Durum Wheat Tolerance to Chlorsulfuron and Chlorsulfuron Mixtures

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Chlorsulfuron controls weeds selectively in small grains. In general, broadleaf plants are highly susceptible to chlorsulfuron, whereas the susceptibility of grasses is more variable (Sweetser et al., 1982). Wild oat (*Avena fatua* L.) is tolerant to chlorsulfuron. Because wild oat is a major grassy weed in small grains, chlorsulfuron could be tank-mixed with other herbicides to control both broadleaf weeds and wild oat, and applied in one field operation.

Several scientists have reported that combinations of some wild oat herbicides with auxin-type herbicides have been antagonistic to weed control. Behrens et al. (1974) reported that tank-mixing diclofop at 0.6 kg/ha with MCPA at 0.3 kg/ha reduced wild oat control 62 percent when compared to diclofop alone at 0.6 kg/ha. The combinations of 0.3 kg/ha of MCPA with 0.7 kg/ha of difenzoquat also reduced the control of wild oat. Miller and Nalewaja (1974) reported similar reductions in wild oat control when tank-mixing MCPA or 2,4-D with diclofop. Even though wild oat control was reduced by tank-mixing auxin-type herbicides with diclofop or difenzoquat, crop phytotoxicity did not occur with these combinations.

Wild oat herbicides have been tank-mixed with chlorsulfuron. Combinations of chlorsulfuron with difenzoquat or diclofop controlled weeds without any apparent antagonism and without injuring spring wheat in eastern North Dakota (Miller and Nalewaja, 1979). In another study at Morris, Minn., Behrens et al. (1980) reported that tank-mixtures of chlorsulfuron with diclofop did not injure 'Era' spring wheat, but the combination of 0.03 kg/ha of chlorsulfuron + 1.12 kg/ha of difenzoquat reduced stand by 10 percent and stunted growth. However, the wheat recovered from the initial suppression and yield was not affected. Behrens et al. (1981) also applied 0.02 kg/ha of chlorsulfuron + 1.12 kg/ha of difenzoquat to Era spring wheat at Crookston, Minn., and reported that yield was not affected.

Because of the potential use of wild oat herbicides and chlorsulfuron in tank-mixes, this research was conducted to determine if tank-mixing chlorsulfuron with two wild oat herbicides (a) controls weeds selectively and/or (b) results in phytotoxicity to durum wheat.

Materials and Methods

The experiment was conducted near Sidney, Mont., on a Williams loam (fine-loamy, mixed, frigid, Typic Argiboroll) with a pH of 7.4 and 2.1 percent organic matter. Cando durum was sown at 67 kg/ha on May 6, 1981, and April 27, 1982, in rows 30 cm apart. Experimental plots consisted of eight rows, 6 m long. The experimental design was a randomized complete block design with four replications. Each year before planting, ammonium nitrate (33-0-0) was applied broadcast at 45 kg N/ha. Chlorsulfuron at 0.04 kg active ingredient/ha was applied alone, and tank-mixed with difenzoquat, and diclofop. The rates for the wild oat herbicides were 0.84 and 1.12 kg ai/ha, respectively, Wild oat was in the two- to five-leaf stage when the treatments were applied post-emergent on May 20, 1981, and June 17, 1982. Durum was in the two-leaf stage in 1981 and in the early tillering stage in 1982. The treatments were applied at the later growth stage in 1982 due to wild oat emerging later. In 1981, the durum was drought-stressed when the herbicides were applied, whereas the durum was growing vigorously at the time of spraying in 1982 due to earlier precipitation.

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The herbicides were applied in 173 L water/ha at a pressure of 2 × 10^5 Pascals. Weed-infested and hand-weeded controls were included for comparison. Weed removal in the hand-weeded control was initiated on the same date as herbicide applications.

The response of durum and weeds to herbicides was assessed four weeks after application of herbicides. Weed control was based on a rating scale in which 100 = weed-free and 0 = completely weed infested, and crop tolerance on a rating scale in which 0 = no injury and 100 = death of all plants. Other data taken each year included the date at which at least 50 percent of the plant heads were 2.5 cm above the flag leaf collar, plant height at maturity, grain yield, and test weight. Durum was harvested from an area 1.5 by 5 m. In 1982, additional information was collected on dry matter production, straw production, and yield components. Plant samples harvested from an area of 0.3 m^2 at the tillering, boot, heading, anthesis, and maturity growth stages were dried at 100°C), then weighed to determine total dry matter production. Yield components were determined by clipping two rows 0.6 m long, counting all heads, and selecting 20 heads at random to determine kernels/head and kernel weight. Straw production also was determined from these plant samples.

