# Clomazone for Weed Control in Chemical Fallow

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Chemical fallow, the use of herbicides instead of tillage to control weeds on fallow land, has been increasing in acreage recently because of growing awareness of soil erosion problems and declining prices of certain herbicides used on chemical fallow. Soil losses from wind erosion on traditional tilled "black fallow" often are unacceptably high and have been particularly apparent during the drought years of 1988 and 1989. Chemical fallow and undercutting tillage greatly reduce soil erosion by maintaining surface residues from the previous crop.

Most chemical fallow has employed such foliar-applied herbicides as glyphosate, paraquat, and 2,4-D. Soil-applied herbicides have not been used extensively on North Dakota fallow acres because available herbicides are either expensive, may injure crops planted after the fallow year, or fail to control all weed species present on fallow land. Chlorsulfuron was probably an exception, having been commonly used for residual weed control in fallow rotated to wheat. Recent chlorsulfuron label changes, however, now preclude its use in fallow.

Clomazone, trade name Command, controls several broadleaf and grass weeds and has Canadian and U.S. registration as a soil-applied herbicide in fallow. Clomazone can be applied alone or tank mixed with atrazine to increase the number of species controlled. Published information on the efficacy of clomazone-atrazine tank mixtures on North Dakota fallow is limited but has indicated excellent control of kochia, Russian thistle, and common lambsquarters and inadequate control of green foxtail (1, 2). These weed species occur frequently in North Dakota fallow fields along with wild mustard, redroot pigweed, volunteer wheat, and others.

Cereal grains often are planted following fallow in North Dakota. Wheat, barley, and oats are extremely susceptible to clomazone (3). Residues of this herbicide may persist in soils long enough to injure susceptible crops planted the year after a clomazone application. Gallandt et al. (4) concluded that clomazone applied at recommended rates in fallow would not be expected to injure winter wheat planted after the fallow period under Montana conditions. Other research, however, has shown that clomazone applied in soybeans can cause carryover injury in winter wheat (5, 6, 7).

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The purpose of this research was to determine the efficacy of clomazone applied in fallow and the injury to wheat planted one year after clomazone application in North Dakota.

## EXPERIMENTAL PROCEDURE

Experiments were conducted from 1986 to 1990 on loam soils at Williston, Minot, Devils Lake, and Carrington, on a silty clay at Fargo, and a sandy loam at Leonard to evaluate the efficacy of clomazone and clomazone-atrazine mixtures in fallow. Fall treatments were applied in mid to late October and spring treatments in late April. Estimates of percentage weed control were taken in late May to early July.

A two-year experiment was established in 1987 and again in 1988 at Minot and Williston (loam soils with 2 to 3 percent organic matter) to evaluate carryover of clomazone applied in fallow. Main plots were tillage practice and subplots were clomazone rates and application times (fall or spring). Clomazone was applied in untilled wheat stubble, either in the spring of the first year or the previous fall. Application dates are given in Table 1. The experiment was fallowed during the first year. Weeds were controlled over the entire experimental area by a fall application of chlorsulfuron (0.25 oz ai/A) followed by application of glyphosate as needed.

Seward hard red winter wheat was seeded in the fall of the first year (see Table 1 for dates) using a no-till drill without seedbed preparation tillage. Winter wheat seeding depth was 1 to 1.5 inches except at Minot in 1988 where

**Table 1. Dates of clomazone application and wheat planting for clomazone carryover experiments.**

| | | Clomazone application | | Wheat planting[1] | |
|---|---|---|---|---|---|
| Site | Year | Fall | Spring | HRWW | HRSW |
| Minot | 1987/88 | 10-9-86 | 5-22-87 | 9-11-87 | 4-20-88 |
| | 1988/89 | 10-14-87 | 5-18-88 | 9-23-88 | 5-3-89 |
| Williston | 1987/88 | 10-8-86 | 5-18-87 | 9-8-87 | 4-26-88 |
| | 1988/89 | 10-15-87 | 5-16-88 | 9-23-88 | 5-17-89 |

[1]HRWW = hard red winter wheat; HRSW = hard red spring wheat.

seeding depth was 0.5 inch. Stoa hard red spring wheat was seeded in the spring of the second year using a no-till drill (Table 1). Spring wheat seeding depth was 1 to 1.5 inches except at Minot in 1989 where seeding depth was 0.75 inch. Tilled spring wheat plots received one 3- to 5-inch-deep pass with a disc or field cultivator prior to seeding while no-till plots were seeded directly into untilled soil.

