MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 20-2016 (CONT.)
2016 ANNUAL REPORT

Title: Weed Management Programs for Mississippi Soybean Production

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BACKGROUND AND OBJECTIVES:

Herbicide programs and their associated crop management practices place selection pressure on weed communities by reducing the frequency of some weed species or by selecting resistant biotypes of others. In addition to weaknesses in glyphosate-resistant (GR) production systems (lack of residual control, poor control of some species, and antagonism with some herbicide mixtures), the GR technology triggered a shift toward total POST weed control programs. Delaying glyphosate applications and increasing application rate and/or number of applications promoted a selection for glyphosate-tolerant weeds and contributed to evolution of GR species.

Glyphosate resistance has spread rapidly with documented cases in 32 species worldwide. Fifteen species in the United States have developed resistance to glyphosate, and Mississippi populations of horseweed, Italian ryegrass, johnsongrass, Palmer amaranth, tall waterhemp, giant and common ragweed, goosegrass, and spiny amaranth have evolved resistance to glyphosate. Nine GR species is most of any state in the United States.

Glyphosate-resistant Palmer amaranth and Italian ryegrass represent the largest threats to crop production in Mississippi. Palmer amaranth competes for nutrients, water, light, and space because of its rapid, upright growth habit and allelopathic properties. Fields with GR Italian ryegrass not controlled at burndown will contain significant residue at planting. Residue will impede planting practices, contribute to competition between soybean seedlings and GR Italian ryegrass, and hinder herbicide programs due to inadequate coverage.

Large populations of herbicide-resistant (HR) weeds can jeopardize weed management programs. This has stimulated renewed interest in alternative weed management tools within the agricultural industry. Therefore, it is important to identify effective programs for managing GR species to prevent competition and yield reductions in Mississippi soybean.

Objectives.

1. Evaluate new and/or currently registered herbicides and HR soybean technologies for positioning into Mississippi weed management programs.
2. Characterize the interaction of glyphosate with PPO herbicides in applications targeting barnyardgrass.
3. Investigate use of PPO herbicides in soybean to (a) evaluate soybean injury and/or efficacy with mixtures of POST herbicides and foliar fertilizer, and (b) determine the influence of plant hormone mixtures on soybean injury and weed control with glyphosate-based herbicide treatments.

REPORT OF PROGRESS/ACTIVITY

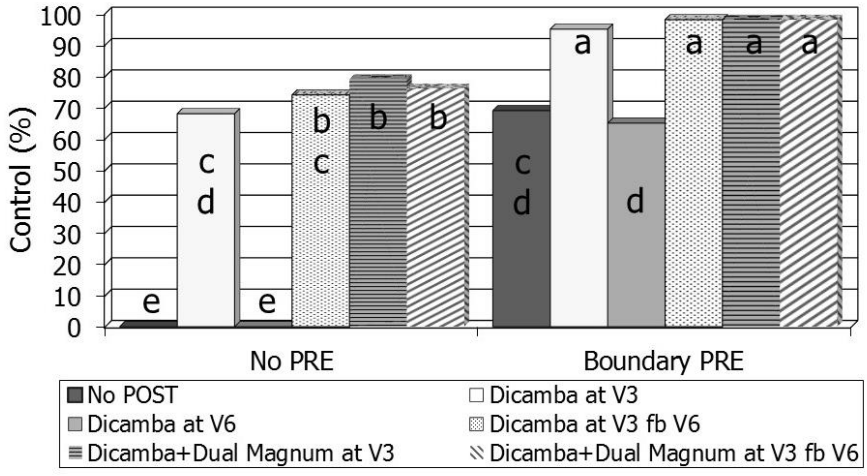
Objective 1 – 2016

Eighteen studies were conducted at the Delta Research and Extension Center in 2016 to evaluate new and/or currently registered herbicides and HR soybean technologies for positioning into Mississippi weed management programs. Unfortunately, most of these studies focused on the efficacy of pre-mixes of currently registered herbicides or generic formulations of commercial herbicides. "New" herbicides under evaluation are Enlist Duo (glyphosate plus 2,4-D), Engenia and Xtendimax (dicamba), flumioxazin plus pyroxasulfone plus chlorimuron (Fierce XLT), flumioxazin plus pyroxasulfone plus metribuzin (Fierce XLT), and a liquid formulation of pyroxasulfone (Zidua SC). Other studies evaluated herbicide applications in Roundup Ready 2 Xtend and Balance GT*LL soybean.

