Contract Approval Form

All stamps other than the actual signature must be placed on this page.

Originator: **Mike Dunn** **Date:** **5/18/2015**

By Checking the box below I state that I have fully read the contract and approve its terms and conditions as presented.

X

Payment terms, deliverables, cancelation clauses and expiration dates must be listed below.

Attachment A for FY15 Purdue University Production Research Project
Subject to Master Agreement
Funding Approved by Research Committee

Project Title:	**Improving Weed Management by Addressing Faulty Herbicide Application Methods and Herbicide Resistant Weed Biotypes**
Principal Investigator:	**Bryan Young**
Project Period:	**May 1, 2015 to April 30, 2016**
Funding Amount & Code(s):	**$90,000 Total (All from 8955)**
Payment Terms & Deliverables:	**70% of budget upon execution of contract and receipt of invoice. 30% due upon receipt of the year end technical report, related financial report, and invoice.**

Please sign page 2 of this document.

ATTACHMENT A
PROJECT RESEARCH AGREEMENT 15055350
between
INDIANA SOYBEAN ALLIANCE
("Sponsor")
and
PURDUE UNIVERSITY
("Organization")

Upon execution of this Project Research Agreement by both parties, the Research Project specified herein will be awarded and performed in accordance with the Master Sponsored Research Agreement that became effective November 4, 2002 and amended March 6, 2008 and this Project Research Agreement between the two parties.

1. Research Project Title: Improving Weed Management by Addressing Faulty Herbicide Application Methods and Herbicide-Resistant Weed Biotypes

2. Research Project: The Research Project means, the research plan discussed in Appendix A attached hereto and by reference made a part of this Project Research Agreement.

3. Principal Investigator: Bryan G. Young and William G. Johnson

4. Principal Investigator's School/ Department: Botany & Plant Pathology

5. Project Period: May 1, 2015 through April 30, 2016

6. Project Cost: $90,000

7. Payment Schedule:According to Master Agreement

8. Equipment to be bought for Project (if any):n/a

9. Special Conditions (if any):n/a

Research Project Authorization:

Purdue University	**Indiana Soybean Alliance**
By: Jenny McDaniel	By:
Printed: Jenny McDaniel	Printed:
Its: Contract Analyst	Its:
DATE: 4/29/2015	DATE:

ATTACHMENT B

FACULTY AGREEMENT

For Indiana Soybean Alliance Grants Between Purdue University

And

Bryan Young and Bill Johnson
Faculty's Name

THIS AGREEMENT, made as of April 17, 2014 by and between Bryan Young and Bill Johnson (herinafter called "Faculty") and Purdue University (hereinafter called "Purdue").

Purdue University ("Purdue") and the Indiana Soybean Alliance, Inc. ("ISA") have entered into a Master Research Agreement, which covers the terms, and conditions under which all reach project sponsored by ISA at Purdue will be governed. If you submit a proposal to ISA and your proposal is funded by ISA you agree to abide by the following terms and conditions which are part of the Master Agreement.

1. You will provide the ISA with the following annual reports:
    a. A progress report of the research for readers without scientific or technical backgrounds;
    b. A summary in lay-person's language, suitable for news media purposes to facilitate producer information;
    c. A year-end technical report including all data collected pursuant to your research for ISA within 60 days of each funding period.
2. You will provide Purdue with a disclosure of any invention developed as part of our research for ISA.
3. In you develop an invention while working on an ISA project, it will be necessary to delay any publication related to the invention until it is determined if patent protection should be pursued and patent protection is obtained. It may take up to two (2) years to determine if patent protection should be pursued and to obtain such protection. You agree to cooperate with Purdue and ISA and to delay publications that could affect obtaining patent protection for a period of time not to exceed two years from the date you disclosed such invention to Purdue.
4. Send a copy of any proposed publication of presentation (hereinafter called "Manuscript") about the ISA research work to ISA at least sixty (60) days in advance of submission of publication or presentation to assure:
    a. That no confidential or proprietary information provided by Sponsor in writing, and designated as confidential or proprietary information, is contained in the Manuscript. Such material will be removed from the Manuscript before it is submitted for publication or presentation; and

b. That the proposed publication or presentation date does not preclude foreign or domestic patent protection on any Invention. Such material will be removed from the Manuscript before it is submitted for publication or presentation or such publication or presentation shall be delayed for a period of time not to exceed two (2) years from the date you submitted the disclosure of invention to Purdue to allow time to obtain patent protection. In case where it is important for the Manuscript to be submitted for review before the two year time period, you may request as shorter time but you must allow a time of up to six (6) months from the date you sent Manuscript to ISA to review to obtain patent protection. A copy of all Manuscripts should also be sent to Purdue Research Foundation's Office of Technology Commercialization.

