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Evaluation of Delayed Glyphosate Burndown in No-Till Soybean

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Abstract

Application of a preplant or preemergence glyphosate burndown is routine in most no-tillage production systems of annual crops, however, time of application may influence overall weed control and grain yield. Six field trials were conducted over a three-year period (2008, 2009 and 2010) near Ridgetown, Ontario, Canada to determine the effect of glyphosate burndown application timing in glyphosate-resistant (GR) no-tillage soybean [*Glycine max* (L.) Merr.]. Soybean growth was reduced 5%, 10% and 20% when the burndown was delayed to 1, 5 and 12 days after planting (DAP), when evaluated one week after application (WAA), respectively. By 8 WAA, predicted burndown timing increased to 9, 14 and 23 DAP, and was 10, 17 and 26 DAP at 12 WAA, to reduce soybean growth by 5%, 10% and 20%, respectively. Similarly, burndown application at 14, 21 and 30 DAP corresponded to a soybean yield reduction of 5%, 10% and 20%. Seed moisture content was generally insensitive to burndown timing; 80 and 140 DAP were required to increase moisture by 5% and 10%, respectively. This research indicates that delaying glyphosate burndown by up to 14 DAP, approximately VE to VC growth stage, has the potential to result in a modest reduction in soybean yield (5%).

Keywords

Burndown, Glyphosate, Soybean

1. Introduction

With record production of nearly 6 million tonnes in 2014, soybean [*Glycine max* (L.) Merr.] continues to be Canada's most popular leguminous field crop [1]. Accounting for more than 60% of total Canadian production, Ontario soybean is valued at approximately 1.5 million dollars and typically occupies greater than 1 million hectares of crop land annually [2]. Soybean production has been met with continued growth over the past two

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decades that has been attributed, in part, to the development of glyphosate-resistant (GR) cultivars and no-tillage production systems. Since introduction in 1997, adoption of GR soybeans has been rapid due to a relatively low cost, excellent crop safety and flexibility for subsequently planted crops [3] [4]. Furthermore, the simplicity of glyphosate application fits well into most weed management programs [5].

In Ontario, problem weeds frequently found in soybean fields include barnyard grass [*Echinochloa crusgalli* (L.) Beauv.], green foxtail [*Setaria viridis* (L.) Beauv.], common lambsquarters (*Chenopodium album* L.), velvetleaf (*Abultilon theophrasti* Medic.) and Canada thistle [*Circium arvense* (L.) Scop.] [6]. Glyphosate-based weed management, although efficacious, is often associated with conservation or no-tillage regimes which may hasten shifts in weed populations [7]. Examples include Canada fleabane (*Conyza canadensis* L.), giant ragweed (*Ambrosia trifida* L.) and common water hemp [*Amaranthus tuberculatus* (Moq ex DC) JD Sauer] [7]. Application of a preplant or preemergence herbicide, commonly referred to as a burndown, is the foundation of most weed control programs. For GR soybeans, glyphosate is generally a component of either applications, however, time of application has been shown to influence weed control and soybean yield [8] [9].

Traditionally, application of a burndown serves to control existing vegetation and prepare the field for soybean planting. Early application ensures effective control of winter annual, perennial and early emerging annual weeds. Weeds present at this time are generally in the juvenile growth stage or actively growing and thus more susceptible to control, however time constraints during this busy time of the season may prevent a punctual burndown application [6]. Alternatively, a delayed burndown may provide better control of later emerging annual weeds, assuming that the intensity of weeds does not negatively affect the newly emerging soybean crop. Reference [10] reported that the critical weed-free period in soybean is up to the fourth trifoliate (V4) growth stage and that weed interference occurring prior to the V4 stage may result in a yield loss of up to 2.5%. However, reference [11] determined that the optimal time to apply glyphosate in GR soybean was approximately 18 to 28 days after planting, under conventional tillage.

Currently, most soybean growers apply a glyphosate burndown prior to or immediately following soybean planting. However, if glyphosate burndown can be delayed without penalty in soybean yield, it may provide growers with additional options and greater flexibility for early season weed control. The objectives of this study were to determine the number of days that glyphosate burndown may be delayed, relative to soybean planting, which result in a 5%, 10% and 20% reduction of soybean growth and yield as well a 5% and 10% increase in seed moisture based on a regression analysis, under Ontario field conditions.

