**Gold Section: Sugarbeet Weed Control** **Page**

# RO-NEET AND EPTAM WEED EFFICACY AND SUGARBEET TOLERANCE

Thomas J. Peters[1] and Alexa L. Lystad[2]
[1]Extension Sugarbeet Agronomist and Weed Control Specialist and [2]Research Specialist
North Dakota State University & University of Minnesota, Fargo, ND

**Introduction**

Sugarbeet yield loss to weed interference averaged 70% in sugarbeet growing areas in North America (Soltani et al. 2018). This equates to about $211 and $369 million loss of income from sugarbeet production in North Dakota and Minnesota, respectively. Cycloate, pyrazon, ethofumesate, and EPTC were applied preplant incorporated (PPI) or preemergence (PRE) for weed control in sugarbeet fields in the Red River Valley and Michigan from 1970 to the mid-1980s (Dale et al. 2006). However, use of soil-applied herbicides declined to less than 5% of sugarbeet acres in North Dakota and Minnesota in the mid-1980s because of reliance on POST herbicides and cultivation (Luecke and Dexter 2003). Weeds continue to be a major concern due to limited herbicide options within sugarbeet. EPTC and cycloate could reemerge as important herbicides for weed control.

The objective of this experiment was to evaluate weed control and sugarbeet tolerance from Ro-Neet and Eptam alone or in mixtures.

**Materials and Methods**

Experiments were conducted on natural weed populations and bioassay species strips near Hickson, ND in 2015, 2016, 2018, and 2019. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage. Sugarbeet was seeded in 22-inch rows at 60,560 seeds per acre with 4.7 inch spacing between seeds.

Herbicide treatments included PPI applications of Ro-Neet, Eptam, and Ro-Neet + Eptam at multiple rates in 2015, 2016, 2018 (Table 1) and 2019 (Table 2). All treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with $CO_2$ at 40 psi to the center four rows of six row plots 35 feet in length. Herbicides were immediately incorporated using a rototiller set 3 to 4 inches deep. The center 8 feet of each plot was rototilled to remove the variability that could otherwise be caused by the incorporating tillage.

**Table 1. Herbicide treatments, rates, and application timing in trials near Hickson, ND in 2015, 2016, and 2018.**

| Herbicide Treatment | Rate (pt/A) | Timing of Application |
|---|---|---|
| Ro-Neet SB | 4.5 | PPI |
| Ro-Neet SB | 5.36 | PPI |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | PPI |
| Ro-Neet SB + Eptam | 4.5 + 2.29 | PPI |
| Eptam | 3.5 | PPI |

**Table 2. Herbicide treatments, rates, and application timing in trials near Hickson, ND in 2019.**

| Herbicide Treatment | Rate (pt/A) | Timing of Application |
|---|---|---|
| Ro-Neet SB | 4.5 | PPI |
| Ro-Neet SB | 5.36 | PPI |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | PPI |
| Ro-Neet SB + Eptam | 4.5 + 2.29 | PPI |
| Eptam | 3.5 | PPI |
| Eptam | 2.5 | PPI |

Sugarbeet tolerance and grass and broadleaf weed control were evaluated visually, beginning approximately seven days after sugarbeet emergence. Sugarbeet emergence date was dependent on growing conditions in each year. Evaluations generally were on weekly intervals following the first evaluation and continued until weeds overtook the plots. Sugarbeet injury and common lambsquarters, redroot pigweed, foxtail millet, and oat control was evaluated in 2019. All evaluations were a visual estimate of control in the four treated rows compared to the adjacent untreated strip. Experimental design was randomized complete block with 4 replications. Data were analyzed with the ANOVA procedure of ARM, version 2019.4 software package.

**Results**

**Eptam and Ro-Neet Across Years**

Sugarbeet injury was greater or tended to be greater from Eptam or Ro-Neet SB plus Eptam compared to Ro-Neet SB alone at 4.5 or 5.36 pt/A. (Table 3). Sugarbeet injury from Ro-Neet SB + Eptam at 2.67 + 2.29 pt/A was the same as sugarbeet injury from Ro-Neet SB + Eptam at 4.5 + 2.29 pt/A. Injury tended to decrease from 7 days after emergence (DAE) to 28 DAE.

**Table 3. Sugarbeet injury 7, 14, and 28 days after emergence (DAE) combined across years.**

| | | Sugarbeet Growth Reduction | | |
|---|---|---|---|---|
| Treatment | Rate | 7 DAE | 14 DAE | 28 DAE |
| | --pt/A-- | -------------------%--------------------- | | |
| Ro-Neet SB | 4.5 | 18 | 5 a | 3 a |
| Ro-Neet SB | 5.36 | 20 | 6 a | 10 ab |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | 44 | 32 b | 26 bc |
| Ro-Neet SB +Eptam | 4.5 + 2.29 | 50 | 33 b | 31 c |
| Eptam | 3.5 | 48 | 43 b | 30 c |
| LSD (0.05) | | NS | 13 | 16 |

Redroot pigweed control from Eptam alone or Ro-Neet SB + Eptam was greater than pigweed control from Ro-Neet SB alone (Table 4). There was no statistical difference in control between Eptam at 3.5 pt/A and Ro-Neet SB + Eptam at 2.67 + 2.29 pt/A or Ro-Neet SB + Eptam at 4.5 + 2.29 pt/A. However, numeric control tended to be greatest from Ro-Neet SB + Eptam at 4.5 + 2.29 pt/A. Redroot pigweed control from Ro-Neet SB at 5.36 pt/A was greater than pigweed control from Ro-Neet at 4.5 pt/A. However, control was less than Eptam or Ro-Neet SB plus Eptam treatments. Treatments that gave the greatest pigweed control 7 DAE also gave the greatest control 14 and 28 DAE. However, control tended to decline as time progressed. Oat control from Eptam or Ro-Neet SB plus Eptam was greater than 95% across all evaluation timings. Oat control from Ro-Neet SB at 4.5 or 5.36 pt/A was less than control from Ro-Neet SB + Eptam at either 2.67 or 4.5 pt/A + 2.29 pt/A.

**Table 4. Redroot pigweed and wild oat control 7, 14, and 28 days after emergence (DAE) combined across years.**

| | | Redroot Pigweed Control | | | Wild Oat Control | | |
|---|---|---|---|---|---|---|---|
| Treatment | Rate | 7 DAE | 14 DAE | 28 DAE | 7 DAE | 14 DAE | 28 DAE |
| | --pt/A-- | ---------------------------------%-------------------------------- | | | | | |
| Ro-Neet SB | 4.5 | 74 c | 61 c | 34 b | 66 c | 60 b | 49 c |
| Ro-Neet SB | 5.36 | 81 b | 72 b | 41 b | 82 b | 74 b | 66 b |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | 94 a | 89 a | 73 a | 100 a | 97 a | 97 a |
| Ro-Neet SB + Eptam | 4.5 + 2.29 | 95 a | 93 a | 82 a | 98 a | 98 a | 98 a |
| Eptam | 3.5 | 92 a | 88 a | 73 a | 99 a | 98 a | 98 a |
| LSD (0.05) | | 4 | 6 | 16 | 12 | 16 | 12 |

This ‘across years summary’ indicates redroot pigweed and oat control were greatest from Eptam alone or Ro-Neet SB + Eptam and not from Ro-Neet SB alone. With treatments containing Ro-Neet SB + Eptam, increasing the rate of Ro-Neet SB from 2.67 to 4.5 pt/A did not provide a statistical improvement in weed control. However, there was greater sugarbeet injury with Eptam alone or Eptam + Ro-Neet SB as compared to Ro-Neet SB alone (Table 3). Previous research and recommendations indicated tank-mixing Ro-Neet SB + Eptam was a technique to improve grass and broadleaf control and to decrease sugarbeet injury, especially shortly after planting (personal communication with A. Dexter). However, we did not observe improved sugarbeet safety with Ro-Neet SB + Eptam compared to Eptam alone in these trials

**Eptam and Ro-Neet 2019**

Sugarbeet injury was least with Ro-Neet SB at 4.5 pt/A or Ro-Neet SB + Eptam at 2.67 + 2.29 pt/A (Table 5). Injury was primarily stature reduction compared to the untreated rows due to delayed emergence. Injury tended to decrease as time progressed but was still evident 28 DAE. However, environmental conditions may have influenced sugarbeet injury. Rainfall was very abundant in July following dry conditions after planting and may have confounded early season stature reduction.

