# Management of Triazine-Resistant Pigweed and Lambsquarters

## An Integrated Approach

The first reported population of triazine resistance in the United States occurred in the late 1960s in Washington State with common groundsel *(Senecia vulgaris)*. Since that first discovery, more than 50 species of weeds scattered throughout the world have developed weed resistance problems. Triazine resistance, however, is by far the most serious weed resistance problem for farmers in the northeastern United States.

Herbicide resistance probably developed through the selection of naturally occurring biotypes of weeds that were exposed to the herbicides over a period of years. A biotype is a population of plants within the same species that have in common specific traits such as resistance to the triazine herbicides. Resistant plants survive, go to seed, and create new generations of herbicide-resistant weeds. Pigweed *(Amaranthus* sp.) and common lambsquarters *(Chenopodium album)* are the most common triazine-resistant species found in the northeast. In addition, isolated patches of barnyardgrass, giant and yellow foxtail, and velvetleaf also have been reported as being resistant to triazine herbicides.

Factors promoting the spread of triazine resistance in the northeast include monoculture cropping patterns such as growing continuous corn; using triazine herbicides such as atrazine and/or Princep (simazine) that are persistent in soil; farming without tillage or with reduced tillage where mechanical control options are seldom used; and spreading viable weed seed along with cattle manure in high livestock and dairy production areas.

At least three species of pigweed have biotypes that show resistance to triazine herbicides. These include smooth pigweed, redroot pigweed, and powell amaranth. Biotypes of smooth pigweed are the most common triazine-resistant pigweed species in the northeast. The spread of resistant pigweed appears linked to reduced tillage along with continuous corn production.

Triazine-resistant lambsquarters often infests the same fields as resistant pigweed. Whereas resistant pigweed appears linked more to reduced tillage, resistant lambsquarters occurs in areas where both reduced and conventional practices are commonly used. Past research suggests that limited crop rotation and ineffective herbicide use have caused resistant lambsquarters to spread.

Managing triazine-resistant pigweed and lambsquarters requires an integrated control program to reduce weed competitiveness. The methods should be preventive, cultural, mechanical, and chemical. The goal of an integrated program is to give reliable, effective weed control, while minimizing environmental hazards.

Techniques for avoiding herbicide resistance include the following:

- Rotate crops.
- Rotate herbicides and herbicide classes or families.
- Use herbicides with shorter residuals.
- Use effective herbicide mixtures from more than one class.
- Use nonchemical control measures such as cultivation.
- Avoid spreading weed seed with machinery, hay, or manure.
- Ensile infested forage crops to help destroy weed seed.

***Table 1. Triazine herbicides commonly used in the northeastern United States.***

| TRADE NAME | COMMON NAME |
|---|---|
| AAtrex, Atrazine | atrazine |
| Axiom | metribuzin + *flufenacet** |
| Bicep | atrazine + *metolachlor* |
| Bladex | cyanazine |
| Bullet | atrazine + *alachlor* |
| Canopy | metribuzin + *chlorimuron* |
| Extrazine II | atrazine + cyanazine |
| FulTime | atrazine + *acetochlor* |
| Guardsman | atrazine + *dimethenamid* |
| Harness Xtra | atrazine + *acetochlor* |
| Laddok | atrazine + *bentazon* |
| Lariat | atrazine + *alachlor* |
| LeadOff | atrazine + *dimethenamid* |
| Lexone | metribuzin |
| Marksman | atrazine + *dicamba* |
| Princep | simazine |
| Salute | metribuzin + *trifluralin* |
| Sencor | metribuzin |
| Shotgun | atrazine + *2,4-D* |
| Surpass 100 | atrazine + *acetochlor* |
| Sutazine | atrazine + *butylate* |
| Turbo | metribuzin + *metolachlor* |
| Velpar | hexazinone |

* Names in *italics* are not triazines.

## PREVENTION

Crop and herbicide rotation are the best methods for preventing the buildup of triazine-resistant weeds. Weeds often can be better managed in an alternate crop since different choices for managing weeds usually are available. For example, rotating to fall-seeded crops such as alfalfa or small grains helps interrupt the summer annual life cycle of pigweed and lambsquarters and ensures the presence of a competitive crop for emerging weeds.