2. Materials and Methods

2.1. Study Establishment

Six field trials were conducted over a three-year period (2008, 2009 and 2010) to determine the effect of delayed glyphosate burndown in GR soybeans. All trials were established at the University of Guelph, Ridgetown Campus near Ridgetown, Ontario, Canada (42˚26'N, 81˚53'W). Ridgetown soils were analyzed each year prior to trial establishment and ranged from fine to very fine sandy loam in texture with sand, silt, clay and organic matter content of 63% to 79%, 12% to 19%, 9% to 18% and 6.4% to 6.9%, respectively; soil pH ranged from 6.4 to 6.9. All experiments were established in no-tillage production systems in the absence of irrigation.

The experimental design of this study was a randomized complete block with four replications. Herbicide treatments consisted of a weedy check and 1800 g·ae·ha^{-1} glyphosate applied 2 weeks before planting (WBP), 1 WBP, 0 weeks after planting (WAP), 1 WAP, 2 WAP and 3 WAP. Soybeans were planted at a rate of approximately 400,000 seeds per hectare with a no-till planter in early May. Dates of herbicide application and soybean planting are listed in **Table 1**. Seeds were planted to a depth of 3 cm in rows spaced 75 cm apart. Plots measured 3 m wide by 10 m long. Herbicide applications were made using a CO_2-pressurized backpack sprayer calibrated to deliver 200 L aqueous solution per hectare at a pressure of 210 kPa. Boom length was 1.5 m with four "Ultra-low drift" nozzles (ULD 120-02) spaced 50 cm apart. All herbicide applications were made in the absence of precipitation at a low-wind velocity to ensure maximum efficacy. To eliminate the confounding effects of post-burndown weed interference each treatment, excluding the weedy check, was maintained free of weeds after the burndown application and for the remainder of the growing season.

2.2. Data Collection

Soybean growth was assessed on a scale of 1 to 10, where 1 was defined as poor growth and 10 as ideal soybean

Table 1. Soybean cultivar and dates of soybean planting and burndown application for experiments conducted near Ridgetown, Ontario from 2008 to 2010.[a]

Environment	Year	Cultivar	Planting date	Burndown application timing					
				2 WBP	1 WBP	0 WAP	1 WAP	2 WAP	3 WAP
S1	2008	Dekalb 31-53	May 29	Apr. 29	May 09	May 29	Jun. 5	Jun. 11	Jun. 19
S2	2008	Pioneer 30-07R	May 21	May 6	May 13	May 23	May 28	Jun. 4	Jun. 11
S3	2009	Dekalb 31-10RY	May 19	May 5	May 12	May 20	May 25	Jun. 2	Jun. 9
S4	2009	Dekalb 31-10RY	May 19	May 5	May 12	May 20	May 25	Jun. 2	Jun. 9
S5	2010	Dekalb 32-60RY	May 21	May 6	May 12	May 26	May 31	Jun. 3	Jun. 11
S6	2010	Dekalb 32-60RY	May 21	May 6	May 12	May 26	May 31	Jun. 3	Jun. 11

[a]Abbreviations: WBP, weeks before planting; WAP, weeks after planting.

growth. Soybean growth was evaluated at 1, 4, 8 and 12 weeks after the last burndown application timing (3 WAP). Additionally, soybean growth stage was recorded per burndown timing, where plants were present (**Table 2**). Weed density per species was quantified at each burndown timing, however, for brevity only total density per environment, per timing were reported (**Table 3**). Soybean was harvested at maturity with a small plot combine. At harvest, weight and seed moisture were recorded; final yields were adjusted to 13% seed moisture content.

