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Influence of Adjuvants on Interactions of Sethoxydim with Selected Broadleaf Herbicides Used in Corn (*Zea mays*)[1]

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Abstract: Field experiments were conducted during 1996 and 1998 to determine the effect of atrazine, bentazon, atrazine + bentazon, the amine salt of 2,4-D, and bromoxynil on broadleaf signalgrass and barnyardgrass control when applied in mixture with sethoxydim. Herbicide combinations were applied with crop oil concentrate, crop oil concentrate + ammonium sulfate, or BCH 815. Bentazon and atrazine + bentazon reduced broadleaf signalgrass and barnyardgrass control by sethoxydim. Bromoxynil reduced barnyardgrass control but had no affect on broadleaf signalgrass control. Including ammonium sulfate with crop oil concentrate or substituting BCH 815 for crop oil concentrate increased barnyardgrass and broadleaf signalgrass control by sethoxydim when applied with bentazon. Ammonium sulfate and BCH 815 increased barnyardgrass control when sethoxydim was applied with bromoxynil but did not affect control when sethoxydim was applied with atrazine + bentazon. Atrazine and the ammonium salt of 2,4-D did not reduce barnyardgrass and broadleaf signalgrass control by sethoxydim regardless of adjuvant.

Nomenclature: Atrazine, 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine; bentazon, 3-(1-methylethyl)-(1*H*)-2,1,3-benzothiadiazin-4(3*H*)-one 2,2-dioxide; bromoxynil, 3,5-dibromo-4-hydroxybenzonitrile; sethoxydim, 2-[1-(ethoxyimino)butyl]-5-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; 2,4-D, (2,4-dichlorophenoxy)acetic acid; barnyardgrass, *Echinochloa crus-galli* (L.) Beauv. #[3] ECHCG; broadleaf signalgrass, *Brachiaria platyphylla* (Griseb.) Nash #, BRAPP.

Additional index words: Antagonism.

Abbreviations: COC, crop oil concentrate; POST, postemergence.

INTRODUCTION

Graminicides are often applied in combination with broadleaf herbicides for convenience and to increase the spectrum of weed control. Antagonism of graminicide activity by broadleaf herbicides often occurs (Hatzios and Penner 1985; Holshouser and Coble 1990). Antagonism can be reduced by applying the graminicides and broadleaf herbicide sequentially or increasing the graminicide rate (Myers and Coble 1992) and by using certain adjuvants (Jordan and York 1989; Wanamarta and Penner 1989).

The antagonism of sethoxydim by bentazon has been extensively studied (Wanamarta and Penner 1989; Wanamarta et al. 1989). Reduced efficacy results from less absorption of sethoxydim when applied in mixture with bentazon. Reduced absorption prevents sethoxydim from reaching the site of action and increases the likelihood of photodecomposition of the parent molecule (Zorner et al. 1989). Ammonium sulfate and BCH 815 have been used to reduce or eliminate antagonism observed with this herbicide combination (Jordan and York 1989; Wanamarta and Penner 1989). Response of sethoxydim to ammonium sulfate and BCH 815 is species dependant (York et al. 1990).

Development of sethoxydim-tolerant corn allows growers to apply sethoxydim postemergence (POST) to corn without crop injury (Dotray et al. 1993). A combination of broadleaf herbicides and sethoxydim is needed for broad-spectrum weed control in sethoxydim-tolerant corn. Various broadleaf herbicides are available for

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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.

POST application in corn. In greenhouse studies, Young et al. (1996) reported that several broadleaf herbicides antagonized sethoxydim control of shattercane [*Sorghum bicolor* (L.) Moench.]. Addition of BCH 815 eliminated antagonism when sethoxydim was applied with atrazine + bentazon or bromoxynil. Reduced antagonism was associated with increased absorption of sethoxydim. In contrast, atrazine + bentazon, bromoxynil, and CGA 152005 (proposed name, prosulfuron) {1-(methyl-6-methyl-triazin-2-yl)-3-[2-(3,3,3-trifluoropropyl)-phensulfonyl]-urea} did not antagonize control of wild proso millet (*Panicum miliaceum* L.) control by sethoxydim (Rabaey et al. 1997). Harvey et al. (1996, 1997) reported that primisulfuron {2-[[[[[4,6-bis(difluoromethoxy)-2-pyrimidinyl]amino]carbonyl]amino]sulfonyl]benzoic acid} antagonized control of giant foxtail (*Setaria faberi* Herrm.) by sethoxydim. However, they also reported no reduction of control when sethoxydim was applied with atrazine, atrazine + bentazon, or bromoxynil. Spivey et al. (1999) reported that atrazine, atrazine + bentazon, and atrazine + dicamba (3,6-dichloro-2-methoxybenzoic acid) reduced control of large crabgrass [*Digitaria sanguinalis* (L.) Scop.] by sethoxydim. Control was not affected by CGA 152005 + primisulfuron, bromoxynil, dicamba, or 2,4-D.