**Table 5. Sugarbeet injury 7, 14, and 28 days after emergence (DAE) in 2019.**

| | | Sugarbeet Growth Reduction | | |
|---|---|---|---|---|
| Treatment | Rate | 7 DAE | 14 DAE | 28 DAE |
| | --pt/A-- | ---------------------%--------------------- | | |
| Ro-Neet SB | 4.5 | 33 ab | 29 a | 24 ab |
| Ro-Neet SB | 5.36 | 51 c | 45 b | 41 bc |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | 30 a | 28 a | 15 a |
| Ro-Neet SB + Eptam | 4.5 + 2.29 | 44 bc | 26 a | 26 ab |
| Eptam | 3.5 | 48 c | 35 ab | 45 c |
| Eptam | 2.5 | 43 bc | 38 ab | 40 bc |
| LSD (0.05) | | 12 | 15 | 17 |

We evaluated redroot pigweed, common lambsquarters, foxtail millet and oat control in 2019 (Table 6). Common lambsquarters density was not as uniform as the redroot pigweed and is reflected in the evaluations. Eptam at 2.5 and 3.5 pt/A, Ro-Net SB + Eptam at 4.5 + 2.29 pt/A and Ro-Neet SB + Eptam at 2.67 + 2.29 pt/A provided or tended to provide redroot pigweed control greater than Ro-Neet SB alone 14 DAE. Eptam at both rates provided greater than 90% visible redroot pigweed control 25 DAE (data not presented). Eptam or Ro-Neet SB + Eptam across rates controlled foxtail millet better than Ro-Neet SB alone. No differences in common lambsquarters control were observed from Eptam rate. Eptam alone or Eptam + Ro-Neet SB provided oat control greater than Ro-Neet SB alone. No statistical difference in oat control was observed between Eptam at 2.5 and 3.5 pt/A at either 7 or 14 DAE. Likewise, oat control from Ro-Neet SB + Eptam at 2.67 + 2.29 pt/A was the same as oat control from Ro-Neet SB + Eptam at 4.5 + 2.29 pt/A. Eptam at 3.5 pt/A gave or tended to give better foxtail millet control than Eptam at 2.5 pt/A. Foxtail millet control was best with Eptam alone or Ro-Neet SB + Eptam. Ro-Neet SB at either 4.5 or 5.36 pt/A was more effective at controlling foxtail millet than oat. Eptam was similar efficacy on both foxtail millet and oat.

**Table 6. Redroot pigweed, common lambsquarters, foxtail millet, and wild oat control at 7 and 14 days after emergence (DAE) in 2019.**

| | | 7 DAE | | | | 14 DAE | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | Rate | rrpw[a] | colq | fxmi | oat | rrpw | colq | fxmi | oat |
| | --pt/A-- | ----------------------------------%-------------------------------- | | | | | | | |
| Ro-Neet SB | 4.5 | 65 c | 50 b | 81 bc | 43 c | 66 c | 84 | 96 b | 48 c |
| Ro-Neet SB | 5.36 | 70 bc | 81 a | 80 c | 53 b | 78 b | 88 | 96 b | 63 b |
| Ro-Neet SB + Eptam | 2.67 + 2.29 | 88 a | 75 ab | 89 ab | 89 a | 88 ab | 90 | 98 ab | 96 a |
| Ro-Neet SB + Eptam | 4.5 + 2.29 | 91 a | 85 a | 89 a | 90 a | 91 a | 93 | 97 ab | 95 a |
| Eptam | 3.5 | 87 a | 81 a | 92 a | 93 a | 92 a | 92 | 99 a | 97 a |
| Eptam | 2.5 | 76 b | 80 a | 80 c | 85 a | 87 ab | 91 | 99 a | 96 a |
| LSD (0.05) | | 9 | 18 | 8 | 8 | 11 | NS | 2 | 4 |

[a]Weed species abbreviations (left to right): rrpw=redroot pigweed, colq=common lambsquarters, fxmi=foxtail millet.

**References**

Dale TM, Renner KA, Kravchenko AN (2006) Effect of herbicides on weed control and sugarbeet (Beta vulgaris) yield and quality. Weed Sci 20:150-156

Luecke JL and Dexter AG (2003) Survey of weed control and production practices on sugarbeet in eastern North Dakota and Minnesota. Sugarbeet Res Ext Rep. 33:35-38

Soltani N, Dille A, Robinson DE, Sprague CL, Morishita DW, Lawrence NC, Kniss AR, Jha P, Felix J, Nurse RE, and Sikkema PH (2018) Potential yield loss in sugar beet due to weed interference in the United States and Canada. Weed Technol 32:749-753

# INTEGRATING HERBICIDES AND INTER-ROW CULTIVATION

Thomas J. Peters[1] and Alexa L. Lystad[2]

[1]Extension Sugarbeet Agronomist and Weed Control Specialist and [2]Research Specialist
North Dakota State University and the University of Minnesota, Fargo, ND

**Introduction**
The spread of glyphosate resistant waterhemp in Minnesota and North Dakota has sugarbeet growers looking into weed control methods that will supplement chemical control.

**Materials and Methods**
An experiment was conducted on common lambsquarters and waterhemp near Moorhead, MN in 2019. The trial site was prepared for planting using a Kongskilde s-tine field cultivator on May 9, 2019. ‘CR 355’ sugarbeet was planted in 22-inch rows at 61,500 seeds per acre on May 10 with a six-row planter. Preemergence (PRE) treatments were applied May 10. Postemergence (POST) treatments were applied June 6 and 19. All herbicide treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with $CO_2$ at 40 psi to the center four rows of six row plots 30 feet in length. A maintenance application of Roundup PowerMax at 22 fl oz/A was applied to the entire trial site on June 13 to reduce competition from common lambsquarters and allow waterhemp emergence. Cultivation treatment was applied June 25 to the center 4 rows of appropriate plots. The cultivator was operated at 4 mph, set 1 to 1.5 inches deep, and equipped with sweeps that tilled 15 inches of soil surface between rows. Sugarbeet injury and common lambsquarters control were evaluated June 6, 26, July 15, and August 9, 2019. Waterhemp control was evaluated June 26, July 15, and August 9. Sugarbeet were harvested September 20 by defoliating the center 4 rows of 30’ long plots and harvesting the center 2 rows with a two-row sugarbeet harvester. Sugarbeets were weighed and a subsample of about 25 lbs. of normal, representative roots from each plot were collected and taken to the American Crystal Tare Lab in East Grand Forks, MN for quality analysis.

**Table 1. Application Information – Moorhead, MN 2019**

| Application | A | B | C | Cultivation |
|---|---|---|---|---|
| Date | May 10 | June 6 | June 19 | June 25 |
| Time of Day | 6:00 PM | 9:00 AM | 12:30 PM | |
| Air Temperature (F) | 64 | 77 | 76 | |
| Relative Humidity (%) | 26 | 42 | 44 | |
| Wind Velocity (mph) | 10 | 2 | 2 | |
| Wind Direction | SW | NW | SE | |
| Soil Temp. (F at 6”) | 50 | 68 | 66 | |
| Soil Moisture | Good | Good | Good | Sli Wet |
| Cloud Cover (%) | 80 | 0 | 0 | |
| Sugarbeet Stage | PRE | 2-lf | 8-lf | 12-lf |
| Common Lambsquarters | PRE | 1 in | 3 in | |
| Waterhemp | PRE | 0 in | 3 in | |

All sugarbeet injury and weed control evaluations were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. The experiment was a 2x4 factorial split-block arrangement in a randomized complete block design with 4 replications. Each replication (block) was “grid split” where the factor A was cultivation at two levels and the factor B was herbicide at four levels. Data were analyzed with the ANOVA procedure of ARM, version 2019.4, software package.

**Results**
Cultivation (factor A) had no impact on sugarbeet injury at either evaluation (Table 2). Herbicide (factor B) had no impact on sugarbeet injury at either evaluation.

**Table 2. Sugarbeet Injury at Moorhead, MN, 2019.**

| Treatment | Rate | Timing[3] | Percent Sugarbeet Injury | |
|---|---|---|---|---|
| | (fl oz/A) | | June 6 | June 26 |
| **FACTOR A - Cultivation** | | | | |
| NO Cultivation | - | - | 9 | 8 |
| Cultivation | - | Cultivation | 8 | 7 |
| **FACTOR A LSD (0.05)** | | | **NS** | **NS** |
| **FACTOR B - Herbicide** | | | | |
| Dual Magnum | 8 | A | 7 | 3 |
| Dual Magnum fb | 8 fb | A fb | | |
| POST[1] + Outlook fb | 1x[2] + 18 fb | B fb | 8 | 8 |
| POST | 1x | C | | |
| Dual Magnum fb | 8 fb | A fb | | |
| POST fb | 1x fb | B fb | 13 | 9 |
| POST + Outlook | 1x + 18 | C | | |
| Dual Magnum fb | 8 fb | A fb | | |
| POST + Outlook fb | 1x + 12 fb | B fb | 7 | 11 |
| POST + Outlook | 1x + 12 | C | | |
| **FACTOR B LSD (0.05)** | | | **NS** | **NS** |

[1] POST = Roundup PowerMax @ 28 fl oz/A + Ethofumesate 4SC @ 6 fl oz/A + Destiny HC @ 1.5 pt/A + NPak AMS at 2.5% v/v

[2] 1x = rates specified in footnote 1.

