

Atrazine Management and Water Quality

A Missouri Guide

by

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Missouri Manual 167



The MSEA Water Quality Projects

A model for protecting water quality through successful integration of research and education.

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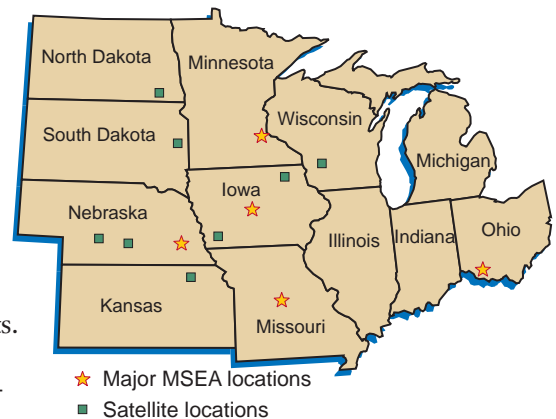
Cover photo by Duane Dailey

Farmers in the Midwest produce approximately 80 percent of the nation's corn and soybean crops. The impact of practices to produce these crops, specifically the use of fertilizers and herbicides, has created concerns about the quality of our water resources. To address these concerns, the U.S. Department of Agriculture (USDA) initiated five comprehensive projects to evaluate and develop profitable cropping systems that safeguard water resources. Known as the Management Systems Evaluation Areas (MSEA), main study sites were established in Iowa, Minnesota, Missouri, Nebraska and Ohio. Sites located in North and South Dakota and in Wisconsin are coordinated through the Minnesota project.

The cornerstone of the MSEA program is the close integration of research and extension activities. This integration exists not only within each project, but also among the states coordinating project efforts. Ongoing research and educational programs among the projects continue to provide useful

information to varied audiences, both inside and outside the agricultural community.

Missouri was also selected to participate in a multistate research and education program called the Agricultural Systems for Environmental Quality (ASEQ) program. It was initiated in 1996 to address water quality and other related environmental issues. Highlights from MSEA and ASEQ water quality research, as well as related findings from the University of Missouri Weed Science and the National Agricultural Pesticide Impact Assessment (NAPIAP) programs, are given in the following pages.



This publication is endorsed by the **Atrazine Working Group**

This group is a consortium of public and private stakeholders in Missouri sponsored by the College of Agriculture, Food and Natural Resources at the University of Missouri-Columbia.

The Atrazine Working Group provides a discussion forum for interested parties and is charged with helping the public understand and interpret current science-based information regarding the responsible use of atrazine by the agricultural community.

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Atrazine use in Missouri

Atrazine is the flagship of the triazine class of herbicides, which includes cyanazine and simazine. Registered in 1958, it has become the most widely used herbicide on corn and sorghum.

In 1994, the Environmental Protection Agency (EPA) initiated a Special Review of these three triazine herbicides. In 1996, DuPont, the basic manufacturer of cyanazine, decided to voluntarily withdraw it from the market. This planned phaseout eliminates all uses of this herbicide by the year 2002. The outcome of the Special Review of atrazine and simazine is still pending. However, it is highly likely that with the phaseout of cyanazine, corn farmers will rely more on atrazine and atrazine premixes for effective and economical weed control.

In 1997, 79 percent of the state's corn crop and 90 percent of the sorghum crop was treated with atrazine. It was applied primarily in mixes with typical application rates ranging from 0.5 to 2.0 lbs. active ingredient (a.i.)/acre, and a statewide average of 1.36 lbs. a.i./acre on corn and 1.25 lbs. a.i./acre on sorghum (Figure 1). However, total usage of atrazine has not changed significantly during the past 20 years (Figure 2). It is primarily applied preemerge

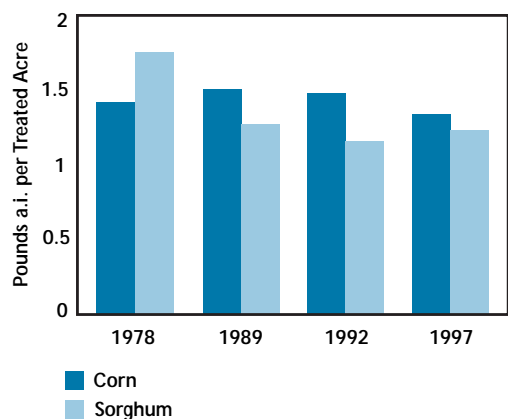


Figure 1. Atrazine usage (lbs. a.i. per treated acre) on corn and grain sorghum in Missouri from 1978-1997.

Source: MU Pesticide Impact Assessment Program



and not incorporated, although post-emerge applications have reached 10 to 25 percent of treated acres. (1997 *Statewide Pesticide Use Survey*, Missouri's National Agricultural Pesticide Impact Assessment Program (NAPIAP)).

Atrazine provides both foliar and residual broad-spectrum weed control and can be used with both conventional and conservation tillage. It also has a higher margin of crop safety and is cheaper than most of its possible replacements.

The benefits of atrazine to Missouri corn and sorghum farmers

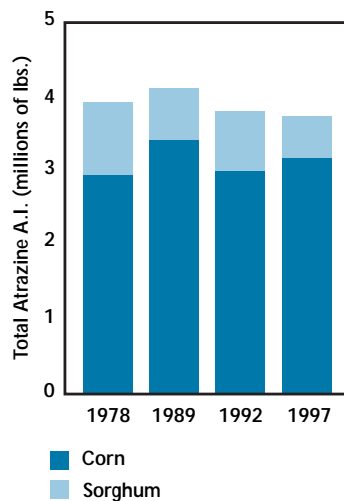
The loss of atrazine in Missouri would increase the estimated annual cost of weed control by more than \$15 million; while losses in yield would cost our producers more than \$63 million each year.

— 1995 *Biologic and Economic Assessment of Pesticide Use on Corn and Soybean*
 NAPIAP Report 1-CA-95



Photo by Mike Chippendale

cannot be understated. In the 1995 *Biologic and Economic Assessment of Pesticide Use on Corn and Soybean* (NAPIAP Report 1-CA-95), it was estimated that the loss of atrazine would lead to alternatives that cost on average \$6 per treated acre above the cost of atrazine-containing weed control programs. The loss of atrazine in Missouri would increase the estimated annual cost of weed control by more than \$15 million; while losses in yield would cost our producers more than \$63 million each year.



With the phaseout of cyanazine, corn farmers will rely more on atrazine and atrazine premixes for effective and economical weed control.

Figure 2. Atrazine usage (total million pounds a.i. applied) on Missouri corn and grain sorghum from 1978-1997.