Understanding interactions among graminicides and broadleaf herbicides can aid in the development of weed-management strategies in sethoxydim-tolerant corn. Additionally, determining if adjuvants reduce or eliminate antagonism may help overcome adverse interactions. Although considerable research has been conducted with grass weeds commonly found in the Midwest of the United States to evaluate interactions of sethoxydim and broadleaf herbicides, published reports of interactions of these herbicides with annual grasses present in the southern United States is limited (Spivey et al. 1999). Therefore, research was conducted in Louisiana to evaluate the effect of atrazine, atrazine + bentazon, the amine salt of 2,4-D, and bromoxynil on broadleaf signalgrass and barnyardgrass control when applied with sethoxydim and to determine the influence of ammonium sulfate and BCH 815 on efficacy of these mixtures.

MATERIALS AND METHODS

The experiment was conducted during 1996 and 1998 in fallow areas at the Northeast Research Station located near St. Joseph, LA, on a Sharkey clay soil (very fine, montmorillonitic, nonacid, Vertic Haplaquept) with 2.1% organic matter and pH 6.1 or a Mhoon silt loam soil (fine-silty, mixed, nonacid, thermic, Typic Fluvaquent) with 1.8% organic matter and pH 6.0. The experiment was also conducted in adjacent fields in 1996 at the Macon Ridge Branch of the Northeast Research Station located near Winnsboro, LA, on a Gigger silt loam soil (fine-silty, mixed, thermic, Typic Fragiudalfs) with 1.3% organic matter and pH 5.6. The experiment was also conducted in 1998 at the Ben Hur Research Farm located near Baton Rouge, LA, on a Tunica clay (clayey over loamy, smectitic, nonacid, thermic, Vertic Haplaquept) with 1.8% organic matter and pH 6.7. Broadleaf signalgrass was present in both experiments at Winnsboro and at St. Joseph in 1998. Barnyardgrass was present in all experiments.

Sethoxydim at 0.22 kg ai/ha was applied alone or with atrazine (1.1 kg ai/ha), bentazon (1.1 kg ai/ha), atrazine + bentazon (0.56 + 0.56 kg/ha), the amine salt of 2,4-D (1.1 kg ai/ha), and bromoxynil (0.42 kg ai/ha). These herbicide mixtures were applied with Agri-Dex® nonionic spray adjuvant[4] (COC) at 1.0% (v/v), COC at 1.0% (v/v) + ammonium sulfate at 2.8 kg/ha, or Dash® HC spray adjuvant[5] (BCH 815) at 1.0% (v/v). Treatments were applied in 140 L/ha at 135 kPa. Plot size was 3 by 5 m.

Barnyardgrass and broadleaf signalgrass density was 10 to 60 plants/m^2. Grasses had three to five leaves at the time of herbicide application and were not experiencing any visible stress. Visual estimates of percent control were recorded 4 wk after application on a scale of 0 to 100%, where 0 = no control and 100 = complete control. Necrosis, chlorosis, and plant stunting were used when making visual estimates.

The experimental design was a randomized complete block with three replications. Data were subjected to analyses of variance with basic partitioning for a six (broadleaf herbicide) by three (adjuvant) factorial treatment arrangement. Pooled data were transformed to the arcsine square root, and means of nontransformed data were separated using Fisher's protected LSD test at $P = 0.05$.

RESULTS AND DISCUSSION

Sethoxydim controlled broadleaf signalgrass at least 93% when applied alone regardless of adjuvant (Table 1). However, when sethoxydim was applied with either COC and bentazon or with COC, bentazon, and atrazine, control decreased from 94% to 66% and 43%, respec-

[4] Agri-Dex® nonionic spray adjuvant, 83% paraffin base petroleum oil and 17% surfactant blend. Helena Chemical Co., 5100 Poplar Avenue, Memphis, TN 38137.

[5] Dash HC® spray adjuvant, 45% petroleum hydrocarbons, 5% napthalene, 1.5% phosphoric acid, and 48.5% inert ingredients. BASF Corp., 100 Cherry Hill Road, Parsippany, NJ 07054.