Including herbicides other than triazines in the weed-control program prevents selection for resistant plants that can survive and reproduce. Triazine herbicides commonly used in the northeastern United States are listed in Table 1. While triazines still may control nonresistant weeds, using herbicides with a different mode of action is necessary for control and management of resistant biotypes. Therefore, it is important to recognize the mode of action (what plant processes are affected) for the different classes of herbicides and their effectiveness on pigweed and lambsquarters as well as other weeds.

Because resistant pigweed and lambsquarters are spread by seed, practices that encourage seed distribution should be avoided. Plant only certified, weed-free seed. Control weeds in fencerows and noncrop areas to reduce sources of seed. Harvest around isolated patches of resistant plants, rather than through them. Harvest infested fields last to prevent carrying seeds into other areas, and thoroughly clean equipment after working in infested fields. When practical, ensile infested crops to destroy seed viability. If corn contaminated with suspected triazine-resistant weeds is fed to cattle, spread the manure back on fields that already have a history of resistant weed problems. Do not infest fields that are currently free of resistant biotypes!

## GENERAL CULTURAL CONTROL

Good cultural control practices will help the crop compete against weeds and ensure that resistant weed populations are held in check or reduced. Here are some general guidelines:

- Follow soil test recommendations for lime and fertilizer.
- Plant high-yielding varieties adapted to your particular climate, soil, and field conditions.
- When possible, use narrow row spacings and high plant populations.
- Scout each field regularly for weeds, plant disease, and insect problems, and control them when necessary.
- Identify weeds resistant to triazine herbicides and control weed escapes to prevent the spread and buildup of resistant biotypes. Although later escapes may not influence crop yield, controlling these may have some benefit in reducing seed production. Preventive control measures, however, must be used in combination with chemical or mechanical controls to reduce the spread of weed seed. (Triazine resistance test kits are available commercially. Contact your local extension agent to learn how to acquire a test kit.)

## MECHANICAL CONTROL

Mechanical methods of weed control include plowing, disking, cultivating, mowing, hoeing, and hand pulling.

Tillage in the fall or spring can bury weed seed deep enough that emergence is reduced. This is particularly true for small-seeded weeds like pigweed and lambsquarters. Such tillage requires the use of a moldboard plow or other tool that inverts soil. Where soil erosion is a major concern, however, intensive tillage may not be possible or practical. Less intensive types of tillage such as chisel plowing, disking, or field cultivating prior to planting can destroy weeds that already have emerged but also may stimulate additional weed emergence.

In row crops, cultivation removes or buries small weeds and makes them less competitive. One or two cultivations during the first six weeks after planting corn or soybeans will help control weeds missed by the herbicide treatment and provides a good alternative to a postemergence herbicide application. Cultivation may not control weeds within the crop rows, however, and is not effective on weeds that germinate following cultivation.

Mowing will prevent resistant pigweed and lambsquarters from setting seed in forages, pastures, and noncrop areas. Hand pulling and hoeing are useful for controlling small patches of weeds. Because infestations of triazine-resistant pigweed usually begin from a few resistant plants, these methods often are worth the extra labor and time they require.

## CHEMICAL CONTROL

Herbicides should be used in combination with preventive, cultural, and mechanical methods. To make herbicides as effective, safe, and economical as possible, always:

- Select the appropriate herbicide for your weed problem and crop. For additional information, refer to *The Penn State Agronomy Guide* or *The Field Crop Weed Contol Guide*, or consult your local extension agent.
- Read the label and carefully follow directions. The label provides important information on the safe use, application, disposal, and storage of the product.
- Apply herbicides at the proper time. Temperature, soil moisture, soil pH, and the stages of weed and crop growth can affect herbicide performance.
- Use the recommended application rate. Inaccuracy can cause crop injury, carryover, or poor control.
- Prevent disposal problems. Mix only the amount of spray solution that you need.
- Calibrate application equipment. Frequent calibration during the season ensures application of the correct amount of herbicide.
- Wear proper protective clothing.
- Learn to predict weed problems. Scout your fields regularly and record the types and locations of weeds present. Use your records to plan an integrated control program for the following season.

