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May 21, 2001

WATER QUALITY TECHNICAL NOTE NO. NM 3

SUBJECT: WQP – "BMPs FOR WATER QUALITY: REDUCING HERBICIDE RUNOFF: ROLE OF BEST MANAGEMENT PRACTICES" BROCHURE

Purpose: To distribute information to the field.

The attached Brochure, "BMPs for Water Quality: Reducing Herbicide Runoff: Role of Best Management Practices", distributed by the Conservation Technology Information Center, provides research information on reducing herbicide runoff using various conservation practices.

File the attached brochure in the Water Quality Tech Note section of your field office reference library.

ROSENDO TREVINO III
State Conservationist

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Team Leaders – (1 ea)
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BMPs FOR:

WATER QUALITY

Reducing Herbicide Runoff:
Role of Best Management Practices

CTIC
CONSERVATION TECHNOLOGY INFORMATION CENTER

Reducing Herbicide Runoff: Role of Best Management Practices

Introduction

The presence of detectable concentrations of pesticides in water (surface and ground) will become more important with the reauthorization of the Clean Water Act. Under existing provisions of the Safe Drinking Water Act (SWDA), water utilities are required to test quarterly for several common pesticides. If the annual average of any regulated contaminant exceeds the Maximum Contaminant Level (MCL) drinking water standard either EPA or the states which have the authority to direct the local water authority to find an alternative water supply, treat the water, or otherwise reduce the contaminant concentration.

TABLE 1

MCL AND LIFETIME HAL FOR SELECTED HERBICIDES

Herbicide	MCL (ppb)	HAL (ppb)
Alachlor	2	--
Atrazine	3	3
2,4-D*	70	70
Pentachlorophenol	1	100
2,4,5 TP*	50	--
Cyanazine	--	10
Metolachlor	--	100
Metribuzin	--	200
Simazine	--	4

*One of 21 chemicals regulated in 1975 under SDWA.

Although certain insecticides are sometimes detected in surface water, herbicides are most frequently detected. Several widely used, soil-applied herbicides are detected in surface waters, primarily in Midwestern and Chesapeake Bay states. These products include atrazine, alachlor, cyanazine, metolachlor, metribuzin, and simazine. In 1989, the U.S. Geological Survey sampled rivers and streams at 149 Midwest sites after the first major spring runoff event following herbicide application (14). They detected herbicides in 90 percent of samples. Detections are much less frequent later in the season, but certain persistent herbicides have been detected in winter months.

The historical surface water monitoring data for these herbicides (i.e., alachlor, atrazine, cyanazine, metolachlor, metribuzin, and simazine) indicate the annual average concentration (based on year-round monitoring) is seldom greater that the SDWA MCL standard or EPA lifetime Health Advisory Level (HAL) for each chemical (Table 1).

Levels can be higher than the lifetime MCL or HAL for some products (e.g., atrazine, alachlor, and cyanazine) in the spring period (May - July) following the field application period for corn, soybeans, and sorghum (16).

EPA has identified granular-activated carbon (GAC) as the Best Available Technology (BAT) process for herbicide treatment by water utilities. While it is technologically possible to treat raw water from river and reservoir water sources (17), it also is possible to reduce the pesticide presence in surface water. The use of Best Management Practices (BMPs) by agricultural production can reduce pesticide entry into surface water and avoid the need for additional water treatment by utilities.

Best Management Practices are actions that dealers and farmers can include in their business plans and activities. Best Management Practices can be structural (i.e., a mixing-load pad) or non-structural (i.e., a tillage practice). They can eliminate agricultural chemical loss from storage, mixing, and loading activities due to spills. Field use BMPs can reduce the amount of herbicide loss in surface water runoff. Often, the same BMP actions can simultaneously reduce soil erosion and water runoff from fields.

Background

Pesticides can enter surface water from point and non-point sources. For example, pesticide losses during storage, mixing/loading, and disposal are considered a point source. One study determined that 22 percent of pesticide detects were caused by careless pesticide mixing, disposal, and equipment operation adjacent to streams(6). These kinds of point source problems can be solved. Improved awareness of point source contamination activities leads to common sense improvements in pesticide handling procedures such as the use of watertight containment systems (cement dikes and pads) at mixing and loading sites.

Herbicide movement from a treated field dissolved in water or attached to eroded soil is considered a non-point source. Any BMP which reduces soil erosion, slows or reduces water runoff, or traps sediment can reduce the annual loading of herbicides to surface waters. As several of the commonly detected herbicides are carried from fields, primarily dissolved in runoff water, practices which increase water infiltration and reduce water runoff are particularly effective in reducing herbicide runoff.

Many of the existing soil conservation practices recommended to farmers to control soil erosion and water runoff are also effective in reducing herbicide runoff. Nation-wide improvements in soil conservation are under way through the USDA Conservation Compliance Program. This program has targeted millions of highly erodible acres, through individual farm plans, to adopt soil and water conservation practices into their farm operations by 1995.

The Environmental Protection Agency, Office of Pesticide Programs, also recognizes the role of agricultural BMPs in protecting and enhancing water quality in agricultural regions of the country. For example, the pesticide ground water protection strategy identifies the use of location-specific BMP management areas within specific geographic areas of a state. The same concept can apply equally well to surface water protection under a watershed management approach.