Source: MU Pesticide Impact Assessment Program

Water quality concerns

About TMDLs

Total Maximum Daily Loads

TMDL studies:

- Identify the contaminant causing the impairment.
- Link the contaminant to watershed characteristics and management practices.
- Establish objectives for water quality improvement.
- Identify and implement new or altered management measures to achieve water quality objectives.
- Bring 303(d) listed waters back into compliance with water quality standards as the overall objective.

Public concern over the widespread use of atrazine centers on its detection in both surface and groundwater. However, research throughout the Midwest has shown that groundwater contamination from pesticides, including atrazine, is a problem only in localized areas where soil conditions allow rapid transport to shallow groundwater (*Midwest Studies Provide Some Answers*, 1999 MSEA Regional Publication). Atrazine concentrations in surface water are of more widespread concern in Missouri.

The Missouri MSEA project monitored nutrients and herbicides, including atrazine, in 14 separate river systems during the 1994-1998 growing seasons. Figure 3 shows maximum atrazine stream concentrations in the major drainage basins throughout northern Missouri and southern Iowa during 1997. Although maximum concentrations vary year to year because of total streamflow, the same general pattern occurs each year with the highest atrazine concentrations in northeast Missouri. Rivers in the deep loess soils of northwest Missouri have lower atrazine concentrations even though these areas are more intensively cropped to corn and use more atrazine

(Figure 4). Less atrazine is lost to surface water because the deep loess soils drain more readily and are less subject to runoff.

Atrazine and most other pesticides are not removed by drinking water treatment plants unless the public water system specifically adds activated carbon technology to the treatment process. So keeping the herbicide on the field is the key to improving water quality. The unpredictable nature of runoff, and the seasonal peak concentrations of atrazine in streams and rivers, makes minimizing loss at the source both difficult and necessary.

In 1994, the maximum contaminant level (MCL) for atrazine was set at 3 parts per billion by EPA. That year 10 public-drinking water supplies in Missouri received notices of violation (NOV) because the average of their four quarterly samples exceeded the MCL for atrazine. Two public-drinking water supplies received NOVs during 1997-1998. During 1998 Missouri also submitted its 303(d) list to EPA. This list identifies waters that exhibit impairment of designated use and thus require additional pollution controls. Total maximum daily loads (TMDLs) will be established for each contaminant identified on this list (see sidebar). Thirteen lakes, which serve as major

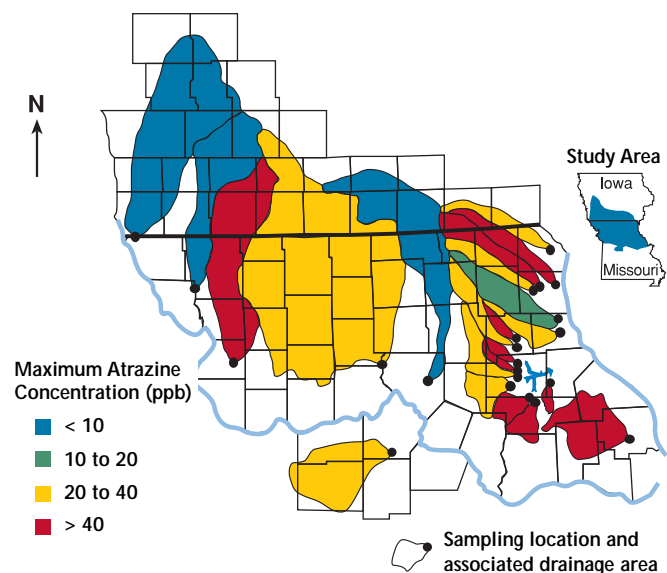


Figure 3. Maximum atrazine concentration (ppb) for northern Missouri and southern Iowa rivers (May - June 1997).

Source: Missouri ASEQ Project

Voluntary Water Quality Management Plans can function as TMDLs

A properly prepared, watershed-scale, voluntary water quality management plan (WQMP) can function as a TMDL if it is:

- thorough
- objective driven
- adequately funded
- fully monitored
- long term

The WQMP must also:

- demonstrate significant commitment by local land owners and managers
- focus on achieving water quality standards at the earliest possible date

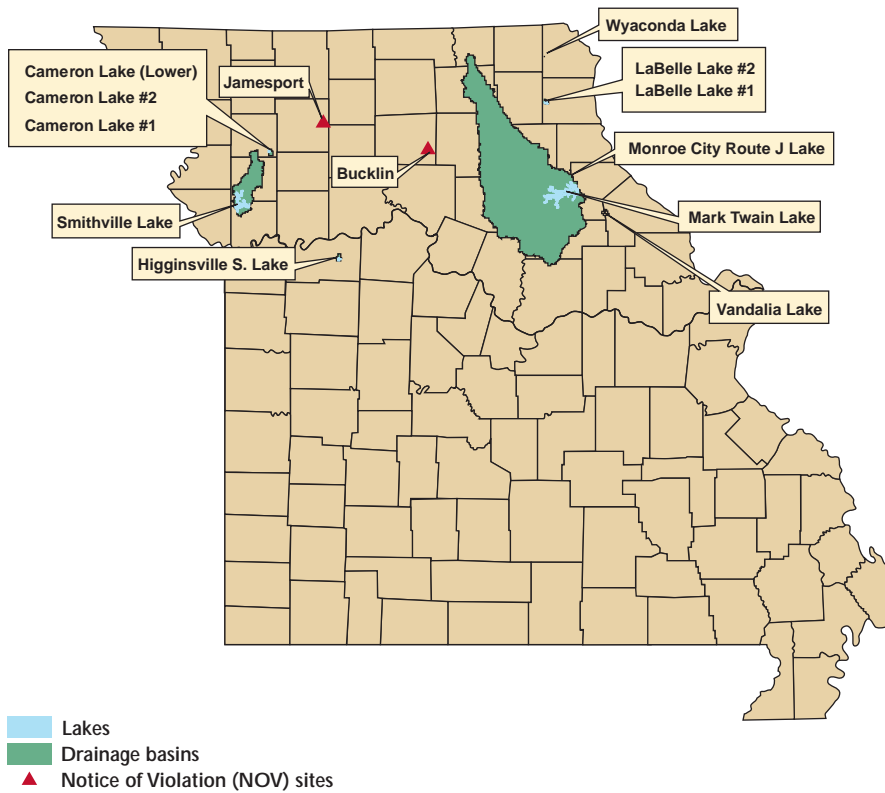


Figure 5. Missouri map showing lakes on the 303(d) list for atrazine and their associated drainage areas (note Jamesport and Bucklin — 1997-1998 NOV sites).

Source: Missouri Department of Natural Resources 303(d) List, 1998. Map prepared by CARES, 1998

sources of drinking water, are on this list specifically for atrazine.

The entire drainage area (watershed) for these lakes is impacted (Figure 5) because each watershed will be required to develop a plan to reduce atrazine levels below the TMDL. Voluntary Water Quality Management Plans (WQMP) can also function as a TMDL (see sidebar).

