**Two Approaches for Palmer Amaranth Control: we need multiple approaches**

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**Two Approaches for Palmer Amaranth Control:**

**we need multiple approaches**

The **research objectives** are to evaluate:

* herbicide options for management of large Palmer amaranth plants (3rd year); and
* investigate utility of late-terminated cereal rye for reducing herbicide inputs for Palmer amaranth management (2nd year).

This proposal was developed based on the priorities outlined by the DSB in their request for proposals as well as conversations with soybean farmers, ag business, and DE Department of Agriculture’s Noxious Weed Program. The first objective is a continuation of 2018/2019 research. The second objective is continuation of 2019 research as well as building upon a completed DSB project. This research will benefit Delaware’s soybean growers and the soybean industry by understanding potential options when spraying large Palmer amaranth plants and expand the options of non-chemical strategies to help control plants with few to no herbicide options. These projects were designed to address weed control in terms of effectiveness, adaptability to Delaware’s specific needs, as well as resistance management.

**Methods:**

The **first objective** is examining the effectiveness of strategies to control Palmer amaranth that is larger than recommended.

 This experiment used soybeans with the following herbicide-tolerance traits: Liberty Link (Enlist: DynaGro S45ES10); 2,4-D-resistant (Enlist: DynaGro S45ES10); dicamba-resistant (Xtend: DynaGro S41XS98) and Roundup Ready (Enlist: DynaGro S45ES10).

 Soybeans were planted no-till in 14-inch rows on June 16. The research area was sprayed with glyphosate plus Liberty before planting to eliminate any emerged weeds. Outlook was applied after planting at 12 fl oz to provided limited control of annual weeds. Unfortunately, the soybean stand was very poor so a second site was planted July 15. The second field was conventionally tilled and soybeans drilled in 7-inch rows, and no preemergence herbicide was used. The first planted site was still used to collect data from portions of the plot with an adequate soybean stand.

 Large Palmer amaranth plants, 14-16 inches tall, were treated July 23 with Engenia (dicamba) plus glyphosate, Enlist Duo (2,4-D choline+glyphosate), Reflex plus glyphosate or Liberty all applied as single as well as first application of sequential treatments. In addition, the sequential treatments included Cobra (lactofen) to assess the potential benefit of including herbicides with additional modes-of-action. The Reflex (fomesafen) label does not allow more than one application so it was not used as part of a sequential application. Sequential applications were made 7 days after the first application. See Tables 1 and 2 for the treatments. For the second planting, the dates were August 10 for the first application and August 17 for the sequential treatment.

Plots were evaluated for Palmer amaranth control. At harvest, five of the largest Palmer amaranth plants were measured for height, clipped at the ground level for recording biomass, and female plants were threshed to determine seed production. Data collected in the first planted site was taken from portions of the plot with an acceptable soybean stand. Plots were harvested to determine impact of treated Palmer amaranth plants on yield. However, using multiple varieties did not allow comparison of yields across the various herbicide programs.

**Results:**

 At the first site, 1 week after the second herbicide application, Palmer amaranth control was best with sequential applications of Liberty, Engenia plus glyphosate, or Enlist Duo. The addition of Cobra did not improve control compared to no Cobra, regardless of when the Cobra was included. At harvest, Palmer amaranth density was lowest in plots treated with Engenia, Enlist Duo, or Liberty compared to Reflex or Flexstar GT treated plots, regardless of single or sequential applications. However, Palmer amaranth weights were lower when two herbicide applications were made compared to a single application.

 At the second planted trial, soybean injury was over 25% for all treatments treated with Cobra at 9 days after the sequential application was made. Palmer amaranth control was highest with all Engenia treatments, regardless of one or two applications and two applications of Liberty or Enlist Duo. Including Cobra with the treatments did not improve Palmer amaranth control. Palmer amaranth seed production was lower with sequential applications compared to single applications and was lowest with Engenia, Enlist Duo, and Liberty treatments compared to Reflex and Flexstar GT. No seeds were recovered from any treatment including Enlist Duo, sequential applications of Engenia plus glyphosate or Liberty.

Given the poor soybean stand at the first site, it is difficult to compare results since soybean canopy can be a big factor in season-long weed control. Nonetheless, a few comparisons can be made. When treating large Palmer amaranth plants, a single herbicide application is unlikely to provide acceptable control or eliminate seed production. While two applications is not desirable, no one herbicide consistently provide excellent control and prevented seed production. Avoid the temptation to add additional products with the postemergence application, since they have not provided additional control. Effective Palmer amaranth management should focus on timely postemergence applications while Palmer amaranth plants are small and most susceptible to herbicides. This timing is typically 3 to 4 weeks after soybean planting.

