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PPP-67

Atrazine Use and Weed Management Strategies to Protect Surface Water Quality

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Cover photograph credit: Ohio State Extension Service.

Introduction

Water quality protection in watersheds using surface water as drinking water is a high priority in Indiana. Agriculture's role in developing and implementing stewardship practices that minimize runoff of sediment, nutrients, and pesticides is crucial to effective watershed management programs. This publication discusses the importance of atrazine products to Indiana farmers, and best management practices (BMPs) for achieving weed control and reducing off-site movement into surface water.

Atrazine Use in Indiana

Atrazine and dozens of products containing atrazine were used on approximately 83 percent of Indiana's 2003 corn acreage at an average rate of 1.25 pounds of active ingredient per acre (ai/A). This amounts to almost 6 million pounds of atrazine applied to Indiana corn in 2003. The reason growers rely on atrazine is simple: Atrazine, used alone or in combination with other products, has a long history of providing residual broad-spectrum weed control in conventional, conservation, and no-tillage systems. It is safe to use on corn and is competitively priced. Growers use atrazine because it controls weeds effectively and economically.

Weeds in a cornfield reduce yield and quality, and corn competing with weeds will always be a problem because every agronomic field has a weed infestation capable of causing economic loss. The average field of corn has over 20 different species of weeds; and the soil contains millions of seeds, some of which can survive up to 20 years in the soil.

Most pesticides have drawbacks: applicator safety requirements, water quality concerns, carryover to other crops, wildlife considerations, etc. Most atrazine applications occur during April and May, coinciding with heavy spring rains that saturate the soil. Heavy rain following atrazine applications can result in runoff from farm fields into nearby streams and reservoirs. This is a major concern, especially in wet years, in communities that process their drinking water from surface water. Surface water accounts for half the drinking water in Indiana (see Figure 1). Growers should keep surface water in mind and practice good stewardship to keep atrazine available for weed control in corn.

Although atrazine has been found in surface water supplies, its weed control benefit to Indiana corn farmers cannot be overstated. The loss of atrazine in Indiana would have a major influence on current weed control strategies. Without atrazine, more postemergence weed control

