WEED MANAGEMENT IN SOYBEAN CONTRIBUTES TO A FIELD-BASED

WEED CONTROL STRATEGY

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**Situation Statement and Objective**

Development of Roundup Ready (RR) crops revolutionized weed management following its introduction in soybean in 1996 and in crops grown in sequence with soybean including canola in 1997, corn in 1998, alfalfa in 2005, and sugarbeet in 2005 (Monsanto, company history). This technology has been a major scientific accomplishment in the 20th century, providing growers with a useful weed management tool in all crops, but especially crops planted on lessor acreages including canola, alfalfa, and sugarbeet. RR soybean was widely adopted by growers following its introduction in 1996 and probably led to the rapid adoption of other RR crops. However, an indirect outcome of RR crops was a change in weed management philosophy used by growers to control weeds. Glyphosate is efficacious on narrow-leaves, broadleaves, and perennial weeds meaning a grower could use a single herbicide to control all of the weeds in a field. Subsequent flushes of weeds following rainfall events were controlled with repeat application of glyphosate since the application window generally ranged from early vegetative stages to or even through flowering, depending on crop.

Weed shifts and development of biotypes with greater glyphosate tolerance, is a natural process but probably is accelerated by intense selection pressure resulting from use of the glyphosate in multiple crops across the crop sequence (Duke et al.; LeBaron and Gressel; Owen and Zelaya). Changes in weed communities resulting from biotypes that do not respond the same to glyphosate are occurring and will continue to occur in North Dakota and western Minnesota (Peters et al.). Kochia, common ragweed, giant ragweed, and waterhemp biotypes, depending on geography, tolerated glyphosate and have become important production challenges in row crops including soybean.

Effective weed control occurs with a weed management strategy implemented in the field and across crops planted in the sequence. Weed management is continuous; it extends from year to year and crop to crop. The strategy begins with scouting and positive identification of weeds. Detailed maps indicating where weeds occur in the field provides greater clarity since in many cases, weed infestations are spatially distributed and attributed to features of the landscape such as topography or proximity to ditches and field boundaries. Weed threats in the field should be prioritized based on their population/density, difficulty to control, and longevity of weed seed viability across years. For example, weeds that if not controlled have a greater impact on crop yield or weeds whose seed remains viable in the soil for many years. Development of a weed control program that combines cultural, chemical, and mechanical control practices and includes a well thought out weed control strategy including use of effective and diverse herbicides in the field and across the sequence is paramount. Finally, an expectation for zero tolerance for weed escapes in fields, even if it means pulling weeds by hand.

Experiments were conducted in 2014, 2015 and 2016 to evaluate the weeds management strategy in soybean and crops grown in sequence with soybean including sugarbeet and corn. This report summarizes results from the 2015 soybean experiments. The objectives in 2015 were to evaluate waterhemp (Amaranthus spp.) and kochia (kochia scoparia) control in soybean utilizing a weed management strategy that:

1. does not include the Roundup Ready herbicide tolerance trait;
2. greater than 95% visual waterhemp and kochia control, season-long;
3. herbicides grouped by site of action (SOA) that compliment herbicides used in the sequence, including sugarbeet;
4. crop rotation restrictions that allow sugarbeet, corn, and soybean in sequence.

**Materials and Methods**

Experiments were conducted on natural populations of waterhemp near Herman, MN, and Moorhead, MN in 2015 and on natural populations of kochia near Barney, ND. The experimental area across locations was fall chisel plowed by the cooperating grower. Secondary tillage occurred in the spring either by grower with a John Deere field cultivator (Herman) or with a Kongskilde ‘s-tine’ field cultivator equipped with rolling baskets (Moorhead and Barney). Tillage was conducted the day before or the day of planting. Peterson Farm S090081 Liberty Link soybeans (untreated seed) were seeded 1.25 inches deep in 22 inch rows at 144,500 seeds per acre.