Research has been conducted annually since 2010 at different sites in the Mississippi Delta to evaluate weed control programs in the Roundup Ready Xtend weed control system, which was developed by Monsanto. In previous years, research was only conducted under contract with Monsanto or BASF; however, because exports of Roundup Ready 2 Xtend soybean were approved in spring 2016, original research was initiated last year.

One study evaluated application timings for dicamba (applied as Clarity) in PRE/POST weed control programs. In this study, Boundary was applied PRE to one half of the plots. POST treatments included Roundup PowerMax plus dicamba in single and sequential applications to V3 and V6 soybean with and without Dual Magnum. Fig. 1 demonstrates that a PRE treatment is critical for Palmer amaranth control in Roundup Ready 2 Xtend soybean. Additionally, the addition of Dual Magnum to mixtures of Roundup PowerMax plus dicamba controlled more Palmer amaranth than mixtures with no Dual Magnum.

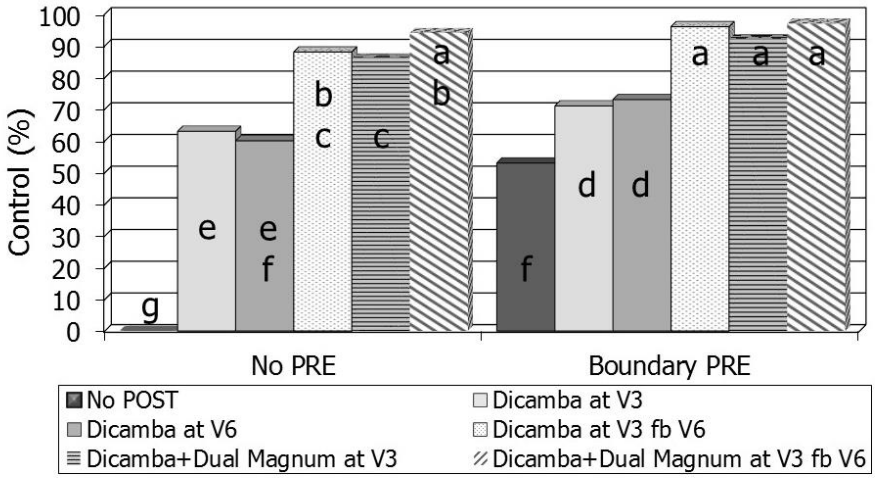
Figure 1. Palmer amaranth control 14 days after initial POST application to V3 soybean in a study evaluating weed control programs in Roundup Ready 2 Xtend soybean at Stoneville, MS, in 2016.



*All POST herbicide treatments contained Roundup PowerMax.

A sequential POST application was applied when soybean reached the V6 growth stage. Fig. 2 demonstrates that Palmer amaranth control 14 days after the sequential POST application was best with treatments containing at least three effective herbicide modes of action. For example, Palmer amaranth control with sequential treatment of Roundup PowerMax plus dicamba plus Dual Magnum with no PRE treatment was similar to control observed with the same POST treatment following Boundary PRE. The Palmer amaranth population at the research site contained approximately 50 to 60% GR individuals. Therefore, the Roundup PowerMax treatment contributed some level of control to these weed control programs. Unfortunately, Palmer amaranth control was not 100% with any treatment, so additional herbicide treatments would be required for complete control.

Figure 2. Palmer amaranth control 14 days after the sequential POST application to V6 soybean in a study evaluating weed control programs in Roundup Ready 2 Xtend soybean at Stoneville, MS, in 2016.



*All POST herbicide treatments contained Roundup PowerMax.

One HR soybean technology evaluated in 2016 was the Balance GT*LL trait from Bayer Cropscience. Table 1 demonstrates that Balance Bean (isoxaflutole) at 0.094 lb ai/acre plus Boundary at 1.63 lb/acre PRE provided greater barnyardgrass and Palmer amaranth control 21 days after planting (DAP) than commercial standards of Fierce at 0.14 lb ai/A and Authority MTZ at 0.42 lb ai/acre. Control of all species was ≥95% 35 DAP when PRE treatments were followed with Liberty 280 at 0.53 lb ai/acre plus Prefix at 1.32 lb ai/acre. These data indicate that PRE followed by POST herbicide programs in Balance GT*LL soybean offer an alternative weed management system with a mode of action that is not currently available in soybean.

