

Final Report to the Delaware Soybean Board for 2016 Funding

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WEED MANAGEMENT FOR NO-TILL AND DOUBLE-CROPPED SOYBEANS: FOCUS ON PROBLEM SPECIES AND HERBICIDE-RESISTANT BIOTYPES

Some weed species have been challenging to control in soybean production. Morningglory species are such weeds, due to their large seeds that are not controlled with most soil-applied herbicides, or requiring timely applications of postemergence (POST) herbicides. The widespread use of only glyphosate with Roundup Ready Soybeans, has selected for weed biotypes resistant to this herbicide. Glyphosate-resistant horseweed (maretail) has been a significant problem for many years, and more recently glyphosate-resistant Palmer amaranth has been increasing. In southern states such as Georgia and North Carolina, populations of Palmer amaranth are resistant to Group 2 herbicides (Classic, Pursuit, Harmony, FirstRate, etc.) as well as glyphosate. Glyphosate-resistance and Group 2 resistance have been confirmed in Delaware populations. Fields infested with Palmer amaranth are found throughout Delaware as well as Eastern Shore of Maryland, southeastern Pennsylvania, and New Jersey. This species is related to our common pigweed, but it is much more aggressive. It is common for this plant to grow as tall as 6 feet, and a single plant will produce a tremendous number of seeds (>500,000). Palmer amaranth has a prolonged germination period that requires the use of postemergence herbicides. However, the rapid growth rate of Palmer amaranth sometimes requires a postemergence herbicide application before the soybeans' have developed a canopy capable of shading later emerging plants. As a result, postemergence applications need to include an herbicide that will provide residual control.

The challenge for a successful weed management program is the diversity of species. Horseweed is a winter annual that emerges from early fall until late spring. While Palmer amaranth emerges from early summer until fall. Therefore, there is not an effective timing that weed management can be implemented for control of both of these species.

Further complicating management issues is full-season and double-cropped soybean production. Double-cropping often involves managing weeds that are relatively large and damaged due to the wheat harvest operation. As a result, these weeds are treated under

stressful conditions. In addition, some of the commonly used herbicides for Palmer amaranth and morningglory control have a 10-month replant restriction that limits what herbicides can be applied postemergence to double-cropped soybeans.

Successful management programs are needed to effectively control these species as well as avoid the development of other herbicide-resistant biotypes. Using cover crops as a tool for weed management is often mentioned, but there is very little research on how best to utilize cover crops in a program approach. Cover crops have many benefits, but the purpose for which the cover crop is used will dictate how that cover crop is managed. More work is necessary to determine the best way to manage cover crops to control herbicide-resistant weeds.

The **research objective** was to examine timing of burndown application for full-season soybeans.

Key findings:

- Overall, winter annual weed control improved with the use of a spring herbicide application.
- For most years, spring herbicide applications were needed to provide effective horseweed control.
- A single burndown application (regardless of timing) did not provide consistent control over all three years.
- Treatments made 10 days before planting or at planting (late spring or double-knock) provided better Palmer amaranth control than those made with a fall only treatment or an early spring treatment.
- It was difficult to time a single pre-plant herbicide application to control both horseweed and Palmer amaranth.

Methodology:

A single spring application timing was compared to multiple application timings for overall weed control in 2014, 2015, and 2016. The application timings included fall, early spring (4 weeks prior to planting [late-April]), late spring (10 days prior to planting [early-May]), or at planting (~May 20). Fall timings were glyphosate plus 2,4-D alone or included residual herbicides. Canopy EX and Valor were used representing 1) herbicides that provide the broadest spectrum of control but limits rotations to only soybeans (Canopy EX) and 2) a herbicide that allows for rotation to both corn and soybeans (Valor). Herbicides selected for treatments represent products that have performed consistently well in our herbicide evaluation program, but other residual products could be substituted based on grower preference. This trial was not designed to test all potential herbicides, rather to evaluate different approaches for control. The entire site received an application of glyphosate + Reflex at 5 weeks after planting (late-June).