2.3. Statistical Analysis

Data were analyzed using non-linear regression (PROC NLIN) in SAS (Ver 9.2, Cary, NC). The weedy check was not included in the regression analysis. Soybean yield data were converted to a percent of the earliest burndown treatment (2 WBP). This treatment was chosen as it consistently rated 10 (ideal soybean growth) in all environments. All parameters were regressed against application timing in days after soybean planting (DAP). On the original scale, two treatments showed a negative DAP therefore all treatments were adjusted by 30 DAP to ensure all numbers were positive; a requirement for a log-logistic model. Following calculation of predicted values, 30 days was then subtracted from each treatment to convert data back to the original scale.

Growth ratings and yield (DAP-response) were determined using a four parameter log-logistic model:

$$Y = C + D - C \Big/ \left(1 + \exp\left[-b\left(\ln \mathrm{DAP} - \ln \mathrm{I}_{50}\right)\right]\right) \tag{1}$$

where C is the lower asymptote, D is the upper asymptote, b is the slope and I_{50} is the application timing which gives a response halfway between C and D [12].

Soybean percent moisture content at harvest was determined using a segmented linear regression:

$$Y_L = a_0 + b_1 * \mathrm{DAP} \tag{2a}$$

$$Y_R = a_0 + b_1 * j + br_1 * \left(\mathrm{DAP} - j\right) \tag{2b}$$

where Y_L and Y_R are the left and right segments, respectively, a_0 is the left intercept, b_1 is the slope of the left segment, br_1 is the slope of the right segment and j is the junction point of the two segments [13].

Regression equations used to calculate predicted burndown application timing (in DAP) that resulted in a 5%, 10% and 20% reduction (R_5, R_{10} and R_{20}, respectively) in soybean growth and yield, as well as DAP resulting in a 5% and 10% increase (I_5 and I_{10}, respectively) in soybean moisture content at harvest. If the predicted burndown application timing was outside the range of days (from the first application to harvest), it was expressed as a missing data point.

3. Results and Discussion

No significant environment by treatment interaction was detected therefore all data from each environment for each variable was pooled. Timing of burndown did not generally impact soybean seed moisture content. According to the analysis, a delay of 80 and 140 DAP would be required to increase soybean moisture by 5% and 10%, respectively (data not shown).

Table 2. Dates of soybean planting, emergence and growth stage 0, 1, 2 and 3 WAP for experiments conducted near Ridgetown, Ontario from 2008 to 2010.[a]

Environment	Year	Planting date	Emergence date	Soybean growth stage			
				0 WAP	1 WAP	2 WAP	3 WAP
S1	2008	May 29	Jun. 8	-	VE	VC	V1
S2	2008	May 21	Jun. 6	-	-	VE	VC
S3	2009	May 19	May 26	-	VE	VC	V1
S4	2009	May 19	May 26	-	VE	VC	V1
S5	2010	May 21	May 28	-	-	VE	VC
S6	2010	May 21	May 28	-	-	VE	VC

[a]Abbreviations: WAP, weeks after planting.

Table 3. Weed density per burndown timing for experiments conducted near Ridgetown, Ontario from 2008 to 2010.[a]

Environment	Year	Planting date	Burndown timing[b] (weeds·m^{-2})					
			2 WBP	1 WBP	0 WAP	1 WAP	2 WAP	3 WAP
S1	2008	May 29	2004	2273	1089	1348	1506	1181
S2	2008	May 21	70	84	52	21	36	31
S3	2009	May 19	30	14	29	29	134	140
S4	2009	May 19	28	50	38	40	29	35
S5	2010	May 21	78	90	99	98	107	71
S6	2010	May 21	151	123	141	131	154	127

[a]Abbreviations: WBP, weeks before planting; WAP, weeks after planting. [b]Weeds present included: *Abutilon theophrasti*, *Ambrosia artemisiifolia*, *Bromus tectorum*, *Chenopodium album*, *Conyza canadensis*, *Daucus carota*, *Lactuca serriola*, *Panicum dichotoflorum*, *Setaria faberi*, *Stellaria media* and *Triticum aestivum*.