Table 1. Control of barnyardgrass, Palmer amaranth, and pitted morningglory with PRE followed by POST herbicide programs in a Balance GT*LL soybean system[a].

			Barnyardgrass		Palmer amaranth		Pitted morningglory	
Treatment	Rate	Timing	21 DAP[b]	35 DAP[c]	21 DAP	35 DAP	21 DAP	35 DAP
	lb ai/A		%					
Balance Bean TriCor® Liberty® 280 Prefix®	0.065 0.25 0.53 1.32	PRE PRE POST POST	85 c	98 a	91 ab	98 a	81 d	98 a
Balance Bean TriCor Liberty 280 Prefix	0.094 0.25 0.53 1.32	PRE PRE POST POST	91 ab	98 a	96 a	98 a	85 bcd	98 a
Balance Bean Dual Magnum® Liberty 280 Prefix	0.094 0.95 0.53 1.32	PRE PRE POST POST	94 ab	95 a	95 a	98 a	86 a-d	98 a
Balance Bean Zidua® Liberty 280 Prefix	0.094 0.08 0.53 1.32	PRE PRE POST POST	91 ab	97 a	91 ab	98 a	86 a-d	98 a
Balance Bean Boundary® Liberty 280 Prefix	0.094 1.63 0.53 1.32	PRE PRE POST POST	95 a	98 a	97 a	97 a	89 abc	98 a
Fierce® Liberty 280 Prefix	0.14 0.53 1.32	PRE POST POST	84 c	96 a	88 b	98 a	84 cd	98 a
Authority MTZ® Liberty 280 Prefix	0.42 0.53 1.32	PRE POST POST	85 c	97 a	86 b	98 a	91 ab	98 a
Canopy DF® Dual Magnum Liberty 280 Prefix	0.23 0.95 0.53 1.32	PRE PRE POST POST	90 b	96 a	94 a	98 a	93 a	97 a

[a]Means within a column followed by the same letter are not different at $P \leq 0.05$.

[b]Columns labeled 21 d after planting (DAP) indicate evaluation 21 d after PRE treatment and prior to application of POST treatments.

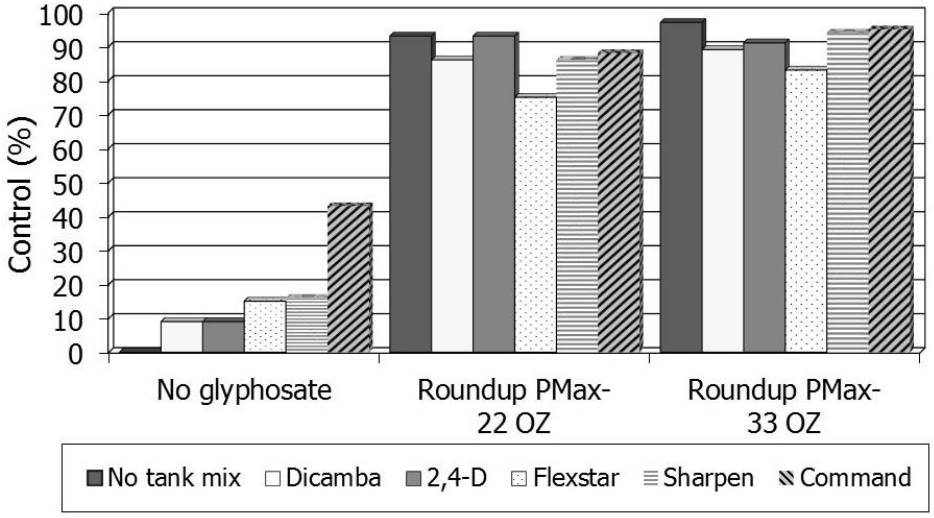
[c]Columns labeled 35 DAP indicate evaluation 14 d after POST treatments.

Different formulations of dicamba are now registered for application in Roundup Ready 2 Xtend soybean. Engenia is a new formulation of dicamba from BASF. Research from 2016 confirmed that weed control programs including Engenia as a POST treatment in Roundup Ready 2 Xtend soybean provide excellent control of GR Palmer amaranth (data not presented). At 28 days after application of POST treatments, Zidua SC plus TriCor PRE followed by Roundup PowerMax plus Engenia plus Outlook controlled Palmer amaranth similar to Boundary PRE followed by Roundup PowerMax plus Prefix. Control with both programs was 98%. For comparison, Roundup PowerMax alone controlled Palmer amaranth 55% at the same evaluation.

