant soybean cultivar 'AG4702RR' was planted on April 14, 2003. Soybean was planted in 102-cm-wide rows using a planter[7] at 325,000 seeds/ha. Metolachlor at 2.30 kg/ha plus flumetsulam at 0.07 kg/ha plus paraquat at 1.12 kg/ha were applied to the entire experimental area immediately after planting. Glyphosate EPOST at 1.26 kg/ha, glyphosate EPOST at 1.26 kg/ha fb glyphosate LPOST at 0.84 kg/ha, and a no-herbicide control were imposed on the respective sub-subplots of the above study. Both EPOST and LPOST treatments were applied at 4 and 6 WAP, respectively.

Redvine and trumpetcreeper plants were counted from two randomly selected, 1-m² areas in the middle of each plot at 8 WAT. Soybeans were harvested from each entire plot using a combine, and grain yield was adjusted to 13% moisture. The data were subjected to analysis of variance and means separation test as previously described. Data were averaged across main effects, because interactions were not significant.

RESULTS AND DISCUSSION

Deep Tillage and Glyphosate Study. Deep tillage decreased redvine density by 95% in year 1, 88% in year 2, and 97% in year 3 compared to that with shallow tillage, but it did not decrease the trumpetcreeper density (Tables 1 and 2). A similar pattern was observed for dry

[7] MaxEmerge 2 planter. Deere and Co., 501 River Drive, Moline, IL 61265.

Table 2. Trumpetcreeper density and dry biomass at 4 WAT as affected by tillage and glyphosate preplant and postemergence applications in glyphosate-resistant soybean at Stoneville, MS, in 2000 to 2002.[a,b]

Main effect	Glyphosate application		Trumpetcreeper density			Trumpetcreeper dry biomass		
	Rate	Timing	2000	2001	2002	2000	2001	2002
	kg ae/ha		stems/m²			g/m²		
Tillage								
Shallow	—	—	3.5 a	2.9 a	2.4 a	17.9 a	22.0 b	28.4 a
Deep	—	—	5.1 a	4.1 a	3.0 a	28.6 a	31.8 a	21.3 a
Preplant								
No glyphosate	—	—	4.9 a	4.5 a	3.4 a	30.8 a	39.2 a	37.4 a
Glyphosate	2.52	Preplant	3.7 a	2.5 b	2.1 b	15.7 a	14.6 b	12.1 b
In-crop postemergence								
No herbicide	—	—	6.6 a	5.5 a	5.4 a	48.8 a	64.5 a	67.4 a
Glyphosate	1.26	EPOST	3.6 b	2.9 b	1.8 b	15.4 b	11.6 b	4.9 b
Glyphosate fb glyphosate	1.26	EPOST	2.7 b	2.1 b	0.9 b	5.4 b	4.6 b	2.1 b
	0.84	LPOST						

[a] Abbreviations: EPOST, early postemergence; fb, followed by; LPOST, late postemergence; WAT, wk after LPOST.

[b] Means within a column for each main effect followed by same letter are not significantly different at the 5% level as determined by Fisher's least-significant-difference test.

biomass of redvine and trumpetcreeper. The reduction in redvine density might be attributed to fall deep tillage. Deep tillage can physically break up the network of rootstocks, and root segments that are brought to the surface may be destroyed by exposure to ambient conditions in the winter and early spring. Redvine is more susceptible to cooler temperatures and shorter root segments compared with trumpetcreeper (Chachalis and Reddy 2005). Redvine control in this study was higher than that reported by Heatherly et al. (2004), partly because of differences in experimental conditions. Plots were deep-tilled twice in this study, compared with once in the study by Heatherly et al. (2004). Redvine control was based on density and biomass in this study, compared with control based on weed ground cover in the study by Heatherly et al. (2004).

Glyphosate applied preplant did not reduce density or dry biomass of redvine compared to that with no glyphosate in all three years (Table 1), a pattern similar to that reported by other researchers (Reddy and Chachalis 2004). In trumpetcreeper, glyphosate applied preplant had no effect on density and dry biomass in 2000 but reduced both density (38 to 44%) and dry biomass (63 to 68%) in the subsequent two years (Table 2).

Glyphosate applied EPOST or EPOST fb LPOST had no effect on density, but reduced dry biomass of redvine (38 to 79%), compared to that with no glyphosate control in glyphosate-resistant soybean (Table 1). However, in a field study by Akin and Shaw (2004), in-crop application of glyphosate reduced redvine density in glyphosate-resistant soybean. Those authors observed that both single and sequential in-crop applications of glyphosate reduced redvine density by 31 and 42%, respectively, compared to that with no glyphosate. In trumpetcreeper, glyphosate EPOST alone or EPOST fb LPOST reduced both density (45 to 83%) and dry biomass (68 to 97%) compared to those with no-glyphosate control (Table 2). The levels of reduction in density of trumpetcreeper were similar to that reported by Bradley et al. (2004). Trumpetcreeper densities ranged from 30 to 66% of the initial population 1 yr after preplant fb POST or POST-only applications of glyphosate in glyphosate-resistant soybean (Bradley et al. 2004). In contrast to redvine, glyphosate preplant and POST applications in glyphosate-resistant soybean was more effective in reducing density of trumpetcreeper. Other researchers have shown that compared to redvine, trumpetcreeper is more susceptible to glyphosate (Chachalis et al. 2001).

Soybean yield was 47 and 142% higher with deep tillage compared to the yield with shallow tillage in 2001 and 2002, respectively (Table 3). Glyphosate applied preplant resulted in higher soybean yield in 2001 and similar yield in 2002 compared to those with no glyphosate. Glyphosate EPOST fb LPOST in 2001 and 2002 as well as glyphosate EPOST alone in 2001 produced higher soybean yield compared to that with no glyphosate control. Overall, increased soybean yield in deep tillage, glyphosate preplant, and glyphosate EPOST and LPOST was reflective of decreased density and dry biomass of trumpetcreeper, redvine, or both.

