Physiological and Yield Response of Transgenic and Non-Transgenic Corn to Glyphosate

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ABSTRACT

A field study investigated physiological and yield responses of transgenic glyphosate-resistant (GR) and GR stacked with glufosinate-resistant (GR/LR) corn to label rates of glyphosate, and conventional (CONV) corn to a drift rate of glyphosate. Glyphosate at 0.84 or 1.26 kg ae/ha was applied twice at 3 and 6 weeks after planting (WAP) to transgenic corn. Glyphosate at 0.105 kg ae/ha was applied once at 3 or 6 WAP to CONV corn. Glyphosate caused injury and increased shikimate levels in CONV corn but not in transgenic corn. Glyphosate decreased leaf N content in CONV corn but not in transgenic corn. Glyphosate reduced nitrate reductase activity in leaves in all three genotypes with severe reduction (49-65%) noted in CONV corn. Glyphosate had no effect on seed nitrogen content in all three corn genotypes. Glyphosate reduced yield (6-54%) in CONV corn with greatest reduction when applied at 3 WAP. Yields were not affected in transgenic corn, regardless of glyphosate rate.

INTRODUCTION

In 2009, 68% of corn area was planted to glyphosate-resistant hybrids in the United States. Twelve years after introduction of GR corn, ~32% of corn area is still planted to conventional corn hybrids. Glyphosate use has increased tremendously with widespread adoption of GR crops (corn, cotton, and soybean). Glyphosate drift onto non-target crops from ground or aerial application has been reported. Glyphosate causes many-fold increases in shikimate levels in sensitive plants and elevated shikimate levels are used as an indicator of glyphosate effects on sensitive plants (Reddy et al. 2008). Although drift rates appear to be sub-lethal, the injury can be severe in sensitive crop such as corn depending on growth stage and could reduce yields (Brown et . Al. 2009).

Glyphosate is known to affect nitrogen assimilation in soybean. Glyphosate significantly reduced nitrate reductase activity and leaf nitrogen in in both GR and CONV soybean (Bellaloui et al., 2006, 2008). In this research, we examine physiological and yield response of GR, GR/LR, and CONV corn to glyphosate under field conditions.

OBJECTIVES

To characterize plant injury, shikimate accumulation, nitrate reductase activity, leaf and seed nitrogen, and yield response of transgenic (GR and GR/LR) corn to label use (1.0 to 1.5X) rates of glyphosate and conventional (CONV) corn to a drift (1/8X) rate of glyphosate in the field.

MATERIALS AND METHODS

General Conditions:

Location: Southern Weed Science Research Farm, Stoneville, MS.
Soil: Dundee silt loam
Years: 2008 and 2009
Plot size: 4.06 m wide and 15.2 m long
Design: Randomize complete block design with 4 replications
Corn: GR corn; P31G97 RR2 – Roundup Ready
Stacked GR/LR corn; P31G71 RR/Liberty Link
Conventional corn; P31P41
Glyphosate treatment as indicated in Table 1 and 2
Planted: On raised beds, fertilized and irrigated as needed.

Data:

Shikimate, nitrate reductase activity, leaf N was determined at 3 d after POST1 and POST2.

Corn Injury: Corn injury was visually estimated weekly on the basis of injury and plant vigor on a scale of 0 (no injury) to 100% (plant death).

MATERIALS AND METHODS – Contd.

Shikimate: Shikimate in leaf was determined as described by Koger et al. (2005). Leaves were excised from ten randomly selected plants from center two rows in each plot. One disc from each leaf, a total of ten discs per vial were frozen until analyzed. Leaf discs were incubated in HCl, periodic acid/meta-periodate, sodium hydroxide/sodium sulfite, and absorbance was read at 380 nm.

Nitrate Reductase Activity (NRA): Five corn plants were randomly sampled from middle rows, immediately transported to laboratory, and assayed for NRA as described by Bellaloui et al. (2006).

Leaf Total Nitrogen: After taking discs for shikimate analysis, the leaves were oven-dried, ground, total nitrogen was determined from duplicate samples using a Flash EA 112 elemental analyzer (Bellaloui et al., 2006).

Corn Yield and Seed Nitrogen: Corn was harvested from each plot using a combine and grain yield was adjusted to 15% moisture. Seed nitrogen was determined as described in leaf nitrogen.

RESULTS

Figure 1. Non-glyphosate-resistant corn injury from glyphosate at a drift rate of 105 g/ha applied at 3 wk after planting. Photo taken at 24 d after application in 2008.