***Table 2. Effectiveness of corn herbicides for triazine-resistant (TR) pigweed and lambsquarters control.***
Weed control rating: 10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, and N = <55% control.

| HERBICIDE CLASS | HERBICIDE FAMILY | FAMILY MEMBERS | TR PIGWEED | TR LAMBSQUARTERS |
|---|---|---|---|---|
| **Soil Applied** | | | | |
| Amino acid biosynthesis | Sulfonamide | Python (flumetsulam) | **9** | **9** |
| | Sulfonylurea | Basis (rimsulfuron + thifensulfuron) | **9** | **8+** |
| Photosynthesis inhibitor (mobile) | Phenylurea | Lorox (linuron) | 8 | **8+** |
| Seedling growth inhibitor | Chloroacetamide/oxyacetamide | Axiom (metribuzin + flufenacet) | N | N |
| | | Dual products (metolachlor) | 8 | 6 |
| | | Frontier (dimethenamid) | 8 | 6 |
| | | Harness/Surpass/TopNotch (acetochlor) | **9** | 7 |
| | | MicroTech (alachlor) | **8+** | 6+ |
| | Dinitroaniline | Prowl (pendimethalin) | 8 | **9** |
| | Thiocarbamate | Sutan (butylate) | 8 | 6 |
| **Postemergence** | | | | |
| Amino acid biosynthesis | Amino acid derivative | Roundup (glyphosate) | **9** | **8+** |
| | Imidazolinone | Lightning (imazapyr + imazethapyr) | **9+** | 8 |
| | Sulfonylurea | Accent (nicosulfuron) | **9** | 6 |
| | | Basis (rimsulfuron + thifensulfuron) | **9** | **8+** |
| | | Beacon (primisulfuron) | **9** | 7 |
| | | Exceed/Spirit (primisulfuron + prosulfuron) | **9/8+** | 8/7+ |
| | | Pinnacle (thifensulfuron) | **9** | **9** |
| | | Permit (halosulfuron) | **9** | N |
| Cell membrane disrupter | Triazolinone | Aim (carfentrazone) | **9** | **9** |
| Phosphorylated amino acid | Amino acid derivative | Liberty (glufosinate) | 8 | **9** |
| Photosynthesis inhibitor (nonmobile) | Nitrile | Buctril (bromoxynil) | 7 | **9** |
| | Benzothiadiazole | Basagran or Laddok (bentazon) | 6+ | 8 |
| | Phenyl-pyridazine | Tough (pyridate) | **9** | **9** |
| Plant growth regulator | Phenoxy and Benzoic | 2,4-D | **9** | **9** |
| | | Banvel, Clarity, or Marksman (dicamba) | **9** | **9** |

### Control of triazine-resistant pigweed and lambsquarters in corn

Triazine herbicides never should be the only class of herbicides used in triazine-resistant fields. Triazine herbicides used in corn include atrazine, simazine (Princep), cyanazine (Bladex), and an atrazine plus cyanazine premixture (Extrazine II). Atrazine also is found in a number of premixed herbicide products (see Table 1), some of which also contain herbicides that belong to different chemical classes. The triazine herbicides in these premixtures may control non-triazine-resistant weeds, but will provide very little or no triazine-resistant pigweed or lambsquarters control. Table 2 shows the effectiveness of corn herbicides on triazine-resistant pigweed and lambsquarters.

Research in the northeast shows that soil-applied herbicides alone often will not provide the season-long control needed to prevent triazine-resistant weed seed production. In addition, most postemergent herbicides used in corn do not have sufficient soil residual activity to control flushes of triazine-resistant weeds that emerge after the herbicide has been applied. Although soil-applied or postemergence herbicides should reduce weed competition, a combination of soil-applied herbicides and postemergence control probably is needed to reduce seed production. Postemergence control could include cultivation or application of a postemergence herbicide.

### Control of triazine-resistant pigweed and lambsquarters in soybean

Chemical control strategies for soybean are similar to those for corn. Metribuzin (Lexone, Sencor, and a component of Canopy) is the only triazine herbicide used in soybean and should not be the foundation for controlling triazine-resistant weeds. Unlike corn weed control, several of the newer soil-applied or postemergence broadleaf herbicides available for soybean weed control are more persistent in soil and may provide season-long control of both pigweed and lambsquarters. If postemergence control measures are necessary, several herbicides are effective on triazine-resistant pigweed. Postemergence control of lambsquarters in soybean is more challenging, but also possible. Table 3 shows the effectiveness of soybean herbicides on triazine-resistant pigweed and lambsquarters.