Objective 2 – 2016

Studies for this objective originally prescribed application on barnyardgrass 3 and 12 inches in height. Due to poor barnyardgrass germination and prolonged rainy weather in August, treatments were modified and applied to barnyardgrass with six to eight leaves. Barnyardgrass control was lower at 14, 21, and 28 days after application (DAT) with mixtures of Roundup PowerMax at 22 oz/acre plus Flexstar compared with glyphosate alone (Fig. 3). The effect of Flexstar was not overcome by increasing the glyphosate rate. Dicamba reduced barnyardgrass control 7 and 14 DAT when added to both rates of glyphosate.

Figure 3. Barnyardgrass control with herbicide mixtures 14 days after application to six- to eight-leaf plants at Stoneville, MS, in 2016.



Objective 3 – 2016

Three studies evaluating combinations of PPO herbicides with foliar fertilizers were conducted in 2015 and 2016 and are components of a Master's Thesis project for Tyler Hydrick. These studies evaluated the impact of combining foliar fertilizer with herbicide applications on soybean injury, weed control, and soybean agronomic performance. Two weedy sites (weed control study) assessing weed control and two weed-free sites (soybean agronomics study) were utilized for the first two studies.

In this research, treatments were arranged as a two-factor factorial in a randomized complete block design with four replications. Factor A was herbicide treatment and included no herbicide, Roundup PowerMax at 28.4 oz/acre, Roundup PowerMax plus Dual Magnum at 1.33 pt/acre, Roundup PowerMax plus Flexstar at 1.5 pt/acre, and Roundup PowerMax plus Cobra at 12.5 oz/acre. Factor B was Brandt Smart Trio (4-3-3-3-0.25% N-S-Mn-Zn-B) applied at 0, 0.2, and 4 pt/acre. Treatments were applied when soybean reached the V3 growth stage.

In the weed control study, foliar fertilizer at 2 and 4 pt/acre produced antagonistic effects on Palmer amaranth control 7, 14, and 21 d after treatment (DAT) when combined with Roundup PowerMax alone or in combination with Dual Magnum (Table 2). Antagonistic effects were also detected on barnyardgrass control 7, 14, and 21 DAT when foliar fertilizer at both rates was

mixed with Roundup PowerMax alone and in combination with Flexstar, Cobra, or Dual Magnum (Table 3). Pooled across herbicide treatments, adding foliar fertilizer reduced barnyardgrass control 28 DAT. Foliar fertilizer did not influence soybean injury, height, or yield at any evaluation interval.

In the soybean agronomics study, foliar fertilizer did not impact soybean injury, height, dry weight, nutrient concentration, or yield (data not presented). Treatments containing a PPO inhibitor reduced soybean height and biomass 14 DAT.

A third study evaluated mixtures of POST herbicides with individual components of the foliar fertilizer. Compared to glyphosate alone, the addition of zinc to Roundup PowerMax reduced Palmer amaranth control and the addition of manganese to Roundup PowerMax reduced barnyardgrass control 7 DAT (Table 4). Pooled across herbicide treatments, the addition of manganese reduced barnyardgrass control 14 DAT compared to treatments that did not receive a single-nutrient foliar fertilizer. Single-nutrient foliar fertilizers did not affect injury or height at any evaluation interval.

Due to the overall inconsistency of adding a foliar fertilizer to a common soybean herbicide application, these combinations should not utilized in POST applications to soybean.

Table 3. Antagonistic responses for Palmer amaranth control 14 d after treatment (DAT) with mixtures of soybean herbicides and a blended foliar fertilizer applied at the V3 growth stage in the Weed Control Study at Stoneville, MS, in 2015 and 2016.

		Foliar Fertilizer Rate (pt/acre)					
		2			4		
Herbicide	Rate	Expected[a]	Observed[b]	p-value[c]	Expected	Observed	p-value
		%			%		
Roundup PowerMax	28.4 oz/acre	66	57	0.0718	66	55*	0.0294
Roundup PowerMax plus Flexstar	28.4 oz/acre + 1.5 pt/acre	81	77	0.3447	81	74	0.1200
Roundup PowerMax plus Cobra	28.4 oz/acre + 12.5 oz/acre	83	80	0.5289	83	78	0.2437
Roundup PowerMax plus Dual Magnum	28.4 oz/acre + 1.33 pt/acre	74	60*	0.0247	74	60*	0.0200

[a] Expected values for each rate of foliar fertilizer are the same due to a lack of herbicidal activity from the foliar fertilizer; therefore, values are the percent weed control without foliar fertilizer.