Review of Best Management Practice Research

University, government, and industry researchers conducted over 140 studies on BMPs and herbicide runoff/infiltration since the early 1970s (15). It is recognized that agricultural field practice changes on the surface water portion of the hydrologic cycle could result in changes in the ground water portion. Those potential effects on ground water need evaluation to see if surface water protection BMPs, when implemented, have a negative, positive, or neutral impact on ground water quality.

While protection of ground water is equally as important as surface water, this review is focused on surface water quality protection.

Five types of BMP research are highlighted: conservation tillage, conventional tillage with herbicide incorporation, field terraces and contours, filter strips and grass waterways and other BMPs.

Conservation Tillage

Conservation tillage (CT) is defined as any tillage and planting system that maintains at least 30% of the soil surface covered by residue after planting to reduce soil erosion by water. These include; no-till, ridge-till and mulch-till.

No-till leaves the soil undisturbed from harvest to planting except for nutrient injection. In contrast, the moldboard plow buries almost all field residue after planting. The moldboard plow is defined here as conventional tillage. All studies compare the other tillage systems to the moldboard plow in evaluating herbicide runoff from treated fields.

Five field studies (2, 7, 9, 10, 12) conducted between 1973 and 1987 illustrate the effect of no-till systems in reducing herbicide runoff (Figure 1). These are the primary studies conducted on small watersheds under natural rainfall. These studies included five major chemicals used on corn, soybean, and sorghum crops: alachor, atrazine cyanazine, metolachlor, and simazine.

The data indicate year-to-year variation in percent of herbicide runoff with the no-till system. For example, alachlor percent runoff varied from 106 percent of moldboard plow run off in 1973 to 12 percent and 9 percent in 1974 and 1975, respectively. There seems to be little variation in product-specific runoff reduc-

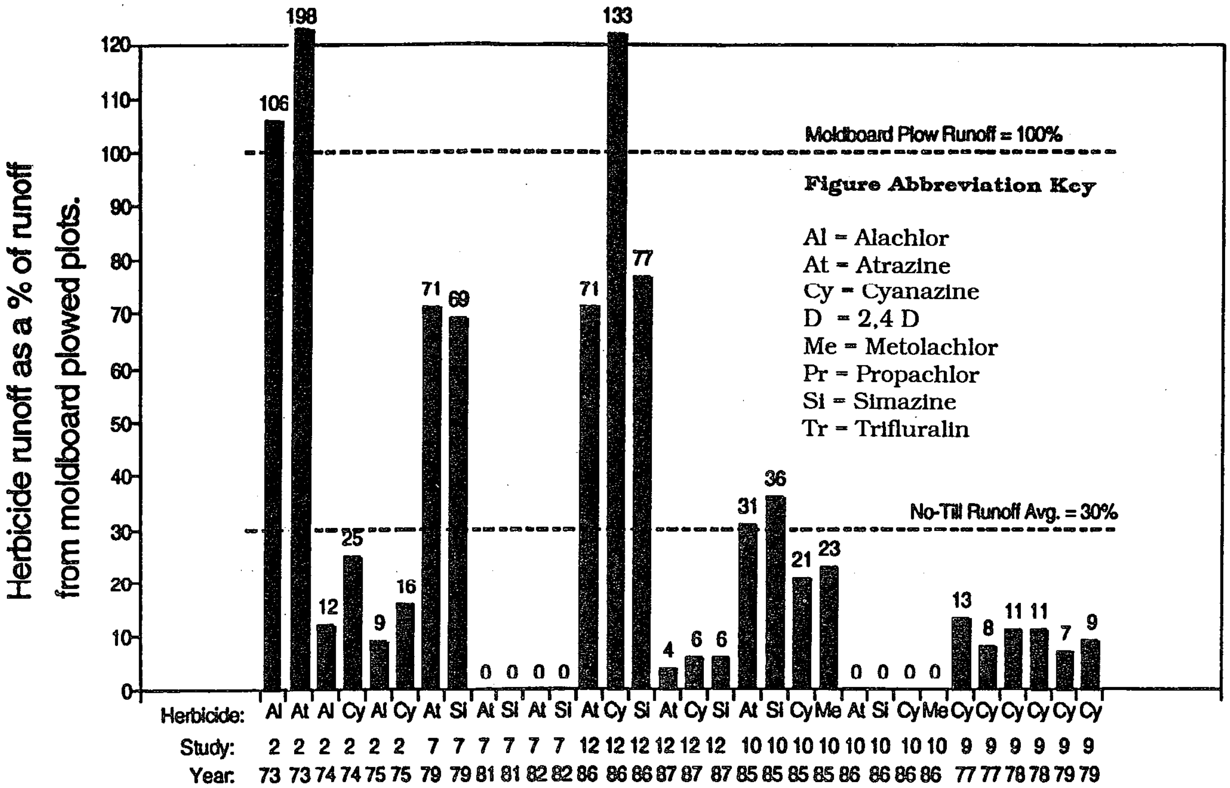

Figure 1. Herbicide runoff from no-till watersheds compared to conventional tillage (moldboard plowed) watersheds. A summary of natural watershed studies.

tion. The no-till systems provide substantial reduction in runoff losses for all active ingredients studied. Average herbicide runoff for all products and years in the no-till systems was 30 percent of the conventional or moldboard plow runoff (Figure 1).