Herbicide treatments were applied at 17 gallons per acre spray solution through 8002 XR flat fan nozzles pressurized with CO2 at 30 pounds per square inch to the center four rows of six row plots 35 feet in length. Ammonium sulfate (AMS) in all treatments was a liquid formulation from Winfield Solutions marketed as N-Pak AMS. Preplant incorporated (PPI) and preemergence (PRE) herbicides were applied the same day as planting. Postemergence herbicide applications were completed according to weed size and/or at approximately 14 to 21 day intervals.

Herman and Moorhead locations had moderate to heavy levels of glyphosate-resistant waterhemp and lambsquarters; the Barney, ND, location had moderate levels of glyphosate-resistant kochia and lambsquarters.

Soybean injury and weed control were a visual estimate of percent fresh weight reduction in the four treated rows compared to the adjacent untreated strip. Experimental design for all locations was randomized complete block with 4 replications. Data was analyzed with the ANOVA procedure of ARM, version 2015.6 software package.

Soybean was planted at Barney on May 21, 2015, into soils with adequate moisture where sugarbeet was the previous crop in 2014 (Table 1).

|  |  |
| --- | --- |
| **Table 1. Application information, Barney, ND, 2015** |  |
| Application code | A | B | C | D |
| Date | May 21 | May 21 | June 15 | June 29 |
| Time of Day | 1:30 PM | 2:00 PM | 11:30 AM | 12:30 PM |
| Air Temperature (F) | 66 | 66 | 70 | 77 |
| Relative Humidity (%) | 29 | 29 | 47 | 63 |
| Wind Velocity (mph) | 2.5 | 2.5 | 5.0 | 3.5 |
| Wind Direction | NW | NW | N | N |
| Soil Temp. (F at 6”) | 56 | 56 | 65 | 68 |
| Soil Moisture | Slightly Wet | Slightly Wet | Good | Slightly Wet |
| Cloud Cover (%) | 0 | 0 | 10 | 100 |
| Soybean stage (avg) | PPI | PRE | V2 | V4 |
| Kochia (untreated avg) | - | - | 5.0” | 10.0” |

The Herman, MN location was planted on June 4th, 2015, into soils with adequate moisture where sugarbeet was the previous crop in 2014 (Table 2).

|  |  |
| --- | --- |
| **Table 2. Application information, Herman, MN, 2015** |  |
| Application code | A | B | C | D |
| Date | June 4 | June 4 | June 24 | July 7 |
| Time of Day | 3:30 PM | 4:00 PM | 5:30 PM | 11:00 AM |
| Air Temperature (F) | 72 | 72 | 83 | 68 |
| Relative Humidity (%) | 55 | 55 | 40 | 43 |
| Wind Velocity (mph) | 3.5 | 3.5 | 5.0 | 3.5 |
| Wind Direction | SE | SE | SW | SE |
| Soil Temp. (F at 6”) | 63 | 63 | 76 | 66 |
| Soil Moisture | Good | Good | Slightly Wet | Dry |
| Cloud Cover (%) | 100 | 100 | 80 | 5 |
| Soybean stage (avg) | PPI | PRE | V2 | V4 |
| Waterhemp (untreated avg) | - | - | 4.0” | 10.0” |

The Moorhead, MN location was planted into corn stalks residues and into soils with good moisture on June 11th, 2015 (Table 3).

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| **Table 3. Application information, Moorhead, MN, 2015** |  |
| Application code | A | B | C | D |
| Date | June 11 | June 11 | July 10 | July 21 |
| Time of Day | 9:30 AM | 10:00 AM | 8:30 AM | 10:00 AM |
| Air Temperature (F) | 73 | 73 | 70 | 74 |
| Relative Humidity (%) | 45 | 45 | 50 | 54 |
| Wind Velocity (mph) | 2.0 | 2.0 | 3.0 | 3.0 |
| Wind Direction | E | E | SE | NE |
| Soil Temp. (F at 6”) | 62 | 62 | 64 | 70 |
| Soil Moisture | Slightly Wet | Slightly Wet | Good | Dry |
| Cloud Cover (%) | 5 | 5 | 0 | 5 |
| Soybean stage (avg) | PPI | PRE | V4 | R2 |
| Waterhemp (untreated avg) | - | - | 8.0” | 16.0” |