If my Project is funded I agree to abide by these terms and conditions.

Signature: Bry D. Yng William G. Johnson

Name: Bryan G. Young

Department: Botany and Plant Pathology

Telephone Number: 765-496-1646 765 494-4656

Email: BryanYoung@purdue.edu WGJ@Purdue

APPENDIX A

Indiana Soybean Alliance **TITLE PAGE**

FY 2015 Research Grant Application Proposal Number (ISA Use): S15 – _____

Goal(s) (check all that apply):

- X Increase and maintain soybean yield
- X Weed Control and Herbicide Resistance
- _____ Development and Updates of BMPs
- _____ Pests and Diseases
- X Production & Management Technologies
- _____ Fungicides
- _____ Sustainability
- _____ Cover Cropping Systems
- _____ Biologicals and Improved Soil Health
- _____ Soil Health/Nutrient Cost Analysis Benefits
- _____ Water Quality
- _____ Water Quantity

Check that all are included (in this order):

- _____ Title Page
- _____ Rationale for Research Proposal
- _____ Proposal Narrative
- _____ Proposal Research Budget
- _____ Current and Pending Support Disclosure

Title of Proposal: Improving Weed Management by Addressing Faulty Herbicide Application Methods and Herbicide-Resistant Weed Biotypes

Principal Investigator(s):

Name Bryan Young
Title Associate Professor of Weed Science
Affiliation Purdue University
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E-mail Address BryanYoung@purdue.edu

Name Bill Johnson
Title Professor of Weed Science
Affiliation Purdue University
Business Address
Phone Number 765-494-4656
Fax Number 765-494-0363
E-mail Address wgj@purdue.edu

Organization to Which Award Should Be Made:

Financial Officer's Name Jason Spall Title Research Administration Manager

Business Address Young Hall 155 S Grant Street, West Lafayette, IN 47907-2114

Phone Number 765-496-1058 Fax Number 765-494-1360

Proposed Starting Date: 5-1-15 **Proposed Ending Date: 4-30-16**

Approval Signatures:

Principal Investigator(s) — Date 4/10/15

Department Head or Research Director — Title Dept. Head — Date 4.13.15

Organization Representative — Title Pre Award Ctr Mgr. — Date 4/14/15

II. Rationale for Research Proposal

Wide-scale adoption of glyphosate-resistant soybean has transformed the way many growers manage weeds. Initially, the use of glyphosate essentially removed weed management as a major challenge for soybean producers, including those weeds already resistant to previous herbicide modes of action. However, the persistent use of glyphosate as the primary weed management tool has resulted in widespread weed resistance to glyphosate with populations of waterhemp, Palmer amaranth, giant ragweed, and horseweed (aka marestail) continuing to increase across Indiana. The proposed research aims to improve weed management in soybean by characterizing the extent of herbicide-resistant weed biotypes in the Indiana landscape, developing management strategies for problematic weeds, and discerning methods to optimize the performance of foliar herbicide applications.

III. Proposal Narrative

A. Abstract

The presence of weeds in Indiana soybean fields that have escaped grower management has progressively increased over the previous decade as a result of faulty herbicide application methods and the escalation of herbicide-resistant weed biotypes. Most notably, common waterhemp, Palmer amaranth, horseweed (aka marestail), and giant ragweed have been the predominant weed species creating management problems in soybean productions systems. To address these challenges three research projects have been developed to reduce the impact of weeds, especially those with resistance to herbicides, on soybean production and profitability.

The first project aims to characterize the presence of herbicide-resistant weeds species throughout Indiana. Due to the progressive evolution and spread of herbicide-resistant weeds this project has been, and will continue to be, a multi-year project that changes in response to the greatest weed challenges or new herbicide-resistant weed threats that are found in soybean production. The first objective of this project is to perform greenhouse and laboratory research to document the confirmation and distribution of Palmer amaranth, common waterhemp and other emerging weeds that are resistant to glyphosate and other key herbicide modes of action. A specific focus for 2015 will be to utilize molecular (DNA) assays that provide a rapid confirmation of known herbicide-resistance mechanisms for glyphosate, PPO herbicides, and the ALS herbicides. The molecular DNA assays, where available, provide a distinct advantage over whole-plant greenhouse screens in that they can be performed quickly (24 hours) and provides definitive confirmation of known resistance mechanisms. A pilot test of the DNA assay was performed for detecting waterhemp resistant to PPO-inhibiting herbicides (ex. Flexstar, Cobra) in 2014. The benefits were clear in our ability to inform crop managers within a few weeks of realizing the failed weed control in the field during the growing season if the waterhemp plants were indeed resistant to the PPO-inhibiting herbicides that were used or if some other aspect of the herbicide application was faulty (ex. poor coverage, excessive weed height). The second objective is to determine control strategies for glyphosate-resistant Palmer amaranth, common waterhemp and other emerging weed problems in both greenhouse and field trials. By characterizing weed populations at being resistant to a single herbicide such as glyphosate or resistant to multiple herbicide modes of action we can develop stronger management recommendations for growers.

