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Michael D.K. Owen
Iowa State University, mdowen@iastate.edu

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Weed management in 2008 – new opportunities, existing issues and anticipated problems
Micheal D. K. Owen, Professor, Agronomy, Iowa State University

Introduction
There are a number of new opportunities in weed management for 2008. However, issues continue to surface and problems are likely to escalate in the future. Specifically, there are new herbicide resistant crop options that will be available in the near future, new herbicides and changes in existing proprietary herbicides. Glyphosate continues to dominate as the weed control tactic of choice, and given the importance of bio-renewable fuels in the future, more herbicide resistant corn will be planted. The selection pressure that will be imposed on the weed communities as a result of grower adoption glyphosate resistant corn, as well as the continued inclusion of glyphosate resistant soybeans in crop plans is increasing. While the benefits of the glyphosate technology are many, there are several unintended consequences. These unintended consequences include new weed problems, evolved glyphosate resistance and volunteer crop management issues. Furthermore, the need for alternative weed management strategies is reinforced and the development of new herbicides becomes critically important. The paper will provide an overview of new herbicide resistant crops, new herbicides, and weed problems.

New herbicide resistant crops
Seed companies have plans in place to introduce a number of new herbicide resistant crop technologies in the near future. In some instances, these new technologies provide important opportunities to improving weed management and addressing effectively problems resulting from the recurrent use of glyphosate as the sole tactic for weed control. However, when herbicide resistant traits are stacked, control of volunteer plants or planning strategies to destroy existing poor stands can be a significant issue.

Optimum GAT
DuPont/Pioneer Hi-Bred International has introduced a new technology that includes a high level of resistance to glyphosate and a broad spectrum of ALS inhibitor herbicides. Regulatory submissions are proceeding and it is anticipated that Optimum GAT soybean varieties will be available in 2009 and corn hybrids in 2010. The genetic basis for resistance to glyphosate is different than in the Roundup Ready technologies. Specifically, Optimum GAT resistance to glyphosate is attributable to the insertion of genetic material that codes for an enzyme that is able to metabolize glyphosate quickly and efficiently. Roundup Ready technologies accrue glyphosate resistance by the insertion of an altered target-site enzyme. The resistance to ALS inhibitor herbicides is a highly effective target-site mutation on the ALS enzyme.

From the weeds perspective, the mechanism of glyphosate resistance in the crop does not matter. However, depending on which ALS inhibitor herbicide is designated, there may be some interesting opportunities to control weeds that are becoming problems in the glyphosate-based crop systems. Recognize that if the weeds have been previously selected by the recurrent use of ALS inhibitory herbicides and have subsequently evolved ALS inhibitor herbicide resistance,
there will be no benefit from the resistance in the crop for that specific weed. Furthermore, many of the weeds that are anticipated to ultimately evolve resistance to glyphosate have previously evolved resistance to ALS inhibitor herbicides (i.e. common waterhemp). Also, it is anticipated that Optimum GAT technologies in corn will include Bt traits which will likely include the trait for resistance to glufosinate. Thus careful management and stewardship of Optimum GAT must be considered to maximize the benefits of this new technology.

**Liberty Link soybeans**

Bayer Crop Science is moving forward to commercialize soybean varieties with resistance to glufosinate (Liberty Herbicide). This technology has been successful in corn and has been on the ‘shelf’ for many years in soybeans, in part due to concerns about acceptance in foreign markets. Liberty Link soybeans will allow broadcast applications of Liberty Herbicide postemergence. The mechanism of resistance is similar to that in the Liberty Link corn hybrids. It is anticipated that Bayer Crop Science will have sufficient seed supplies to allow planting 15,000 acres in 2008 with a full commercial launch expected in 2009.

**Dicamba resistance in soybeans**

Monsanto has collaborated with the University of Nebraska for the rights to the dicamba resistant genetics. The resistance is due to the insertion of a gene that codes for an enzyme that metabolizes dicamba into non-herbicidal products. It is anticipated that soybean varieties that are resistant to dicamba will also have resistance to glyphosate. Inclusion of dicamba resistance will help manage specific weeds that difficult to control with glyphosate, however it must be considered that the off-target concerns that currently exist for many dicamba products will still be an issue. Commercialization is anticipated in 2012 or 2013.

**SmartStax**

Monsanto and Dow AgroSciences recently announced a collaborative agreement to develop hybrids that have 8 genes that code for resistance for multiple insect pests and two herbicides, glyphosate and glufosinate. From a weed management perspective, the SmartStax demonstrates resistance similar to currently available Roundup Ready hybrids that include Herculex Bt and thus managing volunteer corn or destroying an existing stand due to replant necessities will be challenging.

