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Weed Management in Sweet Corn: Herbicide Alternatives to Atrazine Tolerant Weeds, Propane Flaming for In-row Weed Control, and Planter Evaluation for Minimum Tillage Systems.

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Abstract

In 1994 we focused on three aspects of vegetation management in sweet corn: herbicide alternatives to atrazine for atrazine tolerant weeds; propane flaming for in-row weed control; and planter efficiency in cover crop residue, no-till systems. Acetochlor effectively controlled tolerant pigweed plus nightshade and barnyard grass for both PPI and PRE applications; including fair control of proso millet at one site. Slight corn injury was noted at higher rates. Acetochlor plus dimethenamid improved weed control slightly, but was no better than acetochlor plus atrazine. Acetochlor plus halosulfuron controlled weeds with low corn injury. Dimethenamid controlled atrazine tolerant pigweed best when applied PPI, but corn injury was moderate. Dimethenamid plus atrazine improved control of tolerant pigweed compared to either herbicide alone (PRE), but had no advantage if dimethenamid was applied PPI with PRE atrazine. Dimethenamid plus atrazine controlled tolerant pigweed better than metolachlor plus atrazine. Halosulfuron and nicosulfuron severely injured corn except in the early planting. Corn injury was severe with a combination of flumetsalam and metolachlor (Broadstrike). Propane flaming controlled in-row weeds in sweet corn with rates ranging from 6.1 to 12.9 gal/acre. Weed emergence was greatly reduced by eliminating spring tillage in a killed cover crop system, and the cross-slot planter effectively planted through cover crop residues of up to 1.5 tons with no detrimental effect on corn growth.

Introduction

A two-to-three decade reliance on triazine herbicides in sweet corn production, particularly atrazine, has led to the selective development of populations of certain weed species resistant to control with herbicides in this chemical family. Additionally, concern for the presence of triazine herbicides in agricultural area aquifers has caused these materials to be classed as "restricted use" herbicides. These factors encourage the development of additional weed control strategies to maintain profitability in sweet corn production.

The objectives of this years research were: 1) to continue evaluation of new herbicides that may be available in the near future such as dimethenamid, acetochlor, nicosulfuron, and flumetsalam; 2) Evaluate the use of propane flaming in concert with cultivation to control weeds within the corn row; and 3) evaluate a novel planter design for planting in conventional tillage, stale seedbed, and conservation tillage environments.

1. Herbicide Alternatives to Atrazine Tolerant Weeds

Trials were conducted at two grower operated sites near Junction city and Stayton. Treatments were evaluated through the 5 to 6 leaf stage of corn for tolerance and weed control. A third trial was located at the Vegetable Research Farm near Corvallis to assess herbicide impacts on crop yield.

Herbicides were applied pre-plant incorporated (PPI), preemergence (PRE) or post emergence (POST) with several concentrations and combinations. All treatments were applied with a CO_2 unicycle plot sprayer. Golden Jubilee sweet corn was planted at Corvallis and Stayton, and super sweet Golden Jubilee at Junction City. Dyfonate was applied at Stayton and Junction City.

All plots were hoed and cultivated twice at Corvallis after the weed evaluation at 40 days after planting. The weeded treatment was hoed prior to the weed evaluation and the unweeded check plot was cultivated and hand hoed after the initial weed evaluation.

Results and Discussion

Site specifics. Atrazine was effective in controlling pigweed only at the Vegetable Research Farm. Pigweed at Junction City was very tolerant. Pigweed was also tolerant at the Stayton site based on the poor pigweed control with atrazine in the surrounding field. Sweet corn (super sweet Golden Jubilee) injury was very low at the May 10 planting in Junction City for all treatments even though this was a super sweet variety and dyfonate insecticide was applied. This site had nearly perfect moisture at planting and irrigation was not applied till well into June.

Herbicide Performance (Tables 1-6)[1].

Acetochlor: Excellent pigweed, purslane, nightshade, and barnyard grass control for both PPI and PRE applications. Good control of proso millet at Stayton site. Slight corn injury was noted at higher rates of 1.75 and 2.75 lbs ai/A.

Acetochlor plus atrazine (PRE): Slight increase in weed control compared to acetochlor applied alone. Low corn injury.