This publication discusses how atrazine is lost from fields, and the impact of different management strategies on atrazine losses. These strategies reduce atrazine use in a field, reduce the availability of atrazine for loss after application, or allow for infiltration of additional runoff containing atrazine before it leaves the field. Increased adoption of these practices will enable efficient and profitable corn and sorghum production while protecting water quality. On-going research will provide continued evaluation of the effectiveness of atrazine management practices.

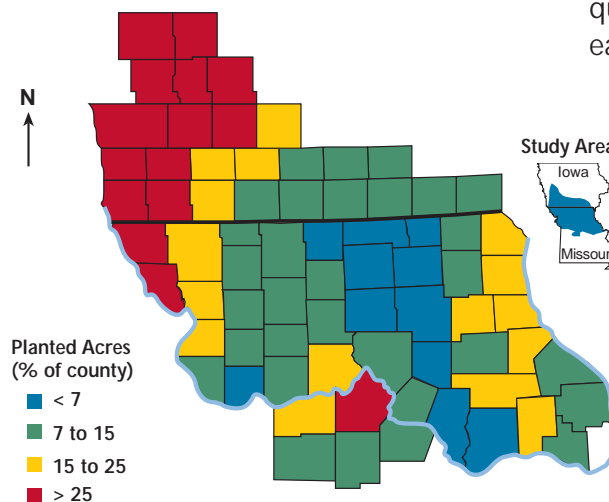


Figure 4. Percent corn and sorghum acres in northern Missouri and southern Iowa, 1997.

Source: 1998 Missouri Farm Facts and 1998 Iowa Ag Statistics

Factors influencing atrazine movement

Atrazine movement from crop fields is determined by the physical/chemical properties of atrazine itself, along with the soil type, tillage practice, and rainfall timing, intensity and duration.

Physical/chemical properties of atrazine

The individual physical/chemical properties of pesticides and nutrients determine how likely they are to wind up in surface waters. Atrazine has been the most frequently detected herbicide in surface water and is usually found in higher concentrations than other herbicides. The most important physical/chemical characteristics that influence atrazine movement are adsorption and persistence. Unlike many pesticides, atrazine is only weakly adsorbed (attached) to soil particles and thus leaves the field primarily in runoff water and not with eroding soil particles (Figure 6). Therefore, atrazine can be lost even if soil erosion is eliminated. Atrazine is also fairly persistent, with almost half remaining 30 to 50 days after application.

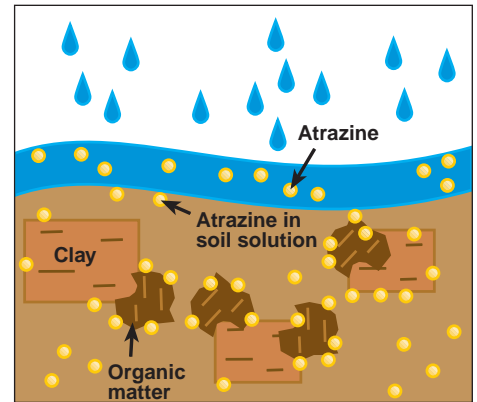


Figure 6. Atrazine is only weakly adsorbed (attached) to soil particles.

Soil type

In Missouri, soil type is the most important factor when determining atrazine loss. Soils are categorized into four main hydrologic groups (A, B, C and D). These groupings are based on estimated water infiltration rates under field conditions. Group D soils have the slowest infiltration rate when wet and the highest runoff potential. They are, therefore, the most susceptible to atrazine loss in runoff. Claypan soils (primarily group D) are prevalent in northeast Missouri and have high runoff potential. The map in Figure 7 illustrates the prevalence and distribution of soils with moderately high to high runoff potential (groups C and D) in Missouri. Table 1 lists some of the predominant soil types found in each group in northern Missouri. The hydrologic soil group for your field(s) can be found in your county's soil survey.

Tillage practice

With most soils, tillage systems that maintain high levels of residue on the soil surface can reduce atrazine losses in runoff by increasing water infiltration. But research on claypan soils in

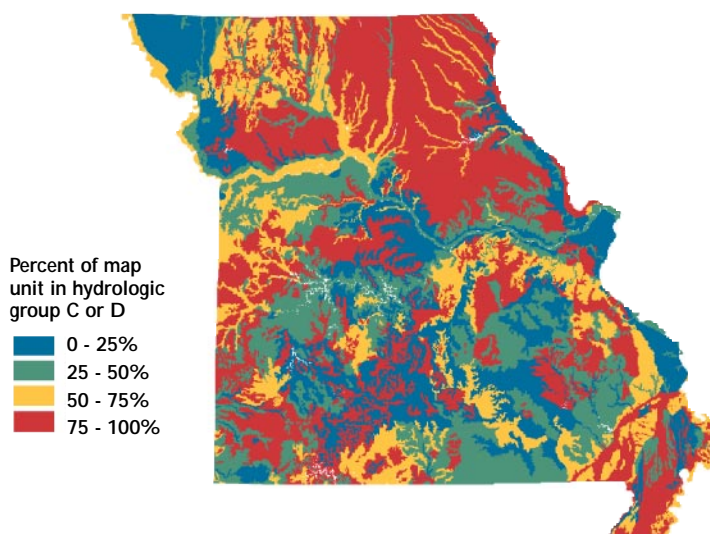


Figure 7. Prevalence and distribution of soils with moderately high to high runoff potential (hydrologic groups C and D) in Missouri.

Source: USDA-NRCS STATSGO Data, 1994. Map prepared by CARES, 1998

Missouri has shown that both runoff potential and loss of atrazine is increased under no-till because the restrictive soil layer limits water infiltration.

... no-till is still considered the preferred tillage practice, even on claypan soils, because of the many other soil and water quality benefits it provides.

These soils tend to be wetter in the spring and herbicide applications are usually applied premerge, or on the surface, where they're more prone to loss in runoff. When heavy rains occur within a few days of application, atrazine losses approaching 20 percent of that applied have been measured (Figure 8). However, no-till is still considered the preferred tillage practice, even on claypan soils, because of the many other soil and water quality benefits it provides.

