Title: Crop Rotation Strategies for Management of Herbicide-Resistant Giant Ragweed (*Ambrosia trifida*) - an Integration of Research and Extension Education

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**Rationale for the Research:**
Weeds are undoubtedly the most important chronic crop pests in commodity crop production resulting, in the USA, in approximately $33 billion in lost crop production plus another $5 billion in herbicide costs, annually. Glyphosate is the most widely-used herbicide in Minnesota, due primarily to the development of glyphosate-resistant corn and soybean. However, the repeated use of glyphosate has led to glyphosate-resistant weed biotypes (32 weed species worldwide). Since 2005, in Minnesota, biotypes of glyphosate-resistant giant ragweed have been identified and the acreage they impact is rapidly growing. It is estimated that in 2014, of the 15.6 million corn and soybean acres grown in Minnesota, 4 million acres contain glyphosate-resistant giant ragweed, of which 1.5 million acres are heavily infested. Herbicide-resistant weeds are an economic and ecological concern. With the advance of glyphosate-resistant Palmer amaranth in the southern USA, the percentage of farmers who indicated they had total weed control costs greater than $50 per acre nearly doubled after the emergence of herbicide-resistant weeds. Rotating herbicide chemistries is one way of dealing with the issues of glyphosate-resistant weed species. However, many of the weeds resistant to glyphosate are also resistant to other herbicide chemistries. Weeds with multiple resistances reduce the efficacy of existing and developing herbicide-resistant crop technologies, limit options for weed control, and decrease profitability. With such large economic consequences and the increasing prevalence of herbicide resistant weeds, new and integrated strategies are needed to improve the timeliness of weed control.

**Part I: Seed-Bank depletion of giant ragweed in various crop rotations**
The objective of this research was to determine how six different three-year crop rotations containing corn (C), soybean (S), alfalfa (A), and wheat (W) (CCC, SCC, CSC, SWC, SAC, AAC) affect giant ragweed seed-bank depletion, and ultimately determine the most appropriate combination of crops to manage glyphosate- and ALS-resistant giant ragweed. Results thus far indicate that there is high potential for the giant ragweed seed bank depletion. Across all crop rotation treatments, there were no differences in seed bank depletion, with an average of 97% of giant ragweed seeds in the seed bank being depleted in two years.

**Part II: Emergence patterns of Giant Ragweed in various Crops and Crop Rotations**
The objective of this research was to determine how these six different crop rotations affect giant ragweed emergence patterns. Giant ragweed emerged early across all treatments, with 90% emergence occurring by June 4th. In comparison to corn or soybean, total emergence was reduced when wheat or alfalfa were planted, indicating that seedling recruitment is affected by crop rotation. When combined with the seed bank depletion work, these results indicate that various crop rotations are more conducive to giant ragweed emergence than others, and that long term giant ragweed management can be accomplished by implementing a zero weed threshold to deplete the weed seed bank.
Part III: Giant Ragweed Seed Production and Retention in Soybean and Field Margins

The objective of this research was to determine the quantity of seed produced during the growing season and the level of seed retention at crop harvest in Midwestern soybean and field margins. Giant ragweed plants produced an average of over 1800 seeds per plant with 66% being potentially viable. Seed began shattering on September 12 and continued through October at 0.75% of seeds per day, indicating that 80% of seeds are retained on giant ragweed on the average Minnesota soybean harvest date of October 8. These results suggest that there is ample time to remove escaped giant ragweed from production fields and margins before the seed shatters, and that the majority of giant ragweed seed is likely passing through the combine at soybean harvest.

Extension/communication plan describing how the research results were transferred to the public:
Extension educators were members of the research team and directly involved with the planning of this research and results are being used in their educational programs. Results have been transferred by the extension educators through various venues including: field days, winter workshops (~60 Private Applicator Training Workshops/year) and YouTube videos have been posted on-line at: https://www.youtube.com/user/UMNCrops. This research has also been integrated into Extension programming sessions developed for the Institute for Ag Professionals (IAP), which conveys research and recommendations to professionals who advise many of Minnesota’s farmers. To illustrate, ~725 people attended the 2014 Crop Pest Management (CPM) Short Course and 401 attended the 2015 Ag Professional Research Update series. The majority of the audience consisted of: seed company agronomists (20%), crop producers (15%), independent crop consultants (14%) and fertilizer/crop protection dealers (13%). A survey of the attendees of the Ag Professional Update series indicated their potential to influence ~5 million acres across the state and surrounding region. This research integrates into the existing Extension educational framework that is encouraging and enabling growers to take control of herbicide resistant-weeds in a proactive manner in order to preserve their valuable herbicide-resistant traits in corn and soybean.

Impacts:
This research has already reached a wide audience. The research was presented in December 2013 and 2014 at the North Central Weed Science Society meetings. Posters have also been presented at both the Production Agriculture and Plant Breeding Symposiums at the University of Minnesota in Saint Paul, MN as well as the 2014 American Society of Agronomy meetings. Results will be presented at the 2015 ASA and NCWSS meetings and one manuscript has been submitted to Weed Technology. The research has also been used in numerous extension programs where the research and recommendations are conveyed directly to professionals who advise many of Minnesota’s farmers. This research was also highlighted in an August 2, 2014 StarTribune article at: http://www.startribune.com/aug-2-herbicide-resistant-superweeds-emerge-to-challenge-farmers/269632941/

Research addressing the giant ragweed seedbank dynamic has led to more durable solutions to preventing and managing herbicide-resistant giant ragweed through the strategic use of diversified cropping sequences and tactics to deplete the weed seed bank via limiting weed seed inputs. The success of these strategies depended upon an understanding of the optimal integration of multiple control tactics based on a sound understanding of giant ragweed biology and ecology. This research improves our ability to determine the appropriate tactics, sequence and combination of crops for managing herbicide-resistant giant ragweed populations and seed banks.