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WEED SCIENCE

Glufosinate-Resistant Cotton Tolerance to Combinations of Glufosinate with Insecticides and Mepiquat Chloride

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ABSTRACT

Field trials were conducted during 2008 and 2009 to evaluate glufosinate-resistant (GLFR) cotton response to glufosinate alone or mixed with the plant growth regulator mepiquat chloride with or without 10 insecticides applied to cotton at pinhead square or first bloom. Less than 2% visual injury was observed with any treatment. At both 14 and 28 d after treatment (DAT), mepiquat chloride mixed with glufosinate reduced cotton height 7 to 8 cm and 2 cm when applied at pinhead square and first flower growth stages, respectively, compared to glufosinate applied alone. Insecticides added to glufosinate alone, or glufosinate plus mepiquat chloride had no impact on plant height. Differences in seed cotton yield were not observed, indicating that minimal cotton injury and early season height differences did not influence cotton yield. Glufosinate combined with insecticides and mepiquat chloride, in accordance with herbicide labeling for glufosinate-resistant cotton, offers producers the ability to integrate pest and crop management strategies with crop safety while reducing production costs.

Since commercialization in 2004, glufosinate-resistant (GLFR) cotton has provided producers an effective alternative transgenic weed control system to glyphosate-resistant cotton. Corbett et al.(2004) reported at least 94% control of a number of 2 to 5 cm annual grass and broadleaf weeds with a single application of glufosinate at 291 g a.i. ha^{-1}. Research has also shown that timely application of a glufosinate-based system can effectively manage glyphosate-resistant Palmer amaranth (Culpepper et al., 2009; Norsworthy et al., 2008; Wilson et al., 2007). Effectiveness of glufosinate on glyphosate-resistant Palmer amaranth has slowly increased the number of acres devoted to the technology. Glufosinate can be applied to GLFR cotton from emergence up to early bloom stage (Anonymous, 2011a).

Multiple chemical applications are often required for crop management and insect control throughout the growing season in cotton. Due to the application range allowed on the glufosinate label, insecticide and plant growth regulator applications can often coincide with in-season applications. The possibility exists for the integration of pest and crop management strategies by combining glufosinate with insecticides and/or plant growth regulators. Such combinations may result in fewer in-season applications and lower production costs, provided a negative response is not observed on target pests or crop safety. Pankey et al. (2004) observed that applying insecticides *lambda*-cyhalothrin or fipronil with glyphosate reduced control of hemp sesbania (*Sesbania exaltata* (Raf.) Rybd. Ex A. W. Hill) by 19 and 9 percentage points, respectively, compared with glyphosate alone. Insecticides acephate, dicrotophos, dimethoate, imidacloprid, oxamyl, and endosulfan did not affect hemp sesbania, pitted morningglory (*Ipomoea lacunosa* L.), prickly sida (*Sida spinosa* L.), and redweed (*Melochoia corchorifolia* L.) control by glyphosate. *Lambda*-cyhalothrin and fipronil did not affect glyphosate control of pitted morningglory, prickly sida, or redweed.

Past research has evaluated the impact of combining insecticides with glufosinate on controlling weeds. Miller et al. (2005) noted that when application of glufosinate occurs within the size restrictions on the herbicide label for hemp sesbania, redroot pigweed, pitted morningglory, prickly sida, and sicklepod (*Senna obtusifolia* (L.) Irwin and Barnaby), control is excellent and unaffected by co-application with the insecticides dicrotophos, acephate, thiamethoxam, acetamiprid, imidacloprid, bifenthrin, lambda-cyhalothrin, cyfluthrin, indoxacarb, spinosad,

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emamectin benzoate, or methoxyfenozide. Research has not documented GLFR cotton tolerance to mixtures of insecticide, plant growth regulator, and glufosinate. Therefore, this research was conducted to evaluate the effects of glufosinate applied alone or with the plant growth regulator mepiquat chloride in combination with 10 insecticides on GLFR cotton at two growth stages.