[3] Timing refers to application timings in Table 1.

Cultivation (factor A) had no significant impact on common lambsquarters control at any evaluation timing (Table 3). Herbicide (factor B) significantly impacted common lambsquarters control at all evaluations taken after all herbicide application timings were completed. Dual Magnum at 0.5 pt/A was applied PRE on all plots and gave 68% to 78% control of common lambsquarters. Plots receiving two applications of POST herbicides following PRE Dual Magnum showed 97% to 99% lambsquarters control later in the season compared to 38% to 70% control in plots receiving only PRE Dual Magnum. Cultivation did not impact common lambsquarters control when POST herbicides were applied (data not shown), but PRE Dual Magnum followed by cultivation tended to give 15% to 20% greater common lambsquarters control compared to PRE Dual Magnum without cultivation (data not shown).

**Table 3. Common Lambsquarters Control at Moorhead, MN, 2019.**

| Treatment | Rate | Timing[3] | Percent Common Lambsquarters Control | | | |
|---|---|---|---|---|---|---|
| | (fl oz/A) | | June 6 | June 26 | July 15 | August 8 |
| **FACTOR A - Cultivation** | | | | | | |
| NO Cultivation | - | - | 72 | 85 | 88 | 86 |
| Cultivation | - | Cultivation | 70 | 81 | 94 | 90 |
| **FACTOR A LSD (0.05)** | | | **NS** | **NS** | **NS** | **NS** |
| **FACTOR B - Herbicide** | | | | | | |
| Dual Magnum | 8 | A | 68 | 38 | 70 | 55 |
| Dual Magnum fb | 8 fb | A fb | | | | |
| POST[1] + Outlook fb | 1x[2] + 18 fb | B fb | 78 | 99 | 98 | 99 |
| POST | 1x | C | | | | |
| Dual Magnum fb | 8 fb | A fb | | | | |
| POST fb | 1x fb | B fb | 69 | 97 | 97 | 99 |
| POST + Outlook | 1x + 18 | C | | | | |
| Dual Magnum fb | 8 fb | A fb | | | | |
| POST + Outlook fb | 1x + 12 fb | B fb | 70 | 99 | 99 | 99 |
| POST + Outlook | 1x + 12 | C | | | | |
| **FACTOR B LSD (0.05)** | | | **NS** | **11** | **11** | **8** |

[1] POST = Roundup PowerMax @ 28 fl oz/A + Ethofumesate 4SC @ 6 fl oz/A + Destiny HC @ 1.5 pt/A + NPak AMS at 2.5% v/v

[2] 1x = rates specified in footnote 1.

[3] Timing refers to application timings in Table 1.

Cultivation (factor A) had no significant impact on waterhemp control at June and July evaluation timings (Table 4). The August evaluation showed cultivation gave an improvement in waterhemp control compared to no cultivation, though the difference was slight. Herbicide (factor B) significantly impacted waterhemp control at all evaluations.

Dual Magnum at 0.5 pt/A was applied PRE and gave 41% to 74% control of wtaerhemp. Plots receiving two applications of POST herbicides following PRE Dual Magnum showed 96% to 99% waterhemp control. Cultivation did not impact waterhemp control when POST herbicides were applied (data not shown), but PRE Dual Magnum followed by cultivation tended to give 10% to 15% greater waterhemp control compared to PRE Dual Magnum without cultivation (data not shown).

**Table 4. Waterhemp Control at Moorhead, MN, 2019.**

| Treatment | Rate | Timing[3] | Percent Waterhemp Control | | |
|---|---|---|---|---|---|
| | (fl oz/A) | | June 26 | July 15 | August 8 |
| **FACTOR A - Cultivation** | | | | | |
| NO Cultivation | - | - | 85 | 89 | 87 |
| Cultivation | - | Cultivation | 82 | 95 | 91 |
| **FACTOR A LSD (0.05)** | | | **NS** | **NS** | **3.3** |
| **FACTOR B - Herbicide** | | | | | |
| Dual Magnum | 8 | A | 41 | 74 | 62 |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST[1] + Outlook fb | 1x[2] + 18 fb | B fb | 96 | 99 | 98 |
| POST | 1x | C | | | |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST fb | 1x fb | B fb | 98 | 97 | 99 |
| POST + Outlook | 1x + 18 | C | | | |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST + Outlook fb | 1x + 12 fb | B fb | 99 | 99 | 99 |
| POST + Outlook | 1x + 12 | C | | | |
| **FACTOR B LSD (0.05)** | | | **16** | **10** | **7** |

[1] POST = Roundup PowerMax @ 28 fl oz/A + Ethofumesate 4SC @ 6 fl oz/A + Destiny HC @ 1.5 pt/A + NPak AMS at 2.5% v/v
[2] 1x = rates specified in footnote 1.
[3] Timing refers to application timings in Table 1.

Impacts of cultivation and herbicide on yield followed a very similar trend as has been discussed with respect to weed control. Cultivation (factor A) had no significant impact on yield parameters (Table 5). There is a slight numeric trend towards greater root yield (1.3 ton/A) and greater extractable sucrose (353 lb/A) from cultivation, but the impact was not statistically significant. Herbicide (factor B) significantly impacted root yield, but did not impact sugar percentage or extractable sucrose per acre. Dual Magnum at 0.5 pt/A applied PRE gave 27.0 ton/A root yield, while plots receiving two applications of POST herbicides following PRE Dual Magnum gave 29.9 to 31.3 tons/A. Cultivation did not impact root yield or extractable sucrose when POST herbicides were applied (data not shown), but PRE Dual Magnum followed by cultivation gave 6.2 tons/A greater root yield and 1,200 lbs/A greater extractable sucrose compared to PRE Dual Magnum without cultivation (data not shown).

**Conclusions**

Common lambsquarters was very dense in this trial in late May and early June and was actually suppressing waterhemp germination. Waterhemp started to emerge following an across trial application of Roundup PowerMax at 22 fl oz/A on June 13. The main influence on weed control as the season progressed was not cultivation, but rather Outlook herbicide. For both common lambsquarters and waterhemp, the greatest control was observed when Outlook was applied early POST (2 leaf), late POST (8 leaf), or as a split application at both timings. Due to the early season interference from common lambsquarters, waterhemp emergence was delayed and both POST timings of Outlook were effective at controlling waterhemp. The broadcast application of Roundup PowerMax at 22 fl oz/A allowed us to observe the PRE followed by a single POST application system. This system was not effective at controlling either waterhemp or common lambsquarters under very dense weed pressure. Higher rates of Roundup may have improved common lambsquarters control, but increased rates of POST applied glyphosate would not have improved control of the glyphosate-resistant waterhemp.

**Table 5. Yield Impacts from cultivation and herbicide at Moorhead, MN, 2019.**

| Treatment | Rate | Timing[3] | Yield | Sugar | Ext. Sucrose |
|---|---|---|---|---|---|
| | (fl oz/A) | | Ton/A | % | Lb/A |
| **FACTOR A - Cultivation** | | | | | |
| NO Cultivation | - | - | 29.1 | 13.7 | 7,154 |
| Cultivation | - | Cultivation | 30.4 | 13.7 | 7,507 |

| | | | | | |
|---|---|---|---|---|---|
| **FACTOR A LSD (0.05)** | | | **NS** | **NS** | **NS** |
| **FACTOR B - Herbicide** | | | | | |
| Dual Magnum | 8 | A | 27.0 | 13.7 | 6,679 |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST[1] + Outlook fb | 1x[2] + 18 fb | B fb | 30.7 | 13.6 | 7,485 |
| POST | 1x | C | | | |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST fb | 1x fb | B fb | 29.9 | 13.9 | 7,485 |
| POST + Outlook | 1x + 18 | C | | | |
| Dual Magnum fb | 8 fb | A fb | | | |
| POST + Outlook fb | 1x + 12 fb | B fb | 31.3 | 13.7 | 7,673 |
| POST + Outlook | 1x + 12 | C | | | |
| **FACTOR B LSD (0.05)** | | | **3.5** | **NS** | **NS** |

[1] POST = Roundup PowerMax @ 28 fl oz/A + Ethofumesate 4SC @ 6 fl oz/A + Destiny HC @ 1.5 pt/A + NPak AMS at 2.5% v/v
[2] 1x = rates specified in footnote 1.
[3] Timing refers to application timings in Table 1.

