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WEED SCIENCE

Yield Of Glyphosate-Tolerant Cotton As Affected By Topical Glyphosate Applications On The Texas High Plains And Rolling Plains

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ABSTRACT

Boll abscission may occur following glyphosate application to glyphosate-tolerant cotton (*Gossypium hirsutum* L.) due to altered male floral morphology and poor pollination. The ability of glyphosate-tolerant cotton to compensate for boll abscission ascribed to glyphosate may be limited with stripper-type cultivars grown on the Texas High Plains and Rolling Plains. The objective of this study was to determine yield response of stripper cotton to glyphosate applied postemergence topically after the four-leaf stage. On the Texas Rolling Plains, yields of cultivar Paymaster 2326RR were recorded following glyphosate applied postemergence at the 6-, 9-, or 12-node stages. On the Texas High Plains, yield of cultivars Paymaster 2326RR and Paymaster 2200RR was recorded following glyphosate applied postemergence at mid-bloom or later. At one of four locations, glyphosate applied postemergence to four-leaf cotton followed by glyphosate applied postemergence to 9- or 12-node cotton reduced yields. Yield also was reduced by glyphosate applied postemergence to mid-bloom cotton but not by glyphosate applied postemergence at six nodes above white flower or later. These studies suggest stripper-type glyphosate-tolerant cotton may suffer yield losses when glyphosate is applied contrary to the label.

Glyphosate-tolerant cotton, first commercially available in 1997, has been readily accepted by growers in the United States (USDA-ERS, 2003). Widespread planting of glyphosate-tolerant cotton is due to a number of advantages offered by this technology, including control of a broad spectrum of annual and perennial grass and broadleaf weeds with the convenience of postemergence topical applications (Culpepper and York, 1998; Faircloth et al., 2001; Scott et al., 2002). Since the onset of commercialization of glyphosate-tolerant cotton, the manufacturer has recommended that glyphosate only be applied over-the-top through the four-leaf stage and all subsequent applications be applied postemergence-directed (Johnson, 1996; Sherrick 1996). In picker-type glyphosate-tolerant cultivars, significant fruit abscission has been observed in Mississippi, North Carolina, Arkansas, and Georgia following both off-label and labeled glyphosate applications (Brown and Bednarz, 1998; Ferreira et al., 1998; Jones and Snipes, 1999; Kalaher and Coble, 1998). Additionally, yield reductions were observed in North Carolina and Georgia with glyphosate applied postemergence after the four-leaf growth stage (Brown and Bednarz, 1998; Kalaher and Coble, 1998).

Boll abscission is likely attributable to lower expression of the inserted CP4-EPSP synthase (E.C.2.5.1.19) in male reproductive tissues, resulting in altered floral morphology in glyphosate-tolerant plants and poor pollination (Pline et al., 2002). Under favorable growing conditions, cotton can compensate for fruit abscission on sympodia at lower nodes by setting more fruit at higher nodes (Jones and Snipes, 1999), but maturity will be delayed, and yield may be reduced (Kalaher and Coble, 1998).

Glyphosate-tolerant cotton cultivars planted on the Texas High Plains and Rolling Plains are primarily stripper-type. Most of the contemporary cultivars of this type are characterized by relatively compact plant height, relatively determinant fruiting habit, and either storm-resistant or stormproof bolls (Niles and Feaster, 1984). Determinant-type cultivars have been shown to terminate reproductive development abruptly, and they do not readily begin a second fruiting cycle (Milroy and Bange, 2003). Determinacy is considered necessary because of

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moisture and temperature factors that limit the effective growing season (Niles and Feaster, 1984). The ability of stripper-type cultivars to compensate for boll abscission attributable to glyphosate may be particularly important since research that has shown long periods of temperature stress exist on the Texas High Plains (Light et al., 2001). Therefore, an examination of the tolerance of stripper-type glyphosate-tolerant cotton to glyphosate applied postemergence on the Texas High Plains and Rolling Plains is needed. The objective of this study was to determine the yield response of glyphosate-tolerant cotton to glyphosate applied postemergence at various rates to cotton in various growth stages.