MATERIALS AND METHODS

Field trials were conducted in 2008 at the Northeast Research Station near St. Joseph, LA, the Dean Lee Research Station near Alexandria, LA, and the Macon Ridge Research Station near Winnsboro, LA, and repeated at the St. Joseph and Alexandria locations in 2009. ‘FM 1735 LLB2’ [Bayer CropScience, Research Triangle Park, NC] cotton variety was planted on May 19 at St. Joseph and May 7 at the other locations in 2008 and on May 19 at St. Joseph and May 13 at Alexandria in 2009. Aldicarb at 560 g a.i. ha^{-1} and pentachloronitrobenzene at 1200 g a.i. ha^{-1} were applied in-furrow at planting to protect against early-season insect infestations and seedling diseases. Plots were at least 7.6 m long with two 101-cm rows separated by an untreated border row. Although the study was conducted in a relatively weed-free area, glufosinate plus S-metolachlor was applied at 594 g a.i. ha^{-1} plus 1050 g a.i. ha^{-1} approximately 14 d after planting with a hooded sprayer to minimize early-season weed competition. Weed-free conditions were maintained throughout the growing season by light hand hoeing. Supplemental insect pest management each year was conducted upon recommendation of LSU AgCenter cotton entomologists and differed by location and year depending on insect species and populations. Supplemental insecticides were applied no sooner than 10 d prior to or 18 d following individual treatment applications in both study years, to avoid confounding results.

Treatments included a factorial arrangement of cotton growth stage (pinhead square or first bloom), herbicide (glufosinate [®Ignite 280 SL, Bayer CropScience, Research Triangle Park, NC] alone at 594 g ai ha^{-1} or combined with mepiquat chloride [®Stance Plant Growth Regulator, Bayer Crop Science, Research Triangle Park, NC] at 24 g ai ha^{-1}, and insecticides and rates as given in Table 1.

Treatments were applied using a tractor-mounted compressed air sprayer delivering 140 L ha^{-1} with four hollow cone nozzles [Spraying Systems Co., Wheaton IL] spaced 51 cm apart. Insecticide treatments and application rates were selected in consultation with LSU AgCenter cotton entomologists (Roger Leonard, personal communication).

Table 1. Insecticides and application rates used to evaluate glufosinate-resistant cotton tolerance to combinations of glufosinate with insecticides and mepiquat chloride.

Insecticide	Trade name Manufacturer	Rate
No insecticide (control)		
abamectin	Zephyr Syngenta Crop Protection Inc., Greensboro, NC	0.656 g ai ha^{-1}
acephate	Orthene 90 S Valent USA Corp., Walnut Creek, CA	560 g ai ha^{-1}
cyfluthrin	Baythroid XL Bayer CropScience, Research Triangle Park, NC	37 g ai ha^{-1}
dicrotophos	Bidrin 8 Water Miscible Amvac Chemical Crop., Los Angeles, CA	448 g ai ha^{-1}
dimethoate	Dimethoate 4E Cheminova Inc., Wayne, NJ	280 g ai ha^{-1}
flonicamid	Carbine 50 WG FMC Corp., Philadelphia, PA	99 g ai ha^{-1}
novaluron	Diamond 0.83 EC Chemtura Corp., Middlebury, CT	65 g ai ha^{-1}
oxamyl	Vydate C-LV E. I. DuPont de Nemours and Company Inc., Wilmington, DE	448 g ai ha^{-1}
spiromesifen	Oberon 2 SC Bayer CropScience, Research Triangle Park, NC	87.5 g ai ha^{-1}
thiamethoxam	Centric 40 WG Syngenta Crop Protection Inc., Greensboro, NC	53 g ai ha^{-1}

Visual assessment of plant injury was made 7, 14, and 28 d after treatment (DAT) using a scale of 0 (no) damage to 100 (plant death). Plant heights were recorded 14 and 28 DAT from 10 randomly selected plants in each plot. At season's end, the entire plot was harvest by machine to determine seed cotton yield.

The MIXED procedure of SAS was used for all analyses, where the location, year, location by year, replication within location by year, and plot within replication effects were random and herbicide, treatment, growth stage, and all interactions were fixed. A 0.05 level of significance was used for all tests for main effects and interaction effects for herbicides, insecticides, and growth stages.