The second project recognizes the continued challenge with control of horseweed in no-till soybean production systems. Multiple herbicide resistance to glyphosate and ALS-inhibiting herbicides such as Firstrate and Classic has created many of the challenges in controlling horseweed in soybean. The long-term goal of this project is to develop cost effective management practices to control herbicide-resistant horseweed and prevent or delay the development of resistance to the new herbicide-resistant crops coming onto the market in the near future. Specific objectives of this project are to 1) develop best management practices that limit the impact glyphosate-resistant horseweed on soybean production and publish the information in a comprehensive management guide, and 2) continue our field survey efforts initiated in 2003 to determine the distribution of glyphosate-resistant horseweed. The database developed from this process will be used to guide our efforts to monitor specific fields more closely for the presence of glyphosate-resistant weeds species.

The third project identifies faulty methods used commercially for foliar herbicide applications as an area for improving weed management. Proper methods for foliar herbicide

applications are critical to optimize herbicide performance, remove weeds from competing with crops, and help discourage the evolution of herbicide-resistant weed biotypes. Effective herbicide treatments require attention to factors that influence efficacy such as product selection and rate, equipment calibration, and application timing. However, one factor that is routinely ignored is the quality of the water used to spray the product. Water comprises about 99% or more of the herbicide spray solutions that are applied to soybeans. There is a fairly substantial body of knowledge regarding the effect of hardness and spray solution pH on glyphosate (Roundup) efficacy. However, little is known about the effect of water quality on glufosinate, dicamba, and 2,4-D. Moreover, information indicating the influence of time on herbicide and hard water cations interaction is limited. It is anticipated that in 2015 or 2016, dicamba-tolerant and 2,4-D-tolerant soybeans will be made available to growers. It is highly probable that these technologies will be stacked with glyphosate (Roundup) and/or glufosinate tolerant (Liberty Link) genes. These new tolerance genes and the ability to use dicamba or 2,4-D tank-mixed with Roundup or Ignite will be very beneficial to growers who have glyphosate, ALS, or PPO resistant weeds. Also, tank-mixes of Roundup or Liberty with dicamba, 2,4-D, and saflufenacil will give information on the compatibility of these mixtures in the presence and absence of hard water cations or at extreme and normal water pH values. The broad, long-term objective is to gain a greater understanding of the effect of spray water quality on dicamba, saflufenacil, and 2,4-D performance on key broadleaf weeds of soybean production system that are difficult to control with glyphosate and glufosinate.

The overall, long-term objective of this research project is to reduce the impact of weeds on soybean production and profitability and develop best management practices for herbicide-resistant weed species. Information generated by these projects will be disseminated to weed management practitioners through various outlets such as print media (ex. bulletins, fact sheets, websites) and personal communication through Certified Crop Advisors, Ag Retailers, Extension personnel, field days, and workshops.

B. Objectives

Broad, long-term objective: Reduce the impact of herbicide-resistant weeds on soybean production and profitability and develop best management practices for herbicide-resistant weed species.

Specific objectives:

Survey and Screening for Herbicide-Resistant Weeds

1) Document the confirmation and distribution of Palmer amaranth, common waterhemp, giant ragweed, horseweed, and other emerging weeds that are resistant to glyphosate and other key herbicide modes of action.

Work Plan – Previous research funded through this project with ISA has shown the presence of herbicide-resistant common waterhemp, Palmer amaranth, giant ragweed, and horseweed (aka marestail) in Indiana. In 2013 and 2014 we increased our efforts to determine the distribution and intensity of fields infested with glyphosate-resistant waterhemp and Palmer amaranth. As a result, we have documented that glyphosate-resistant Palmer amaranth can now be found in over 30 counties and waterhemp in 24 counties. Pilot testing of molecular DNA assays for rapid analysis of certain weed resistance mechanisms in 2014 provided confirmation of PPO-resistant waterhemp populations in 6 counties in Indiana. Plans for 2015 are to continue screening experiments for suspect field populations by using both greenhouse experiments and integrating more DNA confirmation assays to improve the efficiency and accuracy of these efforts. The molecular assays will be performed with some interaction with Dr. Pat Tranel at the University of Illinois who is a global authority on this type of research.