The impact of cultivation on weed control was skewed in this trial. In the plots that received only Dual Magnum PRE, weed pressure was quite heavy. It was in these weedy plots that we observed the greatest impact from cultivation on weed control. This observation is logical and supports what we've known for many years: cultivation in weedy fields generally helps eliminate some weeds and typically improves overall weed control. The weed pressure was lighter in the plots that received POST herbicides and there was less benefit from cultivation. However, no negative effects from cultivation such as increased root disease was observed. Likewise, cultivation did not negatively affect Outlook, which to be effective, must be evenly distributed in the top inch of the soil horizon for weeds to absorb the herbicide and to be controlled.

# SUGARBEET TOLERANCE AND WEED CONTROL FROM POSTEMERGENCE ETHOFUMESATE 4SC

Alexa L. Lystad[1] and Thomas J. Peters[2]

[1]Research Specialist and [2]Extension Sugarbeet Agronomist Weed Control Specialist
North Dakota State University & University of Minnesota, Fargo, ND

**Introduction**
Sugarbeet (*Beta vulgaris* L.) is a high value, root crop with approximately 18% sucrose content in the root (Milford 2006). Weed control is an important component in profitability of sugarbeet production (Soltani et al. 2018). Weeds can also affect sugarbeet quality by reducing sucrose percentage and decreasing the aesthetics of production fields. Ethofumesate is a broad spectrum, soil-applied herbicide for control of broadleaf and grass weeds in sugarbeet (Edwards et al. 2005). Some weed species controlled with ethofumesate are common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* L.), barnyardgrass (*Echinochloa crus-galli*), and wild oat (*Avena fatua* L.), which are known to reduce yield in sugarbeet (Ekins and Cronin 1972). Ethofumesate is a commonly used soil-applied herbicide, however, it can be applied postemergence at 12 fl oz/A. Generic Crop Science has developed a new Ethofumesate 4SC label that increases postemergence use rates from 12 to 128 fl oz/A to sugarbeet with greater than two true leaves. Field and greenhouse experiments were conducted in 2018 and 2019 to evaluate sugarbeet tolerance and herbicide efficacy.

**Materials and Methods**
**Sugarbeet Tolerance**
Experiments were conducted near Downer, MN, Hickson, ND, Horace, ND and Prosper, ND in 2018 and Crookston, MN, Hickson, ND, Prosper, ND, and Wolverton, MN in 2019. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage to each location. Sugarbeet was planted between May 3 and June 7 across 2018 and 2019.

Herbicide treatments were applied when sugarbeet was at the 2-lf stage with a bicycle wheel sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with $CO_2$ at 40 psi to the center four rows of six row plots 30 feet long. Treatments consisted of one application of ethofumesate at 0, 8, 16, 32, 64, and 128 fl oz/A. All treatments contained Destiny HC at 1.5 pt/A which was provided by Winfield United.

Sugarbeet injury was evaluated as a visual estimate of percent growth reduction of the middle 4 rows per plot compared to the adjacent 2 untreated rows. Sugarbeet was harvested from the center two rows of the four treated rows within a plot in the fall and assessed for yield and quality. Yield components were analyzed using SAS Data Management software PROC MIXED procedure to test for significant differences at p=0.05. Experimental design was randomized complete block with 6 replications.

**Ethofumesate Efficacy**
Experiments were conducted on indigenous populations of common lambsquarters, redroot pigweed, and waterhemp in sugarbeet grower fields near Moorhead, Lake Lillian, and Oslo, Minnesota and Minto and Prosper, North Dakota in 2018 and 2019. The experimental area was prepared for planting by applying the appropriate fertilizer and tillage to each location. Sugarbeet was planted between May 7$^{th}$ and 15$^{th}$ in both years.

Herbicide treatments were applied at the 2-lf sugarbeet stage. All treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with $CO_2$ at 40 psi to the center four rows of six row plots 40 feet in length.

Sugarbeet injury and weed control was evaluated. All evaluations were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. Experimental design was randomized complete block with four replications. Data were analyzed with the ANOVA procedure of ARM, version 2019.4 software package.

**Results**

**Sugarbeet Tolerance**

Sugarbeet stature reduction ranged from 0 to 28% 7 DAT (days after treatment) and 0 to 29% 14 DAT (Table 1). Stature reduction increased as ethofumesate rate increased from 8 to 128 fl oz/A. Ethofumesate at 8 and 16 fl oz/A had similar stature to the untreated check at 7, 14 and 28 DAT. Ethofumesate at 32 fl oz/A had slightly reduced stature compared to the untreated check at 7 and 14 DAT but had grown out of the injury and looked similar to the untreated check at 28 DAT. Ethofumesate at 64 and 128 fl oz/A had greater injury compared to the untreated check at 7, 14 and 28 DAT. Visible stature reduction tended to decrease throughout the growing season.

**Table 1. Stature reduction in response to Ethofumesate 4SC rate across 7 environments in 2018-2019[a].**

| Ethofumesate[b] | 7 DAT[c] | 14 DAT | 28 DAT |
|---|---|---|---|
| --fl oz/A-- | -------------------% stature reduction------------------- | | |
| 0 | 0 a | 0 a | 0 a |
| 8 | 2 a | 1 a | 0 a |
| 16 | 2 a | 2 a | 1 a |
| 32 | 7 b | 6 b | 2 a |
| 64 | 16 c | 14 c | 8 b |
| 128 | 28 d | 29 d | 18 c |
| **LSD (0.05)** | **5** | **5** | **4** |
| | ------------------*P*-value------------------- | | |
| | <0.0001 | <0.0001 | <0.0001 |

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.
[b]High surfactant methylated oil concentrate at 1.5 pt/A added to each post treatment.
[c]Stature reduction 7 and 14 days after treatment (DAT).

Sugarbeet root yield and sucrose content were not affected by ethofumesate rate, however, recoverable sucrose content generally decreased as ethofumesate rate increased (Table 2). Ethofumesate decreased recoverable sucrose content at 128 fl oz/A to 8,024 lbs/A compared to the untreated check at 8,484 lbs/A. While ethofumesate at 64 fl oz/A numerically decreased recoverable sucrose per acre, it was still statistically comparable to the untreated check. Root yield and sucrose content was an average of 30 tons/A and 15.6% across all treatments and environments.

**Table 2. Root yield, recoverable sucrose, and sucrose content in response to Ethofumesate 4SC rate across 7 environments in 2018-2019.[a]**

| Ethofumesate[b] | Root Yield[c] | Sucrose Content | Rec. Suc[d] |
|---|---|---|---|
| --fl oz/A-- | ---Tons/A--- | ---%--- | ---lbs/A--- |
| 0 | 30 | 15.7 | 8,484 ab |
| 8 | 30 | 15.6 | 8,343 abc |
| 16 | 30 | 15.7 | 8,440 ab |
| 32 | 31 | 15.7 | 8,511 a |
| 64 | 29 | 15.7 | 8,143 bc |
| 128 | 29 | 15.4 | 8,024 c |
| **LSD (0.05)** | **NS** | **NS** | **349** |
| | -------------------------*P*-value---------------------- | | |
| | 0.1703 | 0.2844 | 0.0410 |

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.
[b]High surfactant methylated oil concentrate at 1.5 pt A added to each post treatment.
[c]Root yield reported in tons per acre.
[d]Recoverable sucrose reported in pounds per acre.

Ethofumesate reduced sugarbeet stature at rates greater or equal to 32 fl oz/A, however, stature reduction decreased as time progressed. Sugarbeet stature and yield components were negatively affected by rates of ethofumesate of 64 fl oz/A or greater.

**Ethofumesate Efficacy Results**

Visible common lambsquarters control ranged from 43 to 100% when herbicide treatments were evaluated 7 DAT and from 26-96% 14 DAT (Table 3). Glyphosate alone gave 98 and 95% control 7 and 14 DAT, respectively. While ethofumesate at 32 and 64 fl oz/A plus glyphosate provided 100% numerical common lambsquarters control 7 DAT, adding ethofumesate with glyphosate did not significantly improve common lambsquarters control compared to glyphosate alone.

Common lambsquarters control from ethofumesate generally increased as the ethofumesate rate increased. Common lambsquarters control from 32 fl oz/A ethofumesate was greater at 7 and 14 DAT than control from 16 fl oz/A ethofumesate. However, increasing the rate from 32 to 64 or 128 fl oz/A did not consistently improve common lambsquarters control.

