# Is there a need for stewardship or is killing weeds good enough?

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## Introduction

Since the introduction of glyphosate resistant (GR) soybean cultivars in 1996, GR crops have become the most rapidly and globally accepted agronomic practice in the history of agriculture(Anonymous 2007; Service 2007). In the United States (US), more than one billion cumulative acres of genetically engineered (GE) crops have been planted with most of these represented by GR crops (Gianessi 2005; Anonymous 2007; Service 2007; Gianessi 2008). Monsanto reported that their 2006 market share of glyphosate resistant crops (GRC) included 71.6 million acres of the soybean area, 34 million acres of corn, 11.3 million acres of cotton, and 5.7 million acres of canola in the US and Canada (Anonymous 2006b). They anticipate that their GRC market share in US corn will approach 60 million acres by 2010 (Anonymous 2006a). In Iowa, GR soybeans are planted on an estimated 97% of the acres and GR corn is approaching 75% of the acres. All of the GR crops likely receive at least one and more often, two or more applications of glyphosate for weed control. Growers like the perception of simplicity and convenience of the GR-based crop systems, the consistent control of weeds and the lack of crop injury from glyphosate. However, despite the appearance of a successful weed control program, the soybean producer often fails to recognize the cost of simplicity and convenience: given the widespread adoption of GR crop systems, weed populations are changing and there is a critical need to include glyphosate stewardship in GR crop systems. The concurrent use of glyphosate in GRCs has resulted in the evolution of weeds that are resistant to glyphosate (Figure 1). There are now 14 different weed species that have glyphosate resistant biotypes (Heap 2004). Nine glyphosate resistant weed species have been identified in the US and six were confirmed glyphosate resistant since 2004. Importantly, it is apparent that weed populations are evolving resistance to glyphosate at an increasing rate. While alternative herbicides may still be effective and provide control of the glyphosate resistant weeds, resistance to many of the alternative herbicides also exists. Currently 183 herbicide resistant weed species are identified and many of these weeds are found in Iowa (Heap 2004). Thus it is critical to understand the implications of current weed control practices on future weed problems and assess the need to implement stewardship proactively to protect the sustainability of GRCs.

## What are the implications of current weed control tactics?

The observed and anticipated problems that are evolving in GR crop systems are a product of the success of the system. Importantly, growers seem unwilling to change what they incorrectly perceive to be a successful weed control system. Many of the problems and issues associated with the GR crop systems are not easily seen or measured. Recognize that weeds behave differently than other pest complexes; their impact on crops (i.e. lost yield potential) is typically subtle and the evolution of new weed problems (i.e. evolved glyphosate resistance) occurs over a number of years. However given the seed production demonstrated by weeds and dormancy in the seeds, once the weed becomes established in a field, the problem will remain for an extremely long

time. By the time growers recognize that there is a new weed problem, it is too late. The primary issues associated with the current weed control tactics in GR crops are ecological problems and economic losses.

## Changes in weeds attributable to current weed control tactics; ecological responses to the system

Throughout the US, weed communities in GR-based crop systems are responding to the recurrent use of glyphosate and weed populations are adapting to the management practices. Furthermore, given the adoption of the GR-based crop systems, particularly in soybean and cotton, there has been a significant decline in the use of "alternative" herbicides (Shaner 2000; Young 2006). The lack of herbicide diversity and the consistent use of glyphosate have created an ecological environment where changes in weed communities are inevitable.