In a few studies (2, 12) and years, no-till runoff was similar to or greater than moldboard tillage. This occurred under field conditions where a large rainstorm soon after herbicide application washed the product off the soil surface and crop residue before it could infiltrate the soil or incorporate into target plants. But, in the majority of these field cases, herbicide runoff was greatly reduced. In two studies (7, 10), essentially no surface runoff was generated. This was attributed to increased infiltration capacity in the no-till fields. Consequently, fewer rainfall events generated a corresponding field water runoff event compared to the moldboard fields.

Soil erosion and water runoff are also substantially reduced with the no-till system (Figures 2 and 3). Three studies on highly erodible land show the average soil erosion loss (tons per acre) is 93 percent less from no-till fields with

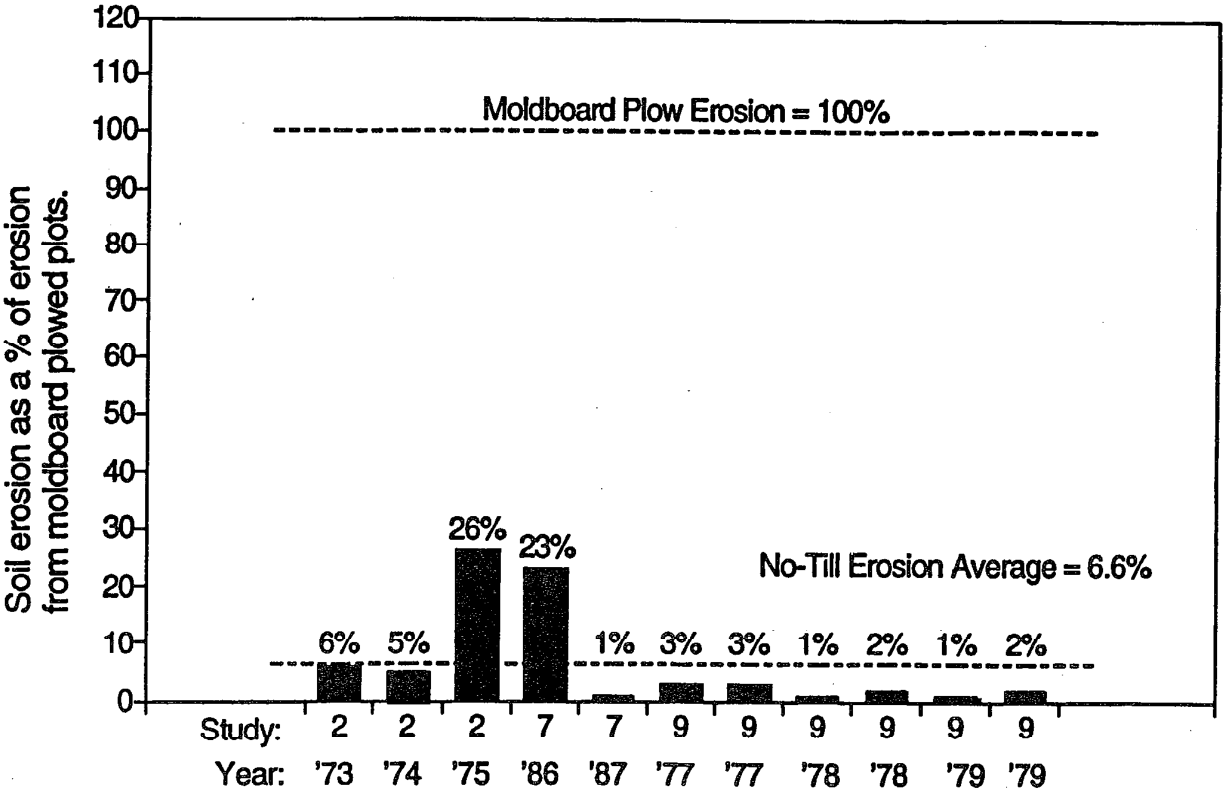

Figure 2. Soil erosion from no-till watersheds compared to conventional tillage (moldboard plowed) watersheds. A summary of natural rainfall studies.