[b] Asterisks denote antagonistic responses between herbicide treatment and foliar fertilizer rate when $p \leq 0.05$.

[c] The p-value nested within each foliar fertilizer rate denotes significant differences between observed and expected values within the corresponding rate of foliar fertilizer.

Table 3. Antagonistic responses for barnyardgrass control 14 d after treatment (DAT) with mixtures of soybean herbicides and a blended foliar fertilizer applied at the V3 growth stage in the Weed Control Study at Stoneville, MS, in 2015 and 2016.

		Foliar Fertilizer Rate (pt/acre)					
		2			4		
Herbicide	Rate	Expected[a]	Observed[b]	p-value[c]	Expected	Observed	p-value
		%			%		
Roundup PowerMax	28.4 oz/acre	87	88	0.7292	87	82	0.0818
Roundup PowerMax plus Flexstar	28.4 oz/acre + 1.5 pt/acre	84	75*	0.0174	83	74*	0.0087
Roundup PowerMax plus Cobra	28.4 oz/acre + 12.5 oz/acre	85	81	0.2404	85	81	0.2942
Roundup PowerMax plus Dual Magnum	28.4 oz/acre + 1.33 pt/A	86	83	0.2163	86	79*	0.0437

[a] Expected values for each rate of foliar fertilizer are the same due to a lack of herbicidal activity from the foliar fertilizer; therefore, values are the percent weed control without foliar fertilizer.

[b] Asterisks denote antagonistic responses between herbicide treatment and foliar fertilizer rate when $p \leq 0.05$.

[c] The p-value nested within each foliar fertilizer rate denotes significant differences between observed and expected values within the corresponding rate of foliar fertilizer.

Table 4. Palmer amaranth control 7 d after treatment (DAT) with mixtures of soybean herbicides and a single-nutrient foliar fertilizer applied at the V3 growth stage in the Single-Nutrient Foliar Fertilizer Study at Stoneville, MS, in 2015 and 2016[a,b].

Single-nutrient foliar fertilizer	Rate	No herbicide	Roundup PowerMax	Roundup PowerMax plus Flexstar
	lb ai/acre		%	
None	0	0 e	69 c	90 a
Boron	0.013	0 e	69 c	88 a
Manganese	0.16	0 e	74 bc	89 a
Nitrogen	0.21	0 e	70 c	89 a
Zinc	0.16	0 e	54 d	87 ab

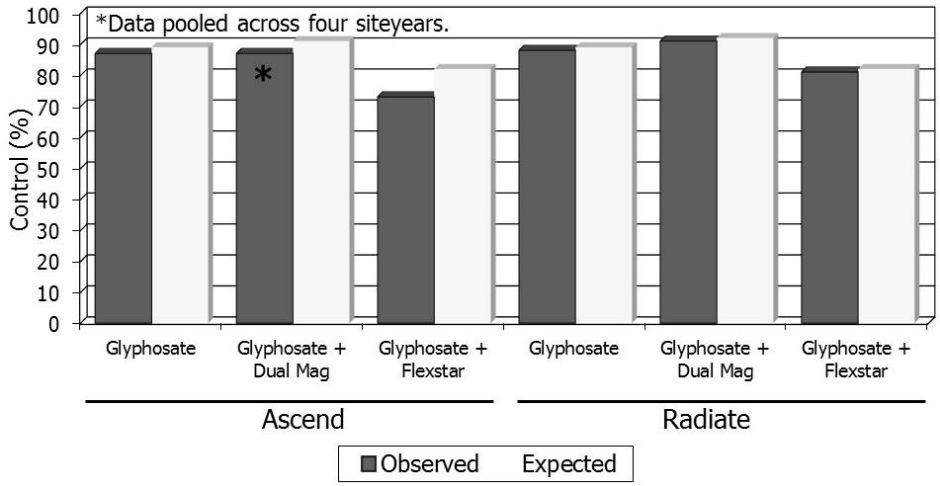
[a] Means followed by the same letter are not different at $p \leq 0.05$.
[b] Applications for herbicide treatments were no herbicide, Roundup PowerMax at 28.4 oz/acre, and Roundup PowerMax plus Flexstar at 1.5 pt/acre.