**Table 3. Common lambsquarters visible control 7 and 14 DAT across 10 environments[a] in 2018 and 2019.**

| | | Common Lambsquarters | |
|---|---|---|---|
| **Treatment** | **Rate** | **7 DAT** | **14 DAT** |
| | ----fl oz/A---- | --------------%--------------- | |
| Glyphosate | 32 | 98 a | 95 a |
| Ethofumesate | 16 | 48 e | 45 e |
| Ethofumesate | 32 | 70 cd | 66 d |
| Ethofumesate | 64 | 64 d | 77 bcd |
| Ethofumesate | 128 | 79 bc | 84 abc |
| Ethofumesate + glyphosate | 32 + 32 | 100 a | 96 a |
| Ethofumesate + glyphosate | 64 + 32 | 100 a | 95 a |
| **LSD (0.05)** | | **13** | **16** |
| | | ------------*P*-value------------- | |
| | | <0.0001 | <0.0001 |

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.

Visible redroot pigweed control ranged from 32 to 100% when evaluated 7 DAT and 15 to 98% when evaluated 14 DAT (Table 4). Ethofumesate alone at rates ranging from 16 to 128 fl oz/A controlled 44 to 64 and 47 to 76% redroot pigweed 7 and 14 DAT, respectively. Redroot pigweed control was greater at 32 fl oz/A ethofumesate alone compared to 16 fl oz/A, 14 DAT, but control did not significantly increase as the ethofumesate rate increased.

Glyphosate alone or with ethofumesate at 32 or 64 fl oz/A provided the greatest redroot pigweed control 7 and 14 DAT, however, the addition of ethofumesate did not improve redroot pigweed control compared to the glyphosate alone at 7 DAT. Glyphosate plus ethofumesate at 32 or 64 fl oz/A tended to be better than glyphosate alone 14 DAT, suggesting the residual control benefit of mixing ethofumesate with glyphosate. Ethofumesate at 32 fl oz/A combined with glyphosate provided redroot pigweed control similar to ethofumesate at 64 fl oz/A combined with glyphosate at both 7 and 14 DAT.

Visual waterhemp control ranged from 46 to 91% and from 31 to 91% at 7 and 14 DAT, respectively (Table 5). Waterhemp control from glyphosate was 62% at 7 DAT and 53% at 14 DAT suggesting waterhemp were glyphosate resistant biotype. Ethofumesate tended to increase waterhemp control as ethofumesate rate increased. This was observed at both 7 and 14 DAT.

Waterhemp control from 64 or 128 fl oz/A ethofumesate was better than control from 16 fl oz/A ethofumesate at 7 DAT. Waterhemp control from 128 fl oz/A ethofumesate was better than 16 or 32 fl oz/A ethofumesate at 14 DAT. Ethofumesate tended to improve waterhemp control 14 DAT compared to 7 DAT, suggesting residual control. There was no difference in waterhemp control between 32 or 64 fl oz/A ethofumesate plus glyphosate at either 7 or 14 DAT. Although ethofumesate alone at 128 fl oz/A provided similar waterhemp control as compared to glyphosate plus ethofumesate, applying ethofumesate alone at 64 or 128 fl oz/A may not be an effective strategy due to less sugarbeet tolerance at higher ethofumesate rates and increased input costs from high rates of ethofumesate compared to lower rates of ethofumesate mixed with glyphosate. Glyphosate applied with ethofumesate also provides greater control of other broadleaf weeds in fields including redroot pigweed and common lambsquarters in addition to potentially controlling germinating waterhemp with susceptible alleles.

**Table 4. Redroot pigweed visible control 7 and 14 DAT across 10 environments[a] in 2018 and 2019.**

| Treatment | Rate | Redroot Pigweed | |
|---|---|---|---|
| | | 7 DAT | 14 DAT |
| | ----fl oz/A---- | -------------%-------------- | |
| Glyphosate | 32 | 99 a | 93 ab |
| Ethofumesate | 16 | 44 fg | 47 e |
| Ethofumesate | 32 | 50 ef | 62 d |
| Ethofumesate | 64 | 54 def | 71 cd |
| Ethofumesate | 128 | 64 cd | 76 cd |
| Ethofumesate + glyphosate | 32 + 32 | 99 a | 98 a |
| Ethofumesate + glyphosate | 64 + 32 | 100 a | 99 a |
| **LSD (0.05)** | | **10** | **14** |
| | | -------------*P*-value----------- | |
| | | <0.0001 | <0.0001 |

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.

**Table 5. Waterhemp visible control 7 and 14 DAT across 10 environments[a] in 2018 and 2019.**

| Treatment | Rate | Waterhemp | |
|---|---|---|---|
| | | 7 DAT | 14 DAT |
| | ----fl oz/A---- | ---------------%---------------- | |
| Glyphosate | 32 | 62 bcd | 53 cd |
| Ethofumesate | 16 | 58 cd | 65 bcd |
| Ethofumesate | 32 | 63 bcd | 66 bc |
| Ethofumesate | 64 | 74 abc | 78 ab |
| Ethofumesate | 128 | 80 ab | 84 a |
| Ethofumesate + glyphosate | 32 + 32 | 86 a | 86 a |
| Ethofumesate + glyphosate | 64 + 32 | 91 a | 91 a |
| **LSD (0.05)** | | **18** | **16** |
| | | -----------*P*-value------------ | |
| | | 0.0001 | <0.0001 |

[a]Means within a main effect not sharing any letter are significantly different by the LSD at the 5% level of significance.

**Summary**

Ethofumesate 4SC applied postemergence at rates from 8 to 128 fl oz/A did not influence sugarbeet density, root yield, or sucrose content. However, Ethofumesate 4SC significantly reduced recoverable sucrose and sugarbeet stature at 128 fl oz/A when sugarbeet tolerance experiments were combined across locations in 2018 and 2019.

Ethofumesate is not a stand-alone postemergence herbicide for common lambsquarters, redroot pigweed, or waterhemp control, however, ethofumesate can increase efficacy of postemergence glyphosate applications. Results suggest a mixture of ethofumesate at 32 fl oz/A plus glyphosate applied early POST can improve burndown and residual control of common lambsquarters, redroot pigweed, and waterhemp compared to ethofumesate or glyphosate alone. However, similar control from glyphosate alone was observed in common lambsquarters and redroot pigweed. Benefits of adding ethofumesate to an early POST glyphosate application may not become apparent until later in the growing season. Benefits of ethofumesate may not be observed if application is not timed to an activating rainfall. Additional research may be conducted to evaluate two-spray programs of glyphosate and ethofumesate.

**References**

Edwards D, Zinn N, Prieto R, Wyatt TJ, Brown L, Al-Mudallal A, et al. (2005) Reregistration eligibility decision for ethofumesate. Environmental Protection Agency. 738-R-05-010. https://www3.epa.gov/pesticides/chem_search/reg_actions/reregistration/red_PC-110601_1-Sep-05.pdf. Accessed: September 26, 2017

Ekins WL, Cronin CH (1972) NC 8438, a promising new broad spectrum herbicide for sugarbeet. J Amer Soc of Sugar Beet Technol 17:134-143

Milford GFJ (2006) Plant structure and crop physiology. Page 30 in Draycott AP ed. Sugarbeet. United Kingdom: Blackwell Publishing Ltd

Soltani N, Dille A, Robinson DE, Sprague CL, Morishita DW, Lawrence NC, Kniss AR, Jha P, Felix J, Nurse RE, and Sikkema PH (2018) Potential yield loss in sugar beet due to weed interference in the United States and Canada. Weed Tech 32:749-753

# HERBICIDE TOLERANCE TRAIT IN SOYBEAN: FLEXIBILITY OR COMPLEXITY

Thomas J. Peters[1] and Alexa L. Lystad[2]

[1]Extension Sugarbeet Agronomist and Weed Control Specialist and [2]Research Specialist
North Dakota State University and the University of Minnesota, Fargo, ND

**Summary**

1. The herbicide treatment used with herbicide traits is more important than trait and respective herbicide(s) applied with the trait.
2. Herbicide traits are opportunities for improved control of troublesome weeds when the herbicide treatment fails to provide control or deliver multiple effective herbicides.
3. Use both effective PRE and timely POST applications to manage weeds, regardless of the herbicide or herbicide trait.

**Introduction**

Weeds continue to concern sugarbeet producers (Soltani et al. 2018). Sugarbeet is a poor competitor with weeds from emergence to canopy closure (Cattanach et al. 1991). Sugarbeet cotyledons are small, lack vigor, and take roughly two months to shade ground between rows, thus providing ample time for weeds to establish and compete. Limited weed control options and herbicide resistance places sugarbeet at a disadvantage compared to other row crops (Soltani et al. 2018). A strategy to aid weed control in sugarbeet is to maximize weed management in the crop sequence with sugarbeet. Crop rotations introduces growth cycle diversification thus changing inputs including pesticides (Liebman and Dyck 1993) and changing weed spectrum and pressure resulting in increased crop yield (Peterson and Varvel 1989). Crop sequences across the region and cooperatives (Southern Minnesota Beet Sugar Cooperative, Minn-Dak Farmers' Cooperative, and American Crystal Sugar Company) all include soybean. Soybean producers in the United States, particularly in the Midwest, list waterhemp as one of their most troublesome weeds to control (Soltani et al. 2009). Waterhemp growth characteristics, including extended emergence patterns, cause waterhemp escapes since waterhemp may germinate, emerge, and produce seed after the producer has completed his / her weed control program.