Results and Discussion

Combining chlorsulfuron with the wild oat herbicides did not reduce herbicidal activity (data not presented). Our results agreed with Miller and Nalewaja (1979) who reported no antagonism to weed control by combining chlorsulfuron with wild oat herbicides. In both years of our study, chlorsulfuron eliminated the broadleaf weeds, common lambsquarter and redroot pigweed, from all treated plots. The wild oat herbicides also controlled wild oat effectively. In 1981, the wild oat infestation was not sufficient to be competitive to Cando durum treated with only chlorsulfuron. However, in 1982, wild oat infestation was competitive, causing a yield loss in this treatment (discussed later).

The heading date of Cando durum was not affected by any treatment in 1981, but in 1982, chlorsulfuron + diclofop delayed heading of Cando four days when compared to the hand-weeded control (Table 1). None of the herbicide treatments affected plant height in either year (data not presented). However, Cando durum treated with chlorsulfuron + diclofop and chlorsulfuron + difenzoquat exhibited significant visual plant injury in both years.

Cando durum treated with chlorsulfuron + diclofop produced significantly less grain than the hand-weeded durum in both years (Table 1). In 1981 the Cando durum treated with chlorsulfuron + difenzoquat recovered from early plant injury and its yield was similar to the hand-weeded control. In 1982 all herbicide treatments produced significantly less grain than the hand-weeded control. The reduction in grain yield where chlorsulfuron was applied alone was due to the competition from wild oat not controlled by chlorsulfuron, the only herbicide treatment in 1982 where weeds were competitive. Since plots treated with combinations of chlorsulfuron + diclofop, or difenzoquat were weed-free, reductions in grain yields were attributed to herbicide phytotoxicity. Other investigators have also reported yield losses when durum was treated with chlorsulfuron + diclofop.

Nalewaja and Miller (1980) reported that Botno durum treated with chlorsulfuron + diclofop at 0.03 + 0.84 kg/ha yielded only 55 percent of that treated with only chlorsulfuron at 0.03 kg/ha or diclofop at 0.84 kg/ha. The application of diclofop alone has not been found to injure

TABLE 1
Effect of chlorsulfuron on Cando durum agronomic variables when applied alone or with other herbicides.

TREATMENT	RATE	HEADING		VISUAL INJURY		GRAIN YIELD		TEST WEIGHT	
		1981	1982	1981	1982	1981	1982	1981	1982
	kg/ha	Days from Jan. 1		Percentage		kg/ha		kg/hL	
Chlorsulfuron	0.04	187a*	188b	0b	0c	1090a	1919bc	70.3b	81.2b
Chlorsulfuron + diclofop	0.04 + 1.12	188a	192a	23a	10a	942b	1960bc	71.0a	82.0b
Chlorsulfuron + difenzoquat	0.04 + 0.84	188a	188b	21a	4b	1117a	2190b	70.3b	82.3ab
Control (hand-weeded)	0.0	187a	188b	0b	0c	1130a	2526a	69.8c	83.8a
Control (weed-infested)	0.0	187a	188b	0b	0c	915b	1755c	68.7d	82.7ab

Means followed by the same letter in the same column are not significantly different at P = 0.05 according to the Duncan's New Multiple Range Test.

durum. Diclofop at 1.12 kg/ha did not affect grain yields, test weights or plant heights of four durum varieties, Crosby, Cando, Rolette and Vic, tested in eastern Montana in 1981 (Anderson, 1982) while in North Dakota, diclofop has not been found to injure any durum varieties (Steve Miller, personal communications). Miller and Nalawaja (1975, 1976, 1977) tested difenzoquat on 10 durum varieties in North Dakota and found that difenzoquat applied alone at 0.84 kg/ha did not injure any durum varieties in 1975 or 1977, but reduced durum grain yields for several varieties 4 to 10 percent in 1976. In our study, chlorsulfuron + difenzoquat reduced grain yields 13 percent, similar to the 10 percent reported by Miller and Nalewaja in 1976. The grain yield loss by this treatment was probably caused by the difenzoquat, but the chlorsulfuron + diclofop damage must be due to the combination, as the herbicides applied alone have not injured durum grain yields.