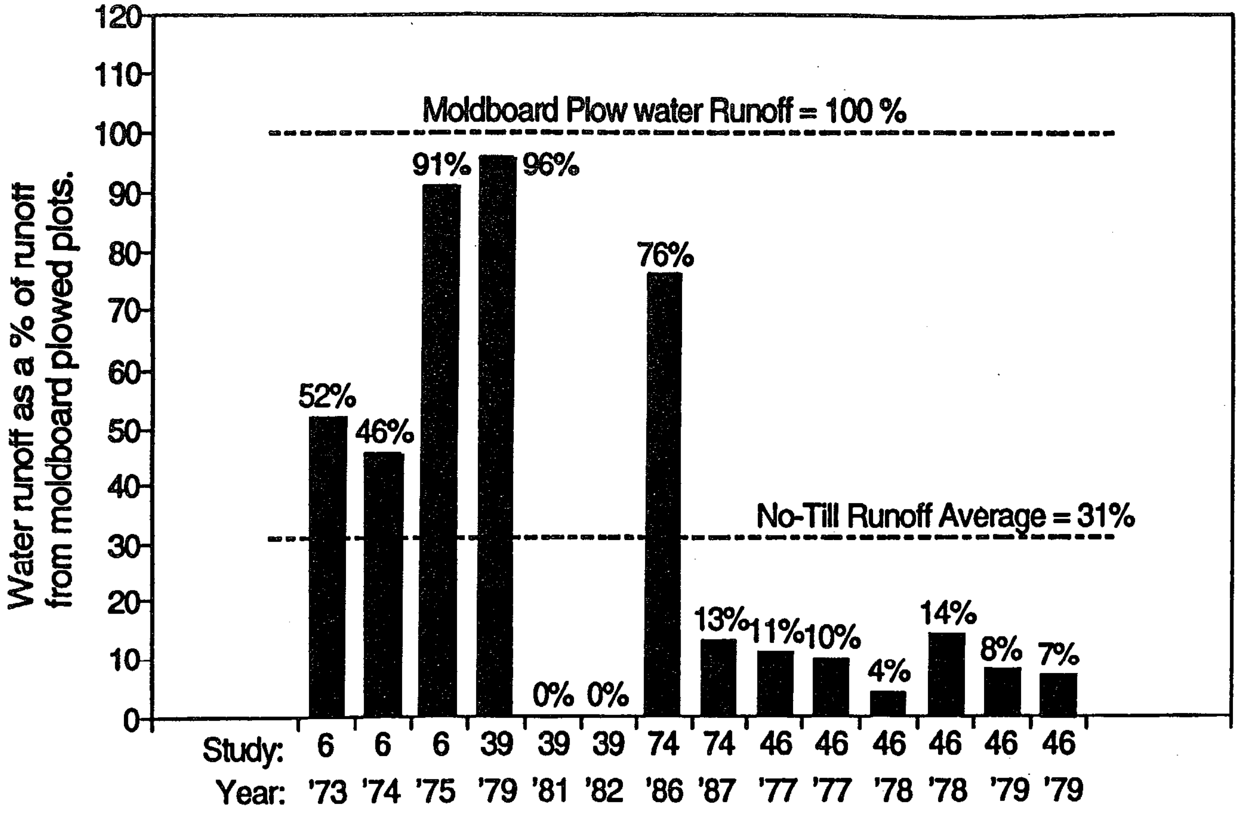

Figure 3. Comparing water runoff from no-till watersheds with conventional tillage (moldboard plowed) watersheds. A summary of natural rainfall studies.

the least reduction at about 25 percent of moldboard plow soil losses (Figure 2). Similarly, though there is greater annual variation with the generation of water runoff events (Figure 3), there is, on the average, less runoff from no-tilled fields than moldboard plow fields. The average runoff percent for the four studies over 10 years was 31 percent of that with conventional tillage.

The fact that no-till usually reduces soil erosion by more than 90 percent illustrates why it is an increasingly popular soil conservation technique. Herbicides are an essential component of no-till systems. The loss of effective herbicides due to regulatory actions prompted by surface water quality concerns could cripple soil conservation efforts. Thus, adoption of BMPs to reduce herbicide runoff is critical in order to maintain the availability of needed products.

Ridge Till - Chisel Plow

Other types of conservation tillage practices, such as ridge-till and chisel plowing, can also reduce herbicide runoff. These systems leave more crop residue than conventional tillage, but less than no-till.

Two studies (1974-75 and 1986-87) which focused on four herbicides (alachlor, strazine, cyanazine, and simazine) compared herbicide runoff from ridge-till and chisel-plow fields to runoff from moldboard plow field (2, 12). The herbicide runoff loss from the chisel-plow study was on average 31 percent (Figure 4), while the ridge-till herbicide average percent loss was 58 percent of moldboard plowed plots. Again, year-to-year variation is noted and these two systems also appear to be effective with all products studied. As with the no-till practice, both ridge-till and chisel-plow reduce soil erosion (Figure 5) and water runoff (Figure 6) compared to moldboard plow fields.