A fourth study tested the hypothesis that inclusion of plant hormone mixtures will have no effect on soybean injury or weed control with POST herbicide treatments. The experimental design was a randomized complete block with a two-factor factorial treatment arrangement.

Factor A was herbicide treatment and consisted of no herbicide, Roundup PowerMax at 28 oz/acre, Roundup PowerMax plus Dual Magnum at 1.33 pt/acre, and Roundup PowerMax plus Flexstar at 1.5 pt/acre.

Factor B was plant hormone mixtures and consisted of no plant hormone mixture, Ascend (mixture of cytokinin, gibberellic acid, and indole butyric acid) at 3.2 oz/acre, and Radiate (mixture of cytokinin and indole butyric acid) at 2 oz/acre. Cytokinin treatment had no effect on soybean injury 3 to 28 DAT, height 14 DAT, or yield. Pooled over cytokinin treatments, Palmer amaranth control 14 DAT was greater with glyphosate plus Flexstar compared with Roundup PowerMax alone. An antagonistic response was detected 14 DAT when Ascend was added to Roundup PowerMax plus Dual Magnum (Fig. 4).

Figure 4. Test of synergistic and antagonistic effects in barnyardgrass control with herbicide mixtures 14 days after application at Stoneville, MS, in 2015-16.



IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS

Mississippi has averaged 1.98 million acres of soybean over the past five years, and a majority of soybean-producing counties contain at least one GR weed species. The data generated from this research will allow producers to implement effective control options for GR weeds, become aware of developing resistance problems, receive information on prevention and control tactics for resistant weeds, and allow them to remain competitive regionally while improving economic returns.

Publications (23):

1. Nandula, V. K., P. Tehranchian, J. A. Bond, J. K. Norsworthy, and T. W. Eubank. Glyphosate resistance in common ragweed (*Ambrosia artemisiifolia* L.) from Mississippi. Weed Biol. Manag. (*In Press*)
2. Mangialardi, J. P., J. M. Orlowski, J. A. Bond, B. R. Golden, A. Catchot, B. H. Lawrence, J. D. Peeples, and T. W. Eubank. 2016. Growth regulation with lactofen does not affect seed yield of irrigated soybean. Agron J. 108:1-4.
3. Molin, W.T., V.K. Nandula, A.A. Wright, and J.A. Bond. 2016. Transfer and expression of ALS inhibitor resistance from *Amaranthus palmeri* to *A. spinosus* X *A. palmeri* hybrid. Weed Sci. 64:240-247.
4. Falconer, L., J.T. Irby, J. Orlowski, T.W. Allen, J.A. Bond, N.W. Buehring, A.L. Catchot, D. Cook, B.R. Golden, J. Gore, L.J. Krutz, and H.C. Pringle. 2016. Soybeans 2017 Planning Budgets. Mississippi State University Extension Service Publication P-3014.
5. 2016 Weed Control Guidelines for Mississippi. 2016. Mississippi State University Extension Service Publication P-1532.
6. Bond, J. A. 2016. Preplant intervals for auxin herbicides in Mississippi. [Online] Available at http://www.mississippi-crops.com/2016/03/18/preplant-intervals-for-auxin-herbicides-in-mississippi/ (03/18/2016)
7. Bond, J. A. 2016. Managing Palmer amaranth on field borders. [Online] Available at http://www.mississippi-crops.com/2016/07/15/managing-palmer-amaranth-on-field-borders/ (07/15/16)
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9. Bond, J.A., H.M. Edwards, J.D. Peeples, B.H. Lawrence, H.T. Hydrick, and T.L. Phillips. 2016. Effect of rice herbicides on soybean with BOLT technology. Page 26 in Mississippi Rice Promotion Board Research Highlights 2015 [Online]. Available at http://rice.msstate.edu/documents/2015ricereport.pdf.
10. Bond, J.A., H.M. Edwards, J.D. Peeples, B.H. Lawrence, H.T. Hydrick, and T.L. Phillips. 2016. Response of BOLT soybean cultivars to rice herbicides. Pages 62-63 in Mississippi State University Delta Research and Extension Center 2015 Annual Report. Stoneville, MS: Delta Research and Extension Center.
11. Bond, J.A., J.P. Mangialardi, B.H. Lawrence, J.D. Peeples, and H.M. Edwards. 2016. Postemergence control of glyphosate-resistant Palmer amaranth with Callisto-based herbicide combinations. Pages 60-61 in Mississippi State University Delta Research and Extension Center 2015 Annual Report. Stoneville, MS: Delta Research and Extension Center.
12. Bond, J. A. D. Reynolds, and J. T. Irby. 2016. Managing PPO-resistant Palmer amaranth in Mississippi soybean. [Online] Available at http://www.mississippi-crops.com/2016/03/25/managing-ppo-resistant-palmer-amaranth-in-mississippi-soybean/ (03/25/2016)