**Results and Discussion**

Barney, ND. Soybean injury was influenced by herbicide (Table 4). Soybean injury was greatest from treatments containing Cadet. Treatments containing only Basagran or Liberty as the POST herbicide, generally gave negligible crop injury. Some late season growth reduction from PRE Dual Magnum + Dimetric followed by (fb) Liberty was observed, but the reason for this injury is unclear.

Barnyardgrass was evaluated and in general, most entries gave very good barnyardgrass control ranging from 94 to 100% (data not included in table). However, barnyardgrass control from two applications of Basagran + Cadet or PRE Verdict fb Basagran was 90%, which tended to be less than from other treatments.

Redroot pigweed and common lambsquarters populations were dense and uniform while the infestation of kochia was light and tended to be variable. There was one flush of kochia at this location. Unfortunately, the majority of that flush was controlled with tillage. This led to excellent kochia control in the experiment. All treatments provided greater than 95% kochia control at the August 4 evaluation timing, with most treatments providing at least 98% control.

Redroot pigweed control was dependent on herbicide treatment and application timing. Pigweed control from two applications of Basagran + Cadet was 78% on August 4, which was less than control from any other treatment. Treatments containing a soil-applied herbicide gave 91% or greater pigweed control on August 4 with the exception of PRE Dual Magnum + Dimetric fb Liberty that gave only 85% control. Liberty followed many of the soil-applied entries and was applied when pigweed was 3 inches or less. Pigweed was slow to die when treated with Liberty. Air temperature was 70F and relatively humidity was 47% at application which may explain the delayed or reduced pigweed control.

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| **Table 4. Soybean injury and common lambsquarters, kochia, and redroot pigweed control, Barney, ND in 2015** |
|  |  | Appl | Soybean |  | colq3 |  | kocz |  | rrpw |
| Treatment | Rate | Code | Jun 29 | Jul 15 | Aug 4 |  | Jul 7 | Aug 4 |  | Jul 7 | Aug 4 |  | Jul 7 | Aug 4 |
|  |  |  | ------% injury------ |  | --------------------% control-------------------- |
| Treflan+Valor SX /Liberty1 | 1.5 pt+3 oz /29 fl oz | A/C | 0 | 0 | 3 |  | 85 | 83 |  | 91 | 95 |  | 81 | 91 |
| Dual Magnum+Valor SX /Liberty1 | 2 pt+3 oz /29 fl oz | B/C | 3 | 3 | 9 |  | 93 | 86 |  | 96 | 98 |  | 96 | 95 |
| Dual Magnum+Dimetric /Liberty1 | 2 pt+5.3 oz /29 fl oz | B/C | 3 | 8 | 13 |  | 81 | 66 |  | 95 | 98 |  | 88 | 85 |
| Sharpen+Valor SX /Liberty1 | 1 fl oz+3 oz /29 fl oz | B/C | 4 | 3 | 5 |  | 91 | 89 |  | 98 | 98 |  | 91 | 98 |
| Verdict+Valor SX /Liberty1 | 5 fl oz+3 oz /29 fl oz | B/C | 0 | 0 | 3 |  | 94 | 89 |  | 100 | 100 |  | 93 | 100 |
| Outlook+Verdct+Valor SX /Liberty1 | 14floz+5floz+3oz /29 fl oz | B/C | 8 | 5 | 5 |  | 93 | 87 |  | 100 | 98 |  | 93 | 98 |
| Valor SX /Cadet2 / Cadet2 | 3 oz /0.7 fl oz / 0.7 fl oz | B/C / D | 5 | 15 | 8 |  | 89 | 80 |  | 100 | 100 |  | 91 | 94 |
| Verdict /Basagran2 / Basagran2 | 5 fl oz /1 pt / 1 pt | B/C / D | 0 | 0 | 0 |  | 74 | 59 |  | 100 | 100 |  | 94 | 96 |
| Sharpen+Warrant /Basagran2 / Basagran2 | 1 fl oz+3pt /1 pt / 1 pt | B/C / D | 8 | 0 | 6 |  | 86 | 70 |  | 96 | 98 |  | 95 | 100 |
| Basagran+Cadet2 /Basagran+Cadet2 | 1 pt+0.7 fl oz/1 pt+0.7 fl oz | C/D | 33 | 23 | 10 |  | 83 | 64 |  | 100 | 98 |  | 84 | 79 |
| Liberty1 / Liberty1 | 29 fl oz /29 fl oz | C/D | 5 | 3 | 5 |  | 86 | 88 |  | 100 | 100 |  | 89 | 98 |
| **LSD (0.10)** |  |  | **7** | **10** | **6** |  | **7** | **14** |  | **5** | **NS** |  | **6** | **9** |