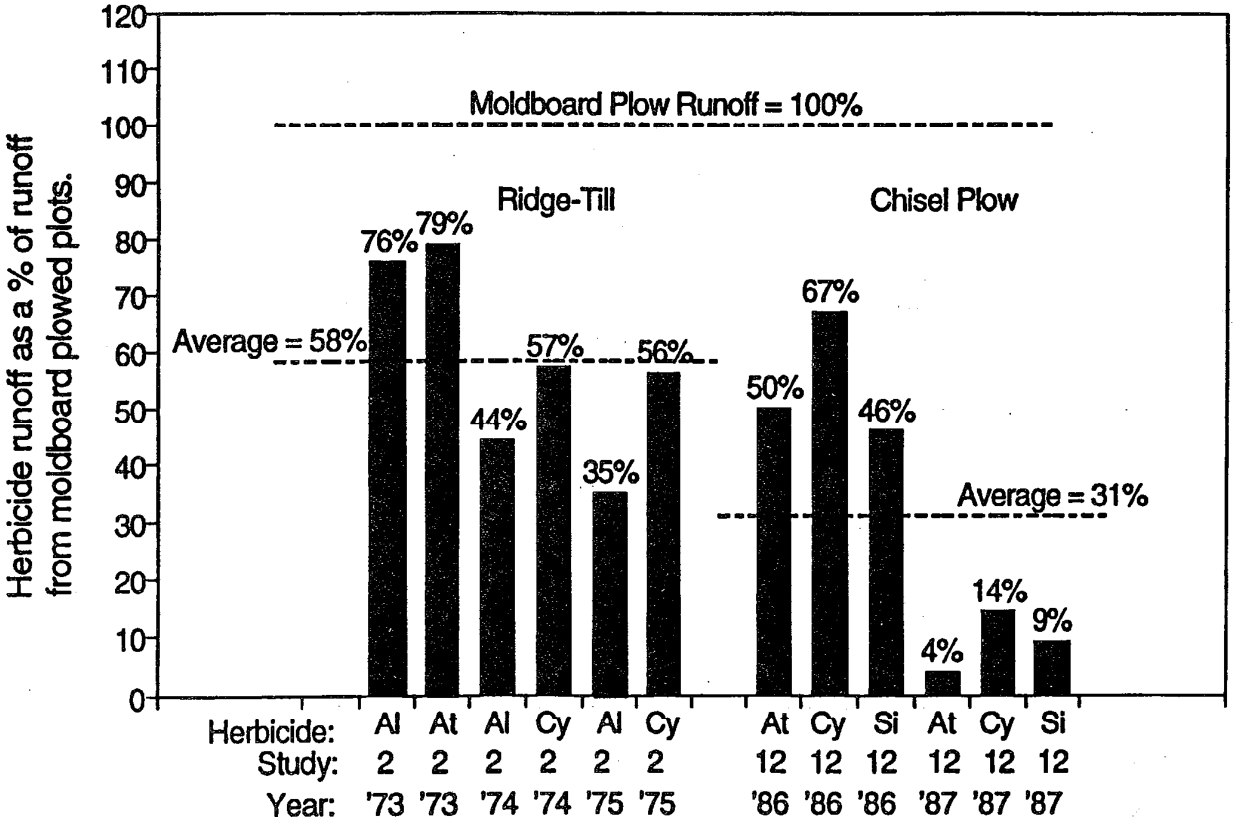

Figure 4. Herbicide runoff from ridge-till and chisel plow plots compared to conventional tillage (moldboard plowed) plots. A summary of natural rainfall studies.

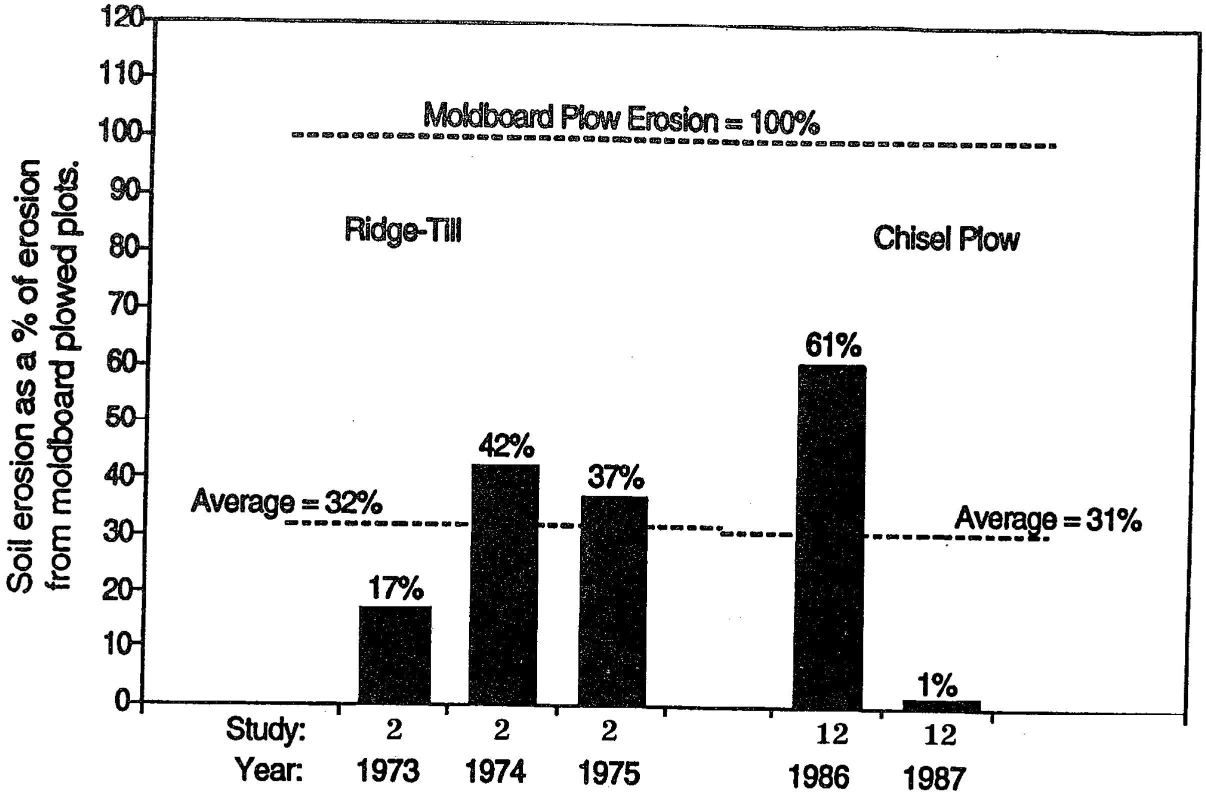

Figure 5. Soil erosion from ridge-till and chisel plow plots compared to conventional tillage (moldboard plowed) plots. A summary of natural rainfall studies.