Redvine and Trumpetcreeper Reestablishment. Redvine did not reestablish in 2003, after skipping fall deep tillage for a 1-yr period following three consecutive

Table 3. Effect of tillage and glyphosate preplant and postemergence applications on glyphosate-resistant soybean yield at Stoneville, MS, in 2001 and 2002.[a,b]

Main effect	Glyphosate application: Rate	Glyphosate application: Timing	Soybean yield: 2001	Soybean yield: 2002
	kg ae/ha		kg/ha	kg/ha
Tillage				
Shallow	—	—	2,170 b	1,140 b
Deep	—	—	3,200 a	2,760 a
Preplant				
No glyphosate	—	—	2,450 b	1,850 a
Glyphosate	2.52	Preplant	2,920 a	2,050 a
In-crop postemergence				
No herbicide	—	—	2,340 c	1,850 b
Glyphosate	1.26	EPOST	2,740 b	1,930 b
Glyphosate fb glyphosate	1.26	EPOST	2,970 a	2,070 a
	0.84	LPOST		

[a] Abbreviations: EPOST, early postemergence; fb, followed by; LPOST, late postemergence.

[b] Means within a column for each main effect followed by same letter are not significantly different at the 5% level as determined by Fisher's least-significant-difference test.

years of deep tillage compared with shallow tillage. In 2003, previously deep-tilled plots had lower density of redvine (95%) and similar density of trumpetcreeper compared with shallow-tilled plots (Table 4). The plots that received preplant applications of glyphosate in previous years had no effect on redvine but decreased the density of trumpetcreeper compared to that in no-glyphosate plots. The trend regarding densities of these vines was similar to that observed in 2000 to 2002 when deep tillage and glyphosate preplant applications were imposed (Tables 1 and 2). In 2003, glyphosate EPOST either alone or fb LPOST reduced the density of trumpetcreeper, but not of redvine, which was a trend similar that observed in 2000 to 2002.

Soybean yield was greater in previously deep-tilled vs. shallow-tilled plots, similar with glyphosate preplant vs. no glyphosate, and higher with glyphosate EPOST alone or fb LPOST vs. no glyphosate (Table 4). Apparently, redvine and trumpetcreeper densities did not reestablish during the 1 yr following three years of deep tillage and glyphosate preplant applications. This response suggests that integration of glyphosate preplant application with deep tillage could be used as a tool in the management of these perennial vines in both glyphosate-resistant and nonresistant soybean.

The results of this study indicate that deep tillage can be an effective tool in the management of redvine but not of trumpetcreeper. Glyphosate applied preplant has the potential to reduce the density of trumpetcreeper, but not of redvine, compared to that with no glyphosate. Similarly, glyphosate in-crop applications (EPOST and EPOST fb LPOST) were more effective on trumpetcreeper (reduced density and reduced growth) than redvine (reduced growth only) in glyphosate-resistant soybean. Preplant application of glyphosate and sequential applications of glyphosate in glyphosate-resistant soybean did not reduce redvine density under the conditions of this study. These findings are in agreement with those of earlier studies (Reddy and Chachalis 2004).

Overall, lack of reduction in redvine density even after multiple applications of glyphosate could be due to severe infestations and long or large rootstocks of redvine

Table 4. Redvine and trumpetcreeper density 8 WAT and glyphosate-resistant soybean yield in 2003 after termination of a 3-yr study (2000–2002) with tillage and glyphosate preplant and postemergence applications at Stoneville, MS. In 2003, glyphosate EPOST, EPOST fb LPOST, and no-herbicide control were imposed on the respective sub-subplot.[a,b]

Main effect	Glyphosate application: Rate	Glyphosate application: Timing	Density: Redvine	Density: Trumpetcreeper	Soybean yield
	kg ae/ha		stems/m²	stems/m²	kg/ha
Tillage					
Shallow	—	—	45.2 a	2.5 a	1,240 b
Deep	—	—	2.3 b	2.3 a	2,420 a
Preplant					
No glyphosate	—	—	28.9 a	3.3 a	1,820 a
Glyphosate	2.52	Preplant	18.6 a	1.4 b	1,840 a
In-crop postemergence					
No herbicide	—	—	31.6 a	4.8 a	1,690 b
Glyphosate	1.26	EPOST	17.8 a	1.1 b	1,850 a
Glyphosate fb glyphosate	1.26	EPOST	21.8 a	1.1 b	1,950 a
	0.84	LPOST			

[a] Abbreviations: EPOST, early postemergence; fb, followed by; LPOST, late postemergence.

[b] Means within a column for each main effect followed by same letter are not significantly different at the 5% level as determined by Fisher's least-significant-difference test.

in the experimental area. Because of limited translocation of glyphosate to rootstocks (Chachalis and Reddy 2004; Reddy 2000), lethal amounts of herbicide may not have been accumulated in underground rootstocks of redvine. Furthermore, translocation is limited to the rootstocks immediately attached to the shoots that intercepted the glyphosate spray. As a result, new flushes of shoots may have emerged from the underground rootstocks. Poor control of redvine likely results from regrowth of plants that were partially controlled. Integration of fall deep tillage that exposes rootstocks to harsh winter conditions and glyphosate POST applications could be an effective strategy to manage these perennial vines in glyphosate-resistant soybean.

ACKNOWLEDGMENT

The author thanks Albert Tidwell and Terry Newton for technical assistance in field work.

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