Table 1. Broadleaf signalgrass and barnyardgrass control by sethoxydim applied alone and with nongraminicide herbicides as influenced by adjuvants.[a]

		Control	
Broadleaf herbicide	Adjuvant[b]	Broadleaf signalgrass	Barnyardgrass
		%	
None	COC	94 ab	76 ab
Atrazine	COC	93 ab	73 abc
Bentazon	COC	66 c	39 ef
Bentazon + atrazine	COC	43 d	23 fg
2,4-D	COC	91 ab	75 abc
Bromoxynil	COC	90 ab	46 de
None	COC + $(NH_4)_2SO_4$	93 ab	84 a
Atrazine	COC + $(NH_4)_2SO_4$	97 a	80 a
Bentazon	COC + $(NH_4)_2SO_4$	87 ab	59 bcd
Bentazon + atrazine	COC + $(NH_4)_2SO_4$	85 abc	26 fg
2,4-D	COC + $(NH_4)_2SO_4$	87 ab	81 a
Bromoxynil	COC + $(NH_4)_2SO_4$	91 ab	70 abc
None	BCH 815	96 a	85 a
Atrazine	BCH 815	97 a	86 a
Bentazon	BCH 815	83 abc	57 cde
Bentazon + atrazine	BCH 815	73 bc	20 g
2,4-D	BCH 815	94 ab	87 a
Bromoxynil	BCH 815	95 ab	80 a

[a] Means for each weed species followed by the same letter are not significantly different according to Fishers Protected LSD test at P = 0.05.

[b] Abbreviation: COC, crop oil concentrate.

tively. Atrazine + bentazon reduced control more than bentazon. Applying ammonium sulfate with sethoxydim + COC or substituting BCH 815 for COC increased control when bentazon or atrazine + bentazon were in the mixture. Previous research (Spivey et al. 1999; Wanamarta and Penner 1989; Young et al. 1996) demonstrated that bentazon and bentazon + atrazine reduce efficacy of sethoxydim. Research has also shown that COC + ammonium sulfate and BCH 815 are more efficacious than COC when sethoxydim and bentazon are applied in mixture (Jordan and York 1989; Wanamarta and Penner 1989). In contrast to results noted for bentazon and atrazine + bentazon, broadleaf signalgrass control by sethoxydim was not affected by bromoxynil, atrazine, or 2,4-D (Table 1).

Bentazon and atrazine + bentazon reduced barnyardgrass control by sethoxydim when herbicides were applied with COC (Table 1). In contrast to results with broadleaf signalgrass, bromoxynil also reduced efficacy. Control by sethoxydim decreased from 76% when sethoxydim + COC was applied alone to 39%, 23%, and 46% when applied with bentazon, atrazine + bentazon, and bromoxynil, respectively. Applying ammonium sulfate with COC or substituting BCH 815 for COC increased efficacy of sethoxydim applied with bentazon or bromoxynil. However, these adjuvants did not improve control by the mixture of sethoxydim and atrazine + bentazon. As was noted for broadleaf signalgrass, atrazine and 2,4-D did not reduce barnyardgrass control by sethoxydim (Table 1).

Interactions of sethoxydim and nongraminicide herbicides can be inconsistent. Dotray et al. (1993) reported greater giant foxtail control when sethoxydim was applied with atrazine compared with control by sethoxydim alone in one of two experiments. In contrast, Spivey et al. (1999) reported that atrazine reduced large crabgrass control when mixed with sethoxydim. Previous research (Corkern et al. 1998; Culpepper et al. 1998) demonstrated that bromoxynil can reduce efficacy of sethoxydim. However, other research suggests that sethoxydim and bromoxynil are compatible (Harvey et al. 1996; Rabaey et al. 1997; Young et al. 1996).

In these experiments, atrazine + bentazon, rather than bentazon alone, reduced sethoxydim's control of broadleaf signalgrass the most (Table 1). Additionally, barnyardgrass control by sethoxydim was reduced more by atrazine + bentazon than by bentazon or bromoxynil. It was expected that applying bentazon at 0.56 kg/ha in the commercial mixture of atrazine + bentazon would be less antagonistic toward sethoxydim than bentazon at 1.1 kg/ha. This was not the case, however, and additional research is needed to explain this interaction. Antagonism of sethoxydim by bentazon has been well documented (Wanamarta and Penner 1989; Wanamarta et al. 1989), although the effect of atrazine on efficacy of sethoxydim has been inconsistent (Dotray et al. 1993; Spivey et al. 1999). The mechanism of the interaction of sethoxydim, atrazine, and bentazon applied in mixture has not been established.

BCH 815 and ammonium sulfate increased broadleaf signalgrass control when sethoxydim was applied with bentazon and atrazine + bentazon. Barnyardgrass control by sethoxydim also increased when applied with these adjuvants in mixture with bentazon or bromoxynil. However, these adjuvants did not improve control of barnyardgrass when atrazine + bentazon was applied with sethoxydim. Barnyardgrass is often more difficult to control by sethoxydim than broadleaf signalgrass (Baldwin et al. 1996), and overcoming antagonism of graminicide activity may also be more difficult on grasses that are hard to control. Based on these results, growers should apply sethoxydim and atrazine + bentazon sequentially to maximize barnyardgrass control. In the case of broadleaf signalgrass control with combinations of sethoxydim, atrazine, and bentazon or broadleaf signalgrass and barnyardgrass control with mixtures of sethoxydim + bromoxynil or sethoxydim + bentazon, adjuvant selection may be sufficient to avoid antagonism of grass control.

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