In order to assess these changes in weed communities, surveys were administered to growers and AgChem professionals from Iowa. The surveys addressed, in a general sense, the ecological implications of current weed control practices and indicated that a number of Iowa growers and AgChem dealers believe that fields are becoming weedier and weeds now require higher rates or more frequent applications of glyphosate for effective control (Tables 1 and 2). Interestingly, AgChem professionals consistently reported a higher concern than growers. There is no question that glyphosate has provided excellent and consistent weed control in most fields. Furthermore, most of the problems reported are likely attributable to poor management strategies (i.e. low glyphosate rate or application to large weeds). However, it is concerning that 40% of the AgChem professionals reported that fields were becoming weedier since the adoption of GR crops (Table 1). While only 26% of Iowa growers surveyed reported that fields were becoming weedier, this percentage is still high and suggests that there is a critical mass of issues developing across the state (Table 1). More telling was that growers were almost equally split as to whether more glyphosate was needed to achieve effective weed control (45% indicating more glyphosate versus 49% indicating their current use practice was still effective) (Table 2). A much higher percentage of AgChem professionals felt that fields were becoming weedier (40%) and more glyphosate was needed for effective control (57%) (Tables 1 and 2). Given that growers tend not to "see" a potential problem until it evolves in their fields, and that AgChem professionals likely have the "bigger picture", the reported differences between the groups are not surprising. Regardless, both responding groups suggested that the situation with GR crops and glyphosate were changing and not in a positive direction.

When these same questions were posed about specific weeds, similar trends between growers and AgChem professionals were observed with one notable exception (Tables 3 and 4). Growers and AgChem professionals were in agreement that common waterhemp problems were increasing and more glyphosate was required for effective control. AgChem professionals reported that common lambsquarters and giant ragweed problems were increasing, 62% and 55%, respectively and that more glyphosate was needed for effective control, 56% and 50%, respectively (Table 3). Only 37% of growers reported that common lambsquarters problems were increasing and 56% reported that control with glyphosate had not declined (Table 4). Similar responses for giant ragweed were reported (Table 4.) AgChem professionals and growers were in agreement that neither Asiatic dayflower or common ragweed were increasing problems

and these weeds continued to be effectively controlled with current glyphosate usage practices (Tables 3 and 4).

It is noteworthy that the three weeds, common lambsquarters, common waterhemp and giant ragweed, most frequently are identified as increasing problems and responding less to current glyphosate usage practices have been identified as having evolved glyphosate resistant populations (Heap 2004). These changes in weed populations are an inevitable consequence of the consistent and widespread use of simple and convenient weed management programs such as those employed by growers when they plant GR crops and apply glyphosate. The selection pressure imposed by consistent use of glyphosate without additional control tactics will result in weeds that no longer to those simple and convenient tactics (Christoffoleti et al. 2008).

## Economic implications of current weed control tactics; reduced crop yield potential

The important issue in current glyphosate use tactics and the lack of stewardship practices is economic. Convenience and simplicity, as the current weed control tactics are deemed, have significant costs and growers must understand these costs in order to make the best objective decision about how to best use the GR crop technology and glyphosate. Economics should play the most important role on glyphosate stewardship. From the perspective of the author, if an objective assessment of the GR crop system is done, there is a strong and pervasive economic argument to implement stewardship for glyphosate. Unfortunately, this requires that weed control tactics assume a greater management posture (i.e. planning and timeliness) which will be less simple and perceived as inconvenient by growers and some AgChem professionals. Growers tend not to do anything to proactively address issues until the problems are experienced locally (Foresman and Glasgow 2008). Furthermore, many growers and AgChem professionals believe that new technologies, either new herbicide or herbicide resistant traits, are eminent and will resolve the current emerging problems with glyphosate. These technologies are not likely to be available for a number of years and by themselves, have limited abilities to fix that which is becoming broken in GR crop systems given the lack of stewardship toward glyphosate (Sammons et al. 2007).

Glyphosate can control most weeds irrespective of size and thus growers tend to favor total postemergence programs. However, given the predominance of GR crops and the use of postemergence applications of glyphosate, the ability to make timely and accurate applications is severely compromised. Unfortunately, many glyphosate applications are delayed beyond a timing that is best for the protection of crop yields. A significant part of the problem is that it is difficult to "see" the impact of weeds on potential yield, particularly when there is no comparison available. Typically, growers and AgChem professionals see dead weeds in the fields and presume that they have implemented a successful weed management program.

However, the reality is that delayed or reduced rates of glyphosate will result in a situation where weeds compete for potential crop yield even though the weeds may ultimately be controlled. Average weed infestations compete early and effectively for crop yield; a one day delayed application of glyphosate may cost more than a preemergence residual herbicide, depending on crop price and yield potential (Hartzler, personal communication). Delayed weed control of five to ten days may result in potential soybean losses of two to six bushels per acre, again depending

on the anticipated yield and weed infestation. Importantly, glyphosate resistant weeds obviously will be poorly controlled are guaranteed to compete with crop yield potential. It is critical to remember that herbicides are used not to control weeds but rather protect crop yield potential.