Rainfall timing, intensity and duration

Herbicide concentrations in runoff also depend on how saturated the soil is when the herbicide is applied, the

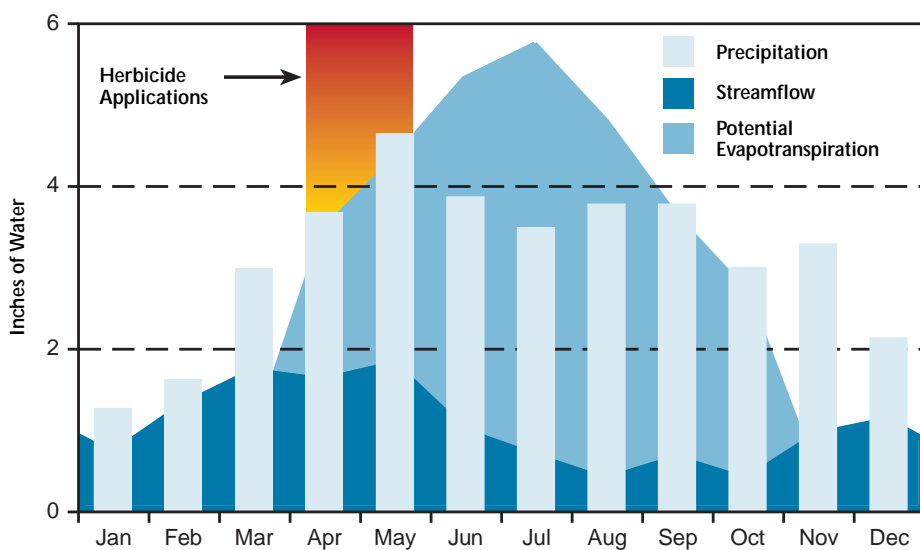


Figure 9. Precipitation and evapotranspiration patterns result most years in saturated soils at planting time. (Typical seasonal patterns for the 28 sq. mi. Goodwater Creek watershed in north central Missouri illustrate how highest streamflow coincides with the primary herbicide application period.)

Source: Missouri ASEQ project

interval between herbicide application and precipitation, the intensity and duration of rainfall events, and the total amount of rainfall. The first two post-application precipitation events are responsible for most of the atrazine lost from fields. In northern Missouri, rainfall intensity peaks in mid- to late May, but runoff events occur most years from April to June. Significant amounts of precipitation are also received earlier in the year. Evapotranspiration rates, however, remain low until May. The net result is that wet to saturated soils are commonplace during the early part of the growing season when atrazine is applied and most vulnerable to offsite

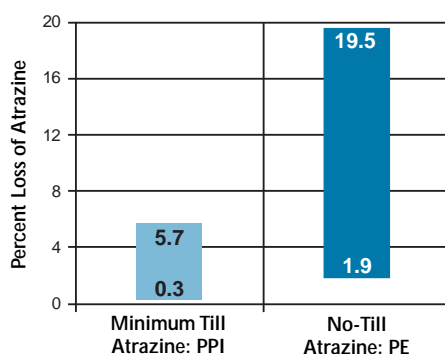


Figure 8. Comparison of annual atrazine losses on claypan soils under no-till and minimum-till (with incorporation).

Source: Missouri ASEQ Project

movement via runoff (Figure 9).

On average, about 40 percent of the total surface water flow in northern Missouri occurs from April to June. For example, 95 percent of atrazine mass loss occurs during this time period in Goodwater Creek. This creek is located at the main MSEA research site in north central Missouri, near Centralia. So it is during this time period when atrazine is transported into lakes and reservoirs.

For more detailed information, consult MU Publication G7520, *Pesticides and the Environment*. See back cover for ordering information.

Table 1. Hydrologic classes of predominant soil types in northern Missouri.

A soils

High infiltration rate, low runoff potential
Sarpy and Hodge

B soils

Moderate infiltration rate, moderately low runoff potential
Judson, Kennebec, Goss, Jemerson, Nodaway, Shelby, and Sharpsburg

C soils

Slow infiltration rate, moderately high runoff potential
Armstrong, Bremer, Chequest, Gara, Keswick, Lindley, and Vesser

D soils

Very slow infiltration rate, high runoff potential
Adco, Clarinda, Gifford, Kilwinning, Leonard, Marion, Mexico, and Putnam

Artificially draining some Group D soils may convert them to Group B or C. These are referred to as B/D or C/D soils.

B/D soils: Blackoar, Colo, Excello, Gilford, and Otter

C/D soils: Haig, Humeston, Moniteau, Piopolis, Twomile, and Zook

Source: USDA-NRCS STATSGO Data, 1994

Best management practices: considerations and recommendations

Losses of sediment and nutrients may be greater threats to surface water quality than atrazine. ... keep the larger picture of overall water quality in mind when selecting BMPs to reduce atrazine runoff.

The following best management practices (BMPs) are designed to improve the quality of the state's waters by promoting practices that reduce atrazine runoff. These practices are designed to keep the herbicide on the field where it provides maximum benefit to the farmer and the least environmental impact.

Research conducted in Missouri and throughout the Midwest indicates that certain management practices can greatly decrease atrazine runoff. These practices are designed to reduce the atrazine rate used in a field, reduce the atrazine available for loss after application, and increase infiltration of runoff containing atrazine before it leaves the field. Increased adoption of these practices will enable efficient and profitable corn and sorghum production while protecting water quality. On-going research will provide continued evaluation of BMP effectiveness.

Effective atrazine management programs will often employ multiple BMPs. Because conditions on each farm and field vary, not every BMP will fit into every corn or sorghum producer's production system. Selection of the most appropriate BMP, or combination of BMPs, under the voluntary approach is a site-specific, individual decision.

Losses of sediment and nutrients may be greater threats to surface water quality than atrazine. Therefore, it is important to keep the over

all picture of water quality in mind when selecting BMPs to reduce atrazine runoff. This will ensure that one water quality problem is not replaced by an even greater problem.

BMP 1 Incorporate atrazine into the top two inches of soil.

This option is viable if tillage is planned. For no-till ground see BMP 2. Apply atrazine, or an atrazine-containing product, 0 to 14 days before planting and incorporate it into the top two inches of soil with a field cultivator type of implement. Mechanical incorporation of atrazine leaves less herbicide at the soil surface where it is most vulnerable to runoff. Incorporation has been shown to reduce atrazine losses up to 75 percent compared with surface applications.

Unfortunately, tillage of any kind can result in increased erosion, which can be a bigger environmental problem than atrazine runoff. Additional erosion control practices, such as in-field contour buffer strips, may help to offset the increased erosion. Overall, no-till systems that maintain high levels of residue on the soil surface are preferred in Missouri because of the total soil and water quality benefits, including reduced sediment and nutrient losses in runoff.

BMPs in Brief

- Incorporate atrazine into the top two inches of soil (only on fields using preplant tillage).
- Use postemergence atrazine applications at reduced rates and alternative herbicides.
- Use integrated pest management strategies including: prevention, avoidance, monitoring, and suppression. Select herbicides based on weeds present.
- Use buffers and other conservation practices.
- Keep your eye on the weather.
- Use buffer zones.
- Use proper mixing, loading, and disposal practices.

BMP 2

Use postemergence atrazine applications at reduced rates.

Using soil-applied herbicides for grass control followed by postemergence applications of atrazine, or atrazine mixed with other herbicides, is an effective method for reducing the total amount of atrazine used. This method is widely used by corn producers in other Midwest states. These programs will typically use 0.5-1 lb. a.i./acre atrazine and provide more effective season-long control of broadleaf weeds such as waterhemp, velvetleaf, common cocklebur, and common sunflower.