2) Determine control strategies for glyphosate-resistant Palmer amaranth, common waterhemp, giant ragweed, horseweed, and other emerging weed problems in both greenhouse and field trials.

Work Plan – The results from Objective #1 will provide herbicide-resistant weed profiles for individual weed populations. The presence of weed resistance to multiple herbicide modes of action beyond glyphosate such as resistance to ALS-, HPPD-, PPO-, and PSII-inhibiting herbicides will dictate what strategy is the most appropriate for each population. Thus, the identification of viable herbicides for improving management will be facilitated through the greenhouse research and research trials located in fields infested with herbicide-resistant weeds. The field trials will focus on individual herbicide components that may contribute to improved weed control as well as overall herbicide programs that demonstrate the necessary strategy to be successful throughout the growing season. The development of sound management strategies will be performed through consultation and potential collaborative research with Mark Loux, Extension Weed Scientist at The Ohio State University and Aaron Hager, Extension Weed Specialist at the University of Illinois. If they are interested and can obtain funding to do these projects, they will conduct similar studies at their sites.

Control Strategies for Herbicide-Resistant Horseweed

3) Develop best management practices that limit the impact glyphosate-resistant horseweed on soybean production and publish the information in a comprehensive management guide and website.

Work Plan – Continue field studies at SEPAC and other sites with HR horseweed to evaluate various herbicides, application timings, and use of cover crops on controlling horseweed. Continue educational to inform growers and the ag industry about the best management strategies for HR horseweed.

Influence of Spray Water Quality on Foliar Herbicide Activity

4) Determine the effect of water hardness on the efficacy of glufosinate, dicamba, and 2,4-D applied alone or in combination with glyphosate in controlling horseweed (marestail), giant ragweed, common waterhemp, Palmer amaranth, and morningglories.

5) Quantify the influence of water pH on the efficacy of glufosinate, dicamba, and 2,4-D applied alone or in combination with glyphosate in controlling horseweed (marestail), giant ragweed, common waterhemp, Palmer amaranth, and morningglories.

Work Plan - Field and greenhouse studies will be conducted in Indiana. Small plot field experiments will be conducted at different sites that contain above mentioned weed species. Standard weed science field research procedures will be used to establish weed species. Weed species will be hand seeded if they are not present at a specific site. Greenhouse experiments will be conducted as follow up of field studies. For objective 1, spray solutions will be prepared with various levels of hardness (calcium carbonate), based on water quality data provided by A and L Labs. We will prepare spray solutions that represent the range of hard water values observed in Indiana water samples. Treatments will be sprayed at two timing intervals i.e. immediately after mixing and 24 hours after mixing. For objective 2, we will prepare spray solutions that represent the range of pH values observed in Indiana water samples. Spray solutions will be prepared with various levels of pH adjusted to 5, 6, 7, and 8. These values were chosen based on water quality data provided A and L Labs. To negate the effect of carbon dioxide on spray solution pH, field and greenhouse studies will be sprayed with nitrogen backpack sprayers. Solution pH will be measured after the addition of herbicides by portable pH meter. Weed control will be visually evaluated at 2 and 4 weekly intervals to record speed of kill and overall control. Moreover, above-ground plant dry weights will be recorded. Data will be subjected to statistical analysis and we will attempt to publish the results in appropriate scientific journals.

Project Communication. For all objectives stated above the deliverables from this research will be communicated through various methods and individuals throughout the project period. During the late-summer field days at Purdue Ag Centers, we will present and explain results to growers. We will also summarize the data and present it in newsletter articles and during private applicator recertification programs (PARP) during the winter Extension meeting season. Each year extension weed scientist Bill Johnson gives presentations in over 30 PARP meetings. Average attendance is 25 to 50

people per meeting. The results will also be shared at the Purdue University Crop Management Workshops (attendance is approximately 900 people over the course of the 5 day workshop), and the Indiana CCA Convention (attendance is approximately 650 people). The number of acres managed by crop advisors at the Indiana CCA Convention is estimated to be in the millions. Other methods of communicating research results include weekly newsletters during the growing season (Pest & Crop) with over 1000 subscribers, and Johnson maintains a website where he can house the results of this work in the form of downloadable decision tools where farmers can evaluate the profitability of a BMP for their operation, and downloadable presentations. This work would be the focus of dedicated workshops as well. Any or all of these workshops could be recorded and uploaded to both Purdue Extension and ISA websites.