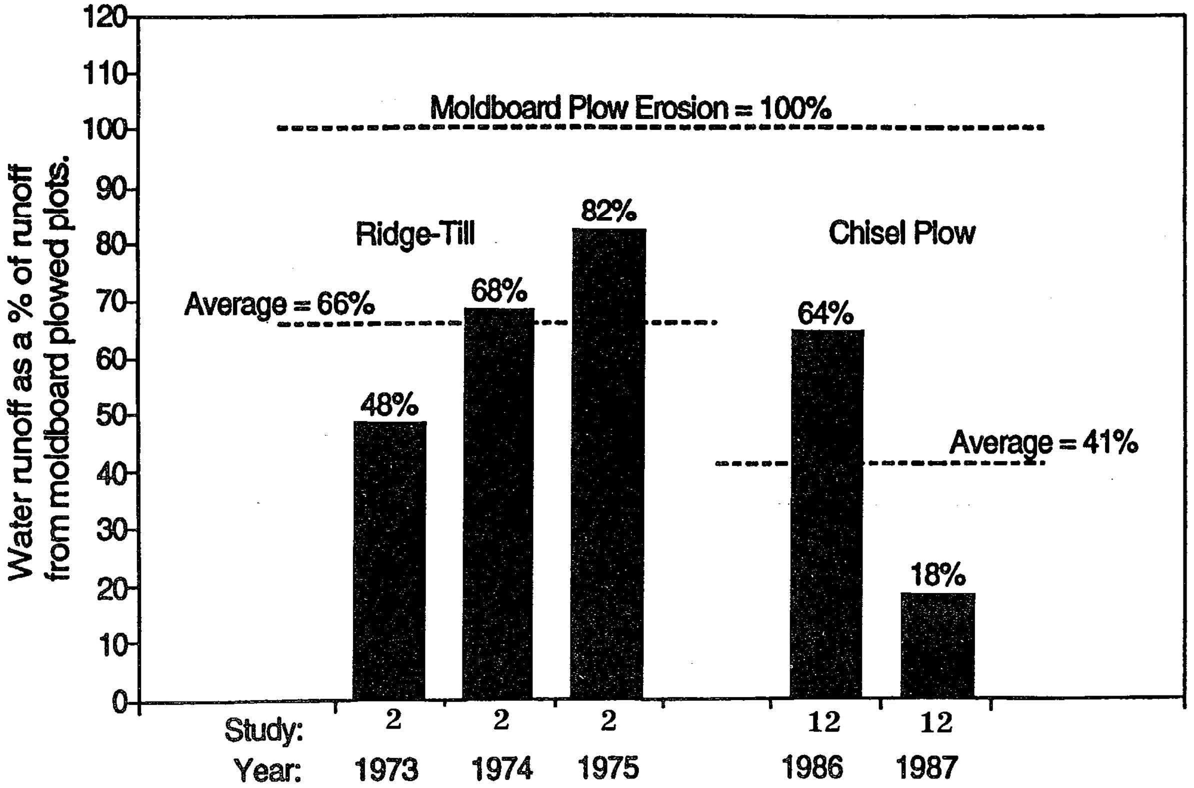

Figure 6. Surface water runoff from ridge-till and chisel plow plots compared to conventional tillage (moldboard plowed) plots. A summary of natural rainfall studies.

Due to the limited number of studies, these averages are difficult to directly compare to the no-till results. However, they illustrate that these practices can also reduce herbicide runoff, soil erosion, and water runoff. Where no-till practices are tillage BMPs of choice for fields with highly erodible land (HEL), ridge-till and chisel-plow practices can be used on flatter, less erodible land with good soil conservation results.

To help illustrate the simultaneous effect of CT systems, such as no-till and ridge-till, in reducing water and soil losses from fields, Table 2 is provided. It is adapted from an Iowa State University Study by J.L. Baker and H.R. Johnson in 1973-1975 (2).

TABLE 2

TOTAL AMOUNTS OF SOIL EROSION, WATER RUNOFF, AND HERBICIDE RUNOFF WITH VARYING TILLAGE SYSTEMS IN AN IOWA SMALL WATERSHED, NATURAL RAINFALL STUDY

(Adapted from J.L. Baker and H.P. Johnson, Reference No. 2)

Tillage Treatment	Soil Erosion Tons/Acre	Water Runoff Gallons/Acre	Alachlor Runoff Pounds/Acre
1973			
Moldboard Plow	7.3	43,700	0.013
Ridge-Till	1.4	21,400	0.009
No-Till	0.5	23,500	0.014
1974			
Moldboard Plow	23.1	87,600	0.080
Ridge-Till	10.1	58,800	0.040
No-Till	0.8	40,600	0.009
1975			
Moldboard Plow	7.7	37,400	0.002
Ridge-Till	3.2	32,000	0.001
No-Till	1.6	34,200	0.0002

Where percentage comparisons were used previously (Figure 1) to show differences between CT practices and the moldboard plow, actual tons of soil erosion and gallons of water runoff per acre are included in Table 2.

The U.S. Department of Agriculture has established soil erosion loss tolerances (T) for every soil type. Depending on soil types, losses above two to five tons per acre per year are considered excessive. In all three years, no-till fields were well below (four to eight times) this erosion threshold while moldboard plow fields exceeded it (Table 2). Soil erosion was greatest with the moldboard plow for the three years. Water runoff varied from year-to-year with each tillage practice, but was always less with the no-till system than the moldboard plow. The ridge-till system provided erosion and water runoff practices intermediate to the other two practices on highly erodible fields (14 percent slope).