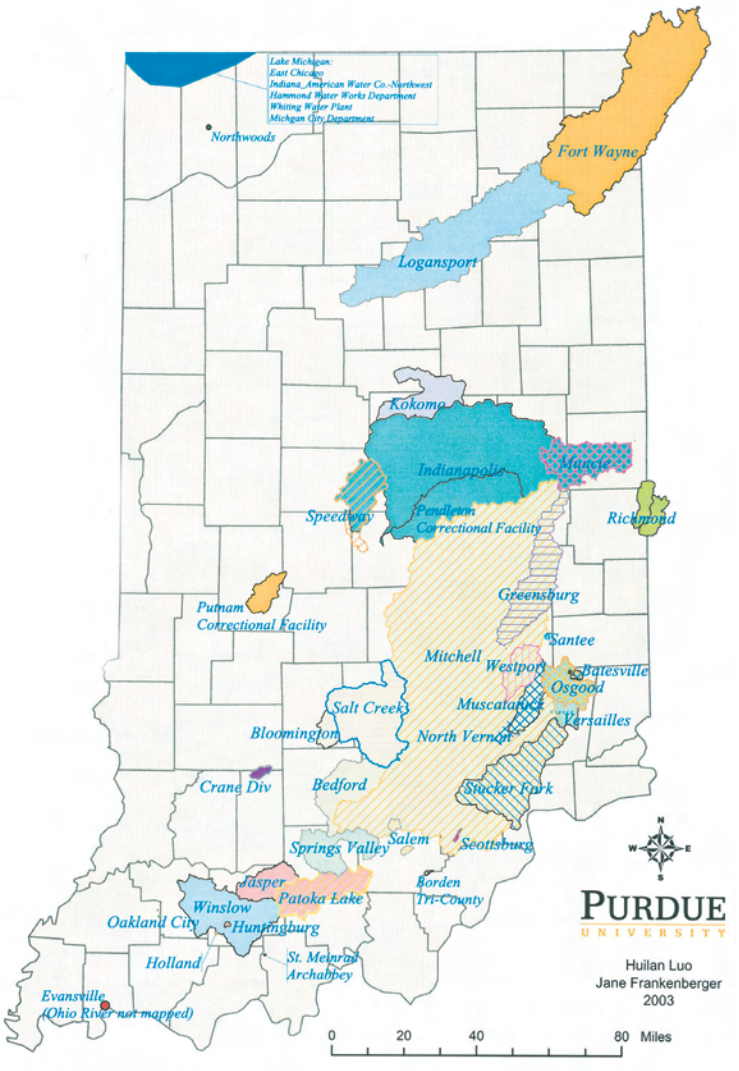

Figure 1. Public drinking water systems and watershed boundaries in Indiana. The eleven watersheds in the atrazine monitoring program include Indianapolis (Eagle Creek), Santee, Batesville, Bedford, Fort Wayne, Jasper, Logansport, Stucker Fork, Versailles, Westport, Winslow.

would be used on both conventional (non-transgenic) and herbicide-resistant corn varieties. Total postemergence weed control programs in corn would increase the pressure on custom and private applicators to spray corn and soybeans at approximately the same time in the spring. Weed control efficacy, crop yields, crop quality, and farm profitability could be negatively impacted because corn is extremely sensitive to early season weed competition. More reliance on glyphosate (Roundup®) and Roundup Ready™ corn varieties would increase selection pressure for resistant weeds since approximately 90 percent of Indiana's soybean acres are planted to Roundup Ready™ varieties. Atrazine is a crucial tool for minimizing yield loss due to weed competition, and for reducing selection pressure for herbicide-resistant weeds.

Atrazine in Indiana Surface Water

The annual average concentration of atrazine in both raw and finished water is well below the maximum contamination level (MCL). However, the presence of pesticides such as atrazine raises concerns among government officials, water utility companies, and consumers. Atrazine at various concentrations has been found in roughly half of all finished surface water samples in Indiana.

Pesticide concentrations in streams and rivers are highly seasonal, peaking during the first few runoff-producing storms after application, followed by rapid decline. However, pesticides remain longer in lakes and reservoirs than in rivers and streams. Reservoirs in watersheds where corn is the predominant crop are especially vulnerable since many do not have outlets: water, sediment, and pollutants that flow into them may remain there indefinitely, flowing out only during wet years.

See companion publication PPP-66, *Atrazine and Drinking Water,* for more specific information on the presence of atrazine in Indiana surface water supplies.

Factors Influencing Atrazine Movement

Atrazine can be applied to the soil surface either before or after planting, incorporated into the soil prior to planting, or sprayed on corn and weeds, postemergence. Knowing that atrazine moves predominately in solution (dissolved in water) versus attaching to soil particles aids our understanding of how to reduce its movement off-site.

It is important to understand how atrazine works to control weeds. When applied on or incorporated into the soil, atrazine reaches the soil profile dissolved in rainwater. It is absorbed through the roots of corn plants and weeds, but corn plants can detoxify atrazine and are seldom affected by root absorption. Atrazine applied postemergence is primarily absorbed through the leaves, but any atrazine that reaches the soil surface is absorbed by plant roots as described above.

Tillage practice. Most growers are familiar with the production and environmental strengths and weaknesses of the various tillage systems. For example, we know that reducing soil tillage leaves more crop residue on the surface, which reduces runoff and topsoil erosion.

Most atrazine moves off-site in solution rather than attached to soil particles. Residue left on minimum-tilled ground slows the movement of water across a field after a rain, thus reducing runoff; and the greater the reduction, the more water—and atrazine—infiltrates the soil at the treatment site. The water carrying dissolved atrazine is more likely to stay on the field longer and be available to weed roots, thus reducing the amount reaching surface water.

Managing atrazine runoff is important. Most soils can absorb a light rainfall, but heavy rain over a short period saturates the soil quickly; the excess water—and the atrazine it contains in solution—exits the field as runoff. The same is true when there is light rain over an extended period of time. In either case, the concern is that atrazine runoff might reach surface water.