**Dow AgroSciences**

Dow AgroSciences has announced plans to include resistance to PGR herbicides (i.e. 2,4-D) into corn and soybeans, and aryloxyphenoxypropionate herbicides into corn by 2012 for corn traits and 2013 or 2014 for soybean traits. These new traits will be combined with existing technologies such as the genes that code for Bt and glyphosate resistance. Dow AgroSciences will begin the development of these new traits in an effort to provide growers with tools to counteract the shift in weed communities to those that tolerate glyphosate.

**New herbicides, premixes and formulations**

There have been a number of changes in several companies concerning their proprietary herbicides. There has also been a number of changes in the companies that are marketing generic herbicides, however these changes are often more difficult to catalog. The general theme
of the new products, with a few exceptions, has been to develop products that provide some residual control and apply prior to planting glyphosate or glufosinate resistant crops. Iowa State University weed scientists are generally in favor of this tactic as it serves several critically important functions in a weed management program. First, the use of the residual herbicides will better protect the potential crop yield while mitigating the risk of a delayed POST herbicide application which misses the critical application timing. Second, the use of the residual herbicide provides better time management opportunities for the POST herbicide application. By providing some early weed control, the critical period where weeds and crops can co-exist without the loss of crop yield potential is extended providing the applicator the opportunity to make the timely POST application when time allows and when the risk of other environmental problems (e.g. herbicide drift) is minimal. Third, the use of alternative herbicides likely includes products with other modes of action which dilutes the selection pressure thus lessening the likelihood of a weed population shift and evolved herbicide resistance. The effectiveness of the third benefit depends on the specific activity of the alternative herbicide(s) on the weed species in question. Obviously, if the alternative products have no activity on the target species, there is no mitigation of the risk of selection for resistant populations.

**Authority MTZ**

FMC introduces a premix of sulfentrazone (Authority) and metribuzin for residual control of broadleaf weeds in soybeans. Authority MTZ is labeled for fall and spring application. In the spring, Authority can be applied up to 45 days prior to planting, preplant or preemergence up to 3 days after planting. Fall applications should be applied when the soil temperature is less than 55 degrees. Authority MTZ does not provide effective control grass weeds. Soybean injury is likely on soils with a pH greater than 7.5. Do not apply on soils with less than 1% organic matter. The Authority MTZ lists a number of soybean varieties that are restricted due to sensitivity to the herbicide(s).

**Halex GT**

Syngenta introduces a three-way mix of S-metolachlor, mesotrione and glyphosate for early POST application to glyphosate resistant corn hybrids. The recommended application rate provides sufficient residual control to give some temporal flexibility for follow-up POST applications of glyphosate. However the anticipated residual control is not sufficient to likely get the crop through the season.

**Laudis (tembotrione)**

Bayer Crop Protection anticipates the registration of Laudis herbicide in 2008. Laudis is a bleaching herbicide (HPPD inhibitor) that will be used in corn for postemergence control of a wide range of annual broadleaf and grass weeds. Activity on annual grasses (i.e. woolly cupgrass) is dependent on weed size. If the grasses are large (> 3”) control will drop off significantly. The herbicide is recommended for use with COC or MSO and UAN. A good strategy is to include atrazine with Laudis for better broadleaf control. Laudis formulation included isoxadifen which is potent proprietary herbicide safener. Thus the Laudis label describes applications to seed corn, sweet corn and popcorn.

**Lumax, Lexar and Camix**

Syngenta has made several important changes on the Lumax, Lexar and Camix labels. With the
new label, applications of solo HPPD herbicides (Laudis, Impact and Callisto) are not allowed to ground previously treated with Lumax, Lexar or Camix. However, Halex GT application over Lumax or Lexar is allowed. Also, the statement that described the POST application of Lumax or Lexar with 2,4-D to corn was deleted – the combination is not restricted but not recommended.

**Rage**

FMC introduces a premix of carfentrazone (Aim) and 2,4-D for a burndown treatment for annual broadleaf weeds prior to corn and soybean planting. The delay for planting following an application of Rage depends on the application rate. In field corn the planting delay is 3 to 14 days, and 7 to 14 days for soybeans.

**Sonic**

Dow AgroSciences introduces a premix of sulfentrazone (Authority) and cloransulam-methyl (FirstRate). The premix is labeled for preplant or preemergence application in soybean and will provide residual control of some broadleaf weeds. Sonic is also positioned to provide residual control in glyphosate resistant soybeans thus mitigating some risks that growers incur when using only glyphosate as the weed management program.