Acetochlor plus dimethenamid (PPI): Excellent pigweed, purslane, nightshade and barnyard grass control. Good control of proso millet at the Stayton site, but no better than acetochlor plus atrazine and alachlor plus atrazine. Slight corn injury except at Corvallis.

[1] Please see appendix on page 15 for brand names of herbicides.

Acetochlor plus halosulfuron (only at Junction city site, PPI): Excellent pigweed and nightshade control. Good control on barnyard grass. Low corn injury.

Dimethenamid: Excellent pigweed control at Junction city when applied PPI, but poor control when applied PRE at same location. Excellent pigweed control at both Corvallis and Stayton. Moderate corn injury when applied at the rate above 1.25 lbs ai/A. Moderate corn injury when applied PPI at the Corvallis site. Better nightshade and proso millet control than metolachlor.

Dimethenamid plus atrazine (PPI/PRE and PRE/PRE): Excellent weed control and no corn injury at Corvallis when applied PRE; slight injury if applied PPI/PRE. Injury severe at Stayton with PPI/PRE and weed control fair. At Junction city, definite advantage in weed control of combined PRE application than either herbicide alone. No advantage if dimethenamid applied PPI. Other sites suggest safety problem with PPI applications however. This combination more effective than metolachlor plus atrazine.

Halosulfuron (both applied tank mix and alone): Excellent pigweed control. Extremely high corn injury except at Junction city site where there was good weed control and very little corn injury.

Nicosulfuron (both applied tank mix and alone): Excellent pigweed control, except for Stayton site. High corn injury at all sites except Junction city. No advantage to combination with halosulfuron.

Metolachlor+flumetsalam (Broadstrike): Excellent weed control at all sites. Extremely high corn injury at Corvallis and Stayton, but very low injury at Junction City.

Table 1. Corn yield and weed control at Vegetable Research Farm, Corvallis, OR, 1994.

Treatment	Rate	Timing	Weed control (6 WAP)[1]			Corn injury	Sweet corn harvest			
	(lbs ai/A)		Pigweed	Nightshade	Purslane	(6 WAP)	Unhusked wt	Husked wt	Ears	Culls[2]
			————	%	————	%	t/ac	t/ac	no/12'	%
1.[3] Atrazine	1.00	PRE	100	100	100	3	13.1	8.7	28	13
2. Atrazine Metolachlor	1.00 2.00	PRE PRE	100	100	100	3	12.2	7.9	20	2
3. Metolachlor	2.00	PRE	100	88	100	6	13.9	9.1	27	12
4. Metolachlor[4] Flumetsalam	2.10 0.0625	PRE	100	100	100	55	13.4	8.2	25	24
5. Alachlor	2.75	PPI	92	53	77	0	11.8	8.2	24	3
6. Alachlor	2.75	PRE	100	100	100	0	12.5	8.1	22	12
8. Dimethenamid	1.25	PPI	100	99	88	17	11.3	7.4	21	24
10. Dimethenamid	1.25	PRE	100	100	100	8	13.4	8.8	25	7
12. Dimethenamid Acetochlor	0.75 1.50	PPI PPI	100	99	100	4	12.6	8.4	26	15
13a. Dimethenamid Atrazine	1.00 1.00	PRE PRE	100	100	100	0	11.6	7.5	22	10
14a. Dimethenamid Atrazine	1.25 1.00	PPI PRE	100	100	100	5	14.9	9.4	29	15
15. Acetochlor	1.50	PPI	95	98	88	1	12.2	8.5	25	22
16. Acetochlor	1.75	PPI	100	100	100	0	12.3	8.1	23	9
18. Acetochlor	1.50	PRE	100	95	85	5	13.3	9.2	25	5
21. Acetochlor Atrazine	1.75 1.00	PRE PRE	100	100	100	5	13.7	9.3	27	12
22. Halosulfuron	0.0375	PPI	100	58	95	31	12.3	7.0	21	17
24. Halosulfuron Alachlor	0.0375 2.75	PPI PPI	100	100	100	41	9.7	6.7	22	22
25. Halosulfuron	0.075	PRE	100	80	100	45	9.6	6.1	23	21
27a. Halosulfuron Nicosulfuron	0.0375 0.0320	POST POST	100	71	100	35	11.0	7.0	23	20
28. Nicosulfuron	0.0320	POST	100	80	100	34	12.7	8.5	26	13
30. Untreated[5]	-	-	0	0	0	0	10.8	7.1	22	5
31. Weeded	-	-	75	40	30	0	10.9	7.9	21	6
LSD (0.05)			15	22	22	12	4.1	2.9	NS	16

[1] WAP: weeks after planting

[2] Includes unfilled and damaged ears.