Interactions with Other Researchers
Mark Loux, Weed Scientist, Ohio State University (conducting similar management and statewide survey studies)
Aaron Hager, Weed Scientist, University of Illinois (conducting similar management and statewide survey studies)

C. Analysis of Economic Impact

Weed biotypes from different states of Midwestern region of United States have been identified resistant to the herbicide glyphosate. Some of these weeds biotypes exhibit resistance to multiple herbicides with different modes of action. Common waterhemp and Palmer amaranth are significant weed issues in soybean system of Indiana. Also, these weeds can easily be spread by wind or other man-made activities and can transfer herbicide resistance traits to susceptible biotypes that favor their survival in soybean system. However, recent control issues of these weed species with glyphosate have raised concerns among Indiana soybean growers. In some parts, this problem has grown to such extent that glyphosate is considered obsolete for their control and adoption of Liberty Link soybean has increased dramatically.

The cost of weed management in soybean has arguably increased from around $10/acre when glyphosate was still effective on all weed species to anywhere between $30 and $75/acre in the presence of one or more glyphosate-resistant weeds. In many cases, the herbicide cost in the initial year of discovering the herbicide-resistant weed infestation can be well beyond $60/acre and still have a 50% reduction in soybean yield that would translate to over $200/acre. Thus, the impact of herbicide-resistant weeds could be greater than $250/acre for some soybean fields. The goal of this project is to limit the economic risk for growers to avoid excessive loss. Although our research will not bring down the cost of weed control back to $10/acre, we hope to provide soybean growers with sound management plans that can achieve effective weed control and maximize soybean yield.

A significant portion of corn and soybean growers do not perform routine tests on spray water quality. Previous research has shown that high concentrations of hard water cations can reduce glyphosate efficacy. However, very little is known about the

effect of pH on herbicide efficacy. Unforeseen circumstances such as adverse weather conditions and equipment failure may prevent timely application of spray solutions. Herbicide efficacy may be influenced when the herbicide remains in the spray tank for extended period of time. However, research showing the effect of time on the interaction of herbicide and polyvalent cations present in the water is limited. Adjusting spray water hardness and pH into the optimal ranges will improve herbicide efficacy and is relatively inexpensive to do. These practices are likely to reduce soybean yield losses, increase profitability, and reduce selection pressure for glyphosate-resistant biotypes. Although some research has been published on the effect of spray water quality on glyphosate efficacy, almost no work has been done to understand the impact of water quality on dicamba, glufosiante, saflufenacil, and 2,4-D efficacy. We assume that if economical solutions can be found to improve herbicide efficacy, they will be adopted on a widespread basis.

D. Research Design and Methods

Objectives 1, 2, and 3

Greenhouse, laboratory, and field experiments will be conducted in Indiana for the screening and control of glyphosate-resistant weed species. Palmer amaranth, common waterhemp, giant ragweed, horseweed, and other weed species will be collected from different counties of Indiana. For Objective #1, both laboratory and greenhouse assays will be performed on the suspect weed populations. In the laboratory, molecular DNA assays will be performed on leaf tissue collection during the growing season or from plants grown from seed in the greenhouse. The molecular assays will include those for confirmation of waterhemp resistance (glyphosate, ALS herbicides, and PPO herbicides) and Palmer amaranth resistance (glyphosate, ALS herbicides). Traditional greenhouse screens will be performed for any herbicide resistance mechanisms where we don't have a molecular assay. Thus, weed resistance to PSII herbicides such as atrazine, HPPD herbicides such as Callisto will be evaluated using the whole-plant screen in the greenhouse. Other herbicide modes of action where weed resistance in Indiana has not yet been confirmed will also be conducted and include Liberty and the auxin herbicides (2,4-D or dicamba).

For Objectives #2 and 3, field studies will be conducted at sites with known populations of glyphosate-resistant weeds to evaluate various control methods. The results from Objective #1 will be an important consideration since that objective provides a full characterization of herbicide-resistance mechanisms within single weed populations to identify the remaining viable herbicide options. These options will include those that are currently labeled for use in soybean, and new herbicide-resistant crop traits (Liberty Link, Enlist, Roundup Ready 2 Xtend, and HPPD-resistant beans). In addition, fall herbicide applications will be conducted for improved management of horseweed.

Objectives 4 and 5

Small plot field experiments will be conducted at sites that contain problematic broadleaf weed species. Standard weed science field research procedures will be used to established weed species. Also, greenhouse studies will be conducted for these broadleaf weed species. For objective 4, spray solutions will be prepared with various

levels of hardness (calcium carbonate), based on water quality data provided A and L Labs. We will prepare spray solutions that represent the range of hard water values observed in Indiana water samples. The spray solutions will be sprayed at two timing intervals i.e. at the time of mixing and 24 hours after mixing. For objective 5, we will prepare spray solutions that represent the range of pH values observed in Indiana water samples. Spray solutions will be prepared with various levels of pH adjusted to 5, 6, 7, and 8. These values were chosen based on water quality data provided A and L Labs. Plots will be sprayed with backpack sprayers and weed control will be visually evaluated at 2 and 4 weekly intervals to record speed of kill and overall control. Data will be subjected to statistical analysis and we will attempt to publish the results in appropriate scientific journals.