**SureStart**

Dow AgroSciences introduces a premix of acetochlor, flumetsulam and clopyralid that will be positioned as an herbicide combination for flexible applications for corn hybrids with herbicide tolerant traits (i.e. Roundup Ready®). SureStart can be applied early preplant (as early as 30 day prior to planting), preplant incorporated, preemergence, post plant preemergence, and early post emergence (corn up to 11” tall and weeds no larger than 2”). The recommended rates are approximately 1/2 of the Surpass and Hornet rates so there will be limited residual control from SureStart.

**Weed population shifts**

Agriculture imparts selection pressure on weed communities that inevitably result in weed population shifts. (Owen 2001b) The most influential selective forces that act on a weed community are tillage (disturbance) and herbicide regimes. The adoption of glyphosate resistant crops (GRCs) does not directly impart selection pressure on the weed community. However, the production systems used in GRCs increases selection pressure on the weed community due to the limited number herbicides (glyphosate) used to control weeds. Increased selection pressure increases weed population shifts. (Heard 2003) The selection pressure imparted by glyphosate will cause weed shifts attributable to the natural tolerance of a particular species to glyphosate or the evolution of glyphosate resistance within the weed population. A definition describing weed population shifts should include both evolved herbicide resistant weed populations and naturally tolerant weed populations which developed as a result of the selection pressure(s) imposed by the crop production system. Specifically for GRCs, both “types” of weed population shifts have occurred in response to grower adoption of GRC-based systems and the resultant application of glyphosate. In Iowa, we have documented weed shifts involving naturally tolerant weed populations, but glyphosate-resistant weed populations have not been identified. However, anecdotal evidence strongly supports the supposition that glyphosate-resistant weed populations have evolved in Iowa.
Speed of weed population shifts

It has been interesting to follow the predictions of how quickly weed shifts would develop. Early predictions suggested that shifts in weed populations would not evolve. (Bradshaw et al. 1997) This prediction was reinforced recently with a suggestion that due to a number of characteristics unique to glyphosate, resistance would evolve slowly and at a relatively low level in weed populations. (Sammons et al. 2007) Other predictions suggested that weed population shifts were inevitable and would occur sooner rather than later. (Owen 1997b; Owen 2000) Shifts to tolerant weed species were predicted to occur between 5 to 8 years after the adoption of GRCs and that species with resistance to glyphosate would evolve slower while others reported that the speed at which weed shifts were expected to occur was uncertain. (Shaner 2000; Duke 2005)

Resistance to glyphosate in isolated common waterhemp plants was observed two years after the commercialization of GR soybean and in horseweed, glyphosate resistance was widely distributed three years after GR soybean commercialization. (Zelaya and Owen 2000; VanGessel 2001; Zelaya and Owen 2002) In the case of common waterhemp, the progression from an occasional glyphosate-resistant individual within a common waterhemp population to a “homogenous” glyphosate-resistant population has taken longer than observed for horseweed. Seed dispersal is a critical component of weed community shifts. Generally, the more dispersal vectors that a species utilizes, the more successful a species is in an ecosystem. (Ozinga et al. 2004) However, environmental conditions impart an effect on weed seed dispersal. Horseweed is an excellent example of a weed species with a specialized dispersal mechanism that has facilitated a widespread, economically important weed population shifts in a relatively short period of time.

Evolved glyphosate resistance in weeds

The evolution of resistance to glyphosate has been aggressively debated for many years and is now an accepted fate of recurrent use of glyphosate in GRCs. It is now apparent that there were fewer constraints on the evolution of glyphosate resistance than originally proposed and resistance to glyphosate has evolved in many species and is widely distributed. (Gressel 1996; Owen and Zelaya 2005) While glyphosae resistant weeds have not been “officially” documented in Iowa, it is highly likely that populations exist and are awaiting “discovery”. Thus there is a need for alternative tactics to manage weeds in GRCs and the lack of alternatives continues to be a concern. New tactics will hopefully emerge in the very near future due to the increasing grower adoption of GRCs. (Owen 1997b; Shaner 2000)

Horseweed/marestail

Horseweed (Conyza canadensis) continues to escalate as a significant weed problem in GRCs and represents a weed shift attributable to ecological adaptation to the lack of disturbance in the agro ecosystems and evolved resistance to glyphosate. Anecdotal reports suggest that glyphosate-resistant horseweed populations are now frequent in the mid-Atlantic, mid-south, and Mississippi River Delta and Midwest regions of the United States and represents serious problems in no tillage cotton production. Herbicide resistance in a weed like horseweed is the worst case scenario for GRC-based production systems, given the ecological adaptation of the species to agro ecosystems with no tillage, the high level of fecundity and the facilitated long-distance transport of seeds. (Buhler and Owen 1997; Ozinga et al. 2004) The difficulty of managing horseweed with alternative herbicides reinforces the fact that horseweed is a significant
agronomic problem. The mechanism of glyphosate-resistance in horseweed is thought to be attributable to differential translocation of the herbicide. (Feng et al. 2004)