Crop residue on the soil surface reduces atrazine runoff in most Indiana fields. However, on clay soils with a restrictive layer (common in southeastern Indiana) the potential for atrazine runoff increases in no-till systems: the restrictive subsoil layer limits water infiltration. These soils tend to be wetter in the spring when herbicide applications are made. Studies on similar soils in Missouri have shown that heavy rainfall following atrazine applications increases atrazine loss by 20 percent. On southeastern Indiana clay soils, incorporation of soil-applied atrazine is recommended to help it move into the soil profile and reduce off-site movement.

> **Key points:** Tillage practices that minimize runoff and increase water infiltration can reduce off-site atrazine movement. No-till practices on well-drained soils increase water infiltration. Light incorporation of soil-applied atrazine is recommended on soils with a restrictive subsoil layer.

Drainage tiles. Tiles that discharge water into a ditch or creek play an important role in draining low-lying areas. Improved water and atrazine infiltration occurs in tiled fields where atrazine can be adsorbed by organic matter and absorbed plant roots. Data collected by Purdue University water quality researchers over the last decade has shown very little atrazine movement in tile flow.

> **Key point:** Drainage tiles reduce off-site atrazine movement by encouraging water and atrazine infiltration into the soil where it is adsorbed by organic matter, clay, and absorbed plant roots.

Field distance to surface water. The greater the distance from field to surface water, the less likely it is that significant amounts of atrazine will enter the body of water. Rainwater runoff from farm fields can travel through grass waterways, ditches, grass filter strips, grass borders, and other fields. The ground itself has the filtering capacity to drain

Figure 2. Crop residue slows water movement across the field, giving it, and dissolved atrazine, an opportunity to soak into the soil profile.

Figure 3. Tile improves a field's internal drainage, encouraging percolation of water and atrazine.

water and absorb atrazine. The more atrazine moves across other fields and soil, the more likely it is to infiltrate the soil profile.

> **Key point:** The greater the distance between an atrazine-treated field and surface water, the less likely it is that atrazine will impact surface water quality.

Timing, intensity, and duration of precipitation. Herbicide concentrations in runoff depend on how saturated the soil is when the herbicide is applied, the interval between herbicide application and precipitation, the intensity and duration of rainfall events, and the total amount of precipitation. In Indiana, rainfall intensity peaks in April and May, but the first two rains after application are responsible for most atrazine lost in runoff.

The worst case scenario is a heavy rain on saturated soils soon after an atrazine application. Instead of infiltrating the soil, the herbicide on or very near the soil surface is carried from the field in runoff.

> **Key point:** Because of atrazine's high water solubility, applications should be delayed as long as soils are saturated and more rain is predicted. Increasing the separation time between heavy rainfall and atrazine application improves the potential to keep it in the field.

Practices to Reduce Atrazine Losses to Surface Water

Best Management Practices to Reduce Atrazine Loss

- ❖ Delay applications when rainfall is imminent.
- ❖ Manage soil to maximize water infiltration.
- ❖ Make applications away from tile standpipes.
- ❖ Use filter strips.
- ❖ Adapt weed control strategies.

Most fields do not require special management to prevent off-site atrazine movement in runoff; but fields that are close to surface water warrant your attention. You may need to make only a few changes to reduce atrazine losses from most fields, but some areas will require more effort. The following suggestions are for your consideration.

Delay applications when soil is saturated and/or rainfall is predicted. The greatest atrazine loss occurs when intense rainfall immediately follows an atrazine application to bare, wet soil. If rainfall is imminent, delay applications until soil and weather conditions improve.

Manage soil to maximize water infiltration by taking steps such as installing tiles to expedite the drainage of water from the soil surface.

Allow soils to dry before tilling or other operations to reduce compaction.

Target applications away from tile standpipes. The atrazine label prohibits its application within 66 feet of a tile inlet or standpipe unless it is incorporated and/or unless greater than 30 percent residue is present. Consider planting grass filter strips around standpipes to keep weeds in check and minimize the entrance of soil into the tile system.