E. Principal Investigator(s)' Previous Work

Dr. Johnson's and Young's research groups have a combined research experience that is broad and practical in regards to the management of herbicide-resistant weed species and herbicide application technologies. They have conducted extensive research on the biology and management of common lambsquarters, glyphosate-resistant horseweed, glyphosate-resistant giant ragweed, glyphosate-resistant Palmer amaranth, and glyphosate/ALS/PPO-resistant waterhemp. This includes the research methods for confirmation of these resistance mechanisms as well as field management research. They have operated an extensive herbicide evaluation program at multiple sites in Indiana on targeted weed populations.

F. References Cited

Ambach, R. M. and R. Ashford (1982). "Effects of Variations in Drop Makeup on the Phytotoxicity of Glyphosate." Weed Science 30(3): 221-224.

Beckie, H. J., I. M. Heap, R. J. Smeda, and M. Linda. (2000). Screening for herbicide resistance in weeds. Weed Technol. 14:428-445.

Brabham, C. B., C. K. Gerber, and W. G. Johnson. (2011). Fate of glyphosate-resistant giant ragweed (*Ambrosia trifida*) in the presence and absence of glyphosate. Weed Sci. 59:506-511.

Bradshaw, L. D., S. R. Padgette, S. L. Kimball, and B. H. Wells. 1997. Perspectives on glyphosate resistance. Weed Technol. 11:189-198.

Braverman, M. P. and J. L. Griffin (1995). "Effects of CO2 on Spray Solution pH." Weed Technology 9(1): 23-28.

Bridges, D. C. (1989). "Adjuvant and pH Effects on Sethoxydim and Clethodim Activity on Rhizome Johnsongrass (Sorghum halepense)." Weed Technology 3(4): 615-620.

Buhler, D. D. and O. C. Burnside (1983). "Effect of Water Quality, Carrier Volume, and Acid on Glyphosate Phytotoxicity." Weed Science 31(2): 163-169.

Callow, K. and J. Deveau (2010). "Water Quality Affects Herbicide Efficacy." from http://www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2010/05hrt10a1.htm

Davis, V. M., G. R. Kruger, J. M. Stachler, M. M. Loux, and W. G. Johnson. (2009). Growth and seed production of horseweed (*Conyza canadensis*) populations resistant to glyphosate, ALS-inhibiting, and multiple (glyphosate + ALS inhibiting) herbicides. Weed Sci. 57:494-504.

Davis, V. M., K. D. Gibson, and W. G. Johnson. (2008). A field survey to determine distribution and frequency of glyphosate-resistant horseweed (*Conyza canadensis*) in Indiana. Weed Technol. 22:331-338.

Davis, V. M. and W. G. Johnson. (2008). Glyphosate-resistant horseweed (*Conyza canadensis*) emergence, survival, and fecundity in no-till soybean. Weed Sci. 56:231-236.

Deer, H. M. and R. Beard (2001). "Effect of Water pH on the Chemical Stability of Pesticides." from http://extension.usu.edu/files/publications/factsheet/AG_Pesticides_14.pdf.

Falk, J. S., D. E. Shoup, K. Al-Khatib, and D. E. Perterson. (2006). Protox-resistant common waterhemp (*Amaranthus rudis*) response to herbicides applied at different growth stages. Weed Sci. 54:793-799.

Green, J. M. and W. R. Cahill (2003). "Enhancing the Biological Activity of Nicosulfuron with pH Adjusters." Weed Technology 17(2): 338-345.

Green, J. M. and T. Hale (2005). "Increasing and Decreasing pH to Enhance the Biological Activity of Nicosulfuron." Weed Technology 19(2): 468-475.

Hartzler, B. and M. Owen (1994). "Water pH and herbicides." from http://www.ipm.iastate.edu/ipm/icm/1994/4-15-1994/waterph.html.

Heap, I. (2014). The international survey of herbicide resistant weeds. http://www.weedscience.org/in.asp. Accessed: November, 2014.

Indiana Department of Natural Resources (1980). "Water Quality." from http://www.in.gov/dnr/water/files/804_Water_Quality.pdf.

Johnson, B., Barnes, J., Gibson, K., and Weller, S. 2004. Late season weed escapes in Indiana soybean fields. Online. Crop Management doi:10.1094/CM-2004-0923-01-BR.