Since herbicide loss from treated fields can occur in runoff water and by adhering to soil particles, reduction in herbicide field loss would be expected to parallel soil erosion and water runoff reduction. This is observed in the Iowa study (Table 2). While the amounts of alachlor leaving the treated fields is relatively small (usually 4 percent or less), less product was removed, on the average, from the ridge-till and no-till fields. The absolute quantity of alachlor loss ranged from 0.080 pounds per acre (moldboard plow) in 1974 to 0.0002 pounds (no-till) in 1975. The application rate for all years was 2 pounds per acre.

Some studies used simulated rainfall to investigate the tillage practice effects on herbicide runoff. These studies usually show conservation tillage systems reduce herbicide runoff, although clear-cut positive results were less than in natural rainfall studies. In some studies, no-till produced similar or greater amounts of herbicide runoff (4, 5, 13). The difference between results for natural and simulated studies is primarily due to the experimental methods. Rainfall simulation studies often use worst-case rainstorms (i.e., once-in-100-year frequency events) within 24 hours after herbicide application. It is under these worst-case conditions that no-till is least likely to reduce herbicide runoff. Under natural rainfall conditions, less intense rain events occur more frequently after application. The rainfall washes the herbicide from the plant residue into the soil. Then, if subsequent storms approach worst-case rainfall, less product is readily available to runoff in the field.

Soil conditions can also influence the effectiveness of conservation tillage in reducing runoff. If soils are poorly drained or have an impermeable clay pan, water infiltration may not be improved with no-till, and herbicide runoff increased. Thus BMPs, such as no-till, will have to be matched to local conditions.

Conventional Tillage and Incorporation

Many modern day herbicides can provide successful weed control through mechanical incorporation of the surface-applied product into the top inch or two of soil. Consequently, less product is readily available for entrainment in the surface water runoff. Two studies (1972 and 1978) compared runoff water loss of three herbicides (alachlor, atrazine, and propachlor) using surface applications with and without mechanical incorporation (Figure 7). Product incorporation resulted in a 62 percent average reduction in runoff compared to surface application.

There are limitations to the wide-scale field use of mechanical incorporation. Since the tillage practice used to incorporate the herbicides also buries the crop residue, incorporation-related tillage may not be the BMP of choice on HEL to meet federal conservation compliance guides for soil erosion. It can be a BMP for use on relatively flat fields with soils of low erosion potential, provided the products selected maintain weed control performance and the crop injury potential is not enhanced.

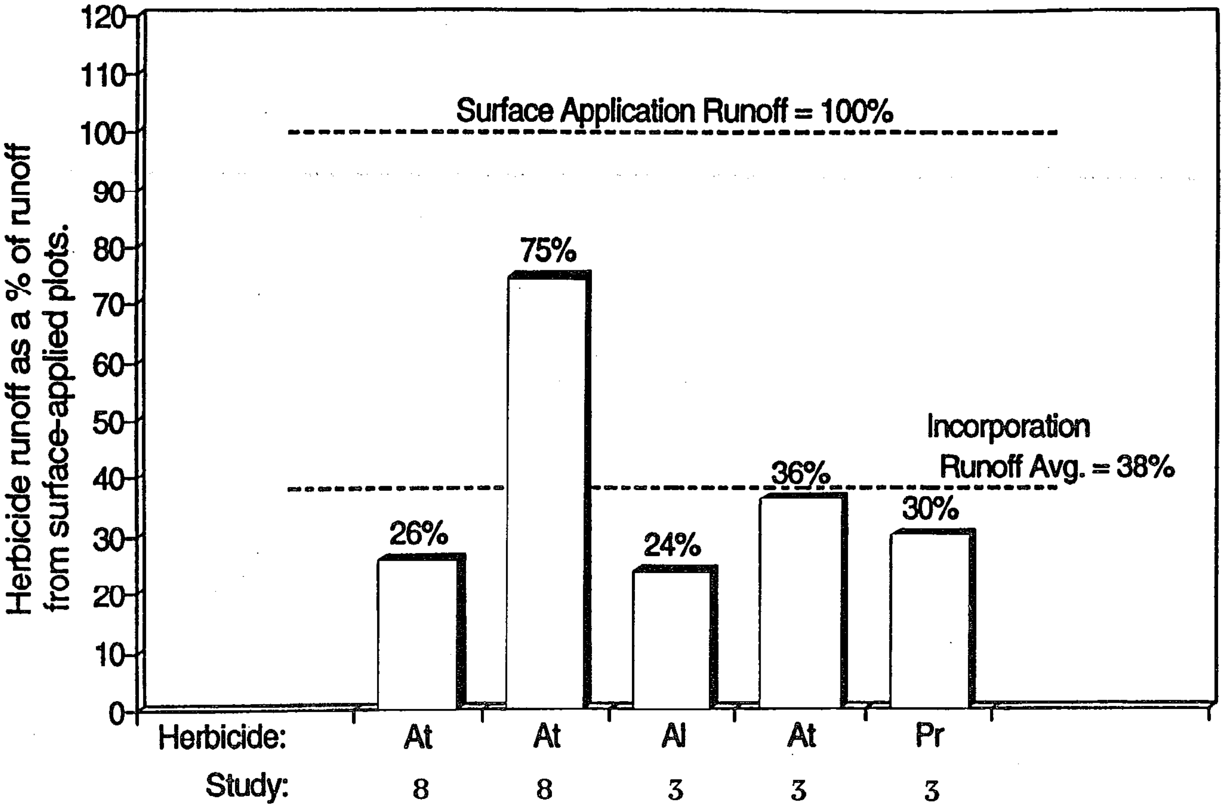

Figure 7. A comparison of herbicide runoff from plots where the herbicide was incorporated to surface-applied plots. A summary of studies.