Use filter strips to slow water movement. Grass waterways and properly

designed filter strips along bodies of water help slow runoff, allowing water and atrazine to percolate into the soil. Filter strips effectually distance herbicide application sites from bodies of water.

Filter strips must be well managed to maintain optimal growth. Eliminate weeds and tall brush that can shade the grass, resulting in bare spots, and prevent water from channeling across narrow areas of grass. Channels conducive to atrazine pooling can develop when a berm is allowed to form along the edge of a buffer strip.

Cool-season grasses such as fescue and bluegrass can be injured by atrazine, keeping waterways and filter strips from functioning properly. Warm-season species such as switchgrass are more tolerant of atrazine, but they are more difficult to establish and maintain. Turn off the sprayer when crossing grass waterways, and avoid spray drift into waterways, streams, and impounded water.

Figure 4. Most atrazine applications in Indiana occur in April and May, coinciding with heavy spring rains. The first two precipitation events following an atrazine application results in the most atrazine lost from a field.

Alterations in Weed Management Tactics

Production changes—tillage, fertilization, variety choice,—and application timing can greatly reduce the amount of atrazine that leaves the field; and you may be able to achieve weed control with less atrazine by using an alternative application method such as incorporation into the soil. There are many herbicides available for use in corn, each with its unique marketing and assurance programs, but we will not address specific products in this publication. Examine the different weed control strategies for corn and choose the herbicides that will work in your specific situation. Additional information on product selection can be obtained through your local agronomist, ag retailer, or crop advisor, or in publications such as the *Weed Control Guide for Ohio and Indiana* (WS-16), *WeedSOFT* or *Indiana Select-A-Herb.*

Incorporate atrazine. Research shows that light tillage following application increases the infiltration of atrazine into the soil, reducing off-site movement. This is because atrazine moves primarily in solution with water as runoff, not by attaching to soil particles, and incorporation reduces the amount of atrazine left on the soil surface. However, erosion losses are greater on highly erodible soils that are tilled, and the effect could be worse than that from herbicide runoff.

Figure 5. In general, wide, uniform filter strips composed of dense, deep-rooted plants are most effective in protecting surface water from contamination from run-off.

Reduce soil-applied atrazine rates by tank mixing atrazine with other herbicides. A low-rate atrazine premix, tank-mixed with another broadleaf herbicide, can reduce the amount of atrazine applied by 30 to 50 percent—without sacrificing overall weed control. Commercially available soil-applied atrazine premixes used in Indiana deliver from 1 to 2 lb ai/A of atrazine at labeled use rates. A use rate of 1 lb ai/A is needed

to provide meaningful residual activity; lower rates usually do not achieve acceptable weed control.

Atrazine premixes have been designed for use in atrazine-sensitive watersheds. Those used in the northern Corn Belt include Bicep II Lite Magnum®, Guardsman Max Lite®, Degree Xtra®, Harness Xtra 6.0®, and Lumax®. These products deliver about 1 lb ai/A compared to the standard products' 1.6 to 2 lb ai/A. They provide good control of most annual grassy weed species but may need tank mix partners to improve control of specific broadleaf weeds; postemergence strategies may be required to control escaped weeds.

Balance Pro®, Callisto™, and Hornet® are soil-applied products commonly added to atrazine premixes. Table 1 shows how well these products performed on specific troublesome broadleaf weed species.

Typically, control of the broadleaf weeds in Table 1 should be 90 percent or higher. Purdue University research shows that the products in Table 2 are effective in controlling specific troublesome species that atrazine misses at low rates—and all are logical, safe, and effective tankmix additives for soil applied atrazine premixes.

Table 1. Control of various broadleaf weeds in corn, 40 to 60 days after planting with atrazine or alternative products.

Herbicide Program	Velvetleaf	Giant ragweed	Common lambs-quarters	Ivyleaf morningglory	Average
	----------% control----------				
Atrazine	69	75	94	70	77
Balance Pro®	93	90	99	56	85
Hornet WDG®	86	93	99	75	88
Callisto™	99	91	99	90	95
Average	87	87	98	73	

Source: Purdue University Weed Science Research Program, 1995–2003.