Johnson, B. and G. Nice. (2011). Waterhemp- an emerging weed problem in Indiana. http://www.ag.purdue.edu/btny/weedscience/Pages/default.aspx

Johnson, W. G., M. White, et al. (2010). "Glyphosate and Foliar Fertilizers." 4/13/2010. from http://www.btny.purdue.edu/weedscience/2010/GlyphosateFertilizers.html.

Jordan, T. N. (1981). "Effects of Diluent Volumes and Surfactant on the Phytotoxicity of Glyphosate to Bermudagrass (Cynodon dactylon)." Weed Science 29(1): 79-83.

Kruger, G. R., V. M. Davis, S. C. Weller, and W. G. Johnson. (2010). Control of horseweed (*Conyza canadensis*) with growth regulator herbicides. Weed Technol. 24:425-429.

Kruger, G. R., W. G. Johnson, S. C. Weller, M.D.K. Owen, D. R. Shaw, J. W. Wilcut, D. L. Jordan, R. G. Wilson, and B. G. Young. (2009). U.S. grower views on problematic weeds and changes in weed pressure in glyphosate resistant corn, cotton, and soybean cropping systems. Weed Technol. 22:162-166.

Legleiter, T. R. and K. W. Bradley. (2008). Glyphosate and multiple herbicide resistance in common waterhemp (*Amaranthus rudis*) populations from Missouri. Weed Sci. 56:582-587.

Lloyd, O. B. and W. L. Lyke (1995). "U.S. Geological Survey - Ground Water Atlas of the United States (IL, IN, KY, OH, TN)." from http://pubs.usgs.gov/ha/ha730/ch_k/K-text1.html#silurian.

Loux, M. M., D. Doohan, A. F. Dobbels, W. G. Johnson, T.R. Legleiter, B.G. Young, and A. Hager. (2015). Weed Control Guide for Ohio, Indiana, and Illinois. Columbus, OH: Ohio State University Extension Bulletin 789.

Matocha, M. A. and S. A. Senseman (2007). "Trifloxysulfuron Dissipation at Selected pH Levels and Efficacy on Palmer Amaranth (Amaranthus Palmeri)." Weed Technology 21(3): 674-677.

McCormick, R. W. (1990). "Effects of CO2,N2 , Air, and Nitrogen Salts on Spray Solution pH." Weed Technology 4(4): 910-912.

McMullan, P. M. (1996). "Grass Herbicide Efficacy as Influenced by Adjuvant, Spray Solution pH, and Ultraviolet Light." Weed Technology 10(1): 72-77.

Mueller, T. C., C. L. Main, et al. (2006). "Comparison of Glyphosate Salts (Isopropylamine, Diammonium, and Potassium) and Calcium and Magnesium Concentrations on the Control of Various Weeds." Weed Technology 20(1): 164-171.

Nalewaja, J. D. and R. Matysiak (1991). "Salt Antagonism of Glyphosate." Weed Science 39(4): 622-628.

Nalewaja, J. D. and R. Matysiak (1993). "Spray Carrier Salts Affect Herbicide Toxicity to Kochia (Kochia scoparia)." Weed Technology 7(1): 154-158.

Nalewaja, J. D., Z. Woznica, et al. (1991). "2,4-D Amine Antagonism by Salts." Weed Technology 5(4): 873-880.

Norsworthy, J. K., D. Riar, P. Jha, and R. C. Scott. (2011). Confirmation, control, and physiology of glyphosate-resistant giant ragweed (*Ambrosia trifida*) in Arkansas. Weed Technol. 25:430-435.

Norsworthy, J. K., G. M. Griffith, R. C. Scott, K. L. Smith, and L. R. Oliver. (2008). Confirmation and control of glyphosate-resistant Palmer amaranth in Arkansas. Weed Technol. 22:108-113.

Ramsdale, B. K., C. G. Messersmith, et al. (2003). "Spray Volume, Formulation, Ammonium Sulfate, and Nozzle Effects on Glyphosate Efficacy." Weed Technology 17(3): 589-598.

Sandberg, C. L., W. F. Meggitt, et al. (1978). "Effect of Diluent Volume and Calcium on Glyphosate Phytotoxicity." Weed Science 26(5): 476-479.

Sarmah, A. K. and J. Sabadie (2002). "Hydrolysis of Sulfonylurea Herbicides in Soils and Aqueous Solutions: a Review." J. Agric. Food Chem. 50(22): 6253-6265.

Seaman, A. J. and H. Riedl (1986). Preventing Decomposition of Agricultural Chemicals by Alkaline Hydrolysis in the Spray Tank. New York's Food and Life Sciences Bulletin.