Herbicide tolerant trait technologies, including Xtend and Liberty Link, have created POST herbicide options creating effective option for control of late germinating waterhemp in soybean, thus reducing seed in the soil seed bank while improving herbicide diversification throughout crop sequence with sugarbeet. The objective of this experiment was to evaluate herbicide treatments and trait technologies in soybean by considering waterhemp and common lambsquarters control, crop rotation flexibility, herbicide diversity, and cost. Our hypotheses is a weed management plan delivering multiple effective herbicides for lambsquarters and waterhemp control will improve overall control. Second, effective weed control can be achieved with multiple herbicide trait technologies thus providing opportunity for improved profitability. The question for producers is selecting a herbicide trait technology the first or last step in finalizing the weed management plan in soybean.

**Materials and Methods**

An experiment was conducted near Moorhead, MN in 2019. The experimental area was prepared for planting using a Kongskilde s-tine field cultivator on May 9, 2019. ND Stutsman conventional, AG0934 Roundup Ready2, S150097 LibertyLink, and AG07X9 Roundup Ready 2 Xtend soybean were planted in 22-inch rows at 160,000 seeds per acre on May 30 with a John Deere 1700XP 6-row planter. Herbicide trait technologies represent some of the many traits available to MN and ND producers in soybean (Table 1).

Experimental design was randomized complete block with four replications for each trial. Treatment arrangement was a two-factor factorial; factors being herbicide treatment and herbicide trait technology. PRE, EPOST, and POST herbicides were applied immediately after planting on May 31, June 19, and July 1, respectively. Herbicide treatment was a soil residual herbicide applied as single herbicide, a mixture, or PRE, and a soil residual herbicide EPOST followed by the herbicide conforming to the herbicide trait (i.e. Liberty applied to LibertyLink soybean) (Table 2). FlexStar was applied POST over conventional soybean. All herbicide treatments were applied with a bicycle sprayer in 17 gpa spray solution through 8002 XR flat fan nozzles pressurized with $CO_2$ at 40 psi to the center four rows of six row plots 30 feet in length. Environmental conditions at application are indicated in Table 3.
Table 1. Soybean herbicide-resistance traits and herbicides that can be used in combination with resistant traits. A checkmark indicates that soybean herbicide trait packages have resistance to various herbicide products.[a]

| Soybean Herbicide Trait | Glyphosate | Glufosinate | 2,4-D | Dicamba[c] | HPPD |
|---|---|---|---|---|---|

| | | | Choline[b] | | Inhibitors[d] |
|---|---|---|---|---|---|
| Conventional | ✓ | | | | |
| Glyphosate Tolerant (GT) | ✓ | | | | |
| Roundup Ready[e] | ✓ | | | | |
| Roundup Ready 2 Yield[e] | ✓ | | | | |
| Roundup Ready 2 Yield Xtend[e] | ✓ | | | ✓ | |
| Roundup Ready 2 Yield Xtendflex[e] | ✓ | ✓ | | ✓ | |
| LibertyLink (LL) | | ✓ | | | |
| LLGT27d | ✓ | ✓ | | | ✓ |
| Enlist | ✓ | | ✓ | | |
| Enlist E3 | ✓ | ✓ | ✓ | | |
| GT27 | ✓ | | | | ✓ |

[a] Always consult herbicide labels for application requirements.
[b] Only approved 2,4-D choline formulations (Enlist Duo, Enlist One) are permitted for over-the top applications to Enlist and Enlist E3 soybeans.
[c] Only approved dicamba formulations (Engenia, FeXapan, Tavium, XtendiMax) are permitted for over-the-top application to Xtend and XtendFlex soybeans.
[d] GT27 and LLGT27 are resistant to isoxaflutole pre-emergence. No HPPD-inhibiting herbicide is approved for use in soybeans in the U.S. as of January 2020.
[e] Always consult herbicide label to determine if glyphosate formulation is approved for RR soybeans.
[f] Not approved for commercial production in the U.S. as of January 2020.

Table 2. Herbicide treatment in soybean

| **Herbicide treatment** | **Timing** |
|---|---|
| Valor / Trait | PRE / POST |
| Valor[a] + Zidua / Trait | PRE / POST |
| Valor + Zidua / chloroacetamide[b] / Trait | PRE / EPOST /POST |
| Valor + Zidua + metribuzin / chloroacetamide / Trait | PRE / EPOST /POST |

[a]Valor or Engenia, depending on seed trait
[b]Dual Magnum, Outlook, or Warrant depending on seed trait

Table 3. Application Information – Moorhead, MN 2019

| **Date** | **May 31** | **June 19** | **July 1** |
|---|---|---|---|
| Time of Day | 2:30 PM | 1:00 PM | 11:00 AM |
| Air Temperature (F) | 79 | 76 | 77 |
| Relative Humidity (%) | 30 | 44 | 57 |
| Wind Velocity (mph) | 8 | 2 | 4 |
| Wind Direction | N | SE | N |
| Soil Temp. (F at 6”) | 65 | 66 | 70 |
| Soil Moisture | Fair | Good | Good |
| Cloud Cover (%) | 0 | 90 | 50 |
| Next Rainfall | June 8 | June 20 | July 3 |
| Soybean Stage | PRE | 1 Trifoliolate | 2 Trifoliolate |
| Common lambsquarters | 0 in | 3 in | 9 in |
| Redroot Pigweed | 0 in | 2 in | 9 in |
| Waterhemp | 0 in | 2 in | 9 in |

Soybean injury and common lambsquarters and waterhemp control described in this report were evaluated on June 26, July 15, and 25, 2019. All soybean injury and weed control evaluations were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. Data were analyzed with the ANOVA procedure of ARM, version 2019.4, software package.

**Results**

Visible soybean injury from herbicide treatments was negligible 26 DAP (days after planting) but increased to 40% when Liberty followed Fierce MTZ and Outlook 30 DAT (days after treatment) (70 DAP) (Tables 4-7). Soybean injury increased when either Zidua, metribuzin or a chloroacetamide herbicide was combined with Valor or Engenia. Soybean injury may have been exacerbated by Iron Deficiency Chlorosis (IDC) which increased soybean injury especially from Valor or Valor plus Zidua (Fierce) plus a chloroacetamide herbicide or Valor, Fierce, and metribuzin combined with the chloroacetamide herbicide. Soybean injury generally was not influenced by Flexstar, PowerMax, or Liberty applied with their respective herbicide trait technology POST.

Table 4. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in conventional soybean, Moorhead MN, 2019.

| | | Growth Reduction | | Lambsquarters | Waterhemp |
|---|---|---|---|---|---|
| **Herbicide Treatment** | **Rate** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | oz/A | % | % | % | % |
| Valor / Flexstar | 2.5 / 12 | 3 | 3 c | 45 | 98 |
| Fierce / Flexstar | 3 /12 | 0 | 16 b | 68 | 99 |
| Fierce + Dual Magnum / Flexstar | 3 / 16 / 12 | 8 | 29 ab | 45 | 99 |
| Fierce MTZ + Dual Magnum / Flexstar | 16 / 16 / 12 | 3 | 35 a | 65 | 99 |
| P-Value | | 0.3076 | 0.0011 | 0.2409 | 0.5896 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) or 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 5. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in Xtend soybean, Moorhead MN, 2019.

| | | Growth Reduction | | Lambsquarters | Waterhemp |
|---|---|---|---|---|---|
| **Herbicide Treatment** | **Rate** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | oz/A | % | % | % | % |
| Engenia / PowerMax | 12.8 / 32 | 0 | 9 b | 97 | 68 |
| Engenia + Zidua / PowerMax | 12.8 + 2.1 / 32 | 3 | 15 b | 99 | 73 |
| Engenia + Zidua / Warrant / PowerMax | 12.8 + 2.1 / 40 / 32 | 0 | 31 a | 99 | 83 |
| Engenia + Zidua + Metribuzin / Warant / PowerMax | 12.8 + 2.1+ 5 / 40 / 32 | 3 | 33 a | 99 | 85 |
| P-Value | | 0.4363 | 0.0355 | 0.4363 | 0.0623 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) or 70 DAP.
[c]Control 38 DAT or 78 DAP.

Common lambsquarters and waterhemp control was influenced by both herbicide treatment and herbicide with its respective herbicide tolerant trait (Tables 4-7). Some POST herbicide treatment and seed trait options provided over 95% lambsquarters and / or waterhemp control regardless of soil applied herbicides regardless of soil residual herbicide. For example, waterhemp control from FlexStar POST applied with conventional soybean, lambsquarters control from PowerMax POST applied with Xtend soybean and common lambsquarters and waterhemp control from Liberty POST applied with LibertyLink soybean provided 95% or greater control regardless of the soil residual herbicides.

