# Application Antagonism Negates Benefit of Foliar Herbicide Combinations for Resistance Management

Estevan G. Cason, Julie M. Young, Bryan G. Young
Botany and Plant Pathology Department. Purdue University, West Lafayette, IN 47907

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## Introduction

High adoption of dicamba- and 2,4-D-resistant soybean in Indiana allows growers to use various postemergence combinations including 2,4-D choline, dicamba, glufosinate, and glyphosate for control of problematic weeds (Green, 2016). Label requirements, improved formulations, and restrictions for applications of dicamba and 2,4-D choline in resistant crops were devised to reduce the risk of off-target movement. However, application requirements for one herbicide may negatively impact the efficacy of other herbicides applied in mixture and result in herbicide failure and further herbicide resistance evolution.

## Hypothesis and Objective

Hypothesis: Application of herbicides not adhering to label recommendations for optimization will reduce efficacy for resistance management.

Objective: Evaluate herbicide efficacy on herbicide-resistant (HR) waterhemp (*Amaranthus tuberculatus*) and Palmer amaranth (*A. palmeri*) when applied according to label recommendations for optimal activity and applied with restrictions from other herbicides applied in mixture.

## Materials and Methods

A field experiment was conducted in 2021 and 2022 at three sites with herbicide-resistant *Amaranthus* spp.

Application parameters:

- Weed height was 15 to 30 cm
- Nozzle type, size, carrier volume, and adjuvants varied by treatment as outlined in Table 1.

**Table 1.** Herbicide treatment, application rates, nozzle types, spray carrier volume, and spray adjuvants.

| | | Sprayer Configuration | | | |
|---|---|---|---|---|---|
| | | Labeled | | Optimized | |
| Herbicide Treatment | Rate (kg ae or ai ha$^{-1}$) | Nozzle | Spray Vol. (L ha$^{-1}$) | Nozzle | Spray Vol. (L ha$^{-1}$) |
| Glyphosate | 1.27 | AIXR 11004 | 94 | AIXR 11004 | 94 |
| Glufosinate | 0.66 | XR 11006 | 187 | XR 11006 | 187 |
| 2,4-D choline | 1.07 | AIXR 11004 | 94 | AIXR 11004 | 94 |
| Dicamba[1] | 0.56 | TTI 11006 | 140 | AIXR 11004 | 94 |
| Glyphosate + 2,4-D | 1.27 + 1.07 | AIXR 11004 | 94 | AIXR 11004 | 94 |
| Glyphosate + dicamba | 1.27 + 0.56 | TTI 11006 | 140 | AIXR 11004 | 94 |
| Glufosinate + 2,4-D | 0.66 + 1.07 | AIXR 11006 | 187 | XR 11006 | 187 |
| Glufosinate + dicamba | 0.66 + 0.56 | TTI 11006 | 140 | XR 11006 | 187 |
| Glyphosate + glufosinate + 2,4-D | 1.27 + 0.66 + 1.07 | AIXR 11004 | 94 | XR 11006 | 187 |
| Glyphosate + glufosinate + dicamba | 1.27 + 0.66 + 0.56 | TTI 11006 | 140 | XR 11006 | 187 |

[1]Optimized treatments included the Clarity formulation of dicamba applied with ammonium sulfate (AMS), labeled treatments included the XtendiMax formulation of dicamba applied with a volatility reducing agent, drift reducing agent and non-AMS water conditioner.

### Data Collection and Analysis

- Visual estimates of control at 14 and 28 days after application (DAT)
- Weed counts (0.5 m$^2$) at 28 DAT
- Spray coverage and droplet density using spray cards
- **Data analysis:** Data were analyzed with an Analysis of Variance. Means were separated using Fisher's protected LSD ( P ≤ 0.05)

## Results and Discussion

### Dicamba- and Glyphosate-Resistant Waterhemp

- Glufosinate was the most effective single herbicide for control of a multiple herbicide-resistant waterhemp population.
- Applying dicamba (Clarity) with glufosinate using application methods optimized for glufosinate resulted in waterhemp control similar to glufosinate alone.
- Waterhemp control was reduced when dicamba (XtendiMax) was applied with glufosinate following labeled application requirements.