RESULTS AND DISCUSSION

With greater than 95% of plots recorded as exhibiting no visible injury, pooling of data resulted in visual injury observations of 2% or less (data not shown). Data analysis did indicate a significant interaction effect of cotton growth stage and herbicide with respect to plant height. At both 14 and 28 DAT, mepiquat chloride reduced plant height 7 to 8 cm and 2 cm when applied at the pinhead square or first flower growth stages, respectively (Table 2). Insecticides did not influence cotton response to mepiquat chloride, which is a plant growth regulator that is used to manage cotton development including reducing height (Anonymous, 2011b). Miller et al. (2008) reported similar results with mixtures of mepiquat chloride with glyphosate and insecticides on glyphosate-resistant cotton. Main or interaction effects were not noted for plant height with respect to insecticides applied (Table 3). Miller et al. (2008) also reported no effects on second generation glyphosate-resistant cotton resulting from addition of insecticides acephate, cyfluthrin, dicrotophos, dimethoate, novaluron, oxamyl, and thiamethoxam, as well as other commonly used insecticides, when compared to glyphosate applied alone or in combination with mepiquat chloride

Differences in seed cotton yield were not noted, indicating that cotton injury and differences in height early season did not influence yield (Table 3). Results were similar to those reported by Miller et al. (2008) with glyphosate, mepiquat chloride, and commonly used cotton insecticides in second generation glyphosate-resistant cotton.

Table 2. Cotton height 14 and 28 d after treatment (DAT) as influenced by herbicide treatment and growth stage at application[Z].

Growth Stage	Herbicide[X]	Height[Y] 14 DAT	Height[Y] 28 DAT
		--------- cm	---------
Pinhead square	Glufosinate	66	84
	Glufosinate + mepiquat chloride	58	77
First bloom	Glufosinate	89	96
	Glufosinate + mepiquat chloride	87	94

[Z] The MIXED procedure of SAS was used for all analyses, where the location, year, location by year, replication within location by year, and plot within replication effects were random and herbicide, treatment, growth stage, and all interactions were fixed. Experiments were conducted at Alexandria, Winnsboro, and St. Joseph, La in 2008 and repeated at Alexandria and St. Joseph in 2009.

[Y] Means presented are significantly different at the 5% level within each growth stage for each evaluation interval. Means are pooled across insecticides abamectin at 0.656 g ai ha^{-1}, acephate at 560 g ai ha^{-1}, cyfluthrin at 37 g ai ha^{-1}, dicrotophos at 448 g ai ha^{-1}, dimethoate at 280 g ai ha^{-1}, flonicamid at 99 g ai ha^{-1}, novaluron at 65 g ai ha^{-1}, oxamyl at 448 g ai ha^{-1}, spiromesifen at 87.5 g ai ha^{-1}, and thiamethoxam at 53 g ai ha^{-1}, and no insecticide.

[X] Application rates included glufosinate at 594 g ai ha^{-1} and mepiquat chloride at 24 g ai ha^{-1}.

These data show that glufosinate-insecticide-PGR combinations can offer producers the ability to integrate multiple pest and crop management strategies to reduce application costs with minimal effect on the crop. Producers are cautioned to make insecticide combinations with glufosinate only when insect threshold levels dictate. Initiating unnecessary insecticide treatments may result in decreased populations of non-target insect pests (Bagwell et al., 2003). In addition, combinations evaluated in this research applied to cotton in earlier growth stages, especially under less than optimal environmental conditions or to cotton under stress, may result in greater injury than observed in this research. Most insecticide applications are recommended for use with spray nozzles that produce fine droplets to maximize spray coverage (Bagwell et al., 2003). Caution must be exercised that use of such application technologies with glufosinate not result in drift to non-target plants.

Table 3. Effect of cotton growth stage, herbicide, and insecticide on cotton height 14 and 28 d after treatment (DAT) and seed cotton yield[Z].