Some soil applied herbicides mixtures improved lambsquarters or waterhemp control. For example, Fierce, Fierce plus metribuzin (Fierce MTZ), or Fierce MTZ and Dual Magnum EPOST fb PowerMax POST with RR2 soybean controlled greater than 95% lambsquarters compared to Valor PRE followed by PowerMax POST alone. Likewise, Fierce or Fierce MTZ and Dual Magnum EPOST followed by PowerMax POST provided greater than 95% waterhemp control compared to Valor or Fierce fb PowerMax POST with RR2 soybean.

Table 6. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in LibertyLink soybean, Moorhead MN, 2019.

| | | Growth Reduction | | Lambsquarters | Waterhemp |
|---|---|---|---|---|---|
| **Herbicide Treatment** | **Rate** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | oz/A | % | % | % | % |

| | | | | | |
|---|---|---|---|---|---|
| Valor / Liberty | 2.5 / 32 | 0 | 21 b | 95 | 92 b |
| Fierce / Liberty | 3 /32 | 3 | 26 b | 96 | 98 a |
| Fierce + Outlook / Liberty | 3 / 10 / 22 | 0 | 37 a | 95 | 99 a |
| Fierce MTZ + Outlook / Liberty | 16 / 10 / 32 | 0 | 40 a | 95 | 99 a |
| P-Value | | 0.4363 | 0.0354 | 0.9838 | 0.0495 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 7. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment in Roundup Ready soybean, Moorhead MN, 2019.

| | | **Growth Reduction** | | **Lambsquarters** | **Waterhemp** |
|---|---|---|---|---|---|
| **Herbicide treatment** | **Rate** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | oz/A | % | % | % | % |
| Valor / PowerMax | 2.5 / 32 | 0 | 13 b | 88 | 69 b |
| Fierce / PowerMax | 3 /32 | 0 | 28 a | 99 | 86 a |
| Fierce + Dual Magnum / PowerMax | 3 / 16 / 32 | 0 | 36 a | 98 | 97 a |
| Fierce MTZ + Dual Magnum / PowerMax | 16 / 16 / 32 | 5 | 37 a | 97 | 96 a |
| P-Value | | 0.4363 | 0.0003 | 0.4326 | 0.0020 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Some herbicide and seed trait combinations did not provide 95% lambsquarters and waterhemp control. For example, Valor, Fierce, Fierce followed by (fb) Dual Magnum or Fierce MTZ fb Dual Magnum EPOST and followed by Flexstar POST failed to provide acceptable lambsquarters control. Likewise, Engenia (dicamba) substituted for Valor and followed by PowerMax POST failed to provide acceptable waterhemp control.

Table 8. Soybean injury and common lambsquarters and waterhemp control in response to Valor at 2.5 oz/A or Engenia at 12.8 fl oz/A PRE across herbicide traits in soybean, Moorhead MN, 2019.

| | | **Growth Reduction** | | **Lambsquarters** | **Waterhemp** |
|---|---|---|---|---|---|
| **Herbicide Trait** | **Herbicide** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | | % | % | % | % |
| Conventional | Valor | 3 | 8 b | 45 b | 98 a |
| Xtend | Engenia | 0 | 9 b | 97 a | 68 b |
| LibertyLink | Valor | 0 | 21 a | 95 a | 92 ab |
| Roundup Ready | Valor | 0 | 13 b | 88 a | 79 ab |
| Average | | 1 | 13 | 81 | 84 |
| P-Value | | 0.4363 | 0.0003 | 0.0008 | 0.0312 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 9. Soybean injury and common lambsquarters and waterhemp control in response to Fierce at 3 oz/A or Engenia plus Zidua SC at 12.8 fl oz + 2.1 oz/A PRE across herbicide traits in soybean, Moorhead MN, 2019[a].

| | | **Growth Reduction** | | **Lambsquarters** | **Waterhemp** |
|---|---|---|---|---|---|
| **Herbicide Trait** | **Herbicide** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | | % | % | % | % |
| Conventional | Fierce | 0 | 16 | 68 b | 99 a |
| Xtend | Engenia + Zidua SC | 3 | 15 | 99 a | 73 b |
| LibertyLink | Fierce | 3 | 26 | 96 a | 98 a |
| Roundup Ready | Fierce | 0 | 28 | 99 a | 86 ab |
| Average | | 2 | 21 | 91 | 89 |
| P-Value | | 0.4363 | 0.0759 | 0.0166 | 0.0223 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Soybean injury and common lambsquarters and waterhemp data was analyzed by herbicide treatment across herbicide trait technologies (Tables 8-11). Once again, soybean injury 26 DAP was negligible but increased and ranged from 8 to 39%, depending on herbicide treatment and herbicide trait 30 DAT / 78 DAP. Soybean injury tended to increase when Zidua, a chloroacetamide herbicide or metribuzin was combined with Valor (Figure 1).

Common lambsquarters and waterhemp control was dependent on herbicide treatment, herbicide trait, and respective POST herbicide (Tables 8-11). For example, lambsquarters and waterhemp control averaged across POST herbicides following Valor PRE provided 81% and 84% control, respectively (Figure 1) which is less than desirable.

Table 10. Soybean injury and common lambsquarters and waterhemp control in response PRE followed by EPOST treatments across herbicide traits in soybean, Moorhead MN, 2019[a].

| | | **Growth Reduction** | | **Lambsquarters** | **Waterhemp** |
|---|---|---|---|---|---|
| **Herbicide Trait** | **Herbicide** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | | % | % | % | % |
| Conventional | Fierce / Dual Magnum | 8 | 29 | 45 b | 99 a |
| Xtend | Engenia + Zidual SC / Warrant | 0 | 25 | 99 a | 83 b |
| LibertyLink | Fierce / Outlook | 0 | 31 | 95 a | 99 a |
| Roundup Ready | Fierce / Dual Magnum | 0 | 29 | 98 a | 97 a |
| Average | | 2 | 29 | 84 | 95 |
| P-Value | | 0.1298 | 0.8085 | 0.0001 | 0.0066 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.
[c]Control 38 DAT or 78 DAP.

Table 11. Soybean injury and common lambsquarters and waterhemp control in response PRE followed by EPOST and POST treatments across herbicide traits in soybean, Moorhead MN, 2019[a].

| | | **Growth Reduction** | | **Lambsquarters** | **Waterhemp** |
|---|---|---|---|---|---|
| **Herbicide Trait** | **Herbicide** | **26 DAP[a]** | **30 DAT[b]** | **38 DAT[c]** | **38 DAT** |
| | | % | % | % | % |
| Conventional | Fierce MTZ / Dual Magnum | 3 | 35 | 65 b | 99 |
| Xtend | Engenia + Zidual SC + metribuzin / Warrant | 3 | 29 | 99 a | 85 |
| LibertyLink | Fierce MTZ / Outlook | 0 | 39 | 95 a | 99 |
| Roundup Ready | Fierce MTZ / Dual Magnum | 5 | 39 | 97 a | 96 |
| Average | | 4 | 36 | 89 | 95 |
| P-Value | | 0.6915 | 0.2477 | 0.0011 | 0.0515 |

[a]Growth reduction 26 days after planting (DAP).
[b]Growth reduction 30 days after treatment (DAT) and 70 DAP.

However, embedded within these averages, Valor fb Flexstar with conventional soybean provided 98% waterhemp control and Engenia fb PowerMax with Xtend soybean provided 97% common lambsquarters control and highlighting the need to review specific herbicide and trait combinations. We observed the same outcome when lambsquarters and waterhemp control was averaged across POST herbicides following more complex treatments. We believe lambsquarters and waterhemp control, in general, improved with more complex herbicide treatments since the number of effective herbicides in the treatment increased.

Effective herbicides were determined by considering weed control scores assigned to herbicides using the 2020 ND Weed Control Guide (Table 12). Herbicide treatment must provide ‘good’ or ‘excellent’ control for treatment to be considered an effective herbicide. Value in table is cumulative score for herbicides representing the treatment. In general, mixtures or sequential treatments increased the number of effective herbicides. Target should be a herbicide treatment delivering two or three effective herbicides. We believe greater than three effective herbicides is excessive but might be required for broad spectrum control.

