Managing Weeds with Limited Options Due to Herbicide Resistance

Three objectives were developed for this research project. A summary of activities and results for each of these will follow. The major expenditure on the grant is salary for a PhD student in the Department of Crop and Soil Sciences (Denis Mahoney.) The student enrolled at NC State University in January 2017. David Jordan, Matthew Vann, Katie Jennings, and Ramon Leon are serving on his PhD committee. Dr. Nilda Burgos (University of Arkansas) is also a member of the student's committee. Dr. Burgos brings a great deal of knowledge on herbicide resistance, especially with respect to the herbicides addressed in this proposal. The graduate student has been responsible for directing or assisting with experiments and activities associated with all three objectives. Since the inception of the research, the project has increased in scope without sacrificing the initial objectives. Several general statements about the student's research are provided with the following three objectives listed in the initial proposal. The student has expanded beyond these, and a brief summary of the five chapters in the dissertation is available upon request. The student successfully defended his PhD dissertation in November 2019 and has completed all requirements for the PhD.

Objective 1. Determine the most effective herbicide program to control Palmer amaranth and common ragweed in cotton, peanut, soybean, sweetpotato, and tobacco.

This objective will be addressed through replicated trials during 2017-2019 in each of the crops listed in the objective. A PPO-inhibiting herbicide standard will be compared to other programs.

The effectiveness of new technologies in cotton and soybean were compared in 2016-2019. These programs are designed to determine the critical period of weed management and how residual herbicides at planting impact use of glufosinate and glyphosate plus dicamba. Research was also conducted in cotton in a high residue cereal rye system to determine how this approach impacts herbicide timing and the number of postemergence sprays needed for complete weed control. While the number of sprays needed is lower following cereal rye compared with native vegetation, multiple herbicides are still needed to control problematic weeds regardless of the cover crop system.

Objective 2. Determine the impact of weed management on populations of Palmer amaranth and common ragweed in selected crop rotations over three years.

This experiment was established in two fields in 2016 with varying weed populations at the Upper Coastal Plain Research Station near Rocky Mount. Treatments in 2016 included: a) diuron preemergence, b) fomesafen preemergence, c) diuron preemergence following by glufosinate postemergence, and d) fomesafen preemergence followed by glufosinate postemergence. In 2017, each of these

treatments were followed by cotton, peanut, sweetpotato, and tobacco with a standard herbicide program including PPO-inhibiting herbicides compared with a total postemergence herbicide programs without a PPO-inhibiting herbicide. In 2018, soybean was planted in all plots. In each year weed populations and crop yield were determined. Economic return is currently being determined for the three-year study. Soil cores were collected in spring 2019 to provide a reflection of seedbank dynamics over the three previous growing seasons.

The most important factor in determining control of Palmer amaranth or common ragweed over three years was herbicide program. In this study, the most effective herbicides were the PPO-inhibiting herbicides. Differences in cropping system during year 2 of the three-year study (cotton, peanut, soybean, tobacco) did not translate into differences in weed populations after 3 years. This was not unexpected given crop diversity was altered in only 1 of 3 years. The impact of herbicide selection, in this case use of PPO-inhibiting herbicides versus other herbicides, occurred in each year if the study.

One additional component of this research included in the student's dissertation was defining the interaction of soybean plant population and timing of herbicide application on Palmer amaranth control in-season and soybean yield. This work also quantified how these factors affected Palmer amaranth control and cotton yield in a following cotton crop. As expected, earlier applications were more effective, and higher seeding rates were more effective in suppressing weeds and protecting soybean yield. Weed control in soybean the previous year translated into differences in weed populations in cotton the following year. Although greater expense was incurred with higher seeding rates, the contribution from these seeding rates due to weed control and yield resulted in similar economic returns compare with the less expensive approach to weed management. Minimizing contributions of weed seed to the soil seedbank is an important component of herbicide resistance management. Greater weed control in general from higher inputs most likely will improve long-term weed management without increasing short-term weed management costs.

In a separate group of studies, the impact of herbicide timing and the number of applications needed in corn, cotton, and soybean was compared. Increasing the number of herbicides was more important for cotton than soybean or corn, and in most cases, corn was more effective in suppressing weeds and reducing the soil seed bank for the following season in cotton. While these findings are not surprising, no studies have been published that allowed a direct comparison of cropping systems within the same experiment, especially as it pertains to contributions of weeds to the soil seedbank. In a separate experiment, the importance of intensive weed management on weed control and yield in peanut was documented, demonstrating the importance of PPO-inhibiting herbicides in peanut-based cropping systems.

Objective 3. Develop a Cooperative Extension bulletin to assist growers in managing herbicide-resistant weeds based on these results.

Results from research conducted for the first two objectives are included in the bulletin. To support the guide, the distribution of PPO resistance/tolerance was documented in the North Carolina coastal plain. Approximately 125 samples of Palmer amaranth were collected during fall 2016 from cotton, peanut, soybean, and sweetpotato fields and screened for PPO resistance. The graduate student found greater tolerance of some of these populations to PPO-inhibiting herbicides (fomesafen) but was unable to confirm resistance. However, he did confirm resistance to the HPPD-inhibiting herbicide mesotrione in one population. Other populations in this collection likely are resistant to this mode of action. Resistance to glyphosate and ALS-inhibiting herbicides (thifensulturon) was widespread in these collections and presented frequencies of resistance on par with 2010 collections in the same general area. Fortunately, no populations expressed resistance or elevated tolerance to glufosinate (Liberty).