MATERIALS AND METHODS

Field experiments on the Texas Rolling Plains were performed in 1997 and 1998 at Childress, Texas, and in 1998 and 1999 at Chillicothe, Texas, using cotton cultivar PM 2326RR. Field experiments on the Texas High Plains were performed in 1997 at Halfway, Texas, using cotton cultivar PM 2200RR and at Lubbock, Texas, using PM 2326RR. Soils at Childress and Chillicothe were a St. Paul silt loam (fine-silty, mixed, superactive, thermic, Pachic Argiustolls) with pH 7.7 and 1.4% organic matter and an Abilene clay loam (fine, mixed, superactive, thermic, Pachic Argiustolls) with pH 8.1 and 0.2% organic matter, respectively. Soils at Halfway and Lubbock were an Olton loam (fine, mixed, superactive, thermic Aridic Paluestoll) with pH 7.6 and 0.8% organic matter and an Acuff sandy clay loam (fine-loamy, mixed, superactive, thermic Aridic Paluestoll) with pH 7.8 and 0.7% organic matter, respectively. Cotton was planted in conventionally tilled seedbeds using 102-cm row spacing on 2 June 1997 and 26 May 1998 in Childress, 21 May 1998 and 1 June 1999 in Chillicothe, 14 May 1997 at Halfway, and 17 May 1997 at Lubbock. Plot size was 2 to 4 m wide by 8 m long at Childress and Chillicothe and 4 m wide by 12 m long at Halfway and Lubbock.

At Childress and Chillicothe, trifluralin (Treflan, Dow AgroSciences LLC, Indianapolis, IN) at 840 g ai ha^{-1} was incorporated prior to planting. Glyphosate isopropylamine salt (Roundup Ultra, Monsanto Company, St. Louis, MO) at 420, 630, or 840 kg ai ha^{-1} was applied postemergence (POST) when the cotton had 6, 9, or 12 nodes. These applications were preceded by glyphosate at 840 g ha^{-1} applied POST at the four-leaf stage. Additional treatments included a standard glyphosate program of 840 g ha^{-1} applied POST at the four-leaf stage followed by 840 g ha^{-1} applied postemergence-directed to six-node cotton, and a standard herbicide program consisting of pyrithiobac (Staple, Dupont Agricultural Products, Wilmington, DE) at 72 g ai ha^{-1} plus non-ionic surfactant (Latron AG-98, Dow AgroSciences LLC, Indianapolis, IN) at 0.25 % (v/v) applied POST to four-leaf cotton followed by prometryn (Caparol, Syngenta Crop Protection, Greensboro, NC) at 0.6 kg ai ha^{-1} plus MSMA (monosodium salt of methylarsonic acid; MSMA 6.6, United Agri Products, Wall Lake, IA) at 2.2 kg ai ha^{-1} applied postemergence-directed to 12-node cotton.

At Halfway and Lubbock, glyphosate at 840 kg ha^{-1} was applied POST when the cotton had 4, 5, or 6 nodes above white flower (NAWF) and at 1680 g ha^{-1} when cotton was at mid-bloom, 3, 4, 5, or 6 NAWF, or at the 20% open boll stage. These applications were preceded by glyphosate at 840 kg ha^{-1} applied POST at the 2- to 3-leaf stage. All locations included untreated checks. All treatments at Childress and Chillicothe were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 187 L ha^{-1} at 103 kPa using 8003 flat-fan nozzles (Spraying Systems Company, Wheaton, IL) and all glyphosate treatments included ammonium sulfate at 3.8 kg ha^{-1}. Treatments at Lubbock and Halfway were applied with a CO_2-pressurized backpack sprayer calibrated to deliver 94 L ha^{-1} at 103 kPa using 80015 flat-fan nozzles (Spraying Systems Company, Wheaton, IL).