Postponing the atrazine application to a postemergence time frame reduces the use rate up to 67 percent compared with the 1997 state average. This also moves the application timing away from some of the heaviest early spring rains when soils are saturated and unprotected. The combined impact of these two benefits could reduce runoff losses significantly compared to earlier surface applications with higher rates.

Research at the University of Missouri has shown that these two-pass alternative herbicide programs also provide better overall weed control and improve yields (Figures 10 and 11). While many of these herbicide programs may cost more, economic analyses have shown that the higher yields often result in increased profits.

A report on this research, *Weed Management with Atrazine and Alternative Herbicides*, along with additional weed management information, is available on the Web at <http://www.psu.missouri.edu/agronx/weeds/>. Also, complete weed management recommendations are available in MU Publication, *Weed Control Guide for Missouri Field Crops*.

See back cover for ordering information.

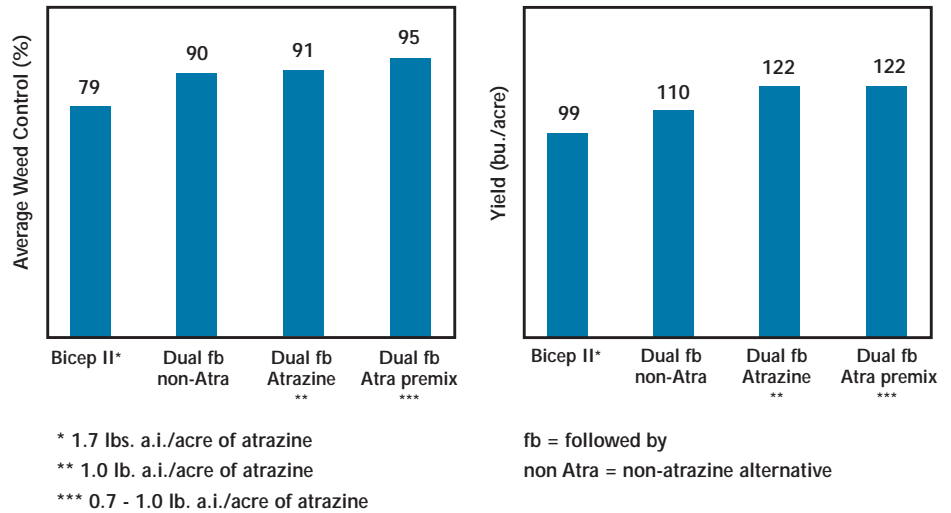


Figure 10. Average weed control, left graph, (July observations) and corn yield, right graph, with preemerge vs. postemergence atrazine applications during 1997-98 at Columbia and Novelty, Mo. Weeds evaluated include: giant foxtail, common waterhemp, smartweed, velvetleaf, common cocklebur, morningglory, common lambsquarters and common ragweed.

Source: Bill Johnson, Dept. of Agronomy, MU

There are a variety of herbicides for corn that do not contain atrazine. However, most of these herbicides are more specific in the weed species they control and more expensive than atrazine. Thus, effective use of alternative products will require careful scouting and knowledge of the weed

species being controlled. However, using these products in combination with atrazine as a tankmix or premix can effectively control a broad spectrum of weeds, keep weed control costs low, and reduce the rate applied by up to 67 percent.

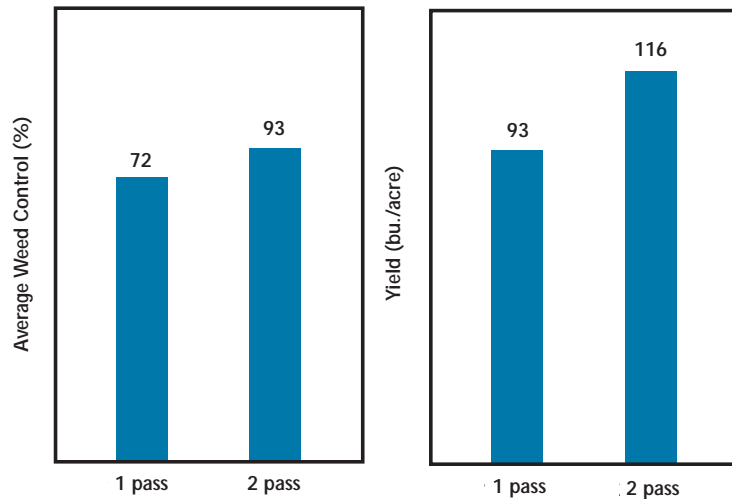


Figure 11. Average weed control, left graph, (July observations) and corn yield, right graph, with one-pass (soil-applied or preemerge only) vs. two-pass (preemerge followed by postemergence) herbicide programs during 1997-98 at Columbia and Novelty, Mo. (Data from four one-pass and 11 two-pass programs are shown.) Weeds evaluated include: giant foxtail, common waterhemp, smartweed, velvetleaf, common cocklebur, morningglory, common lambsquarters and common ragweed.

Source: Bill Johnson, Dept. of Agronomy, MU

BMP 3

Use integrated pest management strategies.

Integrated pest management (IPM) systems rely on a combination of prevention, avoidance, monitoring, and suppression strategies to control pests. In Missouri, IPM programs for weed control rely heavily on herbi-

Photo by Jim Jarman



Scout your fields early and select the herbicide based on the weeds present.

cides to kill or suppress weed growth but also include other strategies to prevent or avoid economic weed infestations. In addition, some type of monitoring program (scouting, record keeping, field mapping, computer-assisted decision aids, etc.) needs to be an integral component of a weed IPM program.

There are currently more than 1,000 known plant species that can potentially infest crop production systems in the United States if given the opportunity. Strong dependence on any single tactic will result in selection pressure for weed species that can exploit the niche left by that tactic. In most cases, weed management programs that employ multiple

Some type of monitoring program needs to be an integral component of a weed IPM program.

tactics (discussed below) are needed to minimize weed interference and maximize weed control and net returns.

Prevention strategies for weeds:

- Use weed-free crop seeds and follow noxious weed laws to prevent introduction and spread of weeds.
- Keep weeds from replenishing the seed bank through tillage, mowing, or late herbicide spot applications.
- Choose crop varieties that can be harvested before late-emerging weeds produce viable seeds.

Avoidance strategies for weeds:

- Rotate crops to manage later emerging weeds such as waterhemp and fall panicum.
- Select for host resistance (this weed management tactic involves the use of herbicide-tolerant hybrids to target major weed species with the appropriate herbicide).

Monitoring strategies for weeds:

- Scout and map fields, preferably three times per crop season, to record weed species and densities over time and by location in the field.
- Consider weather forecasts when making weed management decisions.