Weed control was evaluated within 1 week after planting (WAP), prior to postemergence (POST) application of glyphosate plus Reflex (4 WAP), and 8 WAP. However, no weed control ratings were taken 8 WAP in 2014. Ratings and analysis for Palmer amaranth, large crabgrass, and morningglory did not include treatments that did not receive a spring herbicide application

since poor control of winter annual weeds often interfered with emergence of summer annuals and resulted in variable results.

Results:

In 2015, winter annual weeds were controlled at least 97% when a spring treatment was included, regardless of fall treatment (Table 1). Excellent control was observed for Canopy EX without a spring treatment. In 2016, fall treatments containing Canopy EX followed by a spring treatment, and fall treatments of glyphosate + 2,4-D alone or with Valor followed by double knock spring treatments controlled winter annual weeds at least 95%. In addition, at least 93% control was achieved with glyphosate + 2,4-D alone or with Valor followed by an early spring treatment.

Winter annual weed control varied by species and by year. There were significant fall by spring treatment interactions for field pansy, knawel, and overall winter annual weed control. In 2014, field pansy (Johnny jump-up) control was best with fall treatments containing Canopy EX or Valor, or with the fall treatment of glyphosate + 2,4-D alone followed by a spring treatment (Table 2). In 2016, fall treatments containing Canopy EX followed by late spring or double knock treatments, and fall treatments containing Valor followed by double knock treatments controlled field pansy 97% or greater. In 2014, most all spring treatments controlled knawel 91% or greater. While fall treatments with Canopy EX provided excellent control, the no residual or Valor only treatments did not provide effective control without spring treatments (Table 2.) In 2016, knawel was controlled at least 99% by fall treatments containing Canopy EX. Similar control was observed with fall treatments containing Valor followed by early spring or double knock treatments, or with the fall treatment of glyphosate + 2,4-D alone followed by double knock treatments.

There were significant fall by spring interactions for horseweed control. In 2014, horseweed was controlled 96% or greater by all spring treatments, regardless of fall treatment when rated at 1 and 4 WAP (Table 3). In 2016 at 1 WAP, horseweed was controlled at least 96% when a fall treatment was followed by a spring treatment, or when no fall treatments were followed by early spring or double knock treatments. Horseweed was controlled at least 85% 4 WAP with fall treatments followed by spring treatments, with fall treatments containing Canopy EX or Valor followed by no spring treatment, and when no fall treatment was followed by late spring or double knock treatments (Table 3).

There were no fall by spring interactions for grass control; however, the main effects of fall and spring application were significant. At 4 WAP in 2014, all treatments controlled grass 78 to 91% in 2014 and 54 to 70% in 2015 (Table 4). At 4 WAP in 2016, all treatments had less than 50% control, with fall treatments containing Canopy EX or Valor higher than glyphosate + 2,4-D alone or no fall treatment. At 8 WAP grass control was at least 96% in both 2015 and 2016. For spring treatments evaluated 4 WAP, late spring and double-knock spring treatments provided better grass control than early spring treatments in 2014 (Table 5). While double knock treatments provided better grass control than late or early spring treatments in 2016, no

treatment provided over 50% control (Table 5). The glyphosate + Reflex treatments provided excellent control of large crabgrass, with all treatments providing over 95% control.

There were significant fall by spring interaction for Palmer amaranth control. At 4 WAP in 2014, Palmer amaranth was controlled at least 92% with double knock spring treatments, with glyphosate and 2,4-D alone followed by late spring treatments, and no fall treatment followed by late spring treatments (Table 6). At 4 WAP in 2015, double knock and late spring treatments controlled Palmer amaranth at least 80%, except with fall treatments containing Valor followed by the late spring treatment. At 4 WAP, in 2016, all treatments had less than 78% Palmer amaranth control with no difference in treatment. At 8 WAP in 2015, Palmer amaranth was controlled at least 93% with late spring and double knock treatments, and with the fall treatment containing Valor followed by the early spring treatment (Table 6). At 8 WAP in 2016, Palmer amaranth was controlled at least 96% when a spring treatment was included, except with fall treatments of glyphosate + 2,4-D alone followed by the early spring treatments.