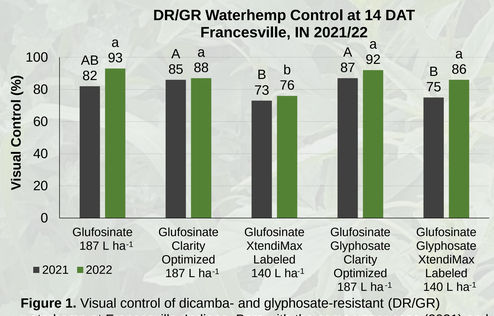
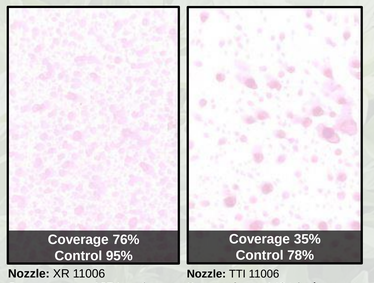



**Figure 1.** Visual control of dicamba- and glyphosate-resistant (DR/GR) waterhemp at Francesville, Indiana. Bars with the same upper case (2021) and lower case (2022) letters are not significantly different according Fisher's protected LSD ($P$ = 0.05).




**Nozzle:** XR 11006
**Spray volume:** 187 L ha$^{-1}$
**Herbicides:** Glufosinate

**Nozzle:** TTI 11006
**Spray volume:** 140 L ha$^{-1}$
**Herbicides:** Glufosinate + XtendiMax

**Figure 2.** Comparison of two application methods using different nozzles and spray volumes at Francesville, Indiana (2022).


**Nozzle:** XR 11006
**Spray volume:** 187 L ha$^{-1}$
**Herbicide treatment:** glufosinate + Clarity + glyphosate

**Nozzle:** TTI 11006
**Spray volume:** 140 L ha$^{-1}$
**Herbicide treatment:** glufosinate + XtendiMax + glyphosate

**Figure 3.** Waterhemp control 14 DAT from glufosinate + dicamba + glyphosate as influenced by application method at Francesville in 2021.

### Glyphosate-Resistant Waterhemp

- Waterhemp control was increased with the addition of glyphosate to dicamba compared with dicamba alone.
- Combining dicamba (XtendiMax) with glufosinate did not increase waterhemp control compared with glufosinate alone.

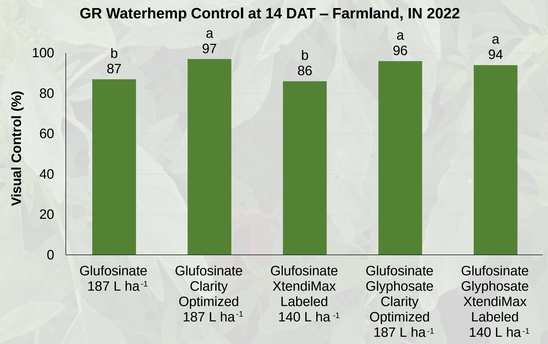



**Figure 4.** Visual control of glyphosate-resistant (GR) waterhemp at Farmland, Indiana. Bars with the same letter are not significantly different according Fisher's protected LSD ($P$ = 0.05).

## Results and Discussion

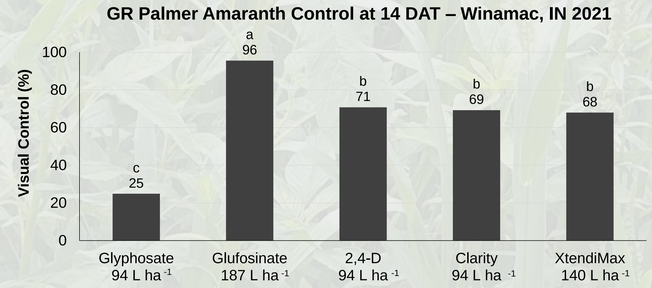



**Figure 5.** Visual control of glyphosate-resistant (GR) Palmer amaranth at Winamac, Indiana. Bars with the same letter are not significantly different according Fisher's protected LSD ($P$ = 0.05).

### Glyphosate-Resistant Palmer Amaranth

- GR Palmer amaranth control was at least 96% from glufosinate while dicamba, 2,4-D and glyphosate provided less than 75% control.
- Combinations of glufosinate with dicamba or 2,4-D provided greater efficacy than combinations with glyphosate regardless of application method.

### Spray Coverage

Spray coverage was positively correlated with herbicide efficacy at 14 DAT, with reduced herbicide efficacy for applications resulting in less than 40% spray coverage.

## Conclusion and Implication

- **Conclusion:** Management of herbicide-resistant weeds necessitates the use of multiple, effective herbicide mode of action groups.
- **Implication:** Current label requirements for the use of dicamba in dicamba-resistant soybean may reduce herbicide efficacy and limit the effectiveness of herbicide combinations.

## Future Research

Herbicide application incompatibility should be investigated as herbicide mixtures are the focus of resistance management practices.

## Acknowledgement

Financial support for this project was provided by the Indiana Soybean Alliance.

INDIANA SOYBEAN ALLIANCE

## References

Green J. M. (2016). The rise and future of glyphosate and glyphosate-resistant crops. *Pest Manag. Sci.* 10.1002/ps.4462