1Applied with ammonium sulfate (N-Pak AMS) at 8.5 lb/100 gal

2Applied with methylated seed oil (MSO) at 1.5 pt/A

3colq=common lambsquarters; kocz=kochia; rrpw=redroot pigweed

Lambsquarters control was dependent on herbicide treatment. There were no herbicide treatments that provided greater than 90% lambsquarters control at the August 4 evaluation. In general, herbicide treatments containing Liberty provided greater lambsquarters control than treatments containing Cadet or Basagran. PRE Dual Magnum + Dimetric fb Liberty provided on 66% lambsquarters control, which was less control than any other PRE fb Liberty combination.

This experiment illustrates the importance of environmental conditions at application for maximizing efficacy from Liberty. To maximize efficacy from Liberty (a contact herbicide), applications should be made no closer than 2 hours before sunset, applications should be made when temperatures are hot and humid and skies are mostly sunny, AMS at 3 lb/A or greater should be used, and spray volumes should exceed 15 gallons per acre. Refer to paragraph B9 on page 77 of the 2015 North Dakota Weed Control Guide for more information on applying Liberty (www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/wcg-files/12-TextCrop.pdf).

With the exception of Dimetric (metribuzin), all herbicides in this experiment allow for rotation to sugarbeet the following season. Liberty Link technology provides an excellent tool to help control tough weeds in the soybean year of a sugarbeet containing rotation. However, repeated use of an herbicide with a single mode of action will increase the likelihood of selecting for weeds with resistance to that mode of action. Using a PRE herbicide from site of action (SOA) 14 and/or SOA15 followed by Liberty (SOA 10) appears to be an excellent option for controlling tough weeds in soybean as part of the sugarbeet rotation.

Herman, MN. The experiment was very uniform with soybean stands being near perfect across the study. Soybean injury was generally negligible except from Cadet, either applied alone or in a mixture with Basagran (Table 5). Neither the soil applied herbicides nor Liberty seemed to cause any visual soybean injury.

In general, lambsquarters control was very good with all treatments providing greater than 90% lambsquarters control. Verdict + Valor followed by (fb) Liberty gave the least numerical lambsquarters control at 94% on September 9. However, there were no statistical differences in common lambsquarters control among treatments.

There was a light infestation of green foxtail in the experiment. In general, foxtail control was very good (data not included in table). However, control was less or tended to be less with treatments that contained Cadet.