There were no treatment differences for soybean yield in 2014 (Table 7). In 2015 and 2016 there were fall by spring interactions for yield. In 2015, yields were similar except for no fall treatment followed by late spring treatment, and fall treatments with Valor followed by early spring treatment. In 2016, no fall treatment followed by the late spring treatment and fall treatments with Valor followed by late spring had lower yields than other treatments.

Control of winter annual weeds was most consistent with two herbicide applications. There was no clear advantage to a fall treatment followed by a spring treatment or two spring treatments. Summer annual weed control was most consistent with a residual herbicide applied at planting or 10 days before planting. Applications 20 days before planting did not provide sufficient residual control if postemergence herbicides were applied 5 weeks after planting.

Table 1. Overall winter annual weed control 7 days after planting in 2015 and 2016.

Fall Application	Spring Application	Winter Annuals	
		2015	2016
		----- % Control -----	
None	None	0 d	0 f
None	Early: glyphosate + 2,4-D** + Canopy	100 a	78 e
None	Late: glyphosate + 2,4-D* + Canopy	97 a	75 e
None	Double knock [#]	100 a	87 d
Glyphosate + 2,4-D	None	27 c	0 f
Glyphosate + 2,4-D	Early: glyphosate + 2,4-D** + Canopy	100 a	93 c
Glyphosate + 2,4-D	Late: glyphosate + 2,4-D* + Canopy	100 a	84 d
Glyphosate + 2,4-D	Double knock [#]	100 a	95 abc
Glyphosate + 2,4-D + Canopy EX	None	93 ab	0 f
Glyphosate + 2,4-D + Canopy EX	Early: glyphosate + 2,4-D** + Canopy	100 a	96 abc
Glyphosate + 2,4-D + Canopy EX	Late: glyphosate + 2,4-D* + Canopy	100 a	99 a
Glyphosate + 2,4-D + Canopy EX	Double knock [#]	100 a	98 ab
Glyphosate + 2,4-D + Valor	None	85 b	0 f
Glyphosate + 2,4-D + Valor	Early: glyphosate + 2,4-D** + Canopy	100 a	94 bc
Glyphosate + 2,4-D + Valor	Late: glyphosate + 2,4-D* + Canopy	100 a	84 d
Glyphosate + 2,4-D + Valor	Double knock [#]	100 a	96 abc

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

[#]Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 2. Field pansy and knawel control with fall and spring herbicide applications 7 days after planting in 2014 and 2016.

Fall Application	Spring Application	Field Pansy		Knaewel	
		2014	2016	2014	2016
		----- % Control -----			
None	None	0 f	0 f	0 c	0 g
None	Early: glyphosate + 2,4-D** + Canopy	75 bcd	65 e	99 a	70 f
None	Late: glyphosate + 2,4-D* + Canopy	70 cde	68 de	93 a	80 e
None	Double knock [#]	53 e	87 c	91 a	91 bc
Glyphosate + 2,4-D	None	57 de	0 f	13 c	0 g
Glyphosate + 2,4-D	Early: glyphosate + 2,4-D** + Canopy	100 a	84 c	100 a	90 cd
Glyphosate + 2,4-D	Late: glyphosate + 2,4-D* + Canopy	81 abc	72 de	92 a	82 de
Glyphosate + 2,4-D	Double knock [#]	100 a	90 bc	100 a	92 abc
Glyphosate + 2,4-D + Canopy EX	None	83 abc	75 d	92 a	99 a
Glyphosate + 2,4-D + Canopy EX	Early: glyphosate + 2,4-D** + Canopy	100 a	91 bc	100 a	100 a
Glyphosate + 2,4-D + Canopy EX	Late: glyphosate + 2,4-D* + Canopy	99 a	100 a	98 a	100 a
Glyphosate + 2,4-D + Canopy EX	Double knock [#]	97 a	100 a	100 a	100 a
Glyphosate + 2,4-D + Valor	None	93 ab	0 f	68 b	0 g
Glyphosate + 2,4-D + Valor	Early: glyphosate + 2,4-D** + Canopy	100 a	87 c	100 a	96 abc
Glyphosate + 2,4-D + Valor	Late: glyphosate + 2,4-D* + Canopy	97 a	72 de	97 a	88 cd
Glyphosate + 2,4-D + Valor	Double knock [#]	100 a	97 ab	100 a	98 ab