[3] Treatment numbers coordinated among sites.

[4] Broadstrike=metolachlor (7.47 lbs ai/gal) and flumetsalam (0.20 lbs ai/gal).

[5] Cultivated after initial weed control estimate.

Table 2. Herbicide Application Record Sheet for Corvallis site.

Location: Vegetable Research Farm, Corvallis
Crop and planting date: sweet corn (Golden Jubilee) June 2, 1994.
Soil type: silty clay loam

	Application 1	Application 2	Application 3
Application date	June 2, 1994	June 2	June 28
Application timing	PPI	PRE	POST
Start/end time	8:00-9:30 AM	11:00-12:30 PM	7:30-8:30 AM
Air temp	70	70	62
Relative humidity	45	45	NA
Soil moisture	Moisture at 1"	Dry surface	Dry surface
Plant moisture	-	-	Wet from dew
Sprayer/PSI	40	40	40
Gallons H_2O/acre	32	32	32
Soil inc depth (PPI/PRE)	2 inch	-	-
Soil inc method/implement	Lely rotera	-	-

Table 3. Weed control and corn injury at Junction city site, 1994.

Treatment	Rate (lbs ai/A)	Timing	Percent weed control (7 WAP)			Sweet corn injury
			Pigweed	Nightshade	Barnyard grass	%
1. Atrazine	1.0	PRE	61	48	78	1
2. Atrazine Metolachlor	1.0 2.0	PRE PRE	73	93	98	2
3. Metolachlor	2.0	PRE	71	100	94	1
4. Metolachlor[1] Flumetsalam	2.1 0.0625	PRE	89	95	93	1
5. Alachlor	2.75	PPI	90	95	98	1
6. Alachlor	2.75	PRE	89	100	88	1
8. Dimethenamid	1.25	PPI	97	95	95	0
9. Dimethenamid	1.5	PPI	96	100	92	1
10. Dimethenamid	1.25	PRE	70	100	92	1
11. Dimethenamid	1.5	PRE	65	100	96	2
12. Dimethenamid Acetochlor	0.75 1.5	PPI PPI	96	95	96	2
13. Dimethenamid Atrazine	1.25 1.0	PRE PRE	90	70	91	0
14. Dimethenamid Atrazine	1.75 1.0	PPI PRE	96	87	98	1
15. Acetochlor	1.5	PPI	98	100	92	1
16. Acetochlor	1.75	PPI	95	95	100	2
18. Acetochlor	1.5	PRE	99	100	98	2
19. Acetochlor	1.75	PRE	98	100	96	1
20. Acetochlor	2.0	PRE	94	100	95	2
21. Acetochlor Atrazine	1.75 1.0	PRE PRE	99	100	97	0
22. Halosulfuron	0.0375	PPI	78	100	70	3
23. Halosulfuron Acetochlor	0.0375 2.75	PPI PPI	97	100	92	2
25. Halosulfuron	0.075	PRE	92	100	68	0
26. Halosulfuron	0.094	PRE	90	100	76	1
27. Halosulfuron Nicosulfuron	0.0375 0.75	POST POST	57	47	67	0
29. Nicosulfuron	0.75	POST	75	77	67	2
30. Untreated	-	-	0	0	0	0
LSD (0.05)			19	15	16	NS

[1] Broadstrike=metolachlor (7.47 # ai/gal) and flumetsalam (0.20 # ai/gal).

Table 4. Herbicide application record sheet for Junction City site.