All plots were maintained weed-free by hand weeding or hoeing as needed. Cotton was furrow irrigated (6.5 cm) mid-season at Chillicothe. Cotton was not irrigated at Childress, Halfway, or Lubbock. At Childress and Chillicothe, a 3-m section from one row in the center of each plot was hand-harvested. At Halfway and Lubbock, 6 m from the middle two rows of each plot were hand-harvested. All cotton was ginned at the Texas A & M Experiment Station, Lubbock, Texas, to determine lint percentage and yield. Lint yields were determined by multiplying the seed cotton weights by lint percentage.

Experimental design and data analysis. Treatments at Childress and Chillicothe were arranged in a randomized complete block with four replications and re-randomized each year. Treatments at Halfway and Lubbock were arranged in a randomized complete block with six replications. Data from experiments in 1997 and 1998 at Childress were combined for a single analysis that tested for the effects of treatment, as well as year and the interaction between treatment and year (Kempthorne, 1952). Similarly, data from 1998 and 1999 from Chillicothe were combined. In 1998, data from Chillicothe and Childress were combined following Kempthorne (1952) in order to test effects of treatment, location, and the treatment by location interaction. The two experiments on the High Plains were analyzed separately, because the effects of cultivar and location are confounded for treatments applied at Lubbock and Halfway. Assumptions of normality were assessed using the procedure defined by Shapiro and Wilk (1965). Data were subjected to analysis of variance using SAS version 8.2 (SAS Institute, Inc., Cary, NC) with treatment means separated using Fisher's Protected LSD ($P = 0.05$).

RESULTS AND DISCUSSION

A treatment by year interaction was observed for lint yield ($P = 0.0001$) at Childress. In 1997, compared with the untreated check, neither the conventional herbicide program nor glyphosate at 840 g ha^{-1} applied POST to four-leaf cotton followed by glyphosate at 840 g ha^{-1} applied post emergence-directed to six-node cotton adversely affected cotton yield (Table 1). Similarly, yield of cotton receiving glyphosate at 840 g ha^{-1} applied POST to four-leaf cotton followed by glyphosate at 420, 630, or 840 g ha^{-1} applied POST to six-node cotton did not differ from the yield of untreated cotton. Glyphosate at 840 g ha^{-1} applied POST to four-leaf cotton followed by glyphosate at 420 g ha^{-1} applied POST to nine-node cotton or glyphosate at 630 or 840 g ha^{-1} applied POST to 9- or 12-node cotton reduced yield 21 to 55% compared with the untreated check. No herbicide treatment affected cotton lint yield relative to the untreated check at Childress in 1998.

A treatment by year interaction was not observed at Chillicothe ($P = 0.2364$). Cotton lint yields at this location, averaged over years, was not different between the untreated check and any herbicide treatment ($P = 0.8486$) (Table 1), but yields were different between years ($P = 0.0001$). Averaged over treatments, yields were 420 and 310 kg ha^{-1} in 1998 and 1999, respectively (data not shown). Lower yield in 1999 may have been due to higher than normal tem-

Table 1. Effect of glyphosate applied postemergence (POST) over-the-top at three growth stages, applied postemergence-directed (PD), and a conventional herbicide program on lint yield of glyphosate-tolerant cotton on the Texas Rolling Plains

Herbicide treatment[y]	Rate (g ha^{-1})	Cotton growth stage	Lint yield (kg ha^{-1})[z]		
			Childress		Chillicothe
			1997	1998	
Glyphosate POST	420	6-node	660 a	420 ab	390
Glyphosate POST	420	9-node	460 cde	460 ab	370
Glyphosate POST	420	12-node	510 bcd	500 ab	340
Glyphosate POST	630	6-node	570 abc	430 ab	370
Glyphosate POST	630	9-node	420 de	450 ab	380
Glyphosate POST	630	12-node	380 e	470 ab	350
Glyphosate POST	840	6-node	520 bcd	540 a	370
Glyphosate POST	840	9-node	260 f	440 ab	370
Glyphosate POST	840	12-node	400 de	500 a	340
Glyphosate PD	840	6-node	670 a	380 b	370
Conventional			540 bc	500 ab	340
Untreated			580 ab	450 ab	380