**Common waterhemp**

Common waterhemp (*Amaranthus tuberculatus*) represents a species that was well-adapted to the prevailing agro ecosystems in the Midwest, secondarily evolved resistance to most ALS inhibitor herbicides and ultimately evolved resistance to glyphosate. (Owen 1999; Zelaya and Owen 2000; Zelaya 2002) The first investigated reports of control problems with glyphosate were in 1998 in fields near Badger and Everly, Iowa. (Zelaya and Owen 2000; Zelaya and Owen 2002) Cursory evidence suggests that the genetically heritable glyphosate response is polygenic. (Zelaya and Owen 2002) Recent anecdotal reports from Iowa growers indicate that the difficulties of effectively managing common waterhemp with glyphosate are increasing rapidly. While these problems may be a function of poor management tactics or may reflect biological adaptation such as delayed emergence, evidence also supports an escalation of glyphosate resistance in populations. (Owen 1997a; Smith and Hallett 2006) The specific mechanism of glyphosate resistance is not currently known. Given the ability of common waterhemp to adapt to ecologically diverse agro ecosystems and numerous herbicide mechanisms of action, management options are often few. However, recent reports suggest that the common waterhemp seedbank is relatively short-lived and with diligence, can be managed effectively within five years. (Boerboom 2007b; Steckel et al. 2007)

**Other species**

Several other weed species have evolved resistance to glyphosate. These weeds were well-adapted to the agro ecosystem and had become a prevalent member of their respective weed communities. Further selection with recurrent applications of glyphosate in GRCs resulted in glyphosate-resistant populations of wild poinsettia (*Euphorbia heterophylla* L.) in Brazil and johnsongrass (*Sorghum halepense*) in Argentina. (Valverde and Gressel 2006; Service 2007; Vidal et al. 2007)

**Naturally adapted species to glyphosate-based systems**

A number of weeds have been described as having inherent tolerance to various herbicides. Adaptation to herbicide management is likely of less importance than ecological adaptation to the agro ecosystem, specifically the tillage regime and specific environmental conditions that prevail. However, several weeds which have historically demonstrated exceptional ecological adaptation to the prevailing agro ecosystem increased in prevalence across the Midwest with the adoption of GRCs.

**Common lambsquarters**

Common lambsquarters is adapted to conservation tillage systems and has been a difficult weed to manage in many crops, irrespective of the tactic used. Anecdotal observations across the Midwest have suggested that common lambsquarters populations were not responding to glyphosate in GR soybean. Common lambsquarters was a prevalent species in field experiments where 1 and 2 pass applications of glyphosate to GR soybean were compared. (Scursoni et al. 2007) However, the escape of common lambsquarters was attributed to biological adaptation (delayed emergence). Other factors such as weed size and light response are also reported to...
affect the variable response of common lambsquarters populations to glyphosate. (Kniss et al. 2004, 2005; Schuster et al. 2007) However, common lambsquarters populations were confirmed as glyphosate resistant in Ohio and current assessments in Indiana and Wisconsin also suggest the presence of glyphosate-resistant populations.(Boerboom 2005) There are populations in Iowa that are suspected to be glyphosate resistant.

**Giant ragweed**

Giant ragweed has been a significant weed problem in Ohio and Indiana for a number of years and is described as the major weed problem in those states.(Leer 2006) In GRCs, giant ragweed populations increased over time in long-term study conducted in Wisconsin. (Stoltenberg 2001) Furthermore, selection from ALS-inhibiting herbicides affected a rapid population shift to the resistant biotype. (Zelaya and Owen 2004; Leer 2006) Given the prevalence of GRCs in the Midwest and the resultant selection pressure from recurrent applications of glyphosate, it is not surprising the glyphosate-resistant giant ragweed populations evolved rather quickly and are now widely distributed across Ohio and Indiana. (Leer 2006) Anecdotal reports from growers in Iowa and Wisconsin suggest that there is a high probability that glyphosate-resistant giant ragweed populations have or will soon evolve in these states. (Boerboom 2007a)

**Velvetleaf**

Velvetleaf (*Abutilon theophrasti*) has historically been described as difficult to control with glyphosate. However, the tolerance of this economically important weed to glyphosate was not an issue until the widespread adoption of GRCs. Recent reports suggested that the survival of velvetleaf after exposure to glyphosate can be high.(Hartzler and Battles 2001) However, overall velvetleaf populations do not appear to be increasing dramatically as a result of GRCs and may likely be declining because the species is not well-adapted to the prevailing conservation tillage systems that are a significant component of GRCs. (Cerdeira and Duke 2006)

