

Herbicide Strategies to Maximize Yield in Glyphosate-Resistant Corn

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Water, nutrients, space, and sunlight are critical resources for the growth and development of all crops. Over the years, recommendations for inputs such as fertilizer, irrigation, and seeding rate have been fine-tuned to maximize yields while minimizing cost. Weeds compete with crops for this limited pool of resources. As resource availability shrinks, crop yields almost immediately begin to decline.

Corn can be very sensitive to weed competition, particularly early in the season. Traditional weed management programs for corn from the 1960s through the late 1990s were built around preemergence (PRE) soil-applied herbicides such as atrazine. The primary benefit of this strategy was the yield protection offered by eliminating weeds early in the season. Growers would then use postemergence (POST) herbicides as a follow-up to soil-applied products to provide season-long weed control.

Glyphosate-resistant (GR; Roundup Ready®) corn was first marketed in the late 1990s and is currently grown on approximately 90 percent of U.S. corn acres (USDA ERS). The GR trait allows glyphosate (Roundup®), a non-selective herbicide, to be safely applied POST to a normally sensitive crop. A glyphosate-based system has many attractive features, including low cost, excellent crop safety, broad spectrum of weed control activity, and application flexibility. The effectiveness of glyphosate has caused many growers to discontinue

the use of soil-applied herbicides and to rely solely on POST weed control with glyphosate.

When using glyphosate in corn, many growers delay POST applications too long in an effort to wait until the majority of the weeds have emerged. Doing so reduces the number of applications needed for a weed-free field at the end of the season. The problem with delaying treatment is that significant yield loss can occur by allowing weeds to compete with the corn early in the season.

Proper Weed Control Timing in GR Corn

To measure the importance of glyphosate application timing in GR corn, Gower et al. (2003) conducted field studies across nine Corn-Belt states



Glyphosate should be applied to corn when weeds reach 2 to 4 inches in height. Weeds allowed to exceed 4 inches can cause significant yield loss.

at 35 sites over 2 years. In these studies, a single application of glyphosate was applied when the weeds reached 2, 4, 6, 9, or 12 inches in height. After this initial application, no additional herbicides were applied.

At the end of the season, the single glyphosate application at the 2-inch weed stage resulted in 74% grass control and 84% broadleaf control (Table 1). With such levels of late-season weed infestation, most growers would be unsatisfied. However, compared to a weed-free check, 100% of the corn yield was protected by controlling weeds early in the season. In other words, these late-emerging weeds might have been unsightly, but they had little to no effect on corn yields.

Contrast this with delaying application until weed height reached 12 inches. Grass and broadleaf control were 95% and 93%, respectively, which is excellent weed control by anyone's definition. However, corn yield was reduced by 21% compared to the weed-free check. Despite the near-perfect weed control from delaying application, the corn was unable to overcome the yield damage that resulted from early-season weed competition.

Although this experiment did not specifically measure silage production, grain and silage yields usually respond similarly to early-season weed competition. This is primarily because the ear makes up approximately 40% to 50% of silage dry matter, and contributes a great deal to silage quality.



Weeds compete with corn for water, nutrients, space, and sunlight. Corn is most sensitive to weed competition in the first 8-10 weeks of growth.

Costs and Causes of Delay

Table 2 shows the effect of delayed application in terms of lost yield and revenue. The glyphosate application timing at 2-inch weeds had maximum yields and resulted in no reductions in yield or return. At the 4-inch weed timing, an average of 6 bu/acre or \$39/acre (based on a 2012 corn price of \$6.50/bu) had been lost. Similar trends continue as weed height increases, culminating in the 12-inch weed height causing a 42 bu/acre yield loss or \$273/acre in lost revenue.

Of particular interest is that delaying application for a few days resulted in significant yield losses. It took only 15 days to progress from 2 to 12 inch

Table 1. Weed control and corn grain yield after a single application of glyphosate. Field studies were conducted at 35 sites in 9 states in the north central U.S. over 2 years. Application timing was based on weed height. Grass and broadleaf control were visually rated at harvest on a scale of 0% (no control) to 100% (complete control). Corn grain yields are expressed as a percent of the weed-free check.