## What are the best tactics for the stewardship of glyphosate?

When weed problems evolve in GR crops, it is likely that there is a lack of diversity in the weed management program. Importantly, the benefits of glyphosate stewardship will be realized first in improved profitability by eliminating early weed competition resulting in higher crop yields. Longer term benefits of glyphosate stewardship include the delay or elimination of evolved resistance to glyphosate in weed populations. It is important to always use a soil-applied residual herbicide either early preplant or preemergence to the crop. Not only does this provide protection to potential crop yield, but it diversifies the weed management program and, importantly, provides an opportunity for better time management later in the growing season. The best choice is an herbicide that has activity on the earliest germinating weeds and those that are most problematic in the field. It is also wise to target the choice of herbicide for weed species that have demonstrated the ability to evolve resistant populations to glyphosate (i.e. common waterhemp). By using a residual herbicide in GR crops prior to postemergence glyphosate application, potential crop yields are protected, selection pressure from glyphosate is reduced, and there is a longer period of time before weeds begin to compete with crop yields.

Another issue is the guaranteed respray programs. Resprays are potentially costly from the perspective that they may not occur in a timely fashion and thus potential crop yield is lost. Also important is the "free" resprays increase selection pressure on the weeds increasing the possibility of evolved resistance to glyphosate. Thus, it is important to diversify the weed management program as much as possible, whether with other herbicides or alternative tactics. Use herbicides with different modes of action but recognize simply using a different herbicide will not improve glyphosate stewardship if the herbicide of choice does not have activity on the target. While crop rotation should generally be considered an effective steward tactic, rotating GR soybeans with GR corn is not a good tactic for glyphosate stewardship unless herbicides other than glyphosate or alternative tactics are used for weed management. Avoid repeated applications of glyphosate. Avoid delaying glyphosate applications in order to be more "efficient"; delaying an herbicide application to accommodate a second pesticide likely costs crop yield potential from both pest complexes.

Simple stewardship tactics can provide considerable benefit and protect the GR crop trail and glyphosate. For example, scout fields and observe and manage weed problems when they are just beginning. Keeping records for each field will provide valuable information about the risks of choosing a weed management program for the future. Develop individual weed management programs that address the problems and conditions unique to that field. While this practice is neither simple nor convenient, it will provide long term stewardship and increase profitability.

## Summary

The biggest problem with implementing glyphosate stewardship is that the growers and AgChem professionals are not convinced that a weed problem exists until it is discovered on locally.

Given weed seed productivity and dormancy, once a problem is discovered, it is too late to "fix". In essence, glyphosate stewardship plans should be implemented before a problem with glyphosate exists. Another issue is that growers are concerned that using residual herbicides will add needless cost to crop production. Importantly, weeds are ubiquitous but yield losses are often overlooked because there is not opportunity to measure difference attributable to different tactics. Ultimately all acres are treated with herbicides. It is critical to recognize that just because the weeds are killed does not mean the weed control program has been successful. Furthermore, the consistent use of glyphosate will ultimately result in problems that cannot be easily managed; these shifts in weed populations will occur sooner rather than later. Thus, it is critically important to implement a glyphosate stewardship program now. Use an appropriate residual herbicide on all crop acres and follow with post-applied glyphosate as needed.