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

[#]Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 3. Horseweed control with fall and spring treatments in 2014 and 2016.

Fall Application	Spring Application	2014		2016	
		1 WAP	4 WAP	1 WAP	4 WAP
		----- % Control -----			
None	None	0 c	23 c	0 c	0 d
None	Early: glyphosate + 2,4-D** + Canopy	100 a	100 a	100 a	79 b
None	Late: glyphosate + 2,4-D* + Canopy	100 a	100 a	92 b	93 ab
None	Double knock [#]	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D	None	50 b	73 b	0 c	62 c
Glyphosate + 2,4-D	Early: glyphosate + 2,4-D** + Canopy	100 a	96 a	100 a	97 a
Glyphosate + 2,4-D	Late: glyphosate + 2,4-D* + Canopy	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D	Double knock [#]	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D + Canopy EX	None	80 a	87 ab	89 b	92 ab
Glyphosate + 2,4-D + Canopy EX	Early: glyphosate + 2,4-D** + Canopy	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D + Canopy EX	Late: glyphosate + 2,4-D* + Canopy	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D + Canopy EX	Double knock [#]	100 a	100 a	100 a	100 a
Glyphosate + 2,4-D + Valor	None	100 a	100 a	0 c	85 ab
Glyphosate + 2,4-D + Valor	Early: glyphosate + 2,4-D** + Canopy	100 a	100 a	100 a	95 ab
Glyphosate + 2,4-D + Valor	Late: glyphosate + 2,4-D* + Canopy	100 a	100 a	96 a	98 a
Glyphosate + 2,4-D + Valor	Double knock [#]	100 a	100 a	100 a	100 a

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

WAP = weeks after planting.

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

[#]Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 4. Grass control with fall herbicide applications over three years.

Fall Application	4 WAP			8 WAP		
	2014	2015	2016	2014	2015	2016
	----- % Control -----					
None	80 a	60 a	21 c	----	96 b	98 a
Glyphosate + 2,4-D	91 a	64 a	31 b	----	98 a	98 a
Glyphosate + 2,4-D + Canopy EX	78 a	54 a	47 a	----	98 a	99 a
Glyphosate + 2,4-D + Valor	79 a	70 a	47 a	----	98 a	98 a

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

WAP = weeks after planting.

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= glyphosate + 1 qt 2,4-D plus Canopy 4 wks prior to planting.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

#Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 5. Grass control with spring herbicide application over three years

Spring Application	4 WAP			8 WAP		
	2014	2015	2016	2014	2015	2016
	----- % Control -----					
Early: glyphosate + 2,4-D** + Canopy	65 b	53 a	18 c	----	96 b	99 a
Late: glyphosate + 2,4-D* + Canopy	89 a	68 a	42 b	----	98 a	98 a
Double knock#	92 a	65 a	50 a	----	98 a	98 a

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

WAP = weeks after planting.

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

#Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 6. Palmer amaranth control with fall and spring herbicide applications over three years.