The **second objective** addresses the potential of cereal rye to reduce herbicide input for Palmer amaranth control.

 This study examined level of rye termination timing and herbicide approach. Rye cover was terminated 1) 4 weeks before planting, 2) 2 weeks before planting, or 3) 1 to 2 days after planting. Herbicide approach included timing of residual herbicide application and/or postemergence application. Postemergence applications were Liberty alone (no residual control) or in combination with residual herbicides. Treatments are listed in Table 3.

 Cereal rye was planted in the fall of 2019 at 2 bu/A and terminated in the spring with glyphosate plus 2,4-D choline. Soybeans (Enlist: DynaGro S45ES10) were planted on May 20, and preemergence herbicides applied within 24 hours of planting.

 This trial is not designed to compare various herbicides; rather this trial is focusing on approaches to weed control. We used metribuzin plus Valor for our soil-applied residual treatment, which has provided very consistent control for Palmer amaranth in our trials. Based on previous research the postemergence combination of fomesafen (Reflex or Flexstar GT) and s-metolachlor (Dual Magnum) has been more consistent than either herbicide alone. In addition to consistent weed control, the use of two effective herbicide mechanism of action is recommended to delay the development of herbicide-resistance.

 Plots were rated visually for weed control.

**Results:**

 Level of cereal rye biomass differed at each of the termination dates. There was 3025 lb/A of dry rye biomass at 4 weeks before planting, 4327 lb/A at 2 weeks before planting, and 5495 lb/A when rye was terminated at planting. Burndown application of glyphosate plus 2,4-D provided excellent control of cereal rye at all three timings.

 Canopeo readings are an indication of ground cover (or size of the soybean canopy), and higher readings indicate larger soybean canopy. In general, soybean canopy was larger when the cover crop was terminated 2 or 4 weeks prior to planting compared to planting green. Planting green often results in soybean taller and thinner seedlings for the first few weeks after which the differences are no longer apparent. In addition, Canopeo reading was higher the burndown plus residual herbicide compared to no residual herbicide. There is not an explanation for why this occurred.

 Weed density of winter annual and summer annual weeds was quite low and variable. Morningglory and annual grasses were the only two weeds we were able to rate and obtain consistent data. Morningglory control was best for all treatments with a postemergence herbicide, regardless if a residual herbicide was included with the postemergence spray. When no postemergence herbicide was used, the delaying the residual herbicide application improved morningglory control.

 Annual grass control was excellent for most treatment, providing at least 89% control. Burndown at 4 weeks before planting with no additional application timing had the lowest grass control. Most of the grasses at this site were giant foxtail, which germinates early and does not have a prolonged germination period.

 Soybean yields were not significantly different among the treatments. The untreated check yielded 48 bu/A

Table 1. Control of large Palmer amaranth plants in soybeans, first site in 2020 with a poor soybean stand.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | P.amarnth |  | P.amarnth |  | P.amarnth |  |
|  |  |  | 8/7/2020 |  | 10/9/2020 |  | 10/9/2020 |  |
| Trt |  |  | Control |  | Plants |  | wt (gms) |  |
| No | First Applicationa | Second Applicationa | % |  | #/plot |  | 5 plants |  |
| 1 | Engeniab+glyphos | None | 79 | bcd | 0 | f | 0.0 | de |
| 2 | Enlist Duoc | None | 74 | cde | 9 | c-f | 24.3 | e |
| 3 | Liberty | None | 69 | d-g | 17 | b-f | 25.9 | b-e |
| 4 | Reflex+glyphos | None | 63 | e-h | 36 | ab | 36.2 | bc |
| 5 | Flexstar GT | None | 63 | e-h | 23 | a-e | 50.9 | b |
| 6 | Engenia+glyphos | Engenia+glyphos | 79 | bcd | 2 | def | 0.4 | e |
| 7 | Enlist Duo | Enlist Duo | 78 | bcd | 2 | def | 6.1 | e |
| 8 | Liberty | Liberty | 91 | ab | 8 | c-f | 11.5 | e |
| 9 | Reflex+glyphos | glyphos | 57 | gh | 44 | a | 27.7 | cde |
| 10 | Flexstar GT | glyphos | 60 | fgh | 38 | ab | 38.9 | cde |
| 11 | Engenia+glyphos | Engenia+glyphos+Cobra | 80 | a-d | 1 | ef | 7.7 | e |
| 12 | Enlist Duo | Enlist Duo+Cobra | 81 | a-d | 4 | def | 4.0 | e |
| 13 | Liberty | Liberty+Cobra | 93 | a | 4 | def | 5.7 | e |
| 14 | Reflex+glyphos | glyphos+Cobra | 81 | a-d | 16 | b-f | 33.3 | b-e |
| 15 | Flexstar GT | glyphos+Cobra | 75 | cde | 17 | b-f | 31.0 | bcd |
| 16 | None | None | 0 | i | 28 | abc | 70.2 | a |
| 17 | Engenia+Cobra | Engenia+glyphos | 87 | abc | 0 | f | 0.0 | e |
| 18 | Cobra+glyphos | FlexstarGT | 71 | def | 24 | a-d | 19.4 | c-g |
|  | LSD P=.05 |  | 12.9 |  | 22.54 |  | 19.55 |  |
|  | CV |  | 11 |  | 91.15 |  | 53.25 |  |
| Treatment Prob(F) |  | 0.0001 |  | 0.0018 |  | 0.0001 |  |