Location: Junction City
Crop and Planting date: Sweet corn (super sweet Golden Jubilee), May 9 1994.
Soil type: loam

	Application 1	Application 2	Application 3
Application date	May 6, 1994	May 12	June 8
Application timing	PPI	PRE	POST
Start/end time	6:00-8:00 AM	8-11:00 AM	3:00-3:30 PM
Air temp/soil temp (2")	60/58	70/70	80/93
Rel humidity	62	47	37
Wind direction/velocity	N/0-1	NW/ 0-2	NW 0-2
Cloud cover	0	0	0
Soil moisture	Dry surface	Dry surface	Dry surface
Plant moisture	-	-	Very dry
Sprayer/PSI	40	40	40
Gallons H_2O/acre	30	30	30
Soil inc depth (PPI/PRE)	2 inch	-	-
Soil inc method/implement	vibrashank	none	-

Notes

1. Dyfonate insecticide applied at this site.
2. Preemergence halosulfuron applied 5/13; air temp 56, soil temp 60, humidity 66%.

Table 5. Weed control and corn injury at Stayton site, 1994.

Treatment	Rate	Timing	Percent weed control (6 WAP)			Sweet corn injury
	(lbs ai/ac)		Pigweed	Lambsquarter	Wild proso millet	%
3. Metolachlor	2.0	PRE	82	100	55	1
7. Alachlor Atrazine	2.75 1.0	PRE PRE	99	100	91	6
9. Dimethenamid	1.5	PPI	98	100	81	12
10. Dimethenamid	1.25	PRE	97	62	80	10
12. Dimethenamid Acetochlor	0.75 1.5	PPI PPI	99	100	87	10
14a. Dimethenamid Atrazine	1.25 1.0	PPI PRE	95	87	86	20
15. Acetochlor	1.5	PPI	100	82	81	7
16. Acetochlor	1.75	PPI	100	100	76	10
17. Acetochlor	2.75	PPI	87	100	81	5
18. Acetochlor	1.5	PRE	99	100	67	2
19. Acetochlor	1.75	PRE	100	100	80	1
21. Acetochlor Atrazine	1.75 1.0	PRE PRE	100	100	93	1
24. Halosulfuron Alachlor	0.0375 2.75	PPI PPI	100	100	68	51
27a. Halosulfuron Nicosulfuron	0.032 0.029	POST POST	99	100	97	48
28. Nicosulfuron	0.032	POST	99	25	98	23
30. Unweeded	-	-	0	0	0	0
LSD (0.05)			14	28	26	18

Table 6. Herbicide application record sheet for Stayton site.

Location: Stayton
Crop and planting date: sweet corn (Golden Jubilee), June 23, 1994
Soil type: Gravelly silt loam

	Application 1	Application 2	Application 3
Application date	June 20, 1994	June 24	July 22
Application timing	PPI	PRE	POST
Start/end time	1:00-3:00 PM	3-3:45 PM	10:15-10:45 AM
Air temp/soil temp (2")	87/86	75/83	90/NA
Rel humidity	50	50	70
Soil moisture	Dry	Dry	Moist
Plant moisture	-	-	Dry leaf surface
Sprayer/PSI	40	40	40
Gallons H_2O/acre	30	30	30
Soil inc depth (PPI/PRE)	3 inch	-	-
Soil inc method/implement	rototiller	none	-

2. Propane Flaming for In-row Weed Control in Sweet Corn.

Sweet corn (Golden Jubilee) was planted on 36 inch rows on June 1, 1994. The flame dispensers were mounted on directed-sprayer skids to keep the nozzles at an even height above the ground. Flame was applied with two shielded nozzles directed from both sides of the row, offset 12 inches from each other, and held 8 inches from the corn row. The shielded flamers were directed at the base of the corn plants at a 45 degree angle. Each plot consisted of two rows in the middle of the plot that were flamed and two outside rows in each plot that were not flamed, allowing a more reliable assessment of flaming as each flamed section had an unflamed treatment immediately adjacent. All treatments were applied at 3 MPH.

Treatments 2-6 were flamed (See Table 7 for timing and rate) 27 days after planting (DAP). Then the entire experimental plot was cultivated and soil was hilled next to the corn. Thereafter, treatments were flamed according to the schedule in Table 7. The entire plot was again cultivated 38 DAP (July 8).

Weed biomass was collected from adjacent flamed and unflamed rows on July 14 (43 DAP) from 3 foot of row and in a band that included 4 inches on both sides of the row. After weed samples were cut, Trs. 1-7, 9, and 11-13 were hand hoed to reduce weed competition effects on growth and permit evaluation of corn growth responses to burning without competition factors. Treatments 8 and 10 had good weed control at this point and remained unweeded for a full-season weed evaluation. The last flame application was applied to Trs. 10 and 13 after the plots were weeded.