Fall Application	Spring Application	4 WAP			8 WAP			
		2014	2015	2016	2014	2015	2016	
		----- % Control -----						
None	Early: glyphosate + 2,4-D** + Canopy	67 cd	60 c	78 a	----	77 b	100 a	
None	Late: glyphosate + 2,4-D* + Canopy	99 a	92 ab	70 a	----	95 a	100 a	
None	Double knock [#]	100 a	87 ab	73 a	----	98 a	99 a	
Glyphosate + 2,4-D	Early: glyphosate + 2,4-D** + Canopy	70 cd	73 bc	68 a	----	79 b	91 b	
Glyphosate + 2,4-D	Late: glyphosate + 2,4-D* + Canopy	95 a	88 ab	68 a	----	97 a	100 a	
Glyphosate + 2,4-D	Double knock [#]	99 a	90 ab	75 a	----	95 a	100 a	
Glyphosate + 2,4-D + Canopy EX	Early: glyphosate + 2,4-D** + Canopy	55 d	58 c	68 a	----	81 b	96 ab	
Glyphosate + 2,4-D + Canopy EX	Late: glyphosate + 2,4-D* + Canopy	70 cd	99 a	77 a	----	100 a	100 a	
Glyphosate + 2,4-D + Canopy EX	Double knock [#]	92 ab	80 abc	73 a	----	97 a	100 a	
Glyphosate + 2,4-D + Valor	Early: glyphosate + 2,4-D** + Canopy	73 c	91 ab	66 a	----	96 a	95 ab	
Glyphosate + 2,4-D + Valor	Late: glyphosate + 2,4-D* + Canopy	75 bc	74 bc	73 a	----	93 a	100 a	
Glyphosate + 2,4-D + Valor	Double knock [#]	98 a	97 a	72 a	----	96 a	100 a	

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

WAP = weeks after planting.

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= 22 oz glyphosate + 1 qt 2,4-D plus 4.5 oz Canopy 4 wks prior to planting.

*Late= 22 oz glyphosate + 1 pt 2,4-D plus 4.5 Canopy 10 days prior to planting.

[#]Double knock is 22 oz glyphosate plus 1 pt 2,4-D applied 4 wks prior to planting followed by 3 pt Gramoxone plus 4.5 oz Canopy at planting.

Table 7. Soybean yields following fall and spring applications over three years.

Fall Application	Spring Application	2014	2015	2016
		----- Yield (bu/A) -----		
None	Early: glyphosate + 2,4-D** + Canopy	61 a	28 abc	54 ab
None	Late: glyphosate + 2,4-D* + Canopy	55 a	21 bc	41 c
None	Double knock [#]	48 a	29 abc	57 a
Glyphosate + 2,4-D	Early: glyphosate + 2,4-D** + Canopy	47 a	28 abc	51 abc
Glyphosate + 2,4-D	Late: glyphosate + 2,4-D* + Canopy	59 a	33 ab	58 a
Glyphosate + 2,4-D	Double knock [#]	61 a	29 abc	52 abc
Glyphosate + 2,4-D + Canopy EX	Early: glyphosate + 2,4-D** + Canopy	54 a	33 ab	50 abc
Glyphosate + 2,4-D + Canopy EX	Late: glyphosate + 2,4-D* + Canopy	48 a	32 ab	52 abc
Glyphosate + 2,4-D + Canopy EX	Double knock [#]	46 a	32 ab	53 abc
Glyphosate + 2,4-D + Valor	Early: glyphosate + 2,4-D** + Canopy	46 a	19 c	52 abc
Glyphosate + 2,4-D + Valor	Late: glyphosate + 2,4-D* + Canopy	47 a	23 abc	42 bc
Glyphosate + 2,4-D + Valor	Double knock [#]	60 a	35 a	52 abc

Data in same column, followed by the same letter are not significantly different from one another (P=.05, LSD).

Fall application = 22 oz glyphosate + 0.75 qt 2,4-D with 2.2 oz Canopy EX or 3 oz. Valor.

**Early= glyphosate + 1 qt 2,4-D plus Canopy 4 wks prior to planting.

*Late= glyphosate + 1 pt 2,4-D plus Canopy 10 days prior to planting.

[#]Double knock is glyphosate plus 2,4-D applied 4 wks prior to planting followed by Gramoxone plus Canopy at planting.

Data in same column, followed by the same letter are not significantly different from one another.