Factor	Height[Y] 7 DAT	Height[Y] 28 DAT	Seed cotton Yield[Y]
	--------- cm ---------		kg ha^{-1}
Growth stage			
Pinhead square	N/A	N/A	1499
First bloom	N/A	N/A	1453
Herbicide[X]			
Glufosinate	N/A	N/A	1460
Glufosinate + mepiquat chloride	N/A	N/A	1490
Insecticide[X]			
Abamectin	76	89	1493
Acephate	74	85	1422
Cyfluthrin	73	87	1389
Dicrotophos	76	88	1475
Dimethoate	76	87	1438
Flonicamid	75	88	1500
Novaluron	77	89	1495
Oxamyl	75	87	1500
Spiromesifen	77	89	1505
Thiamethoxam	75	89	1510
No insecticide	75	89	1502

[Z] The MIXED procedure of SAS was used for all analyses, where the location, year, location by year, replication within location by year, and plot within replication effects were random and herbicide, treatment, growth stage, and all interactions were fixed. Experiments were conducted at Alexandria, Winnsboro, and St. Joseph, La in 2008 and repeated at Alexandria and St. Joseph in 2009.

[Y] Numbers within each column are not significantly different at the 5% level.

[X] Application rates included glufosinate at 594 g ai ha^{-1}, mepiquat chloride at 24 g ai ha^{-1}, abamectin at 0.656 g ai ha^{-1}, acephate at 560 g ai ha^{-1}, cyfluthrin at 37 g ai ha^{-1}, dicrotophos at 448 g ai ha^{-1}, dimethoate at 280 g ai ha^{-1}, flonicamid at 99 g ai ha^{-1}, novaluron at 65 g ai ha^{-1}, oxamyl at 448 g ai ha^{-1}, spiromesifen at 87.5 g a I ha^{-1}, and thiamethoxam at 53 g ai ha^{-1}.

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REFERENCES

Anonymous. 2011a. Ignite 280SL herbicide label. http://www.cdms.net/LDat/ld7AQ022.pdf. Accessed March 23, 2011.

Anonymous 2011b. Stance plant growth regulator label. http://www.cdms.net/LDat/ld7LI005.pdf Accessed March 23, 2011.

Bagwell, R.D., B.R. Leonard, G. Burris, S. Stewart, J. Faircloth, S. Kelly, C. Pinnell-Alison, T. Erwin, M. Farris, and S. Micinski. 2003. Cotton insect control 2003. LCES Pub. 1083 5/2003 Rev. pp. 5.

Corbett, J.L., S.D. Askew, W.E. Thomas, and J.W. Wilcut. 2004. Weed efficacy evaluations for bromoxynil, glufosinate, glyphosate, pyrithiobac, and sulfosate. Weed Technol. 18:443-453.

Culpepper, A.S., A.C. York, P. Roberts, and J.R. Whitaker. 2009. Weed control and crop response to glufosinate applied to 'PHY 485 WRF' cotton. Weed Technol. 23:356-362.

Miller, D.K., R.G. Downer, E. Burris, B.R. Leonard, and B.J. Williams. 2005. Control of selected broadleaf weeds with glufosinate as influenced by insecticide co-application. Weed Technol. 19:719-723.

Miller, D.K., J.X. Zumba, D.C. Blouin, R. Bagwell, E. Burris, E.L. Clawson, B.R. Leonard, D.M. Scroggs, A.M. Stewart, and P.R. Vidrine. 2008. Second- generation glyphosate-resistant cotton tolerance to combinations of glyphosate with insecticides and mepiquat chloride. Weed Technol. 22:81-85.

Norsworthy, J.K., G.M. Griffith, R.C. Scott, K.L. Smith, and L.R. Oliver. 2008. Confirmation and control of glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) in Arkansas. Weed Technol. 22:108-113.

Pankey, J.H., J.L. Griffin, B.R. Leonard, D.K. Miller, R.G. Downer, and R.W. Costello. 2004. Glyphosate-insecticide combination effects on weed and insect control in cotton. Weed Technol. 18:698-703.

Wilson, D.G., Jr., A.C. York, and D.L. Jordan. 2007. Effect of row spacing on weed management in glufosinate-resistant cotton. Weed Technol. 21:489-495.