For example, the addition of Balance Pro® to an atrazine premix would improve control of velvetleaf, giant ragweed, and lambsquarters, but it would not be effective on morningglory. Hornet WDG® would improve control of velvetleaf, giant ragweed, and lambsquarters, but not morningglory. Callisto™ would improve control of all four species shown in Table 1.

Although you might consider using the aforementioned products in place of atrazine, be aware that the total number of species controlled by each product listed is less than the number controlled by atrazine alone (Table 2). The best use of these products is as a tank additive to an atrazine premix.

Table 2. Relative effectiveness of soil-applied atrazine replacements on selected troublesome broadleaf weed species. Ratings are based on labeled application rates.

	Annual morning-glory	Burcucumber	Cocklebur	ALS-resistant giant ragweed	Triazine resistant Lambs-quarters	Velvetleaf	Number of broadleaf weeds controlled
Atrazine	80-89%	60-69%	80-89%	80-89%	No control	80-89%	13
Balance Pro®	Poor control	70-79%	Poor control	60-69%	90-100%	80-89%	9
Callisto™	60-69%	70-79%	Poor control	60-69%	90-100%	90-100%	8
Hornet®	60-69%	Poor control	80-89%	70-79%	90-100%	90-100%	10
Python®	Poor control	Poor control	70-79%	No control	90-100%	80-89%	6

Source: 2004 Weed Control Guide for Ohio and Indiana. Purdue Extension publication WS-16.

Use atrazine postemergence. One of the positive aspects of atrazine is that it can be applied either before or after planting, but postemergence application is recommended.

Rates, tank mix products, and adjuvants can be adjusted according to application timing. Atrazine rates are reduced 30 to 75 percent if application is delayed until the weeds emerge because the herbicide can be placed directly on the weed foliage, which is preferable to relying on uptake from the soil. Control of specific weeds such as burcucumber, morningglory, and cocklebur is improved when atrazine is applied postemergence (Table 3). Giant ragweed and velvetleaf control is similar with preemergence and postemergence applications.

The downside to making a postemergence application of atrazine, alone or tank-mixed with other products, is a narrower window of opportunity to make the application: the label requires atrazine to be applied on corn 12 inches high (or shorter) and two hours before rain. Target fields with the greatest runoff potential for postemergence application to reduce the risk of a missed application.

Although atrazine can be used alone, it is more commonly used in combination with other herbicides; and applying atrazine postemergence allows you to reduce the total amount applied (because it reaches the foliage immediately). Consider other farm operations that must occur during the same time to determine if you can make a timely postemergence application. Atrazine applied preemergence to unprotected soil is vulnerable to escaping the field in runoff if rain occurs shortly thereafter.

If you tank-mix atrazine with postemergence broadleaf herbicides, consult the labels of each product for appropriate spray additives. If tank mixing with a postemergence grass herbicide such as Accent®, Celebrity Plus®, Equip®, Steadfast®, Option®, or Beacon®, it is recommended not to use more than 0.75 lb ai/A of atrazine to avoid reduced grass control.

Table 3. Relative effectiveness of atrazine applied preemergence versus postemergence on selected broadleaf weed species.

Atrazine Application at Labeled Rates	Pre	Post
Annual morningglory	80-89%	90-100%
Burcucumber	60-69%	80-89%
Common cocklebur	80-89%	90-100%
ALS-resistant giant ragweed	80-89%	80-89%
Velvetleaf	80-89%	80-89%

Source: 2004 Weed Control Guide for Indiana and Ohio Extension publication WS-16.

Use herbicide-resistant corn varieties. Herbicide-resistant corn varieties allow the use of broad-spectrum herbicides directly to corn, with little risk of crop injury. Roundup Ready™, Liberty Link™, and Clearfield™ corn varieties are widely available, and numerous studies have shown that—if managed properly—weed control, crop yields, and net returns are competitive with conventional varieties. These types of weed management programs allow you to use alternative herbicides in lieu of atrazine; and in many ways this is the perfect option. However, the potential for development of resistant weeds, particularly glyphosate (Roundup®) resistant weeds, raises concerns among agricultural scientists and the crop protection industry. This is of particular concern since glyphosate is already used on most Indiana soybeans.