Suppression strategies for weeds:

- Use mechanical practices such as hand-roguing weeds, mowing and burning, as well as tillage, including cultivation, on soils not prone to erosion.
- Use cultural practices such as narrow row spacings, optimum plant populations, and cover crops or crops with allelopathic potential (e.g., wheat).
- Implement biological control practices that use natural enemies for the control of specific weed species.
- Use chemical weed control practices.

While the use of herbicides is the most widely used suppression tactic in corn, sound herbicide management should incorporate the following practices as part of an IPM program: evaluate the cost-benefit ratio prior to use (economic threshold); calibrate sprayers properly; select herbicides based on efficacy, economics, and least negative effects on the environment and human health; alternate herbicide modes of action to avoid developing resistant weeds; and when available and economically feasible, use precision agricultural technology to limit herbicide application to areas in fields where economic weed infestations occur.

BMP 4

Use buffers and other conservation practices.

Vegetative filter strips, terraces, contour farming, and grass hedges are especially effective in slowing down runoff and reducing sediment losses. They can also be effective in increasing infiltration of nutrients and pesticides. Infiltration is greatest when the runoff is distributed over a large surface area. It is important to realize, however, that atrazine is not removed from the water when passing over a buffer strip. It is the proportion of water containing atrazine that infiltrates into buffer strip soils that reduces atrazine loss from the field area.

The actual impact that these practices have on reducing atrazine loss in runoff in Missouri, especially in our claypan areas, is still under evaluation. However, their value in reducing losses of sediments, and nutrients adsorbed to that sediment, is substantial.



Buffers and other conservation practices are especially effective in slowing runoff and reducing losses of sediment, but can also increase infiltration of nutrients and pesticides. Infiltration is greatest when the runoff is distributed over a large surface area.

Photo by Fred Fishel

BMP 5

Keep your eye on the weather.

Delay herbicide application if heavy rain is forecast or if fields are saturated from recent rains and excess water has not had sufficient time to drain or evaporate. Modern weather forecasts use satellite and radar imagery to track the predicted movement of weather systems on a local basis. Use this information, when possible, to help time herbicide applications.

University of Missouri-Columbia



Delay herbicide applications when your fields are saturated.

BMP 6

Use buffer zones.

Buffer zones provide a measure of protection against runoff losses and spills of agricultural chemicals during mixing and application.

Evaluate each field to determine which fields are highly erodible or those containing wells, sinkholes or points where surface water runoff enters intermittent or perennial streams, rivers, lakes, or reservoirs. Stake out or flag these areas so anyone applying atrazine can easily see them.

Wells and sinkholes



Mix, fill and rinse your sprayer at least 50 feet from any well or sinkhole. Do not apply atrazine within 50 feet of any well or sinkhole.

Streams and rivers

Do not mix or load atrazine within 50 feet of any stream or river. Establish a 66-foot application buffer from points where surface runoff enters an intermittent or perennial stream or river. Label changes now allow atrazine application up to a tile inlet if it is incorporated or if more than 30 percent residue is present at planting. If the soil is highly

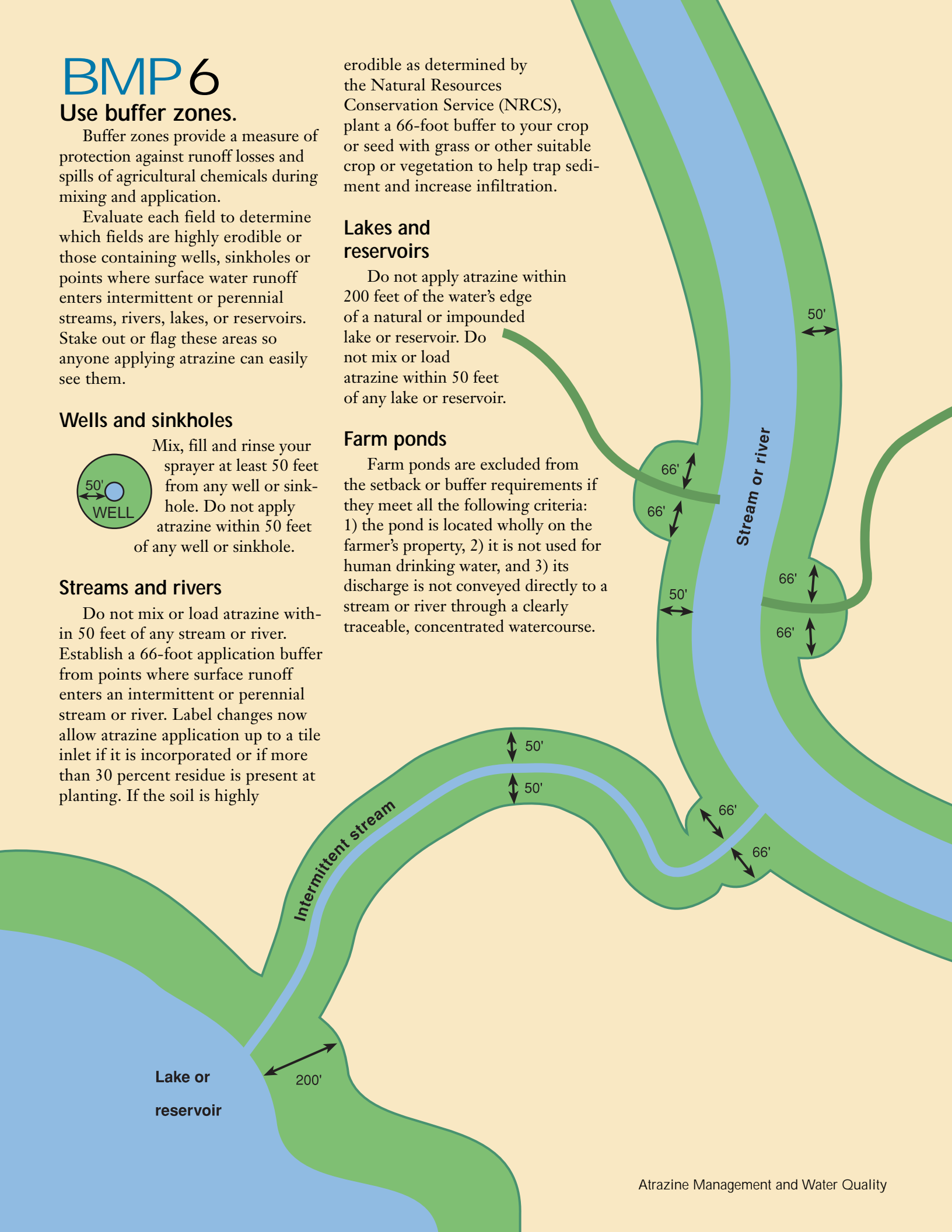
erodible as determined by the Natural Resources Conservation Service (NRCS), plant a 66-foot buffer to your crop or seed with grass or other suitable crop or vegetation to help trap sediment and increase infiltration.

