Minimum Effective Levels and Interaction of Three Herbicides with Atrazine Residues *

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INTRODUCTION

The trend in sugarbeet weed control has been to use more specific herbicides, singularly and in combination (8,9) to achieve complete weed control. This could result in (a) using more herbicide than is required to control weeds satisfactorily and (b) beneficial or detrimental herbicide interactions. In addition, sugarbeets are usually grown in rotation with other crops and trace amounts of persistent herbicides from a previous crop may interact with sugarbeet herbicide(s).

The major weeds of sugarbeets were identified by Yun and Sullivan (12) as redroot pigweed (*Amaranthus retroflexus* L.), common lambsquarters (*Chenopodium album* L.), kochia [*Kochia scoparia* (L.) Schrad.], black nightshade (*Solanum nigrum* L.), yellow foxtail [Setaria glauca (L.) Beauv.], barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], and wild oat (*Avena fatua* L.).

Diclofop-methyl (methyl 2-[4-(2,4-dichlorophenoxy)phenoxy] propanote) is registered for postemergence wild oat and annual grass control in wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), and soybeans (*Glycine max* L.) (9). It does not control broadleaf species, but at rates of 1.7 to 3.4 kg ai/ha it controls 90 to 100% of annual grass weeds without injuring sugarbeets (11). It also has

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preemergence activity since it is root absorbed (9).

Cycloate (S-ethyl N-ethylthiocyclohexanecarbamate) is a thiocarbamate herbicide which is applied preplant to control a number of annual weed species. A single preplant incorporated application of cycloate will not control foxtail spp., redroot pigweed, or kochia satisfactorily (6).

Ethofumesate (±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate) was evaluated extensively in sugarbeets in the United States during 1971-72 and in Europe in 1972 (7). At 2.5 kg ai/ha it has controlled 87% of broadleaf weed species (11). Kochia is less sensitive to ethofumesate than redroot pigweed or green foxtail [*Setaria viridis* (L.) Beauv.] (11). Ethofumesate causes slight, temporary growth retardation in sugarbeets (3). A combination of ethofumesate plus diclofop has been cited as promising for preplant annual weed control in sugarbeets (12). Schweizer (8) evaluated this combination and found it reduced the stand of sugarbeets on sandy loam but not on clay loam. This combination has been reported to cause less crop injury than ethofumesate/diclofop (11).

Sugarbeets are known to be sensitive to atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) residues (1,5). Zimdahl et al. (13) found sugarbeets could be injured by as little as 0.1 ppmw atrazine. The interaction of minimum effective rates of sugarbeet herbicides used for weed control and atrazine residues in soil has not been studied.

The aforementioned commonly used sugarbeet herbicides were selected for study to determine:

a. the minimum effective herbicide levels within an acceptable field use range when applied singularly or in combination (ethofumesate/diclofop and ethofumesate/cycloate) on five weed species and on sugarbeet seedlings, and

b. interactions of the determined minimum effective level with 0.02 ppmw of atrazine soil residue as measured by the effect on the five weed species and sugarbeets.

METHODS AND MATERIALS

General. Experiments were conducted in the greenhouse in a clay loam (aridic argiustoll; fine, Montmorillonitic mesic) with 40% sand, 31% silt, 29% clay, 2.4% organic matter, and 7.5 pH. All herbicides were incorporated into soil before planting seed of kochia, redroot pigweed, barnyardgrass, yellow foxtail, and sugarbeets.

Soil was sieved through a 6.4-mm or a 13-mm sieve. The 6.4-mm sieved soil was treated with an aqueous emulsion of commercially formulated[2] herbicide by pipetting the aqueous emulsion over an exposed mound of soil. The treated soil was mixed for 0.5 h. Plastic pots (8 by 8 by 9 cm) were filled with 4 cm of air-dried, 13-mm sieved soil, followed by 4 cm of treated soil. Seeds were planted at the depths and numbers indicated in Table 1 and

Table 1. Depth of planting and seeds planted for six test species.