The most reliable weed control strategies in all types of herbicide-resistant corn still require the use of residual herbicides applied preemergence or tank-mixed with an appropriate postemergence herbicide. Atrazine can be used in herbicide-resistant corn and, in fact, most studies have shown that adding 0.75 lb ai/A of atrazine with a postemergence herbicide has enhanced overall weed control and crop yields. These strategies reduce atrazine rates 50 to 100 percent compared to using full soil-applied rates of atrazine premixes.

Use lower soil-applied atrazine rates with zone herbicide application (ZHA). Reduced-rate ZHA uses a soil residual herbicide banded over crop rows at reduced rates; and it uses the same herbicide banded between rows at rates higher than in rows but lower than the maximum registered rate (Figure 6). The net result is that ZHA reduces not only the total herbicide use per acre but also your herbicide input costs in competitive field crops—without compromising net returns.

ZHA does not require major or expensive changes to current weed management and crop production practices. Because reduced herbicide rates are used, ZHA probably should not be used for weeds that are herbicide-resistant or for those that are only "suppressed" by the herbicide. In Missouri research conducted over a five-year period, atrazine + s-metolachlor (e.g., Bicep II®) use in field corn was reduced approximately 47 percent without reducing annual weed control (mostly giant foxtail and common waterhemp), corn yield, or net returns.

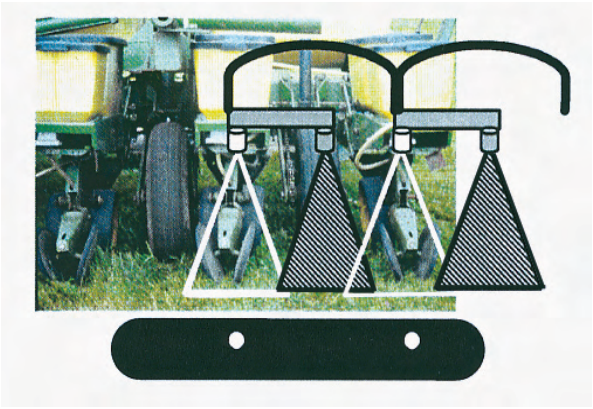

Figure 6. Zone herbicide application of preemergence herbicide is best made at planting. Spray nozzles can be attached to planter boxes so that herbicide is applied at different rates in-row and between-row.

Atrazine Label Setback Requirements

The label specifically states how, when, and where applications are to be made to prevent atrazine from leaving the application site and reaching surface water. Key points on the label include the following.

For streams and rivers:

1. Do not mix or load within 50 feet of any stream or river.
2. Do not apply within 66 feet of points where surface water enters an intermittent or perennial stream or river.
3. Do not apply within 66 feet of a tile inlet unless atrazine is incorporated and/or greater than 30 percent residue is present. Consider establishing a 66-foot filter strip around the inlet.

For lakes and reservoirs:

1. Do not mix or load within 50 feet of the water's edge.
2. Do not apply within 200 feet of the water's edge.
3. Consider establishing filter strips.