aSingle herbicide application made to 16 to 18 inch tall Palmer amaranth plants; sequential applications applied 7 days later.

bdicamba formulation is Engenia; UD research has not shown any difference in Palmer amaranth control among the various formulations.

cEnlist Duo is a combination of glyphosate plus 2,4-D choline

Table 2. Control of large Palmer amaranth plants in soybeans; second site in 2020.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Soybean |  | P.amarnth |  | P.amarnth |  | P.amarnth |  |
|  |  |  | 8/26/2020 |  | 9/16/2020 |  | 11/1/2020 |  | 11/1/2020 |  |
| Trt |  |  | Stunting |  | Control |  | Plants |  | Seeds |  |
| No | First Applicationa | Second Applicationa | % |  | % |  | #/plot |  | #/plant |  |
| 1 | Engeniab+glyphos | None | 0 | d | 93 | ab | 5 | cd | 1,850 | de |
| 2 | Enlist Duoc | None | 0 | d | 92 | b | 1 | d | 0 | e |
| 3 | Liberty | None | 0 | d | 66 | g | 19 | b | 15,874 | b-e |
| 4 | Reflex+glyphos | None | 0 | d | 81 | c | 6 | cd | 18,274 | bc |
| 5 | Flexstar GT | None | 0 | d | 68 | fg | 10 | bcd | 26,615 | b |
| 6 | Engenia+glyphos | Engenia+glyphos | 0 | d | 94 | ab | 13 | bc | 0 | e |
| 7 | Enlist Duo | Enlist Duo | 15 | c | 98 | ab | 2 | cd | 0 | e |
| 8 | Liberty | Liberty | 0 | d | 98 | ab | 0 | d | 0 | e |
| 9 | Reflex+glyphos | glyphos | 0 | d | 73 | ef | 9 | bcd | 5,779 | cde |
| 10 | Flexstar GT | glyphos | 0 | d | 77 | cde | 7 | cd | 8,759 | cde |
| 11 | Engenia+glyphos | Engenia+glyphos+Cobra | 30 | ab | 97 | ab | 5 | cd | 0 | e |
| 12 | Enlist Duo | Enlist Duo+Cobra | 32 | ab | 97 | ab | 0 | d | 0 | e |
| 13 | Liberty | Liberty+Cobra | 28 | b | 99 | a | 0 | d | 0 | e |
| 14 | Reflex+glyphos | glyphos+Cobra | 40 | a | 79 | cd | 8 | bcd | 9,497 | b-e |
| 15 | Flexstar GT | glyphos+Cobra | 35 | ab | 74 | de | 7 | cd | 16,719 | bcd |
| 16 | None | None | 0 | d | 0 | h | 41 | a | 50,293 | a |
| 17 | Engenia+Cobra | Engenia+glyphos | 0 | d | 97 | ab | 9 | bcd | 0 | e |
| 18 | Cobra+glyphos | FlexstarGT | 28 | b | 81 | c | 3 | cd | 1,592 | de |
|  | LSD P=.05 |  | 11.12 |  | 5.97 |  | 11.56 |  | 16,363 |  |
|  | CV |  | 53.59 |  | 4.4 |  | 87.11 |  | 107.45 |  |
| Treatment Prob(F) |  | 0.0001 |  | 0.0001 |  | 0.0001 |  | 0.0001 |  |