Shea, P. J. and D. R. Tupy (1984). "Reversal of Cation-Induced REduction in Glyphosate Activity with EDTA." Weed Science 32(6): 802-806.

Shoup, E. E., K. Al-Khatib, and D. E. Peterson. (2003). Common waterhemp (*Amaranthus rudis*) resistance to protoporphyrinogen oxidase-inhibiting herbicides. Weed Sci. 51:145-150.

Stahlman, P. W. and W. M. Phillips (1979). "Effects of Water Quality and Spray Volume on Glyphosate Phytotoxicity." Weed Science 27(1): 38-41.

Thelen, K. D., E. P. Jackson, et al. (1995). "The Basis for the Hard-Water Antagonism of Glyphosate Activity." Weed Science 43(4): 541-548.

Westhoven, A. M., V. M. Davis, K. D. Gibson, S. C. Weller, and W. G. Johnson. (2008). Field presence of glyphosate-resistant horseweed (*Conyza canadensis*), common lambsquarters (*Chenopodium album*), and giant ragweed (*Ambrosia trifida*) biotypes with elevated tolerance to glyphosate. Weed Technol. 22:544-548.

VanGessel, M. J. 2001. Glyphosate-resistant horseweed from Delaware. Weed Sci. 49:703-705.

IV. Proposed Research Budget

In accordance with 2 CFR 200, Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards, Purdue University tracks and reports its professional personnel on a percent of effort and not on an hourly basis. Salaries are adjusted by standard University inflation rates each fiscal year (July 1): 3% for faculty, 2.5% for professional/technical assistants, and 2% for post docs, graduate/undergraduate students and service staff.

Personnel: $48,230

Funding is requested for salary to provide partial support of a PostDoctoral student (50%) who will be involved in the coordination of the greenhouse and laboratory screening for herbicide resistance. In addition, two months of salary for a Research Associate is requested to assist with implementing the field research trials on herbicide-resistant weed populations. Likewise, a 50% graduate assistantship is requested for a PhD student to manage the daily operations of the water quality and herbicide efficacy research. Funds for the associated fringe benefits are also requested for the above individuals as required.

Fringe Benefits: $10,818

Fringe benefits are budgeted in accordance with university policy outlined in a memorandum dated November 5, 2014. Rates are as follows:

Post-Doc	33.4%
Professional	35.8%
Graduate Student	8.5%

Travel: $2,050

We are also requesting $2,050 for travel to collect weed samples and to field research sites.

Other Direct Cost: $15,402

Materials and Supplies: $5,032

Funds of ($5,032) are requested for supplies to support the molecular DNA assays (microfuge tubes, pipets, pipet tips, DNA primers, fluorescent tags, etc.), whole-plant screens in the greenhouse (pots, labeling stakes, potting mix, fertilizer, etc.), and for the field management research (sprayer parts, plot stakes, wire flags, personal protective equipment, etc.).

Graduate Fee Remissions: $10,370

Graduate student fee remissions are budgeted in accordance with university policy. These fees are part of the overall compensation package for graduate student employees.

Indirect Cost: $13,500

Indirect costs are budgeted at 17.65% of total direct cost which is equivalent to 15% of the total cost of project.

Total Sponsor Cost: $90,000

Indiana Soybean Alliance **PROPOSED RESEARCH BUDGET**

FY 2015 Research Grant Application Proposal Number (ISA Use): 15 – _____

Title of Proposal Improving Weed Management by Addressing Faulty Herbicide Application Methods and Herbicide-Resistant Weed Biotypes

Principal Investigator(s) Bryan Young and Bill Johnson

Project Starting Date 5/1/15-4/30/16

Line-Item Budget Summary (Attach supplemental detail for line items of $5,000 or more)	Funds Requested	Total Funds Requested	Your Organization's Investment
	Year 1		
A. Salaries and Wages			
1. Principal Investigator(s)*	– 0 –	– 0 –	
2. Senior/Post-Doctoral Associates	$17,792		
3. Other Professionals	$8,378		
4. Graduate/Undergraduate Students	$22,060		
5. Secretarial/Clerical Staff			
6. Other Staff (technical, shop, other)			
B. Fringe Benefits* (Sum for all personnel, except P.I.)	$10,818		
C. Nonexpendable (Capital) Equipment**			
D. Expendable Materials and Supplies	$5,032		
E. Travel	$2,050		
F. Publication Costs			
G. Computer Costs			
H. All Other Direct Costs (Attach supporting data. List name and dollar amount for each item.)	$10,370		
I. SUBTOTAL	$76,500		
J. Indirect Costs (Not to exceed 15% of project cost. Show balance as Your Organization's Investment.)	$13,500		
K. **TOTAL AMOUNT OF THIS REQUEST**	$90,000		