**Table 1.** Fields are becoming more "weedy"

| Sample population | Yes | No |
|---|---|---|
| Iowa growers (n=6588) | 26% | 70% |
| Iowa AgChem professionals (n=568) | 40% | 57% |

**Table 2.** More glyphosate is needed (application frequency or rate)

| Sample population | Yes | No |
|---|---|---|
| Iowa growers (n=6588) | 45% | 49% |
| Iowa AgChem professionals (n=568) | 57% | 39% |

**Table 3.** Survey conducted in 2007 to assess the attitudes of Iowa AgChem professionals on glyphosate and weed problems (568 respondents)

| Weed | % responses: weed problem increasing | % responses: control with glyphosate declined |
|---|---|---|
| Common lambsquarters | | |
| Yes | 62% | 56% |
| No | 37% | 39% |
| Common waterhemp | | |
| Yes | 61% | 53% |
| No | 36% | 42% |
| Asiatic dayflower | | |
| Yes | 8% | N/A |
| No | 81% | N/A |
| Giant ragweed | | |
| Yes | 55% | 50% |
| No | 40% | 46% |
| Common ragweed | | |
| Yes | 29% | 29% |
| No | 68% | 64% |

**Table 4.** Survey conducted in 2008 to assess the attitudes of Iowa growers on glyphosate and weed problems (6588 respondents)

| Weed | % responses: weed problem increasing | % responses: control with glyphosate declined |
|---|---|---|
| Common lambsquarters | | |
| Yes | 37% | 34% |
| No | 55% | 56% |
| Common waterhemp | | |
| Yes | 51% | 42% |
| No | 43% | 49% |
| Asiatic dayflower | | |
| Yes | 5% | N/A |
| No | 77% | N/A |
| Giant ragweed | | |
| Yes | 35% | 35% |
| No | 60% | 55% |
| Common ragweed | | |
| Yes | 26% | 25% |
| No | 63% | 63% |

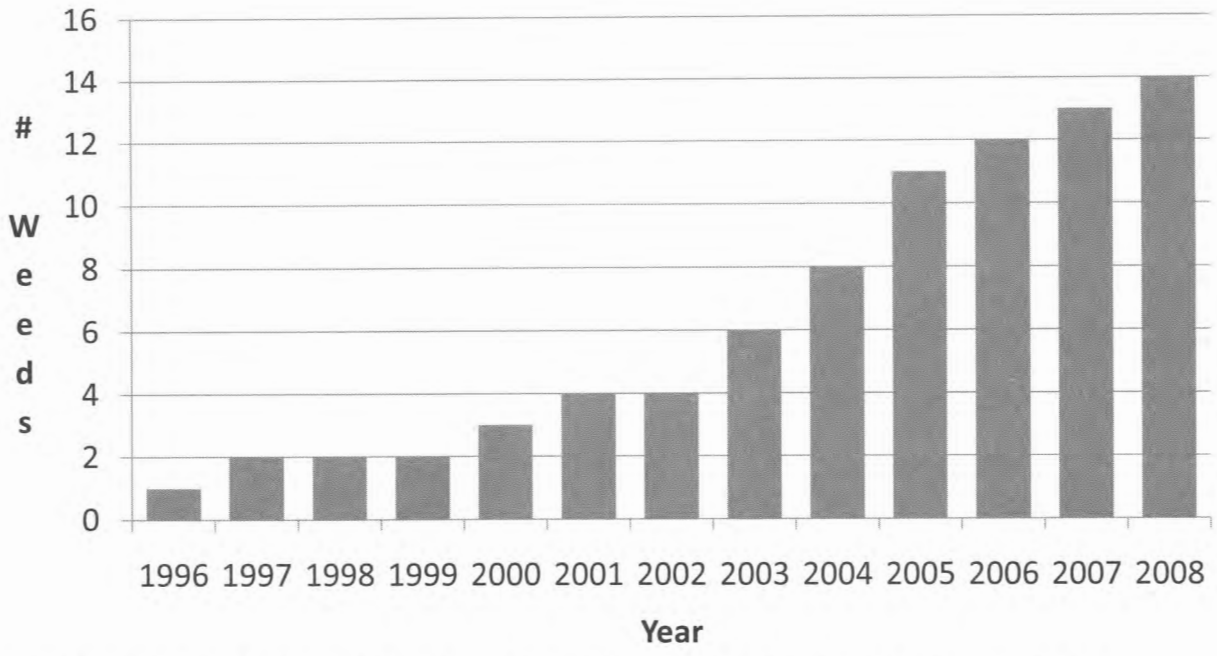


**Figure 1.** Evolved weed resistance to glyphosate since the introduction of glyphosate resistant soybeans.

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