Glyphosate hormesis evolution in velvetleaf from 1988 to 2016

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Introduction

- Weed problems are exacerbated by low crop diversity and the reliance on few herbicide mechanisms of action,. This leads to strong selection pressure resulting in highly adapted weed genotypes[1,2].
- Therefore, it is critical to determine the evolutionary potential of weed species to increase weediness[3,4] and mitigate this process with adequate changes in practices that reduce selection pressure[3].
- In the 1980s and 90s, glyphosate was widely and rapidly adopted due to having low application rates, broad spectrum weed control, low toxicity[5], and glyphosate resistant crops.
- The intensity, scale, and uniformity of the use of a postemergence herbicide, as in glyphosate, has no precedent. This has caused not only selection pressure for glyphosate resistance, but also dramatic changes in crop management, weed control tools, weed community composition, and interspecific competition.
- There have not been studies that directly track multigenerational changes of herbicide tolerance in weed species.

Hypothesis and Objective

- Hypothesis: Velvetleaf has been able to adapt and maintain its populations in highly disturbed, agricultural environments as the result of rapid and continuous evolution of increased tolerance to sublethal rates of glyphosate.
- Objective: Understand herbicide tolerance of a population of velvetleaf from a seed collection spanning 28 years.

Materials and Methods

- Velvetleaf seeds were collected from the same field in Story County, Iowa from 1988 to 2016.
- A seed increase was performed to produce all year-lines under the same conditions and to reduce maternal effects.
- Greenhouse conditions:
  - Peat moss and vermiculite growing medium
  - 30 C during the day, 26 C during the night
  - Supplemental lighting provided to extend the day length to 14 hours
- Plants were grown in germination trays with 5cm x 5cm cells, with one plant per cell
- Rates of 0, 0.125X, 0.25X, 0.5X, and 1X of recommended label rates of Roundup PowerMAX II were applied at the 4-6 leaf stage.
- Herbicides were sprayed at the four- to six-leaf stage considering target dates for effective weed control and for plants to have enough leaves for herbicide uptake and characterization of symptoms.
- Plants were harvested at the flowering stage and biomass was collected for dried weights.
- Data was analyzed using SAS using PROC GLIMMIX with means were separated by Tukey's Honestly Significant Difference (α=0.05) and SigmaPlot 14.0.