Soil was fertilized according to soil test for yield goals of 30 bushels per acre for Williston and 50 bushels per acre for Minot. Diclofop, bromoxynil, and MCPA were applied at recommended rates for weed control.

Visual estimates of percentage winter wheat chlorosis were taken in the fall when wheat was in the two- to three-leaf stage. Stand reduction and chlorosis of winter wheat and chlorosis of spring wheat were estimated in the spring when crop stages were fully tillered and two- to three-leaf, respectively. Wheat was combine harvested at maturity and yields adjusted to 12 percent moisture.

## RESULTS AND DISCUSSION

Green foxtail, kochia, and Russian thistle control by clomazone at 0.75 or 1 pound per acre applied alone in the fall was extremely inconsistent (Table 2). Control was especially poor in 1988, probably because of prolonged dry weather during the spring of that year. Chlorsulfuron at 0.015 pound per acre applied in this same dry environment controlled kochia 100 percent but provided only 33 percent Russian thistle control (Table 2).

The other rates of fall-applied chlorsulfuron shown in Table 2 represent applications in a different year and illustrate the 85 to 95 percent Russian thistle control typically observed with chlorsulfuron in fallow. Best foxtail, kochia, and Russian thistle control by fall-applied clomazone was observed when spring rains occurred during weed emergence. Data for fall-applied clomazone plus atrazine were obtained during the moist early summer of 1990 and show excellent control of all species (Table 2).

Clomazone at 0.5 pounds per acre applied in the spring (late April) and tank mixed with 0.5 pounds per acre atrazine consistently controlled kochia, Russian thistle, common lambsquarters, wild mustard, and wild buckwheat in fallow (Table 2). Green foxtail control, however, averaged only 76 percent. This degree of foxtail control would leave a fallow field appearing quite weedy and would require further control measures even though broadleaf weeds had been essentially eliminated. Unfortunately, this could mean from one to four additional weed control operations (tillage or spraying) during the summer, depending on rainfall events and the number of new flushes of green foxtail emergence. Thus, failure to control green foxtail could limit the effectiveness of clomazone-atrazine in chemical fallow in North Dakota, given the prevalence of this species in the state.

In general, our research indicates that clomazone or clomazone-atrazine combinations are most effective when the soil is moist during weed emergence. Weeds emerging when the surface 1 to 2 inches is relatively dry may escape control if significant rainfall does not occur within 10 to 20 days of emergence. This seems particularly the case with green foxtail and to a lesser extent with Russian thistle and kochia.

Clomazone injury on susceptible plants appears as "whitening" or "bleaching" of leaves. Clomazone applied in fallow at recommended rates of 0.5 to 0.75 pounds per acre caused less than about 10 percent visible injury to spring wheat, with the exception of the Williston site in 1989 where injury was 10 to 20 percent (Tables 3 and 4). Similarly, injury on winter wheat was about 10 percent or less when clomazone at 0.5 and 0.75 pounds per acre was applied 11 months earlier, except at Williston in 1988-89 where visible injury was more severe (Table 5). The only grain yield reductions attributable to clomazone residues were observed at Minot in 1989 after application of 1.5 to 2 pounds per acre, representing 2 to 2.7 times the maximum use rate in fallow.

At first glance, the lack of grain yield reductions from carryover residues of clomazone applied at labeled rates suggests that clomazone carryover is not a concern in fallow-wheat rotations in North Dakota. However, double rates of herbicide are difficult or impractical to avoid due to sprayer overlap on headlands and around potholes and other field irregularities. Growers using clomazone in a fallow-wheat rotation may need to accept the possibility of injury symptoms and yield reductions in these areas of the field. In addition, sprayers used to apply clomazone probably should be equipped with marker systems to prevent double coverage that occurs between adjacent sprayer passes.