13. Irby, J. T., J. Orlowski, T. W. Allen, J. A. Bond, A. Catchot, J. Gore, D. Cook, L. J. Krutz, and B. R. Golden. 2016. Identifying late season soybean growth stages. [Online] Available at http://www.mississippi-crops.com/2016/08/19/identifying-late-season-soybean-growth-stages/ (08/19/16)
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15. Orlowski, J.M., J.A. Bond, B.R. Golden, and J.P. Mangialardi. 2016. Growth regulation with lactofen does not affect yield of irrigated soybean. Pages 18-19 in Mississippi State University Delta Research and Extension Center 2015 Annual Report. Stoneville, MS: Delta Research and Extension Center.
16. Edwards, H. M., J. D. Peeples, B. H. Lawrence, H. T. Hydrick, T. L. Phillips, and J. A. Bond. 2016. Effect of rice herbicides on soybean with BOLT Technology. Proc. South. Weed Sci. Soc. 69:32.
17. Hydrick, H. T., J. A. Bond, B. R. Golden, B. H. Lawrence, J. D. Peeples, H. M. Edwards, and T. L. Phillips. 2016. Weed control in soybean with mixtures of herbicides and foliar nutrition products. Proc. South. Weed Sci. Soc. 69:471.
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Technical Meetings/Training Sessions (18):

1. Mississippi Row Crop Short Course – Management of auxin-resistant crops; Starkville, MS (December 6, 2016)
2. Mississippi Soybean Promotion Board Strategic Planning Meeting – Weed science research in Mississippi soybean; Starkville, MS (November 15, 2016)
3. Mississippi Congressional Delegation Mississippi State University Tour – Weed science research at the Delta Research and Extension Center; Stoneville, MS (November 7, 2016)
4. Dow Agrosciences Research Exchange – Sonic and Surveil performance in Mississippi soybean; Venice, LA (September 28, 2016)
5. Mississippi State University Provost DREC Tour – Weed science research at DREC; Stoneville, MS (September 1, 2016)
6. USDA Area-wide Project Annual Meeting – Herbicide resistance in Mississippi; Beltsville, MD (August 18, 2016)
7. Mississippi Agriculture Industries Council Certified Crop Advisor Training – Weed control issues in Mississippi row crops; Orange Beach, AL (July 27, 2016)
8. United Soybean Board Rotation Project Annual Meeting – Crop rotation for weed control in the Midsouth; Casscoe, AR (July 11, 2016)
9. BASF Technology Tour, Helena Chemical Company – Cotton, corn, soybean, and rice weed control in Mississippi; Stoneville, MS (July 7, 2016)
10. BASF Technology Tour, Crop Production Services – Cotton, corn, soybean, and rice weed control in Mississippi; Stoneville, MS (July 7, 2016)
11. BASF Technology Tour, Jimmy Sanders, Inc. – Cotton, corn, soybean, and rice weed control in Mississippi; Stoneville, MS (July 6, 2016)
12. BASF Technology Tour, Green Point Ag – Cotton, corn, soybean, and rice weed control in Mississippi; Stoneville, MS (July 6, 2016)
13. Valent U.S.A. PPO Seminar – Herbicide resistance in Mississippi; Memphis, TN (June 27, 2016)
14. Nova S.A. U.S. Tour – Weed management challenges in MS; Stoneville, MS (June 17, 2016)
15. Mississippi State University Extension Service Scout School – PRE and POST herbicide symptomology; Raymond, MS (April 13, 2016)
16. Mississippi State University Extension Service Scout School – PRE and POST herbicide symptomology; Verona, MS (April 8, 2016)
17. Mississippi State University Extension Service Scout School – PRE and POST herbicide symptomology; Stoneville, MS (April 6, 2016)
18. Mississippi State University Extension Service Scout School – PRE and POST herbicide symptomology; Clarksdale, MS (April 4, 2016)