Results

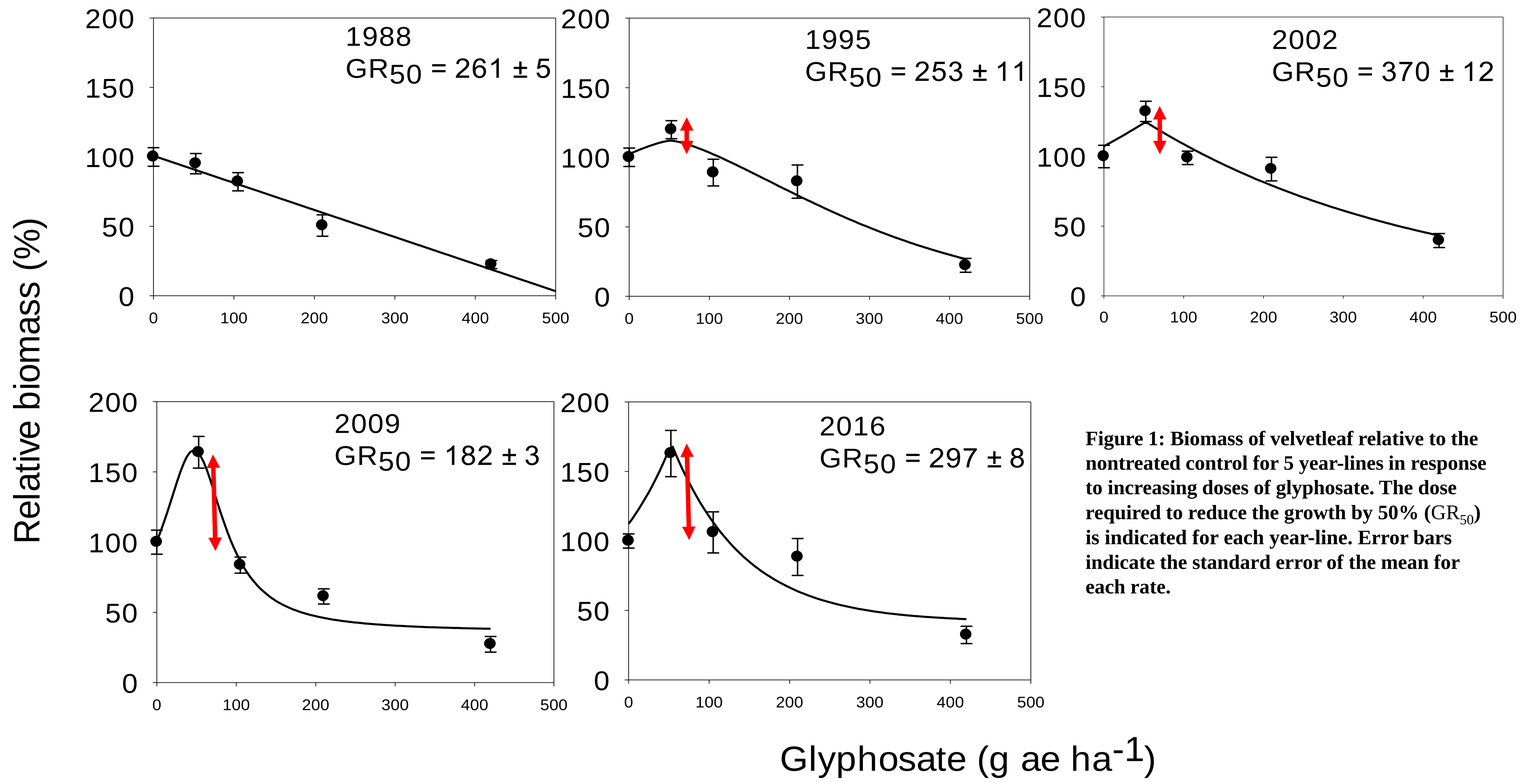


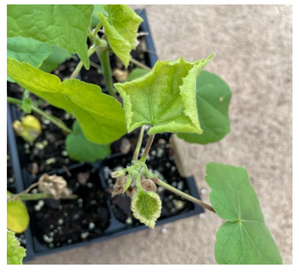
Figure 1: Biomass of velvetleaf relative to the nontreated control for 5 year-lines in response to increasing doses of glyphosate. The dose required to reduce the growth by 50% (GR_{50}) is indicated for each year-line. Error bars indicate the standard error of the mean for each rate.

Results

- The glyphosate dose needed to reduce the growth 50% (GR_{50}) ranged from 117 to 370 g ae ha^{-1} (Figure 1), which was below the field-use dose of 420 to 840 g ae ha^{-1}.
- Although there were differences in GR_{50} among year-lines, those did not show a clear pattern.
- Each year-line after 1988 had a hormetic response to the lowest dose of glyphosate, 52.5 g ae ha^{-1}, where relative biomass increased as a result of the application (Figure 1).
- The magnitude of the hormesis increased progressively overtime at a rate of approximately 5% $year^{-1}$, with 2009 and 2016 having more than 50% higher biomass than the nontreated control (Figure 1).

Conclusions

- For this study, from 1995 and on, there seems to be a strong directional selection for a hormetic response to glyphosate.
- This progressive response is likely due to the extensive adoption of glyphosate resistant crops and the rapid increase in the use of this herbicide[6].
- Although it has been proposed that sub-lethal rates triggering hormesis could be increasing the plant's ability to evolve resistant biotypes from sensitive populations[7], our results indicate that hormesis evolution can occur without major changes in sensitivity to commercial herbicide doses (Figure 1).



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