Waterhemp control was dependent on herbicide and application timing. Treatments containing a PRE herbicide fb Liberty gave greater waterhemp control than a PRE herbicide fb Basagran. Two POST applications of Basagran +

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| **Table 5. Soybean injury and common lambsquarters and waterhemp control at Herman, MN in 2015.** |
|  |  | Appl | soybean |  | colq3 |  | wahe |
| Treatment | Rate | Code | Jul 6 | Jul 17 | Jul 31 |  | Jul 17 | Sep 9 |  | Jul 17 | Sep 9 |
|  |  |  | --------% injury-------- |  | -----------% control------------ |
| Treflan+Valor SX /Liberty1 | 1.5 pt+3 oz /29 fl oz | A/C | 0 | 0 | 0 |  | 99 | 99 |  | 88 | 84 |
| Dual Magnum+Valor SX /Liberty1 | 2 pt+3 oz /29 fl oz | B/C | 3 | 5 | 0 |  | 98 | 96 |  | 98 | 96 |
| Dual Magnum+Dimetric /Liberty1 | 2 pt+5.3 oz /29 fl oz | B/C | 4 | 5 | 6 |  | 95 | 98 |  | 86 | 82 |
| Sharpen+Valor SX /Liberty1 | 1 fl oz+3 oz /29 fl oz | B/C | 3 | 0 | 0 |  | 99 | 100 |  | 90 | 84 |
| Verdict+Valor SX /Liberty1 | 5 fl oz+3 oz /29 fl oz | B/C | 0 | 3 | 3 |  | 93 | 94 |  | 89 | 78 |
| Outlook+Verdict+Valor SX /Liberty1 | 14floz+5floz+3oz /29 fl oz | B/C | 5 | 3 | 6 |  | 100 | 100 |  | 98 | 95 |
| Valor SX /Cadet2 / Cadet2 | 3 oz /0.7 fl oz / 0.7 fl oz | B/C / D | 10 | 20 | 19 |  | 96 | 98 |  | 94 | 81 |
| Verdict /Basagran2 / Basagran2 | 5 fl oz /1 pt / 1 pt | B/C / D | 0 | 3 | 0 |  | 100 | 100 |  | 66 | 20 |
| Sharpen+Warrant /Basagran2 / Basagran2 | 1 fl oz+3pt /1 pt / 1 pt | B/C / D | 3 | 6 | 5 |  | 96 | 98 |  | 76 | 58 |
| Basagran+Cadet2 /Basagran+Cadet2 | 0.5 pt+0.7 fl oz/0.5 pt+0.7 fl oz | C/D | 16 | 33 | 28 |  | 94 | 100 |  | 85 | 63 |
| Liberty1 / Liberty1 | 29 fl oz /29 fl oz | C/D | 1 | 5 | 0 |  | 100 | 100 |  | 91 | 98 |
| **LSD (0.10)** |  |  | **6** | **4** | **6** |  | **NS** | **NS** |  | **5** | **10** |

1Applied with ammonium sulfate (N-Pak AMS) at 8.5 lb/100 gal

2Applied with methylated seed oil (MSO) at 1.5 pt/A

3colq=common lambsquarters; wahe=waterhemp

Cadet provided only 63% waterhemp control by September 9. To maximize efficacy, Basagran and Cadet should be applied to very small (<2”) weeds. Waterhemp was 3” tall at the first POST application. While poor waterhemp control from Basagran and Cadet in this experiment may be partially due to spraying large waterhemp, this illustrates the importance of spraying very small weeds with these herbicides. All treatments containing Liberty, with the exception of PRE Verdict + Valor gave greater than 80% waterhemp control on September 9.

Three treatments gave excellent waterhemp control. Preemergence Outlook + Verdict + Valor fb Liberty gave 95% control, PRE Dual Magnum + Valor fb Liberty gave 96% control and Liberty fb Liberty gave 98% control on September 9. These treatments also gave 99 to 100% waterhemp control at the Moorhead location.

Moorhead, MN. The Moorhead experiment was not included in the summary due to severe iron deficiency chlorosis (IDC) in the experiment. Soybean remained chlorotic and in some cases became necrotic, allowing the canopy to remain open much longer than soybean at the Barney or Herman experiment.

**Discussion**

Universities recommend growers use multiple herbicides from multiple SOA for control of weeds. While in principle, this makes sense, researchers fail to realize the implementation stage; that farming is far more complex than just about anything researchers can replicate experimentally. For example, grower fields do not contain just one weed species; it is common for three, four, five or more weeds to be potentially problematic in any single field. We do not know ahead of time which of these weed species will develop resistance, nor do we know which herbicide to which weeds may develop resistance. In addition, not all crops have equally effective herbicides against a suite of weeds. Finally, some crop rotations preclude the use of some effective herbicides.