Plant	Depth of planting	Seeds planted
	(mm)	(no.)
Kochia	13.0	200
Redroot pigweed	6.5	100
Barnyardgrass	6.5	100
Green foxtail	6.5	100
Yellow foxtail	6.5	50
Sugarbeets	13.0	15

two g of Osmocote 14-14-14 slow release fertilizer[3] were sprinkled on the soil surface. Plants were thinned to ten/pot after an adequate stand was attained and later harvested by cutting at the soil surface. Pots were arranged on a greenhouse bench in a completely randomized design with five replications and each experiment was repeated. Natural light was supplemented with a 16 h photoperiod of fluorescent light. The minimum effective rate was determined by comparing the dry weight of treated

[2]Cycloate - 6.0 lb ai/gal ec., Ro-Neet, Stauffer Chemical Co., Diclofop - 3.0 lb ai/gal ec., Hoelon, American Hoechst Co., Ethofumesate - 1.5 lb ai/gal ec., Nortron, BFC Chemicals, Inc., [3]American Clay Works and Supply Co., Denver, CO.

plants to untreated controls.

Experiment 1. Minimum effective rates of sugarbeet herbicides. Rates of 0, 0.5, 1.7, and 2.2 kg ai/ha of each of the three sugarbeet herbicides were tested on each of the five weed species and sugarbeets to determine the minumum effective rate. The same rates were used to test herbicide injury to sugarbeet seedlings. The average time from planting to harvest was 16 days. Analysis was done with a factorial two-way analysis of variance and the LSD mean separation test.

Experiment 2. Minimum effective rates of ethofumesate/diclofop and ethofumesate/cycloate combinations. All possible rate combinations of 0, 0.5, 1.7, and 2.2 kg ai/ha were used to determine the minimum effective rates of these two sugarbeet herbicide combinations on five weed species and sugarbeet seedlings. The average time interval from planting to harvest was 20 days. Analysis was done with a factorial two-way analysis of variance and Tukey's mean separation test.

Experiment 3a and b. Interaction of minimum effective herbicide rates with atrazine residue. Soil sieved through a 6.4-mm sieve was treated with 20 ppmw atrazine, mixed in a soil mixer for 4 h, and stored dry until needed. Soil was diluted with untreated soil to obtain 0.02 ppmw atrazine. This soil was then treated with the minimum effective rate of the sugarbeet herbicide alone (experiment 3a as determined in experiment 1, Table 2) or in combination (experiment 3b determined in experiment 2, Table 3) for each weed species and sugarbeets. Controls without atrazine residue and sugarbeet herbicides were used. The average interval from planting to harvest for experiments 3a and b was 18 and 14 days, respectively. Analysis was done with a factorial two-way analysis of variance, single degree of freedom sum of squares and Tukey's mean separation test.

RESULTS AND DISCUSSION

Diclofop killed barnyardgrass, yellow foxtail, and green foxtail at the lowest rate tested (0.5 kg ai/ha) and, as expected, the two broadleaf weed species were not controlled (Table 2). Cycloate controlled all weed species, except kochia, at 0.5 kg ai/ha which is consistent with a previous observation (10). Ethofumesate controlled the two foxtail species and redroot pigweed at a rate of 1.7 kg ai/ha which was three times higher than that required with the two other herbicides. Ethofumesate did not control barnyardgrass or kochia. Sugarbeet injury occurred at the lowest level of ethofumesate application but such injury has been reported to be temporary(4). Neither diclofop nor cycloate affected the growth of sugarbeets at 2.2 kg ai/ha.

Table 2. Minimum effective herbicide rate.

		Minimum effective level				
Herbicide	Kochia	Redroot pigweed	Barnyard grass	Yellow foxtail	Green foxtail	Sugar-beet
	(kg/ha)					
Diclofop	*	*	0.5	0.5	0.5	*
Ethofumesate	*	1.7	*	1.7	1.7	0.5
Cycloate	*	0.5	0.5	0.5	0.5	*

*When no lower rate was effective, 2.2 kg ai/ha was assumed to be the minimum effective rate even when it had no effect.

The species controlled by combination of ethumesate with cycloate or diclofop (Table 3) were identical to those controlled when diclofop and cycloate were applied

Table 3. Minimum effective rates of combinations of ethofumesate plus diclofop or ethofumesate plus cycloate.

