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Economic and Behavioral Drivers of Herbicide Resistance Management in the U.S.

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Economic and Behavioral Drivers of Herbicide Resistance Management in the U.S.

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Weeds are a major constraint for agricultural production. Alleviation of this constraint has primarily been accomplished through the use herbicides for more than half a century. Indeed, in 2015, farmers spent $14.6 billion on herbicides to protect crops from weeds. This reliance on herbicides has resulted in repeated bouts with the evolution of herbicide resistant weeds and increased crop damage due to lost herbicide efficacy. In the past, the emergence of herbicide resistant weed species was addressed through the development and release of new classes of herbicide that could control the resistant weed species. However, two decades ago a new strategy emerged. Crops such as corn, cotton, and soybean were genetically engineering with tolerance to herbicides such as glyphosate. This made it possible for farmers to respond to herbicide resistant weeds with existing herbicides that were not previously used on the crop because they would severely damage it as well as the weeds. With this new strategy in place, it has been more than three decades since the last new class of herbicides was introduced. Yet, with sixteen different weed species identified to have glyphosate resistant populations in the U.S. and at least one weed species resistant to 23 out of the 26 known herbicide classes, it has become clear that engineering herbicide tolerant crops is also only a temporary solution to the weed management problem.

Throughout this period of heavy reliance on herbicides, weed scientists have encouraged farmers to use a more diverse set of weed management practices that include cultural (e.g., planting date and narrow rows) and mechanical (e.g., cultivation and tillage) in addition to chemical tactics in an effort to avoid the emergence of herbicide resistant weeds. Adoption of such diverse sets of tactics has been low. Explanations for low adoption are wide ranging. For example, farmers may choose not to use diverse tactics to reduce the risk of herbicide resistant weeds because the benefits are delayed and uncertain, while the costs are immediate and certain. Movement of weeds across farm boundaries can create an externality with free rider effects where farmers prefer to rely on their neighbors to manage herbicide resistance. Farmers can be overly optimistic about the prospects of the development and release of new classes of herbicide or herbicide tolerant crop varieties. The complexity, lack of flexibility, inconvenience, and additional time requirements of using more diversified tactics may discourage use. While there are many explanations for low adoption, there has been relatively little research that attempts to sort out which explanations are likely the most important drivers of a farmer's weed management decisions.

The objective of this research was to identify what factors are most strongly associated with a farmer's use of a range of herbicide, mechanical and cultural weed management tactics. This objective was accomplished using 2016 farmer survey data collected by Michigan State University and multivariate regression analysis. The contribution of the research is the broader behavioral as well as economic perspective it takes to better understand farmers' weed management decisions when compared to previous literature. The benefits of taking this broader perspective is the opportunity it offers to identify novel pathways for encouraging farmers to proactively manage herbicide resistance through the use of more diverse management tactics. Such pathways can serve as new targets for regulatory policy, education, and private or public

incentives to address the current and significant challenge posed by herbicide resistant weeds to U.S. agriculture.

Farmers from 28 predominately corn, cotton, and soybean producing states were surveyed using mixed mode (internet and mail) methods. The weed management tactics explored in this paper include the use of inter-row cultivation, tillage, hand weeding, mulches, pre-emergent herbicides, post-emergent herbicides, post-harvest herbicides, crop rotation, planting densities, planting dates, row widths, and weed maps. Herbicide use was further explored in terms of the use of herbicide mixes, multiple herbicides (unmixed), full labeled herbicide application rates, and herbicide class rotation. These various tactics were associated with typical farm and farm level controls including gender, farming experience, farm household income, and farm acres operated. They were associated with measures of a farmer's risk and time preferences, and the importance of human health and environmental, agronomic performance, convenience, and cost considerations for making weed management decisions. Additional measures that were associated with a farmer's use of alternative weed management tactics included concerns that herbicide resistant weeds could spread from neighbors' fields, concerns that new herbicides would not be available soon to control resistant weeds, and level of optimism that new herbicides would be available soon to control resistant weeds. Reduced form regression equations were jointly estimated using the user written cmp (conditional mixed process model) command in STATA. This command produces an estimate of the correlation in the unexplained errors, which was further analyzed using factor analysis in an effort to identify complementary or substitutable combinations of management tactics. Multiple model specification with and without state fixed effects were estimated to test the robustness on the results.

As one would expect from economic theory, our preliminary results show that farmers' risk and time preferences are consistently found to be significantly associated with a farmer's decision to use alternative weed management tactics. Interestingly, we also find a consistent attenuating interaction between risk and time preferences in relation to weed management decision. Farm operations with greater income are associated with significantly higher pre- and post-emergent herbicide use. Farmers that are more concerned that herbicide resistant weeds can spread from neighbors' fields appear to use a greater diversity of management tactics, which is contrary to the free riding hypothesis. Farmers who are optimistic that new herbicides will soon be available to deal with resistant weeds are significantly less likely to use multiple herbicides or rotate classes of herbicides, both of which are increase the risk of resistant weeds emerging. Farmers who report that human and environmental health concerns are important to weed management decisions are significantly less likely to use the full label herbicide application rate, which points to an interesting tradeoff between the risk of herbicide resistant weeds and human and environmental health risks. Farmers who reported that convenience, flexibility and saving time were important considerations for their weed management decisions were significantly less likely to use multiple herbicides, full labeled herbicide application rates, herbicide class rotations, and crop rotations, all factors that have been identified to reduce the risk of herbicide resistant weeds—a result that suggests these non-monetary factors are likely one of the more important driver of herbicide resistant weeds. Costs appeared to be an important consideration that discourages farmer use of post-harvest herbicide applications.

These results raise a range of interesting questions regarding the types of strategies that might be most successful at encouraging more diverse weed management in an effort to address the current challenges U.S. agriculture faces with increasing herbicide resistance. These questions

have a strong potential to generate discussion during the meetings after as well as during the selected poster or paper session.