Results

All treatments listed in Table 8 except Tr. 2 reduced weed biomass compared to the unflamed controls, even though purslane was very common and the predominate weed at some locations within this trial. Purslane is very tolerant to flaming because of its fleshy leaves. Crop yield was significantly reduced in only one treatment (Tr. 3), where extensive burning of the foliage occurred (see Table 7). There was little advantage for weed control when the corn was flamed at less than 10 inches. At 10 inches, sweet corn tolerated rates of to 2.3 gal/A and reduced weed biomass by nearly 50 percent. Increasing the number of applications greatly improved weed control. Corn tolerated very intense heat at rates as high as 6.8 gal/A when 16 inches tall, indicating that higher pressures may be possible at the 24 inch stage. As a rule of thumb at 3 MPH and this configuration, corn can tolerate approximately 1 gal/acre for every four inches of corn growth.

The plots that were not handweeded for the full season demonstrated propane flaming can be effective for full season, in-row weed control in sweet corn with these flaming units and configuration (data not shown). Treatment 8 with two applications reduced weed biomass by 90 percent at harvest and had a yield comparable to the control. Treatment 10 with 3 flamings had the highest yield and controlled weeds throughout the season (greater than 90 percent control at harvest). However, cost, inconvenience, and timeliness of application may deter use unless inexpensive herbicides such as atrazine are unavailable. Cost of Trs. 8 and 10 for the propane only was approximately $6.10 and $12.90/acre, respectively[1]. Comparatively, the cost of the herbicide only for Atrazine (2 lbs ai/A) and Dual (2 lbs ai/acre) in an 8 inch band would be $1.57 and $3.85 respectively on 36 inch rows.

Another trial was set up late in the season to evaluate tolerance of sweet corn when flamed at emergence. Sweet corn was affected very little when propane flame at 3.8 gal/acre was oriented directly over the row just as the corn emerged from the soil. Future research will evaluate full season corn growth with this system.

[1] Estimate based on 36 inch row spacing and propane price of $0.99/gal.

Table 7. Effect of propane flaming on sweet corn yield, Corvallis, OR, 1994.

Treatment	Corn ht. in. (max.)	DAP[1]	Propane (gal/A) gal/A/ application	Propane (gal/A) total gal/A[2]	Unhusked wt. t/ac[3]	Shucked wt t/ac	Total no ears no/20' row	Ear wt lbs	Filled ears %
1.	Control (handweeded, no flaming)				11.4	7.4	44	0.72	95
2.	6	27	1.6	1.6	10.6	7.4	37	0.76	99
3.	6	27	2.3	2.3	8.7*	5.9*	29	0.83	93
4.	6 10	27 31	0.9 2.3	3.2	10.7	7.6	42	0.71	99*
5.	6 10 16	27 31 37	0.9 2.3 3.8	7.0	9.8	7.3	36	0.75	99*
6.	6 18	27 39	0.9 7.0	7.9	10.8	7.8	36	0.81	98
7.	10	31	2.3	2.3	12.3	8.5	38	0.87	100*
8.	10 16	31 37	2.3 3.8	6.1	11.1	7.8	37	0.81	98*
9.	10 16 18	31 37 39	2.3 3.8 6.8	12.9	9.9	6.9	31	0.85	93
10.	10 16 24	31 37 43	2.3 3.8 6.8	12.9	12.3	7.6	38	0.90	98
11.	10 16	31 39	2.3 6.8	9.1	10.4	7.3	36	0.79	98
12.	16	37	6.8	6.8	10.6	8.1	47	0.65	96
13.	16 24	37 43	6.8 6.8	13.6	9.9	7.3	38	0.72	99

1 DAP: days after planting that propane was applied to corn.

2 Propane use for 36" rows at 3 MPH. Propane cost approximately $0.99/gal.

3 Values designated with (*) within the same column differ statistically with the control (Treatment 1).

Table 8. Effect of propane flaming on weed biomass and sweet corn yield 7 weeks after planting, Corvallis, OR, 1994.