Figure 2. Non-glyphosate-resistant corn injury from glyphosate at a drift rate of 105 g/ha applied at 6 wk after planting. Photo taken at 16 d after application in 2009.

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Table 1. Effect of glyphosate (0.84 and 1.26 kg/ha) applied twice at 3 and 6 wk after planting on shikimate accumulation, nitrate reductase activity, leaf and seed nitrogen content, and yield in glyphosate resistant (GR) and GR stacked with glufosinate-resistant corn in 2008 and 2009.

Corn type/Glyphosate, kg/ha	Shikimate, ng/ml		Nitrate reductase activity, µmol nitrite/g/h		Leaf N, %		Seed N, %	Corn yield, kg/ha
	3 d after POST1	3 d after POST2	3 d after POST1	3 d after POST2	3 d after POST1	3 d after POST2		
Glyphosate-Resistant Corn (GR)								
No glyphosate	14 a	12 a	6.8 a	7.1 a	4.1 a	4.4 a	1.7 a	6920 a
Glyphosate, 0.84 fb 0.84	16 a	10 a	5.2 b	6.3 b	4.3 a	4.6 a	1.7 a	7340 a
Glyphosate, 1.26 fb 1.26	16 a	9 a	4.2 c	4.3 c	4.2 a	4.9 a	1.7 a	7530 a
Glyphosate- and Glufosinate-Resistant Corn (GR/LR)								
No glyphosate	15 a	11 a	6.1 a	6.4 a	4.1 a	4.7 a	1.6 a	7420 a
Glyphosate, 0.84 fb 0.84	15 a	11 a	5.4 b	5.2 b	3.9 a	4.6 a	1.5 a	7590 a
Glyphosate, 1.26 fb 1.26	14 a	13 a	3.6 c	3.8 c	4.0 a	4.4 a	1.5 a	6840 a

Note: Abbreviations: fb, followed by; na, not analyzed, POST1, postemergence at 3 wk after planting; POST2, postemergence at 6 wk after planting.
Means within a column for each corn type followed by same letter are not significantly different at the 5% level as determined by Fisher's LSD test.
Seed N and corn yield data from 2008 and all other data averaged across 2008 and 2009.

Table 2. Effect of glyphosate applied at drift rate (0.105 kg/ha) once at 3 or 6 wk after planting on shikimate accumulation, nitrate reductase activity, leaf and seed nitrogen content, and yield in non-transgenic (conventional) corn in 2008 and 2009.

Corn type/Glyphosate, 0.105 kg/ha	Shikimate, ng/ml		Nitrate reductase activity, µmol nitrite/g/h		Leaf N, %		Seed N, %	Corn yield, kg/ha
	3 d after POST1	3 d after POST2	3 d after POST1	3 d after POST2	3 d after POST1	3 d after POST2		
Conventional Corn (CONV)								
No glyphosate	16 b	14 b	5.9 a	6.0 a	4.1 a	4.5 a	1.6 a	6640 a
Glyphosate, 3 WAP	24 a	26 a	3.0 b	2.1 c	3.4 b	4.1 b	1.5 a	3060 b
Glyphosate, 6 WAP	na	25 a	na	3.0 b	na	4.1 b	1.6 a	6270 a

Note: Abbreviations: na, not analyzed; POST1, postemergence at 3 wk after planting; POST2, postemergence at 6 wk after planting; WAP, weeks after planting.
Means within a column followed by same letter are not significantly different at the 5% level as determined by Fisher's LSD test.
Seed N and corn yield data from 2008 and all other data averaged across 2008 and 2009.

CONCLUSIONS

1. Glyphosate applied at drift rate either at 3 or 6 WAP caused visual injury in conventional corn (Figures 1 and 2), but glyphosate at 1 and 1.5X label use rates applied twice at 3 and 6 WAP caused no injury in transgenic corn.
2. Glyphosate at drift rate increased shikimate levels in conventional corn, but glyphosate at 1 and 1.5X label use rates had no effect on shikimate in transgenic corn.
3. Nitrate reductase activity was reduced 3 days following glyphosate application in conventional and transgenic corn.
4. Leaf nitrogen content was reduced 3 days following glyphosate application in conventional corn, but not in transgenic corn.
5. Glyphosate had no effect on seed nitrogen content regardless of corn genotype.
6. Glyphosate applied at drift rate reduced yield in conventional corn, but not in transgenic corn.
7. These results suggest potential yield loss in conventional corn exposed to glyphosate spray drift.

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