[y]All treatments, except the untreated check and the conventional herbicide program, received glyphosate at 0.84 kg ha-1 applied POST at the four-leaf stage and trifluralin preplant incorporated at 0.84 kg ha-1. Conventional herbicide program consisted of pyrithiobac at 72 g ha^{-1} applied POST to four-leaf cotton followed by prometryn at 0.6 kg ha^{-1} plus MSMA at 2.2 kg ha^{-1} applied PD to 12-node cotton.

[z]Means within a column at followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P = 0.05$). Means at Chillicothe averaged over 2 years (1997 and 1998) were not significantly different.

peratures in August. Maximum temperature exceeded 37C for 26 days in August (NNDC, 2003). It has been shown that significant fruit shed occurs at temperatures above 35C (Reddy et al., 1992). Averaged over treatments, lint yields of 460 kg ha^{-1} at Childress in 1998 and 420 kg ha^{-1} at Chillicothe in 1998 were not different ($P = 0.2107$).

A treatment by location interaction was observed in the experiment on the Texas High Plains ($P = 0.0306$). Lint yield was reduced 26 and 17% at Halfway and Lubbock, respectively, by glyphosate at 840 g ha^{-1} applied to 2- to 3-leaf cotton followed by glyphosate at 1680 g ha^{-1} applied at mid-bloom (Table 2). Regardless of application rate, glyphosate applied to cotton with six NAWF or later following application to 2- to 3-leaf cotton did not impact yield at Halfway. Glyphosate at 840 g ha^{-1}, but not 1680 g ha^{-1}, applied to cotton with six NAWF reduced yield at Lubbock. Glyphosate at 840 g ha^{-1} applied to 2- to 3-leaf cotton followed by glyphosate at 840 or 1680 g ha^{-1} applied to cotton with five NAWF or later did not affect yield.

Table 2. Effect of glyphosate applied postemergence over-the-top of glyphosate-tolerant cotton on lint yield on the Texas High Plains

Glyphosate (g ha^{-1})[x]	Cotton growth stage[y]	Lint yield (kg ha^{-1})[z]	
		Halfway	Lubbock
1680	Mid-bloom	510 b	450 b
840	6 NAWF	790 a	450 b
1680	6 NAWF	800 a	480 ab
840	5 NAWF	800 a	520 ab
1680	5 NAWF	660 a	490 ab
840	4 NAWF	680 a	470 ab
1680	4 NAWF	730 a	480 ab
1680	3 NAWF	810 a	520 ab
1680	20% open bolls	770 a	530 ab
Untreated		690 a	540 a

[x] All treatments, except the untreated check, received glyphosate at 840 g ha^{-1} applied postemergence over-the-top of 2- to 3-leaf cotton.

[y] NAWF = nodes above white flower.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's Protected LSD test ($P = 0.05$).

In these experiments with stripper-type cotton, yield losses due to glyphosate application were noted only when the herbicide was applied POST after the four-leaf stage. Yield was not reduced by glyphosate applied POST to four-leaf cotton followed by a postemergence-directed application of glyphosate. The results are similar to those of Matthews et al. (1998) and Vargas et al. (1998) who showed that glyphosate applied according to the manufacturer's recommendations did not adversely affect cotton yield. Glyphosate applied POST after the four-leaf stage did not always reduce cotton yield. Although no determinations were made, it is likely that the cotton at Childress in 1998 compensated for any fruit abscission on lower sympodia by setting more bolls at higher sympodia. Under environmental conditions not conducive to compensation, fruit abscission following POST applications beyond the four-leaf stage may reduce yield.

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