Experiments were treatments representing mostly two or three effective herbicides for kochia or waterhemp control in soybean (Table 4, 5). To be selected, herbicides must be efficacious against target weeds and have rotational crop safety allowing corn, soybean, or sugarbeet to be planted in sequence in the field. Finally, to minimize selection pressure, herbicide treatments were planned across the soybean, sugarbeet, and corn phases of the experiment to achieve a diverse weed management program.

Seventeen unique herbicides were used in the field across the soybean, sugarbeet, corn sequence (Table 6). Twelve of the seventeen herbicides were applied for weed control in a single crop in a three year cropping sequence. Glyphosate and Sharpen (SOA 9, SOA 14) were applied for weed control in two crops planted in the sequence; three herbicides (Dual Magnum, Outlook and Warrant) were applied for weed control in all crops planted in the sequence in the field (SOA 15). Herbicides may also represent the same SOA family. For example, atrazine, Betamix, and Dimetric are herbicides used in corn, sugarbeet and soybean, respectively, which represent the same SOA family, photosystem II inhibitors. Twelve herbicides applied in and across crops represented four SOA families (Table 6).

**Table 6. Herbicide Site of Action (SOA) diversity across crops**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Herbicide | Timing ofApplication | Site of Action1 | Corn | Soybean | Sugarbeet | Total  |
| atrazine | Pre/Post | 5 | x |  |  | 1 |
| Betamix | Post | 5+5 |  |  | x | 1 |
| Cadet | Post | 14 |  | x |  | 1 |
| dicamba | Post | 4 | x |  |  | 1 |
| Dimetric | Pre | 5 |  | x |  | 1 |
| Dual-Magnum | Pre/Post | 15 | x | x | x | 3 |
| ethofumesate | Pre/Post | 8 |  |  | x | 1 |
| glyphosate | Post | 9 | x |  | x | 2 |
| Laudis | Post | 27 | x |  |  | 1 |
| Liberty | Post | 10 |  | x |  | 1 |
| Outlook | Pre/EPost | 15 | x | x | x | 3 |
| Status | Post | 4+19 | x |  |  | 1 |
| Sharpen | Pre | 14 | x | x |  | 2 |
| Treflan | PPI | 3 |  | x |  | 1 |
| UpBeet | Post | 2 |  |  | x | 1 |
| Valor | Pre | 14 |  | x |  | 1 |
| Warrant | Pre/EPost | 15 | x | x | x | 3 |

1Site of action numbering scheme developed by the Herbicide Resistance Action Committee (HRAC) and Weed Science Society of America (WSSA), to support a cooperative approach to the management of herbicide resistance.

How diverse was the herbicide program? A subjective assessment is the current approach but there are no clear definitions, especially across crops in the sequence. An objective approach would be better and would remove bias but we first need to quantify ‘diversity’ to derive the answer to this question. Diversity indices such as the Shannon Diversity Index are statistics used to summarize the diversity of a population in which each member belongs to a unique group (Spellerberg and Fedor). For example, in ecology, groups are typically unique plant species and species richness refers to number of plants within each species. Plant species evenness refers to homogeneity of plant species number across plant species That is, the more equal the proportions for each of the groups, the more homogeneous they are. In our example, richness would be the number of herbicides and SOA families represented in a cropping sequence and evenness would be the frequency each herbicide/SOA family was represented across the sequence in fields.

Diversity indices, evenness, and models that aid farmers in making herbicide selection decisions based on SOA families, weed efficacy, rotational crop safety, and economics choices are ideas for making informed decisions, for establishing a diversity ‘baseline’, and for quantifying diversity ‘improvement’ across the crop sequence. These ideas represent the next phase of this project.

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