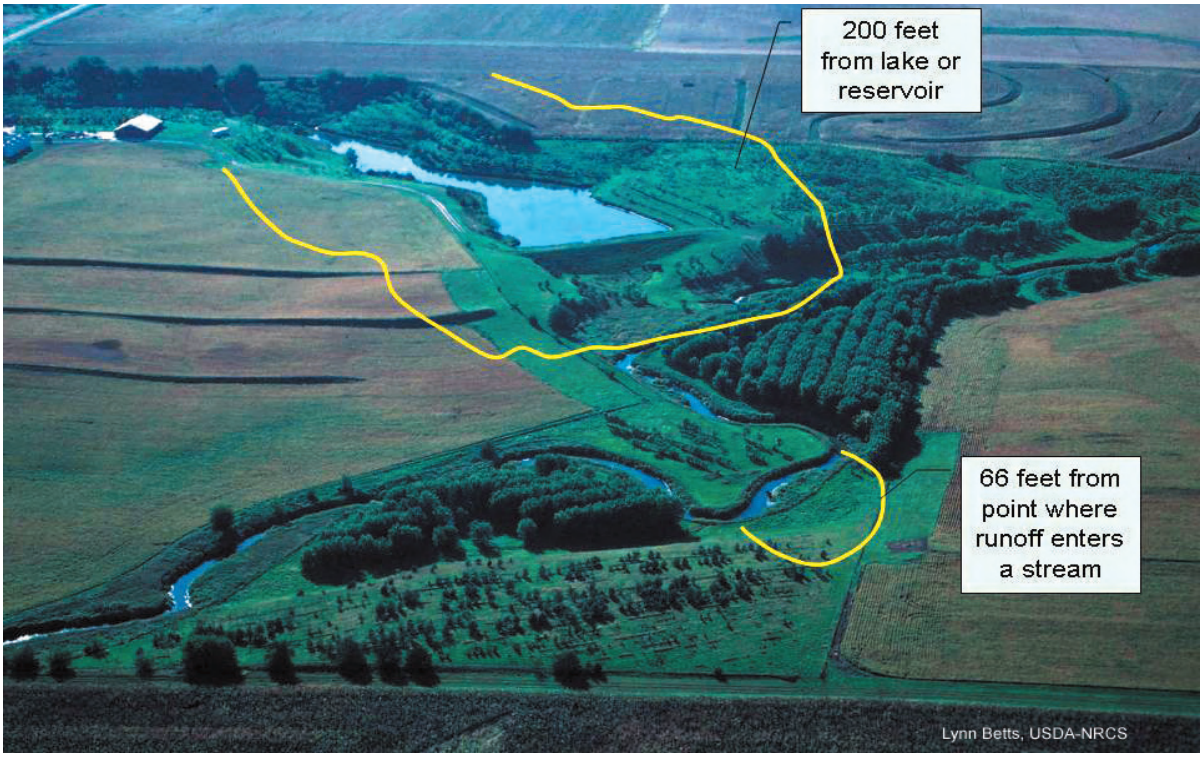

Figure 7. Setback distances reduce the chances of pesticides entering surface water from run-off or spills during mixing and application.

What Approaches Are Less Effective

Early preplant applications of atrazine. While early preplant herbicide applications offer flexibility in corn production, they often fail to control weeds for the entire growing season, thereby requiring postemergence weed management strategies to achieve control. This is more likely to occur in the southern portion of the state where the growing season is longer. Applying herbicides as close to planting as possible and using supplemental postemergence weed management strategies will provide the most consistent weed control and yields in Indiana corn.

In a four-year study in Missouri, herbicide applications made 15 days or more prior to planting resulted in lower weed control and crop yield than did applications made at or near planting (Table 4).

Table 4. Influence of Bicep® (a premix of atrazine and metolachlor) date of application on weed control and corn yield in Novelty, Missouri. 1991–1999.

Herbicide Application Date (days before planting)	Weed Control (percentage)	Corn Yield (bu./acre)
0	73	148
15	56	126
30	57	114
45	52	123

Source: University of Missouri Extension and Research

Weed control was assessed in early July and individual ratings were averaged over all species present: giant foxtail, fall panicum, velvetleaf, common cocklebur, and common lambsquarters.

Programs to Assist Farmers

The Indiana Conservation Partnership helps farmers meet public environmental goals by providing cost-share programs and technical assistance. Listed below are government-sponsored programs that you might find beneficial as you attempt to reduce the amount of atrazine reaching surface water. Contact the local agency for the availability of technical and financial support and application requirements.

Continuous Conservation Reserve Program (CRP)—administered by the Farm Service Agency and Natural Resources Conservation Service

Farmers can receive an annual rental payment and cost share for the establishment (seeding, site preparation, fencing, etc.) of grass filter strips or riparian buffers on eligible acreage. For more information go to http://www.fsa.usda.gov/IN/.