## OTHER RESISTANCE CONCERNS

The sulfonylureas are another class of herbicides for which weed resistance is a concern. Sulfonylurea-resistant biotypes of kochia *(Kochia scoparia)*, Russian thistle *(Sasoli kali)*, and prickly lettuce *(Lactuca serriola)* were discovered in the western United States where Glean (chlorsulfuron) was used over a 5- to 6-year period in winter wheat. Although Glean is not available in the northeast, other members of the sulfonylurea herbicide class are used in corn, soybean, wheat, or pasture. Members of this class include Accent (nicosulfuron), Ally

***Table 3. Effectiveness of soybean herbicides for triazine-resistant (TR) pigweed and lambsquarters control.***
Weed control rating: 10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, and N = <55% control.

| HERBICIDE CLASS | HERBICIDE FAMILY | FAMILY MEMBERS | TR PIGWEED | TR LAMBSQUARTERS |
|---|---|---|---|---|
| **Soil Applied** | | | | |
| Amino acid biosynthesis | Imidazolinone | Pursuit (imazethapyr) | **9** | 8 |
| | | Scepter (imazaquin) | **9+** | **9** |
| | Sulfonamide | Python (flumetsulam) | **9** | **9** |
| | Sulfonylurea | Canopy (chlorimuron + metribuzin) | **9** | **8+** |
| Amino acid biosynthesis + cell membrane disrupter | Sulfonylurea + triazolinone | Canopy XL (chlorimuron + sulfentrazone) | **9** | **9** |
| Photosynthesis inhibitor (mobile) | Phenylurea | Lorox (linuron) | 8 | **8+** |
| Seedling growth inhibitor | Chloroacetamide/oxyacetamide | Axiom (metribuzin + flufenacet) | N | N |
| | | Dual products (metolachlor) | 8 | 6 |
| | | Frontier (dimethenamid) | 8 | 6 |
| | | MicroTech (alachlor) | **8+** | 6+ |
| Pigment inhibitor | Isoxazolidinone | Command (clomazone) | 7 | **9+** |
| **Postemergence** | | | | |
| Amino acid biosynthesis | Amino acid derivative | Roundup (glyphosate) | **9** | **8+** |
| | Imidazolinone | Pursuit (imazethapyr) | **9** | 7 |
| | | Raptor (imazamox) | **9** | **8+** |
| | Sulfonamide | FirstRate (cloransulam) | N | N |
| | Sulfonylurea | Classic (chlorimuron) | **9** | 7 |
| | | Pinnacle (thifensulfuron) | **9** | **9** |
| Cell membrane disrupter | Diphenyl ether | Blazer (acifluorfen) | **9** | 7 |
| | | Cobra (lactofen) | **9** | 7 |
| | | Reflex/Flexstar (fomesafen) | **9** | 7 |
| | N-phenyl-phthalimide | Resource (flumiclorac) | 7+ | 7 |
| Phosphorylated amino acid | Amino acid derivative | Liberty (glufosinate) | 8 | **9** |
| Photosynthesis inhibitor (nonmobile) | Benzothiadiazole | Basagran (bentazon) | 6+ | 8 |

(metsulfuron), Beacon (primisulfuron), Canopy (chlorimuron + metribuzin), Classic (chlorimuron), Exceed (primisulfuron + prosulfuron), Harmony Extra (thifensulfuron + tribenuron), Permit (halosulfuron), and Pinnacle (thifensulfuron).

In addition, the imidazolinone herbicides, which include Lightning (imazethapyr + imazapyr), Pursuit (imazethapyr), Raptor (imazamox), and Scepter (imazaquin), have the same mode of action as the sulfonylurea herbicides and may develop a similar weed resistance problem in the future. Imidazolinone-resistant pigweed and water hemp already have become problems in some areas of the northeast and midwest. Herbicide rotation in an integrated control program can prevent future problems. Dependence on a single strategy and herbicide class for weed control surely will increase the likelihood of additional weed resistance problems in the northeast.

## SUMMARY

Triazine-resistant pigweed and lambsquarters require an integrated control program for effective management. A successful control program depends on early and accurate identification as well as consistent use of preventive, cultural, mechanical, and chemical control methods.

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