Lakes and reservoirs

Do not apply atrazine within 200 feet of the water's edge of a natural or impounded lake or reservoir. Do not mix or load atrazine within 50 feet of any lake or reservoir.

Farm ponds

Farm ponds are excluded from the setback or buffer requirements if they meet all the following criteria: 1) the pond is located wholly on the farmer's property, 2) it is not used for human drinking water, and 3) its discharge is not conveyed directly to a stream or river through a clearly traceable, concentrated watercourse.



BMP 7

Use proper mixing, loading and disposal practices.

Use the proper amount of herbicide:

Avoid temptations to use more herbicide than the label directs. Overdosing will not do a better job of controlling weeds and will increase both the cost and the chance that the material may contaminate water.

Calibrate equipment carefully:

Measure concentrates accurately before adding them to the tank. Check individual nozzles separately and calibrate sprayers frequently to maintain accuracy. For additional information on calibration, consult MU Publications G1270, G1272, and G1273. See back cover for ordering information.

Follow mixing and loading recommendations:

Mix and load in the field or on an impervious pad to minimize chances for spills, leaks, or rinse water to contaminate water resources. Use nurse equipment in the field, or add extra lengths of fill hoses to move away from wells or water supplies when mixing, loading, or rinsing equipment. Prevent back-siphoning. Install backflow prevention devices on faucets where hoses are attached to fill sprayers or mixing tanks. Avoid leftover product by mixing the quantity needed. Small amounts of surplus pesticide can be diluted and reapplied to the treated area.

Use proper disposal practices:

Triple or pressure rinse empty containers before recycling or reusing according to respective product labels. Do not drain rinse water from equipment near or into ditches, ponds, lakes, or other water sources. For additional information on storage and disposal of pesticides, consult MU Publication G1916, *Pesticide Application Safety*. See back cover for ordering information.



Calibrate your sprayer frequently to maintain accuracy.

Photos by Fred Fishel



Check individual nozzles separately and calibrate sprayers to maintain accuracy.



Keep records of pesticide use.



Triple or pressure rinse all pesticide containers before recycling or reusing.



Store pesticides separately.

Recycle pesticide containers.

What doesn't work in Missouri

Some BMPs that have been highly successful in neighboring states just don't seem to work in Missouri.

Early preplant applications of atrazine

In Nebraska and Kansas, herbicide applications before April 15th can, on average, reduce the potential runoff loss of atrazine by 40 to 50 percent. This results because of a different rainfall pattern in these two states as compared to Missouri. In these states, both rainfall amounts and storm intensities are substantially less in March and early April than in late April through June. This results in significantly less runoff during the earlier time frame. A comparison of the total monthly streamflow for most northern Missouri rivers will show very little overall difference from March to June. If we use the North Fork of the Salt River as an example, the mean monthly streamflow from 1934 to 1997 in cubic feet per second was 447 for March, 520 for April, 509 for May and 426 for June.

Mean annual rainfall in Missouri is also higher than it is in Nebraska and Kansas. This results in runoff and dilution of soil-applied herbicides and

subsequently poorer performance of herbicides applied before April 1st.

While early preplant herbicide applications can offer growers some increased flexibility in corn production, they usually fail to control weeds for the entire growing season unless postemergence weed management strategies are also used. Weed control and corn yields with soil-applied herbicide treatments made 15 days or more before planting were lower during a 4-year period than with soil-applied treatments made at or near the date of planting (Figure 12). Applying herbicides as close to planting as possible combined with supplemental postemergence weed management strategies will provide the most consistent weed control and yields in Missouri corn production.

Reduced soil-applied atrazine application rates

Herbicide efficacy trials by the University of Missouri have shown that soil-applied atrazine rates need to be 1.5 lbs. a.i./acre or higher if atrazine is the primary broadleaf herbicide. These rates are required for effective, season-long weed control, unless supplemental herbicides or weed management tactics are also used.

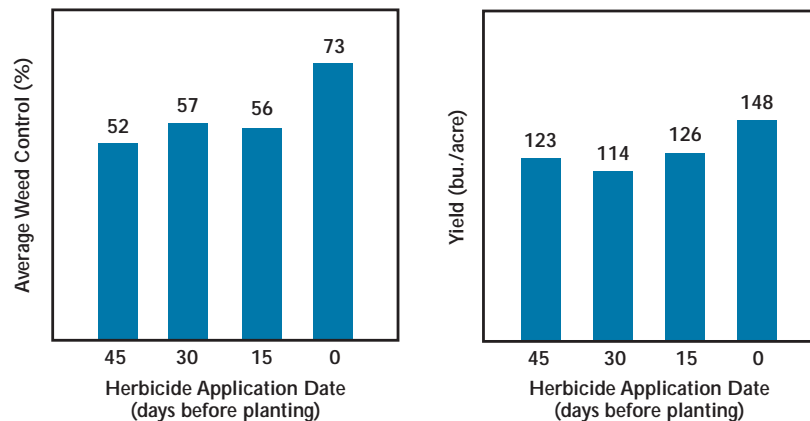


Figure 12. Weed control, left graph, (7 weeks after planting) and corn yield, right graph, with Bicep applied 0, 15, 30 and 45 days before planting during 1991-1994 at Novelty, Mo. Weeds evaluated include: giant foxtail, fall panicum, velvetleaf, common cocklebur and common lambsquarters.

Source: Bill Johnson, Dept. of Agronomy, MU

Additional research

Additional research is needed to determine the efficacy of other atrazine BMPs.

Split applications of atrazine

This BMP is touted in a number of neighboring states. However, in Missouri, runoff events occur most years from April to June. Preliminary research (one site, one year of data) suggests that split applications may actually increase atrazine losses by providing two periods of runoff vulnerability. Additional evaluation is planned to determine whether or not this BMP is, in fact, applicable in Missouri.

Fall applications of atrazine

In December 1998, Kansas received a Section 24C label allowing fall applications of atrazine up to 2.5 lbs. a.i./acre. This was based on research conducted at both Ottawa and Manhattan, Kansas. The soils at both sites are silt loams to silty-clay loams with poor permeability. Like our claypan soils, total runoff is higher under no-till than with conventional tillage

(chisel-disk); and atrazine loss is higher when surface applied in no-till than when incorporated using conventional tillage. Since the primary rotation in this area is sorghum/soybean, atrazine is usually applied mid-May, the time period when they have the most runoff. Atrazine losses as high as 8 percent of that applied in 1997 were found following spring-applied, surface treatments in no-till. In contrast, incorporating atrazine in a conventional tillage system resulted in a maximum loss of only 1.6 percent in 1997. Fall vs. early April vs. planting time studies were conducted near Manhattan, Kansas under no-till over soybean stubble. Fall applications (December) reduced atrazine runoff significantly compared to spring applications. Similar research would need to be conducted in Missouri to determine if these practices would work on our claypan soils.