Environmental Quality Incentive Program (EQIP)—administered by the Natural Resources Conservation Service and the Farm Service Agency

EQIP offers financial and technical assistance with installation and implementation of pesticide management practices. More details can be found at http://www.in.nrcs.usda.gov/programs/2003eqip/eqip.html.

Lake and River Enhancement (LARE)—administered by Indiana Department of Natural Resources, Division of Soil Conservation

In select watersheds, a filter strip and/or pest management incentive payments may be available. For more information contact IDNR, Division of Soil Conservation. For more details go to http://www.in.gov.dnr/soilscons/programs/lare.html.

Conclusion

Weeds must be managed to maximize production. They not only reduce yields but also impede planting and harvesting, lower grain quality, and create problems in subsequent years. Mechanical cultivation reduces weed infestations, but it increases soil erosion and requires more time and fuel. Reducing dependence on mechanical cultivation helps to reduce these negative impacts, but it increases reliance on herbicides to control weeds.

Keep in mind that most soil-applied corn herbicides are quite water soluble and that many have been detected in surface water throughout the Midwest. Therefore, many of the best management practices, particularly those that minimize lateral water movement, should be followed for all corn herbicides.

A failure to take preventive action increases the probability of exceeding water quality standards established to protect public health and natural resources. These factors must guide you in choosing to produce crops competively. Implementation of recommended crop management techniques adjacent to surface water resources will help prevent further regulation of this effective weed management tool.

Figure 8. Today's farmers are asked to produce high quality, low-cost food, fiber, and meat without disrupting the environment. In some areas, EPA, USDA, and state agricultural and environmental agencies are asking the agricultural community to reduce off-site movement of atrazine into surface water to ensure its continued availability.

References

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http://www.btny.purdue.edu/pubs/ppp/ppp-66.pdf

Indiana Agricultural Statistics Service
http://www.nass.usda.gov/in/index.htm
(800) 363-0469

USDA
http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?navtype=SU&navid=RESEARCH_SCIENCE

Weed Control Guide for Ohio and Indiana (WS-16)
http://www.btny.purdue.edu/Pubs/WS/WS-16

William Donald USDA-ARS, Univ. of MO
http://www.fse.missouri.edu/ars/Donald/Home%20Page.htm

Resources

Atrazine Re-Registration website hosted by Syngenta Crop Protection.
http://www.syngentacropprotection.com/prod/herbicide/atrazine/index.asp?nav=relabeling

Indiana Select-a-Herb Lists herbicides by effectiveness rating that control or suppress specific weeds in different crop categories for use in Indiana.
http://btny.agriculture.purdue.edu/herbsel/

WeedSOFT an interactive software package that aids in the herbicide selection process.
http://weedsoft.unl.edu

Indiana Department of Natural Resources (DNR) Soil Conservation Division
http://www.ai.org/dnr/index.html
317/233-3870

Indiana Farm Service Agency (FSA)
http://www.fsa.usda.gov/IN/
317/290-3030

Indiana Natural Resource Conservation Service (NRCS)
http://www.in.nrcs.usda.gov/
317/290-3200

Office of Indiana State Chemist
http://www.isco.purdue.edu/pesticide/index_pest1.html
765/494-1492

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http://www.btny.purdue.edu/ppp/
765/494-4566

Purdue University Cooperative Extension Service
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Purdue Weed Science
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Acknowledgements

This publication was funded by the Office of Indiana State Chemist, Purdue University Cooperative Extension Service, Purdue Pesticide Programs, and EPA Region 5.

The information in this publication was reviewed by the Indiana Pesticide Watershed Working Group. The mission of this group is to promote pesticide stewardship in order to protect water quality and retain the ability to use pesticides. The group consists of personnel from Purdue Extension, Purdue University faculty, Office of Indiana State Chemist, Department of Environmental Management, Indiana Farm Bureau, USDA Natural Resources Conservation Service, Association of Soil and Water Conservation Districts, Indiana Plant Food and Ag Chemical Association, U.S. Geological Survey, Indiana American Water Company, Veiolia Indianapolis Water, and the primary atrazine registrant, Syngenta.

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