The Cando durum was drought stressed in 1981, thus may have reacted differently to the herbicides than the durum growing with more early season moisture in 1982. However, when chlorsulfuron + diclofop was applied to Cando durum at different growth stages and in different environments, it reduced grain yields in both situations. Thus, this combination appears to be more toxic to Cando than the combination of chlorsulfuron + difenzoquat. Chlorsulfuron alone did not damage Cando durum. The yield reductions for the chlorsulfuron treated Cando durum in 1982 were caused by the wild oat infestation, while in 1981, the durum grain yield was not affected by chlorsulfuron as wild oat was not competitive.

The yield components for 1982 show that the number of heads/m² was not significantly different for the chlorsulfuron + wild oat herbicide treatments and hand-weeded control (Table 2). The yield loss for the herbicide combination treatments was due to a reduction in kernels/head and weight/kernel, even though these components were not significantly less than those of the hand-weeded control for all herbicide treatments. These data indicate that the yield reduction resulted from interference in floret development and grain filling of kernels. The wild oat competition in the chlorsulfuron-alone treatment reduced all components of yield compared to the hand-weeded control, even though not significantly. The amount of straw produced in the herbicide-treated plots was significantly less than in hand-weeded control Cando durum. Thus, both grain and straw production was decreased by the herbicide combination treatments. The highest straw/grain ratio occurred with the lowest yielding treatments, the weed-infested control and where chlorsulfuron was applied alone.

Dry matter production at five growth stages was measured to determine if early plant injury is followed by compensatory plant growth at a later growth stage. Figure 1 shows dry matter production at five growth stages of Cando durum for the hand-weeded control, chlorsulfuron + difenzoquat, and chlorsulfuron + diclofop treatments. Only at the maturity growth stage was dry matter production significantly affected. At this stage, the mixture of chlorsulfuron + diclofop produced less dry matter than the hand-weeded control. The plant growth damage due to the chlorsulfuron + difenzoquat and chlorsulfuron + diclofop treatments apparently occurred after anthesis as no differences in total dry matter production were detected until the durum was mature.

In summary, combining chlorsulfuron with wild oat herbicides did not affect weed control.

TABLE 2
Effect of chlorsulfuron applied alone or with other herbicides on yield components and straw production of Cando durum, 1982.

		YIELD COMPONENTS				
TREATMENT	RATE	HEADS/M²	KERNELS HEAD	WGT/ KERNEL	STRAW PRODUCTION	STRAW/GRAIN RATIO
	kg/ha	no.	no.	mg	kg/ha	
Chlorsulfuron	0.04	236a*	35.8a	24.9b	1975b	1.03a
Chlorsulfuron + diclofop	0.04 + 1.12	278a	34.0a	25.3ab	1872b	0.96b
Chlorsulfuron + difenzoquat	0.04 + 0.84	264a	34.5a	25.9ab	1950b	0.89b
Control (hand-weeded)	0.0	249a	37.3a	28.1a	2227a	0.88b
Control (weed-infested)	0.0	180b	37.4a	25.0b	1843b	1.05a

Means followed by the same letter in the same column are not significantly different at P = 0.05 according to the Duncan's New Multiple Range Test.

Cando durum was tolerant to chlorsulfuron applied alone, but chlorsulfuron + diclofop reduced durum grain yields in both years. Chlorsulfuron + difenzoquat reduced grain yields in 1982 when Cando durum was in the early tillering stage at time of herbicide application and was not drought stressed. The combination of chlorsulfuron + diclofop appears to be toxic to Cando durum, while other studies (see footnote 3) have shown Cando durum to be tolerant of either herbicide applied alone. The injury by chlorsulfuron + difenzoquat in 1982 may be due to difenzoquat, as Miller and Nalewaja (1976) reported yield losses in durum caused by difenzoquat similar to the yield reduction recorded in this study. Yield component data in 1982 indicated chlorsulfuron + wild oat herbicides affected floret development and grain filling of kernels, resulting in grain yield loss.

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FIGURE 1. Effect of applying chlorsulfuron with other herbicides on durum dry matter production, 1982.