Treatment					Weed biomass reduction	Sweet corn yield
No.	Corn ht	DAP[1]	Propane use[2]			
	in (max.)		gal/acre/ application	total gal/A	%	t/ac
1		Control			-	11.4
2	6	27	1.6	1.6	0	10.6
3	6	27	2.3	2.3	6	
4	6 10	27 31	0.9 2.3	3.2	48	10.7
5	6 10 16	27 31 37	0.9 2.3 3.8	7.0	72	9.8
6	6 18	27 39	0.9 6.8	7.7	58	10.8
7	10	31	3.8	3.8	47	12.3
8	10 16	31 37	2.3 3.8	6.1	80	11.1
11	10 18	31 39	2.3 6.8	9.1	70	10.4
12	16	37	6.8	6.8	68	10.6

1 DAP: days after planting that propane was applied,

2 Propane application rate is for 36" rows at 3 MPH. Propane cost is $0.99/gal.

3. Cross-slot Planter Evaluation.

Significant improvements in weed control may be pioneered by improving or fine tuning tillage or planting strategies and equipment. Emergence of some weed species such as nightshade can be greatly reduced by avoiding tillage in the spring or limiting disturbance at planting in both no-till and stale seedbed systems. Cover crop residues also decrease weed emergence in no-till systems. However, double disk openers have difficulty planting through even moderate crop residues and cause excessive soil disturbance because of the double disk arrangement and shanks or disks for banded fertilizer placement. The cross-slot planter has been designed to challenge these problems. The cross-slot planter can plant through residues of up to 1.5 tons drymatter per acre with very little soil disturbance while precisely placing fertilizer without additional shanks or openers.

A single row unit of the cross-slot planter was tested in three different systems for sweet corn planting. These included untilled soil with residues of fall-planted *Hesk* barley, untilled soil with spring-planted cereal and mustard cover crops, and conventional tillage.

Hesk barley was fall drilled on Oct 21, 1993 and killed with glyphosate on April 15, 1994. Sweet corn was planted in 36 inch rows on May 21 along with 250 lbs of banded 12-29-10 fertilizer. Corn biomass was cut on August 21 and weighed. Additionally, sweet corn was planted into residues of *Micah* barley, *Wheeler* rye, annual ryegrass, and *Humus* rape seed that were planted May 10 and killed with glyphosate June 6. On June 21 the standing cover crop residues were flailed and sweet corn planted with the cross-slot planter. This trial also included a rototilled treatment.

Results

Sweet corn emergence and sweet corn biomass (after 8 weeks) were equal to seedling emergence and biomass in the conventionally tilled control in a fall-planted cover crop (Table 6). Weed suppression was exceptional in the cover crop residue plot. Nightshade plants completely covered the soil within a few weeks after planting in the tilled plot, while the undisturbed cover crop plots were nearly weed free. Mowing was used to reduce competition in the tilled plot.

The cross slot planter also performed well in residues of spring planted cereals (Table 7). While emergence was unaffected, corn biomass in the cover crop plots was greater than or equal to biomass in the conventionally tilled plots. However, this trial was planted near the end of June, and soil conditions were very warm. Earlier planting may have reduced this effect.

Though a one-row unit was used in these experiments, plans are being developed for a two-row unit. This project was funded by the sweet corn commission but the unit was not built in time for the 1994 season. Expectations are to have this planter functional by spring of 1995.

Table 9. Efficiency of cross slot planter in untilled soil with residues of fall-planted cereals.

Treatment	Emergence	Corn biomass (lbs/10 ft row)
Cover crop residue, untilled	35	30.4
Conventional tillage	36	30.4

Table 10. Efficiency of cross-slot planter in minimum tillage situation with cover crop residues.

Treatment	Corn emergence (no./4 ft row)	Corn biomass 12 weeks after planting (lbs/10' row)	Cereal biomass (t/acre)
Micah barley	28	25.3	1.5
Wheeler rye	25	29.9	1.0
Annual ryegrass	25	24.3	0.7
Humus rape	21	30.2	1.2
Conventional tillage	23	22.1	0
LSD	NS	7.5	0.4

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Thanks to the Belden Farm of Stayton and The Bryce Brothers Farm of Junction City for cooperating in these trials.

Appendix. Chemical and brand names for herbicides used.

Acetochlor	Harness
Alalchlor	Lasso
Atrazine	Aatrex
Dimethenamid	Frontier
Halosulfuron	Battalion
Metolachlor	Dual
Nicosulfuron	Accent