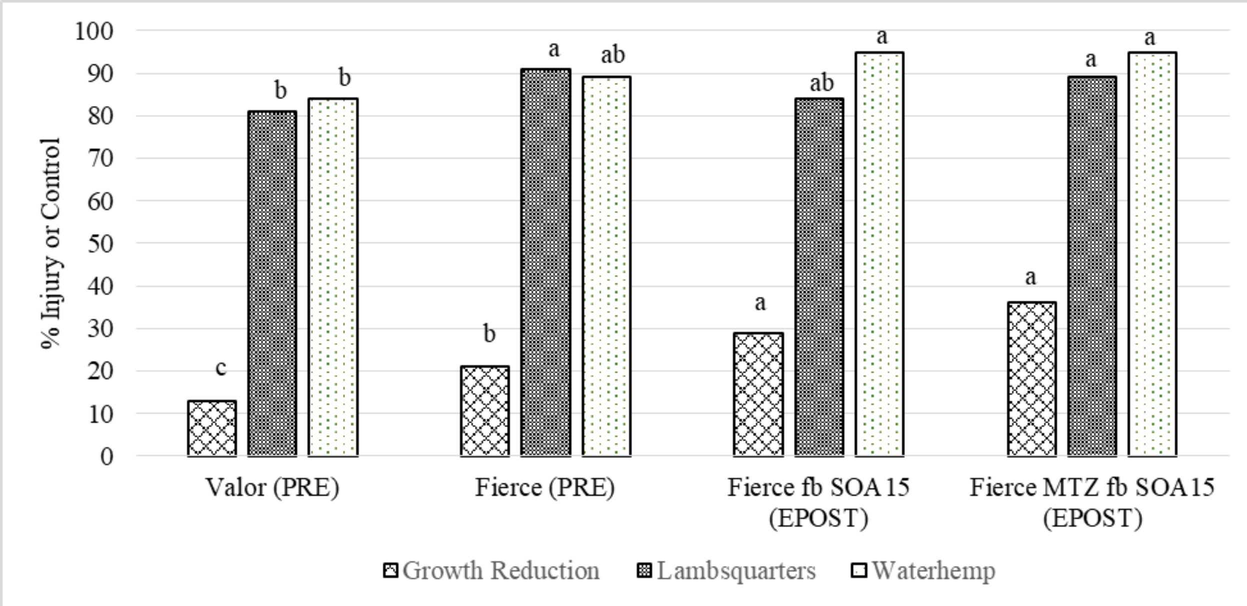


Figure 1. Soybean injury and common lambsquarters and waterhemp control in response to herbicide treatment averaged across herbicide trait, Moorhead MN, 2019.

Table 12. Effective sites of action against common lambsquarters or waterhemp.[a]

| **Herbicide Treatment** | **Flexstar** | | **Roundup** | | **LibertyLink** | | **Xtend[b]** | | **Avg.** |
|---|---|---|---|---|---|---|---|---|---|
| | **LQ[a]** | **WH** | **LQ** | **WH** | **LQ** | **WH** | **LQ** | **WH** | |
| Valor | 1 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 1.6 |
| Fierce (Valor + Zidua) | 1 | 3 | 2 | 2 | 2 | 3 | 2 | 2 | 2.1 |
| Fierce / chloroacetamide | 1 | 4 | 2 | 3 | 2 | 4 | 2 | 3 | 2.6 |
| Fierce MTZ / chloroacetamide | 1 | 5 | 2 | 4 | 2 | 5 | 2 | 4 | 3.1 |

[a]Abbreviation: LQ= common lambsquarters; WH= waterhemp; Avg = average.
[b]Includes glyphosate or dicamba.

We were interested in profitability plotted against performance metrics. Profitability was calculated by subtracting cost of the herbicide treatment and soybean seed plus trait technology fee from an estimate of revenue. Revenue was estimated simply as the average soybean yield in Cass county by $8.35 soybean per bushel. No application cost estimates were included since we applied herbicides using our owned equipment.
Performance metrics considered were less than 30% soybean injury (1 point), greater than 95% lambsquarters (1 point) and waterhemp control (1 point) and treatments containing at least two (1 point) or three (2 point) effective herbicides against lambsquarters or waterhemp.

The data suggests greater cost (less profitability) with treatments delivering more effective herbicides or treatments providing broad spectrum weed control. However, a more detail review of the analysis reveals that profitability is not as simple as selecting the cheapest trait. Profitability is a function of understanding your most important weed control needs for a field and matching it up against herbicide treatments and possible crop rotation restrictions that one may have depending on your crop sequence.

In my opinion, the take home message of this experiment is that while the new herbicide resistant traits provide opportunities for improved waterhemp or lambsquarters management, the herbicide system used with these traits is more important than the individual trait or their respective herbicide. This experiment emphasizes the importance of using both effective PRE and timely POST applications to manage waterhemp and / or lambsquarters, regardless of the herbicide or trait.

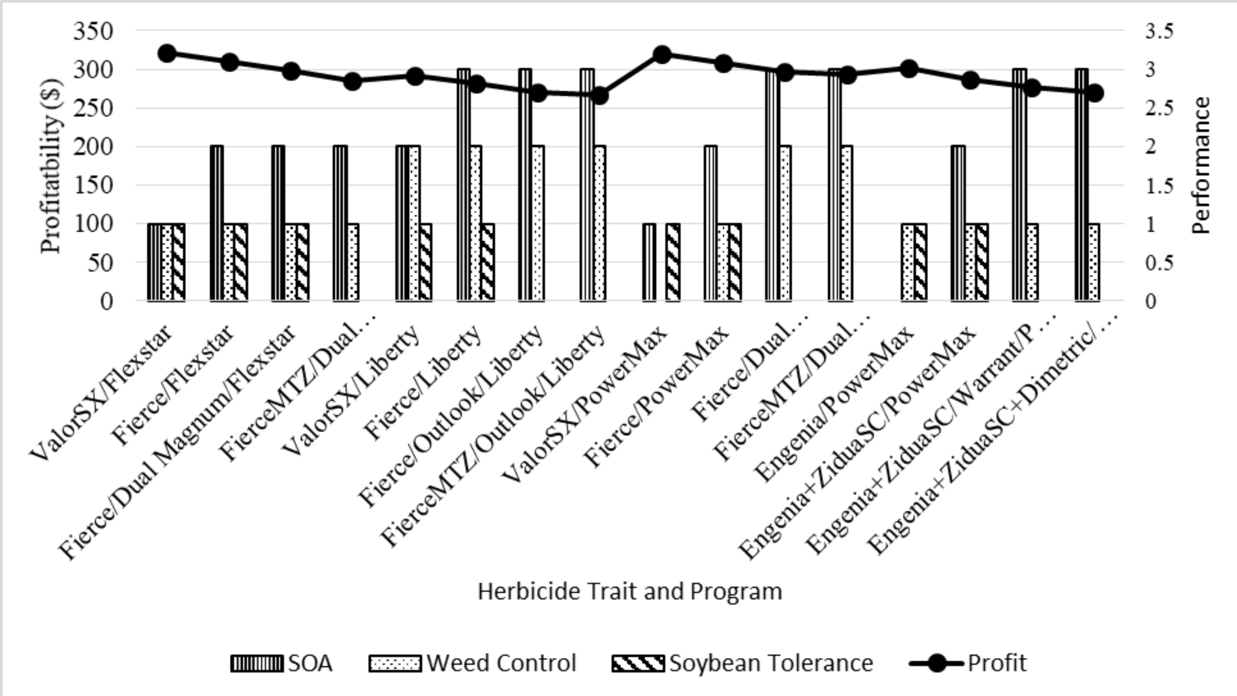


Figure 2. Herbicide treatment and trait performance plotted against profit (revenue minus herbicide treatment and trait cost)

**Conclusions**

Herbicide treatments (mixtures or PRE fb POST combinations) provided greater than 95% lambsquarters and waterhemp control. Herbicide mixtures usually provide multiple effective sites of action. Herbicide traits use strategically solve field specific weed control challenges. Finally, profitability is more complex than simply plotting the cost of herbicide treatment and herbicide trait.

**References**

1. Cattanach AW, Dexter AG, Oplinger ES (1991) Sugarbeets. Alternative Field Crops manual. Madison: University of Wisconsin Cooperative Extension.
2. Liebman M and Dyck E (1993) Crop rotation and intercropping strategies for weed management. Ecological Society of America. 3(1):92-122
3. Peterson TA and Varvel GE (1989) Crop yield as affected by rotation and nitrogen rate. I. soybean. Agronomy Journal. 81:727-731
4. Soltani N, Vyn JD, Sikkema PH (2009) Control of common waterhemp (*Amaranthus tuberculantus* var. *rudis*) in corn and soybean with sequential herbicide applications. Can. J. Plant Sci. 89:127-132
5. Soltani N, Dille A, Robinson DE, Sprague CL, Morishita DW, Lawrence NC, Kniss AR, Jha P, Felix J, Nurse RE, and Sikkema PH (2018) Potential yield loss in sugar beet due to weed interference in the United States and Canada. Weed Technol 32:749-753