**Table 2. Summary of weed control by clomazone plus atrazine in fallow.[1]**

| | | | Weed control | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Green foxtail | | Kochia | | Russian thistle | | Common lambsquarters | | Wild buckwheat |
| Herbicide | Rate | Application timing | Avg. | Range | Avg. | Range | Avg. | Range | Avg. | Range | Avg. |
| | lb/A | | % | | | | | | | | |
| Clomazone | 0.75 | Fall | 35 (3) | 0-99 | 50 (2) | 0-100 | 37 (3) | 0-98 | 100 (1) | | 100 (1) |
| Clomazone | 1 | Fall | 25 (3) | 8-55 | 62 (2) | 25-99 | 41 (2) | 0-82 | — | | — |
| Clomazone + atrazine | 0.75 + 0.5 | Fall | 99 (1) | | 100 (1) | | 100 (1) | | 100 (1) | | 100 (1) |
| Chlorsulfuron | 0.012 | Fall | 20 (2) | 8-32 | 94 (1) | | 88 (1) | | — | | — |
| Chlorsulfuron | 0.015 | Fall | 0 (1) | | 100 (1) | | 33 (1) | | 99 (1) | | — |
| Chlorsulfuron | 0.023 | Fall | 33 (2) | 19-46 | 99 (1) | | 93 (1) | | — | | — |
| Clomazone + atrazine | 0.5 + 0.5 | Spring | 76 (9) | 27-99 | 99 (10) | 95-100 | 98 (9) | 94-100 | 98 (7) | 89-100 | 100 (5) |

[1]Numbers in parentheses indicate the number of experiments comprising the control values.

**Table 3. Injury to spring wheat by carryover residues of clomazone applied in fallow at Minot.[1]**

| Wheat tillage system | Clomazone application timing | Clomazone rate | 1988 Spring wheat | | 1989 Spring wheat | |
|---|---|---|---|---|---|---|
| | | | Injury | Grain yield | Injury | Grain yield |
| | | lb/A | % | bu/A | % | bu/A |
| No-till | — | 0 | 0 | 27 | 0 | 37 |
| | Fall | 0.75 | 2 | 26 | 2 | 37 |
| | | 1 | 3 | 24 | 2 | 36 |
| | | 1.25 | 4 | 27 | 6 | 36 |
| | | 1.5 | 5 | 26 | 8 | 34 |
| | | 2 | 7 | 25 | 12 | 32 |
| | Spring | 0.5 | 2 | 23 | 3 | 36 |
| | | 0.75 | 4 | 25 | 5 | 35 |
| | | 1 | 6 | 26 | 9 | 34 |
| | | 1.25 | 11 | 26 | 18 | 34 |
| | | 1.5 | 11 | 25 | 16 | 35 |
| | | 2 | 18 | 24 | 39 | 32 |
| Tilled | — | 0 | 0 | 21 | 0 | 42 |
| | Fall | 0.75 | 4 | 22 | 5 | 39 |
| | | 1 | 9 | 22 | 6 | 37 |
| | | 1.25 | 9 | 24 | 9 | 33 |
| | | 1.5 | 17 | 21 | 12 | 34 |
| | | 2 | 32 | 23 | 37 | 37 |
| | Spring | 0.5 | 5 | 20 | 3 | 38 |
| | | 0.75 | 12 | 20 | 22 | 37 |
| | | 1 | 23 | 21 | 20 | 36 |
| | | 1.25 | 33 | 22 | 30 | 35 |
| | | 1.5 | 44 | 25 | 45 | 31 |
| | | 2 | 43 | 22 | 63 | 30 |
| LSD (0.05) Rate x Tillage | | | 8 | NS | 12 | 7 |

[1]There was no significant effect of tillage on grain yield but injury was significantly greater in tilled plots.

**Table 4. Injury to spring wheat by carryover residues of clomazone applied in fallow at Williston.[1]**

| Clomazone application timing | Clomazone rate | 1988 Spring Wheat | | 1989 Spring Wheat | | |
|---|---|---|---|---|---|---|
| | | Injury | Grain yield | Injury | Stand reduction | Grain yield |
| | lb/A | % | bu/A | % | | bu/A |
| — | 0 | 0 | 4.5 | 0 | 4 | 5.1 |
| Fall | 0.75 | 1 | 6.5 | 19 | 14 | 5.8 |
| | 1 | 2 | 5.4 | 27 | 21 | 6.3 |
| | 1.25 | 4 | 6.0 | 36 | 22 | 6.8 |
| | 1.5 | 3 | 6.2 | 56 | 53 | 4.7 |
| | 2 | 11 | 4.2 | 62 | 46 | 4.8 |
| Spring | 0.5 | 2 | 5.8 | 9 | 12 | 6.4 |
| | 0.75 | 4 | 5.5 | 19 | 14 | 6.5 |
| | 1 | 11 | 3.7 | 27 | 21 | 8.1 |
| | 1.25 | 17 | 4.4 | 42 | 29 | 6.9 |
| | 1.5 | 23 | 4.9 | 51 | 46 | 6.7 |
| | 2 | 36 | 4.7 | 63 | 54 | 4.7 |
| LSD (0.05) | | 10 | NS | 18 | 27 | NS |