In addition to the above study, the student determined seed production for Palmer amaranth in corn, cotton, peanut, and soybean. Seed production was similar in cotton and peanut, and production in these crops exceeded production in corn or soybean. Corn was more effective in preventing seed production than soybean. These results were observed when whether or not the weeds emerged with the crop or three weeks after the crop emerged. However, the amount of seed produced for later emerging weeds was 8- to149-fold lower than for weeds emerging with crops. These data underscore the importance of delaying weed emergence through control practices early in the season.

Faculty with weed management responsibilities in the Departments of Crop and Soil Sciences and Horticultural Science have prepared a NC State Extension (*Value of Cultural Practices in Managing Weed: Examples from Research in North Carolina*.) The focus of the bulletin is examples of cultural practices that impact weed populations and evolution of herbicide resistance. Distribution of herbicide-resistant weeds will be presented along with examples of how these populations most likely developed. Data from research in North Carolina will be used as examples of principles that can minimize the impact of weeds and their reproduction (tillage systems, plant populations, crop rotations, timing and intensity of weed management, etc.) The bulletin is currently being reviewed in the EP-3 process with Extension communications. The electronic version is expected to be available in early spring for distribution.

Authors and chapter outline includes the following:

Authors: Ramon Leon, David Jordan, Katie Jennings, David Monks, Matthew Vann, Loren Fisher, Wesley Everman, Charles Cahoon, Matthew Inman, Chris Reberg-Horton, Rachel Atwell-Vann, Denis Mahoney, Drew Hare, Alan York. Chapters: Major weeds in North Carolina (Herbicide-Resistant Biotypes in Agronomic and Vegetable Crops in North Carolina, Fundamentals of Herbicide Resistance Management), Variety selection, Crop rotation, Plant population and timing of weed management, Deep tillage and hand removal, Cover crops, Summary, References.

Contributions of Research to the Literature:

Peer-reviewed articles published:

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. The effect of nozzle selection and carrier volume on weed control in soybean in North Carolina. Crop Forage Turfgrass Manage. doi:10.2134/cftm2019.05.0037

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. The influence of postemergence herbicide timing and frequency on weed control and soybean yield. Crop Forage Turfgrass Manage. doi: 10.2134/cftm2019.05.0036

Hare, A. T., D. L. Jordan, R. G. Leon, K. L. Edmisten, A. R. Post, **D. J. Mahoney**, D. Washburn. 2019. Impact of weed management on peanut yield and weed populations the following year. Peanut Sci. doi: 10.3146/PS19-9.1

Dissertation Chapters under Review for Peer-reviewed Journals:

Resistance to Herbicides Among Palmer Amaranth Collected in the North Carolina Coastal Plain

Soybean Population and Postemergence Herbicide Application Timing Influence on In-Season and Subsequent-Season Weed Control and Profit

Palmer amaranth (*Amaranthus palmeri*) growth and seed production when in competition with row crops in North Carolina

Other Manuscripts in Preparation from Activities on the Project:

Influence of Crop Rotation and Herbicide on Weed Populations

Influence Shade Timing and Duration on Herbicide Efficacy

Abstracts and Proceedings at Professional Meetings:

American Peanut Research and Education Society

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2018. Presence and distribution of suspected Palmer amaranth resistant to PPO-inhibiting herbicides in the North Carolina Coastal Plain. Pp. 42.

Southern Weed Science Society

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2018. The effect of soybean population and herbicide application timing on in- and subsequent-season weed control. Pp. 186-187.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. State of resistance for Palmer amaranth populations from the North Carolina Coastal Plain. Pp. 204.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2018. Presence and distribution of suspected Palmer amaranth resistant to PPO-inhibiting herbicides in the North Carolina Coastal Plain. Pp. 59-60.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. Herbicide efficacy as influenced by density and duration of shade. Pp. 98.

Weed Science Society of America

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. Palmer amaranth growth and fecundity in competition with various row crops in North Carolina. Pp. 265.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. State of resistance for Palmer amaranth populations from the North Carolina Coastal Plain. Pp. 76.

Weed Science Society of North Carolina

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2018. Presence and distribution of suspected Palmer amaranth resistant to PPO-inhibiting herbicides in the North Carolina Coastal Plain.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. Palmer amaranth growth and fecundity in competition with various row crops in North Carolina.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2018. Light-dependent herbicide efficacy as influenced by shading density and interval.

Mahoney, D. J., D. L. Jordan, A. T. Hare, R. G. Leon, M. C. Vann, N. R. Burgos, and K. M. Jennings. 2019. State of resistance for Palmer amaranth populations from the North Carolina Coastal Plain.

Graduate Student Recognition:

Denis Mahoney, the student funded by this grant, has been recognized as the top speaker in oral PhD presentations at annual meetings of the Southern Weed Science Society and American, Weed Science Society of North Carolina, and the American Peanut Research and Education Society. He also was recognized as the Outstanding PhD student at the Weed Science Society of North Carolina in 2019.

Impact:

Results from this research have characterized the current status of herbicide resistance in the North Carolina Coastal Plain in areas where cotton, peanut, sweetpotato and tobacco are dominant crops. The project has also provided meaningful strategies to manage weed populations in this region. Results from this research are an important contribution to an Extension bulletin on this topic for North Carolina farmers.