		Minimum effective rate				
Herbicide	Kochia	Redroot pigweed	Barnyard-grass	Yellow foxtail	Green foxtail	Sugar-beet
	(kg/ha)					
Ethofumesate plus diclofop	*	*	0.5 + 0.5	0.5 + 0.5	0.5 + 0.5	*
Ethofumesate plus cycloate	*	* + 0.5	0.5 + 0.5	1.7 + 0.5	0.5 + 0.5	*

*When no lower rate was effective, 2.2 kg ai/ha was assumed to be the minimum effective rate even when it had no effect.

alone (Table 2). The rates also were identical except a higher rate of ethofumesate was required in the ethofumesate/cycloate mixture to control redroot pigweed. The minimum effective rate of ethofumesate in combination was less than required in experiment 1 for green foxtail. Ethofumesate, therefore, was not a major contributor to control of the tested weed species when combined with diclofop or cycloate. Kochia was not controlled by either herbicide combination.

When cycloate or diclofop was combined with ethofumesate sugarbeet injury was not observed. Ethofumesate plus diclofop has been reported to cause less crop injury than ethofumesate used alone (11).

Consistent with our earlier results (13) there was an effect of 0.02 ppmw atrazine on sugarbeets (Table 4). This level of atrazine also significantly decreased the growth of kochia, redroot pigweed, and barnyardgrass which was surprising. It did not affect the growth of yellow or green foxtail. With two exceptions, 0.02 ppmw of atrazine did not affect any species except kochia, nor did it interact with any herbicides except when they were applied to kochia. There was no affect of atrazine on kochia when diclofop was applied at 2.2 kg ai/ha which is consistent with our previous results and the known activity of diclofop. The first exception was the effect of the low residue of atrazine on the yield of yellow foxtail when ethofumesate plus cycloate were applied at 1.7 plus 0.5 kg ai/ha. We have no explanation for this observation. Based on previous work it is not likely that ethofumesate was the primary cause of injury in this combination (2,3). Sugarbeets are quite tolerant to ethofumesate but they can be affected by the amount of desmedipham [ethyl m-hydroxycarbanilate carbanilate (ester)] in mixtures. The injury from desmedipham was related to an increase in its rate of penetration when it was applied in combination with ethofumesate (3). The basis for the observed interaction has not been investigated. The second exception, similarly unexplained, was the increase in yield of redroot pigweed

Table 4. The effect of minimum effective rates of three herbicides and two herbicide combinations applied with and without 0.02 ppmw atrazine on sugarbeets and five weed species.

		Species*					
Herbicide	Atrazine presence	Kochia	Redroot pigweed	Barnyard-grass	Yellow foxtail	Green foxtai	Sugar-beet
Control	-	0.58*	1.30*	0.78*	1.32	0.86	1.26*
	+	0.15	0.52	0.28	1.10	1.34	0.48
Dichlofop	-	0.23	1.20*	0.72	1.08	0.80	1.46
	+	0.16	1.50	0.48	1.12	0.48	0.76
Ethofumesate	-	0.59	0.34	0.18	0.64	0.26	1.70
	+	0.21	0.64	0.28	0.48	0.28	1.56
Cycloate	-	0.11	0.86	0.74	1.82	0.92	1.34
	+	0.12	0.38	0.54	0.86	1.20	0.62
Ethofumesate plus dichlofop	-	0.44	1.00	0.80	0.90	0.24	2.06
	+	0.50	0.30	0.36	0.70	0.18	1.36
Ethofumesate plus cycloate	-	0.16	0.84	0.84	0.90*	0.28	1.62
	+	0.24	0.14	0.46	0.30	0.20	1.18

*There was a signifiant difference for the indicated pair when analyzed by a single degree of freedom sum of squares ($P = 0.05$).

when diclofop was applied at 2.2 kg ai/ha.

Our general conclusion is that low levels of atrazine in soil may interact with some sugarbeet herbicides to affect kochia control in a succeeding crop of sugarbeets. While the results are highly suggestive they do not prove that interactions occur in the field. Atrazine is phytotoxic to kochia and sugarbeets. Based on our earlier work (13) we are more confident that atrazine is phytotoxic to sugarbeets at very low concentrations and that extrapolation to the field is justified. We have no evidence of interactions that affect control of other common weeds in sugarbeets. It is also interesting that the same low level of atrazine that affected sugarbeets when applied alone did not affect sugarbeets when minimum effective rates of accepted sugarbeet herbicides were applied to soil containing the atrazine residue.

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