**Asiatic dayflower**

Asiatic dayflower (*Commelina communis*) has been a serious, albeit scattered weed problem in soybean, peanut and cotton fields in the Midwest, Mid-south and Southeast US for a number of years. Recent information suggests that Asiatic dayflower is spreading although not quickly (Boerboom, personal communication). Apparent natural tolerance to glyphosate and other biological characteristics (i.e. extended germination period) contribute to the inability of growers to effectively manage this weed.(Fawcett 2003) The mechanism(s) of tolerance to glyphosate exhibited by Asiatic dayflower have not been reported. Recent research has not demonstrated any consistent herbicide control tactics and it is anticipated that Asiatic dayflower populations will continue to increase given the predominance of GRCs. (Ulloa and Owen 2005)

**Other species**

There are a number of anecdotal reports from Iowa of weeds that are increasing in GRCs. Evening primrose (*Oenothera biennis*) has been reported to be an isolated but significant problem in specific Iowa fields where GRCs are cultivated. Evening primrose is a biennial and biennials are not commonly associated with crop production fields. However, with the adoption of GRCs and the concomitant use of no tillage, it is likely that some biennial plants could adapt to these systems. Reports suggest that evening primrose is not sensitive to glyphosate.
Wild parsnip (*Pastinaca sativa*) is another biennial plant that has been reported to be invading GRCs (and other non-GR cultivars) in Iowa. Wild parsnip is commonly found in roadsides, ditches and right-of-ways, but until recently was not observed to be a significant problem in row crops. Again, GRC-based systems which include conservation tillage practices and glyphosate may contribute to the successful invasion of this species into crop fields.

Pokeweed (*Phytolacca americana*) is a perennial weed that has increased in fields. It is unlikely that the ecological adaptation is attributable to GRCs other than the fact that GRC-based systems are predominately no tillage. Furthermore, the use of glyphosate provides effective control of most annual weeds thus providing an ecological opportunity for pokeweed to increase in the weed community.

Finally, field horsetail (*Equisetum arvense*) has effectively invaded row crop fields from field margins. Field horsetail is extremely tolerant of most herbicides including glyphosate, but the primary factor supporting this weed population shift is likely the conservation tillage systems that are prevalent in the Midwest US and the generally effective and consistent control of annual weed communities in GRCs with glyphosate.

**Managing “traited” corn as a volunteer or when replanting is necessary**

The 2007 spring planting conditions were not ideal and resulted in a significant number of corn acres that required replanting. ISU has discussed problems with destroying a corn stand or controlling volunteer corn in soybeans when the hybrid has herbicide resistance trait(s) in the past, but the message was reinforced this in 2007. With regard to destroying a corn stand, if the hybrid is Liberty Link, the task is relatively simple. Glyphosate will effectively destroy an unwanted corn stand if the only herbicide resistant trait is for glufosinate or the corn is not herbicide resistant. However, even in non-herbicide resistant corn hybrids, traits for glyphosate resistance show up and result in ineffective destruction of the stand. When the herbicide resistance trait is for glyphosate, the use of glufosinate is less consistent. And when traits are stacked, the tactics for managing corn in corn can be difficult at best. Some states in the Eastern corn belt received special labels for post grass herbicides labeled but the delay between application and replanting was problematic. Tillage may be the best solution. For controlling volunteer corn in soybean, glyphosate can be very effective unless the previous corn crop was Roundup Ready®. Another consideration is whether or not the glyphosate resistance trait moved into a non-herbicide resistant corn crop resulting in de facto Roundup Ready® volunteers. Thus, management of volunteer corn in soybeans is better handled by using a post grass herbicide registered for soybeans.

**Conclusions**

The number of new herbicides is beginning to increase slowly, however no new mechanisms of action have been discovered and are not likely to appear in the next decade. Thus stewardship of weed management tools is of premier importance. Use as many alternative tactics as possible in order to maintain effective, consistent and economically rewarding weed management. With regard to weed shifts, the pervasive question that must be answered is if a weed population shift is economically important. While it is apparent that weed population shifts and the evolved
glyphosate resistance are inevitable consequences of the widespread adoption of GRCs, the relative economic importance has not been determined and is likely a factor of the individual adapted weed population and the specific field. (Owen 2001a) Regardless, there is an urgent need to establish stewardship to protect glyphosate resistant crops and extend the utility of glyphosate as an effective herbicide.

References


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