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cEnlist Duo is a combination of glyphosate plus 2,4-D choline

Table 3. Cereal rye termination and approaches for residual herbicide treatments.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  | Canopeo | Morningglry | Ann. grass | Soybean |
| Trt. | Termination |  | Readings | % Control | % Control | Yield |
| No. | Timinga | Herbicide Program | 6/25/2020 | 7/16/2020 | 7/16/2020 | bu/A |
| 1 | 4wks EPP | Burndown (BD) only | 58 | a-d | 0 | f | 0 | c | 63 | a |
| 2 | 4wks EPP | Residualb at BD | 64 | a | 40 | e | 46 | b | 46 | a |
| 3 | 4wks EPP | Residual at BD fb POSTd (+Rc) | 54 | b-f | 86 | a | 99 | a | 56 | a |
| 4 | 4wks EPP | Residual at BD fb POST (-R) | 56 | a-e | 98 | a | 99 | a | 54 | a |
| 5 | 4wks EPP | BD fb residuals at planting fb POST (+R) | 52 | c-f | 99 | a | 99 | a | 56 | a |
| 6 | 4wks EPP | BD fb POST (+R) (2nd trifoliate) | 41 | hi | 91 | a | 99 | a | 52 | a |
| 7 | 2wks EPP | Burndown (BD) only | 51 | c-f | 50 | de | 89 | a | 48 | a |
| 8 | 2wks EPP | Residual at BD | 60 | abc | 57 | cd | 99 | a | 50 | a |
| 9 | 2wks EPP | Residual at BD fb POST (+R) | 56 | a-d | 99 | a | 99 | a | 54 | a |
| 10 | 2wks EPP | Residual at BD fb POST (-R) | 61 | ab | 99 | a | 99 | a | 48 | a |
| 11 | 2wks EPP | BD fb residuals at planting fb POST (+R) | 58 | a-d | 99 | a | 99 | a | 51 | a |
| 12 | 2wks EPP | BD fb POST (+R) (2nd trifoliate) | 42 | ghi | 98 | a | 99 | a | 52 | a |
| 13 | 2 DAP | Burndown (BD) only | 47 | fgh | 70 | bc | 99 | a | 52 | a |
| 14 | 2 DAP | Residual at BD | 46 | f-i | 65 | cd | 99 | a | 56 | a |
| 15 | 2 DAP | Residual at BD fb POST (+R) | 52 | c-f | 99 | a | 99 | a | 49 | a |
| 16 | 2 DAP | Residual at BD fb POST (-R) | 47 | e-h | 99 | a | 99 | a | 55 | a |
| 17 | 2 DAP | BD fb residuals at planting fb POST (+R) | -- |  | -- |  | -- |  | -- |  |
| 18 | 2 DAP | BD fb POST (+R) (2nd trifoliate) | 37 | i | 99 | a | 99 | a | 52 | a |
| 19 | 2wks EPP | BD fb EPOST | 46 | fgh | 99 | a | 99 | a | 54 | a |
| 20 | 4wks EPP | BD fb EPOST | 51 | d-g | 85 | ab | 79 | a | 53 | a |
| 21 | Untreated | None | 39 | hi | -- |  | -- |  | 48 | a |
|  | LSD P=.05 |  | 8.81 |  | 15.11 |  | 22.63 |  | 12.81 |  |
|  | Standard Deviation | 5.34 |  | 9.13 |  | 13.68 |  | 7.75 |  |
|  | CV |  | 10.53 |  | 11.19 |  | 15.2 |  | 14.75 |  |

Treatments 15 and 17 are identical; included only to show factorial arrangement of treatments.

Abbreviations: BD= burndown; DAP= days after planting; EPP= early pre-plant; fb= followed by; POST=postemergence; +R is with residual herbicides; -R is Liberty application alone

aTermination treatment is a tankmixture of glyphosate plus 2,4-D choline.

bResidual herbicide is a tankmixture of metribuzin plus Valor

cPostemergence residual was a tankmixture of Liberty plus Reflex; treatments applied at 2nd trifoliate also included FirstRate

dPostemergence treatments were made 4 weeks after planting unless noted