What are some of the potential advantages of this program? First, a fall application is just one part of a programmed approach that also includes postemergence herbicide(s). Second, atrazine applications at this site have helped control winter annual weeds. While this may eliminate the need for a burndown in the spring for fields planted to corn, the later planting date for sorghum will still require a burndown. Using the higher rate (2.5 lbs. a.i./acre) will suppress grasses until the planned early postemergence application of a herbicide containing 1 lb. a.i./acre of atrazine or less. This can result in a very economical programmed approach in which the postemergence herbicide can be targeted at the weeds that emerge.

What are some of the potential disadvantages of this program? Most importantly, fall applications of atrazine in no-till fields at rates of 2.0-2.5 lbs. a.i./acre could negate many of the erosion control benefits no-till systems normally provide. Elimination of the winter annuals could expose the soil surface to erosion by both wind and rain. While the impact of fall-applied herbicides on erosion has not yet been

documented, Kansas extension will address this concern by strongly discouraging fall applications for anything other than no-till fields with significant residues. It's also important to note that the fall application of atrazine does not provide season-long control. Additional applications of atrazine and/or other herbicides will be a part of the early postemergence treatment, bringing the total amount of atrazine applied for that crop as high as 3.5 lbs. a.i./acre. The agricultural community has been trying to reduce its reliance on atrazine, so this program may appear to be heading in the wrong direction and may cause a public relations backlash. Late fall and winter is also the primary time for groundwater recharge. Research throughout the Midwest has documented that groundwater contamination from pesticides, including atrazine, is a problem only in localized areas where soil conditions allow rapid transport to shallow groundwater; however, in these studies atrazine was applied in the spring, not in the fall.

Similar research has not been conducted in Missouri, but may be evaluated in the future, depending on subsequent data received from Kansas.

Width, placement and composition of grass buffers

The actual impact that buffer strips and other conservation practices have on reducing atrazine loss to runoff in Missouri, especially in our claypan areas, is a critical research need. Studies are being planned to evaluate how factors such as width, placement, and composition of buffers impact herbicide and nutrient losses.

BMPs for tile outlet systems

Tile outlets often provide a direct conduit to surface waters. Moving the tile outlets back from waterways and spreading their discharge across some type of buffer strip may increase infiltration and reduce losses of herbicides and nutrients. The actual impact of these practices on herbicide and nutrient losses will be determined in studies initiated in 1999.

Regional applications

This information may be of special interest to four of Missouri's neighboring states.

Although this publication was designed specifically for Missouri, this information is also applicable to other areas of the Midwest with climatic conditions, land use, and soils with moderately high to high runoff potential similar to those of northern Missouri. It may be of particular interest to those in four of Missouri's neighboring states (Figure 13) that have runoff-prone soils within Major Land Resource Areas 109 (Iowa and Missouri Heavy Till Plain), 112 (Cherokee Prairies), 113 (Central Claypan Area), and 114 (Southern Illinois and Indiana Thin Loess and Till Plain). These soils are runoff prone, primarily because they have high clay content subsoils (argillic horizons) like the claypan soils. The short-term goal is to reduce herbi-

cide losses from these soils. The long-term goal is to improve soil quality.

Erosion of these soils has caused significant losses of topsoil, which in turn reduced water infiltration because of the subsoil's low permeability. Reduced infiltration increases surface runoff. But increasing the quality of the topsoil will not have a measurable impact on increasing infiltration because the hydraulic conductivity of the subsoil is so low. If surface runoff is to be reduced on these soils, the quality of the restrictive horizon must be improved. Improving the quality of these restrictive subsurface horizons will lead to higher production. This in turn will provide greater economic returns to producers and at the same time reduce nonpoint erosion and chemical transport from farm fields to stream and river systems. Research is underway to evaluate how BMPs impact soil quality.

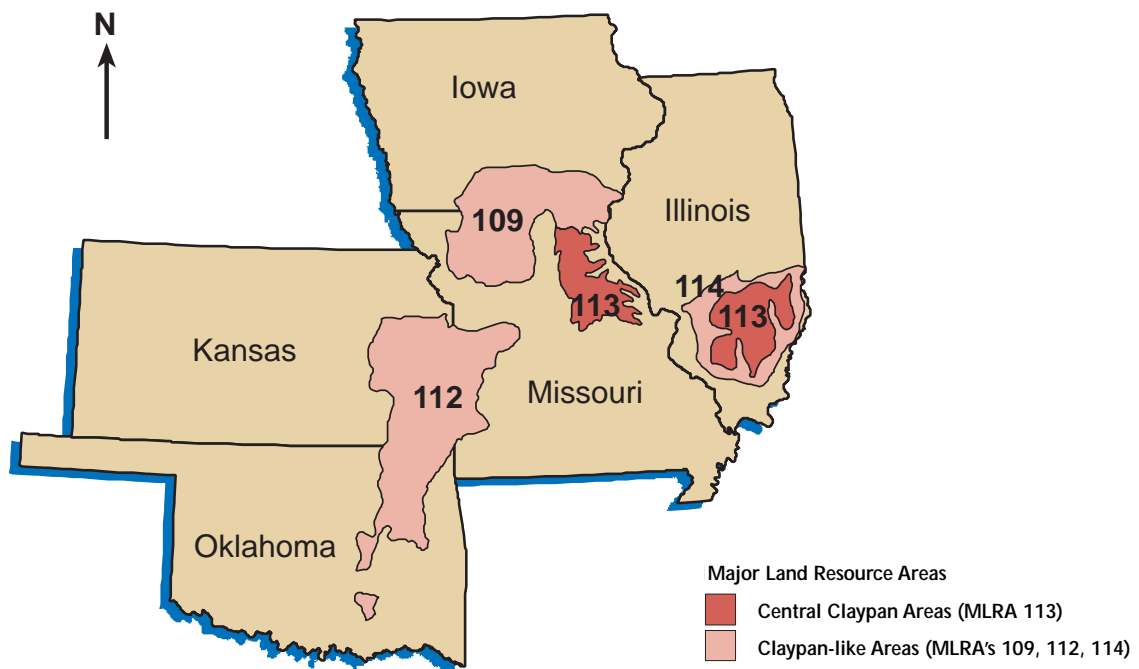


Figure 13. Distribution of claypan (MLRA 113) and claypan-like soils in the Midwest. Source: USDA Agricultural Handbook 296, 1981. Map prepared by CARES, 1998

Acknowledgements

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For additional assistance contact your local University Outreach and Extension Center.

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G1270	Calibrating Field Sprayers
G1272	Sprayer Calibration: Spray Mix Calculations
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