At 1 WAA, burndown applications at 1, 5 and 12 DAP were predicted to reduce soybean growth by 5%, 10% and 20%, respectively (**Table 4**). By 8 WAA, predicted burndown timings for R_5, R_{10} and R_{20} doubled and were 9, 14 and 23 DAP, respectively. Burndown applications remained relatively constant for 12 WAA and were 10, 17 and 26 DAP for the same reductions, respectively. The results of this study indicate that despite soybean growth being sensitive to burndown 1 WAA, the lasting effects on soybean growth became diminished over time, evident by declining slope (*b*) values from 1 to 12 WAA. Furthermore, the predicted delay in burndown required to reduce soybean yield by 5%, 10% and 20% was 14, 21 and 30 DAP, respectively. This study evaluated soybean growth and yield in response to burndown timing in the absence of post-burndown weeds, thus suggesting that any reduction in growth or yield be attributed to early season weed interference prior to the burndown application (**Table 3**). Therefore, based on this study, a grower who delays glyphosate burndown to 14 DAP, at approximately the cotyledon (VC) to unifoliate (VE) growth stage, would incur a yield reduction of 5% solely from delayed burndown applicaiton (**Table 2** and **Table 4**).

In other studies, reference [14] reported variable GR soybean yield in response to timing of glyphosate application (cracking to V7), but reported consistently high yields for V2 to V4 treatments that were paired with a preplant burndown. In a related study, reference [15] evaluated the role of delayed burndown in GR corn (*Zea mays* L.) planted into a wheat (*Triticum aestevum* L.) cover crop and found that increasing DAP significantly reduced corn height, relative to the weed-free control. However, for treatments not planted into a cover crop, weed control increased (up to 28%) as the burndown application timing was delayed; when accompanied with a sequential glyphosate application weed control increased to 90%. The latter implies that while there may be an inherent benefit to delaying burndown, a single glyphosate application is not likely to be sufficient for season-long weed control [11] [16]. This is further supported by existing research that reports that the critical time of weed removal in soybean is between the vegetative and early reproductive growth stages; and a delay in burndown is not recommended in these studies [10] [17] [18]. Similarly, a related survey assessed perceptions

Table 4. Regression parameter estimates and predicted burndown application timings from dose (DAP)-response models of soybean growth ratings and yield.[a]

Variable	WAA	Parameter estimates[b] (±SE)								Predicted burndown timing (DAP)[c]		
		C		*D*		*b*		I_{50}		R_5	R_{10}	R_{20}
Growth rating	1	7.1	(0.2)	10.0	(0.2)	7.8	(2.5)	38	(2)	1	5	12
	4	6.2	(0.3)	10.0	(0.0)	5.7	(1.2)	44	(2)	1	6	15
	8	5.6	(0.2)	10.0	(0.0)	5.9	(1.4)	55	(3)	9	14	23
	12	4.6	(0.2)	10.0	(0.0)	5.4	(1.4)	62	(5)	10	17	26
Yield		29.3	(4.4)	99.8	(2.2)	5.2	(3.9)	72	(20)	14	21	30

[a]Abbreviations: DAP, days after soybean planting; WAA, weeks after the final burndown application. [b]Dose response parameters (Equation (1)): *b*, slope; *C*, lower asymptote; *D*, upper asymptote; I_{50}, burndown application timing in DAT that gives a 50% response. [c]R_5, R_{10}, and R_{20} are the DAP that result in 5%, 10% and 20% reduction in soybean growth or yield.

about the importance of weed control timing for Indiana soybean growers [19]. The survey found that despite the perceived importance of planting into a clean field, almost a third of the growers surveyed did not feel a compelling need to do so. The survey concluded that weed size and density were the most common criteria when determining when to spray, suggesting that crop scouting plays a substantial role in the decision-making process.

4. Conclusion

In summary, application of glyphosate up to 14 DAP, at about the VE to VC growth stage, may reduce soybean growth and yield up to 10% and 5%, respectively. However, timing of application does not appear to impact soybean seed moisture content. This study evaluated the impact of delayed burndown in the absence of weed interference post-burndown and thus all soybean growth and yield predictions made are attributed primarily to the impact of early-season weed interference. Consequently, the implementation of a postemergence weed control application will most likely be required to ensure season-long control. Future research should consider the implications of delayed burndown on weed control and if the perceived benefit to delaying burndown brings about a reduction in control.

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