[1]Tillage effect was not significant for both injury and grain yield; date are combined across tillage treatments.

**Table 5. Injury to winter wheat by carryover residues of clomazone fall-applied in fallow at Minot and Williston.**

| Clomazone rate | 1987/88 Winter Wheat | | | 1988/89 Winter Wheat | | | |
|---|---|---|---|---|---|---|---|
| | Injury[1] | | Grain yield | Injury[1] | | Stand reduction | Grain yield |
| | Fall | Spring | | Fall | Spring | | |
| lb/A | % | | bu/A | % | | | bu/A |
| **Minot** | | | | | | | |
| 0 | 0 | 0 | 18 | 0 | 0 | 31 | 34 |
| 0.5 | 0 | 1 | 21 | 6 | 1 | 41 | 33 |
| 0.75 | 0 | 2 | 24 | 11 | 1 | 32 | 35 |
| 1 | 0 | 5 | 21 | 23 | 1 | 62 | 32 |
| 1.25 | 0 | 12 | 19 | 30 | 2 | 49 | 30 |
| 1.5 | 0 | 14 | 22 | 33 | 1 | 55 | 30 |
| LSD (0.05) | NS | 8 | NS | 22 | NS | NS | NS |
| **Williston** | | | | | | | |
| 0 | 0 | 0 | 3.1 | 0 | 0 | 7 | 19 |
| 0.5 | 1 | 0 | 4.5 | 13 | 3 | 37 | 15 |
| 0.75 | 2 | 0 | 4.0 | 32 | 6 | 55 | 10 |
| 1 | 1 | 0 | 4.4 | 41 | 5 | 68 | 12 |
| 1.25 | 3 | 1 | 3.7 | 44 | 9 | 62 | 13 |
| 1.5 | 5 | 2 | 3.9 | 60 | 8 | 78 | 10 |
| LSD (0.05) | NS | NS | NS | 23 | NS | 24 | NS |

[1]Winter wheat injury by clomazone (chlorosis) was determined either in the fall (mid October) or the following spring (mid May).

Grain yield reductions attributable to clomazone did not occur at Williston in 1989 despite high visible injury for both spring and winter wheat and high stand reductions for winter wheat (Tables 4 and 5). Lack of yield response to herbicide injury was undoubtedly due to drought (Table 6) and consequent low crop yield potential. Under normal moisture conditions, yield reductions due to clomazone carryover likely would be expressed. On the other hand, drought during the years of clomazone application (1987 and 1988) probably increased the persistence of the herbicide and led to greater carryover injury to wheat than might otherwise have occurred.

Perhaps the worst-case scenario for carryover injury and yield reductions by clomazone (or most any herbicide that is persistent in soil) is dry conditions during the year of application and high rainfall in the following year. Dry conditions during the year of application would allow minimum opportunity for herbicide breakdown; high moisture during the crop year would facilitate maximum availability and uptake of herbicide residues as well as good yield potential to allow expression of herbicide injury.

Clomazone or clomazone-atrazine mixtures have potential as a tool for weed control on fallow land. In North Dakota, however, use of clomazone on fallow may be limited by a weakness in controlling green foxtail, inconsistent control under dry conditions, and the possibility of wheat injury the year after application.

**Table 6. Annual rainfall measured at clomazone carryover experimental sites.**

| Location | Parameter | 1987 | 1988 | 1989 |
|---|---|---|---|---|
| | | ..... inches ..... | | |
| Minot | Rainfall | 15.90 | 11.41 | 15.18 |
| | Deviation from average | -1.28 | -5.77 | -2.00 |
| Williston | Rainfall | 11.68 | 10.64 | 11.54 |
| | Deviation from average | -2.17 | -3.21 | -2.31 |


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