Weed Height at Application	Grass Control	Broadleaf Control	Corn Yield
inches	----- % control -----	-----	% of weed free
2	74	84	100
4	84	91	97
6	90	94	93
9	93	95	91
12	95	93	79

Adapted from Gower et al. (2003)

Table 2. Corn yield and dollars lost based on a single application of glyphosate in the field studies described in Table 1. Days delayed is the number of days the application was delayed after the 2 inch timing. Calculated corn yield and economic losses are based on 200 bu/A corn yield at a market value of \$6.50/bu.

Weed Height at Application	Days Delayed	Corn Yield	Yield Lost	Dollars Lost
inches	no. days	% of weed free	bu/acre	\$/acre
2	--	100	0	0
4	+5	97	6	39
6	+9	93	14	91
9	+13	91	18	117
12	+15	79	42	273

Adapted from Gower et al. (2003)

weeds, and 21% of the overall yield was lost. That is equivalent to a 1.5% reduction in yield per day

Sometimes the delay in making a POST application of glyphosate is intentional, where a grower attempts to wait as long as possible until most of the weeds have emerged. Other times the delay is due to external factors. How often are spring field operations delayed due to wet or windy conditions? What about if a grower has a large number of acres to cover, experiences an equipment breakdown, or needs to address other pressing activities on the farm? Sometimes the delay can easily extend for days or even weeks on end. Remember that each day weeds are allowed to compete with corn, yields are dropping.

Three Strategies to Protect Corn Yields

The following approaches will allow growers to minimize yield loss in GR corn due to weeds:

Apply POST glyphosate to small weeds

Applying a single application of glyphosate when weeds are no more than 2 to 4 inches in height is usually sufficient to eliminate the effects of weed competition in corn. A second or third application can be applied to maintain a clean field and prevent seed production later in the season but doing so is primarily cosmetic, having little to no effect on yields. Although weeds can be successfully managed using this approach, the potential for

missing this narrow window of application represents a large risk that can devastate yields.

Apply a soil-residual PRE herbicide followed by POST glyphosate

The best way to maximize corn yields is to apply POST herbicides in conjunction with pre-emergence (PRE) products. This strategy employs a two-pass system where a soil-applied herbicide is applied at or before planting, then POST glyphosate is applied after the crop has emerged as a backup treatment. The PRE herbicide reduces weed density and delays emergence, thereby widening the window for POST application since fewer weeds are present after corn emergence. According to the Pacific Northwest Weed Management Handbook (accessed November 2012), examples of PRE herbicides labeled in corn include acetochlor (Harness, Surpass), alachlor (Bullet, Lariat, Micro-Tech), atrazine, dimethenamid-P (outlook), flumioxazin (Chateau), mesotrione (Callisto), pendimethalin (Prowl), rimsulfuron (Resolve), saflufenacil (Sharpen), and S-metolachlor (Dual II Magnum).

Some growers are reluctant to invest in a PRE herbicide since they have already paid a technology fee for the GR trait with their seed purchase. However, Table 2 shows that the reduction in revenue associated with any yield loss due to improper glyphosate application timing can easily cover the cost of the PRE herbicide, often many

times over. One strategy that can help reduce cost is to apply the PRE herbicide at a low labeled rate. Such an approach may not result in picture-perfect weed control, but it can provide enough weed suppression to allow more flexibility in the timing of POST applications (Loux et al., 2011).

Tank mix a soil-residual herbicide with POST glyphosate

A second strategy is to tank mix a soil-residual herbicide with POST glyphosate. Such an approach does not alleviate the narrow application window (2-4 inch weeds) of a glyphosate-only program. It does, however, allow for season-long weed control to be achieved in a single pass. Furthermore, it also introduces a second mechanism of action (the process whereby the plants are killed) into the system that can help reduce the onset of herbicide resistance in the weed population.

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POST herbicide strategies for GR corn:

- **Scout fields** – All fields should be scouted around 2-3 weeks after planting.
- **Know your enemy** – A good understanding of the growth and emergence patterns of dominant weed species is necessary to plan the best strategy for a specific field.
- **Control weeds early** – If fields are clean for 8-10 weeks after planting, yields should be unaffected by later emerging weeds.
- **Include a residual herbicide** – Corn yield is maximized when POST herbicides are applied 1) following a reduced rate of a PRE herbicide, or 2) early POST with residual herbicides.
- **Target small weeds** - To avoid yield loss from early-season weed competition, apply POST herbicides when weeds are no more than 4 inches tall.

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