Contour Farming and Field Terraces

Physical Modification of field slopes and grades, or farming direction changes represent BMPs which reduce soil erosion, water runoff, and associated herbicide loss. On hilly fields, contour farming or planting crops in rows across the slope reduces herbicide loss, through less soil erosion and water runoff, by as much as 60 percent (5).

Terraces are constructed to shorten the length of slopes and reduce soil erosion. Although few studies have been conducted on terrace effects on herbicide runoff, terraces reduce soil erosion and water runoff, and should reduce herbicide runoff. There is the potential that terraces with tile outlets could increase runoff of herbicides since this terrace system carries field water runoff through tile lines directly into surface water. More research is needed to determine the water quality implications of this type of terrace.

Filter Strips and Grass Waterways

A filter strip is an intermediate buffer area between the crop field edge and a surface waterbody. It is usually placed at the base of a field slope on the edge of a field where runoff water enters a stream or waterbody. It can vary in width and provides greater soil erosion effectiveness when vegetated. The filter strip physically slows the flow of water and traps eroded soil particles. Similarly, a grassed waterway is an infield defined water runoff pathway to a stable water course outlet. Where constructed and planted with a vegetative cover, this BMP reduces gully and emphemeral erosion.

Three small plot studies assessed the effectiveness of filter strips (1972) and grass waterways (1977 and 1980) in reducing herbicide runoff. Three products (atrazine, 2,4-D and trifluralin) were evaluated. A filter strip with a width of 15 feet reduced atrazine runoff from a conventionally tilled 40-foot long plot by an average of 78 percent, compared to a similar tilled plot without it (Figure 8). Grassed waterway comparisons of herbicide runoff reduction resulted in an 81 percent reduction compared to field sites without them (Figure 9).

The ability of these techniques to reduce soil erosion is well documented (1, 18, 19). As noted, few studies have investigated their impact on herbicide runoff, but results to dated are promising. More research in needed to determine the best design of filter strips to match varying topography and amounts of water flow.

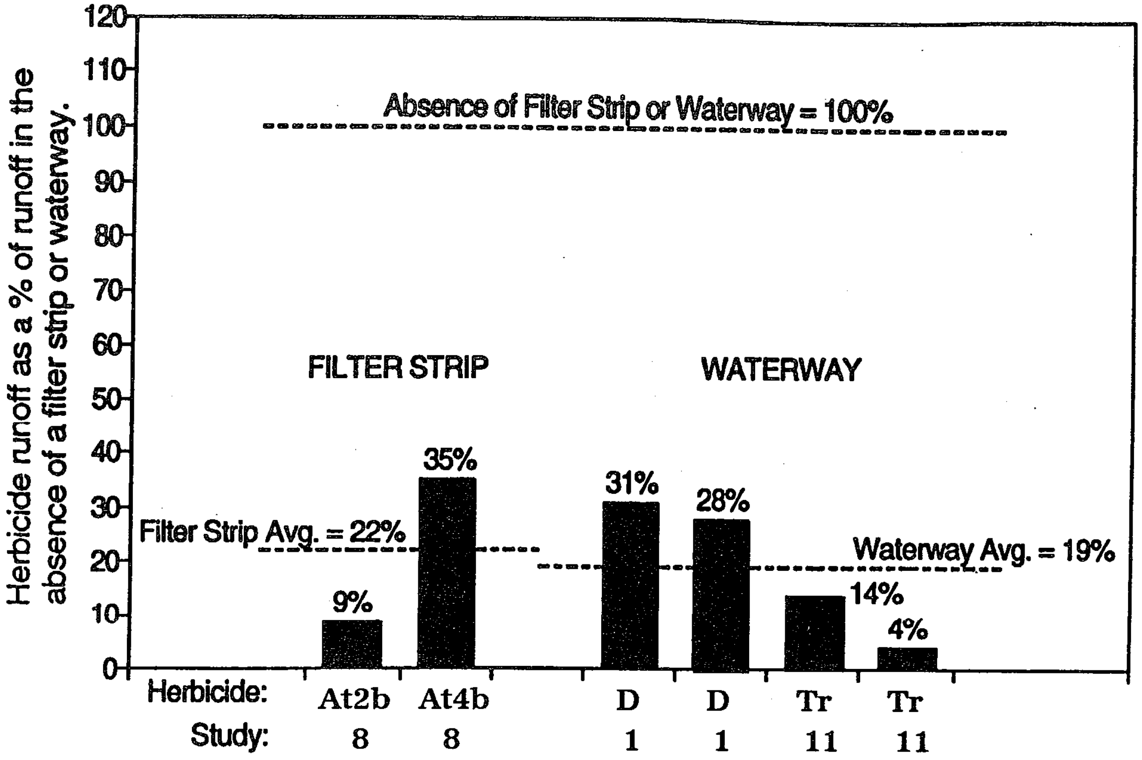

Figure 8. Herbicide runoff as affected by filter strips or grassed waterways compared to the absence of filter strips of waterways. A summary of studies.

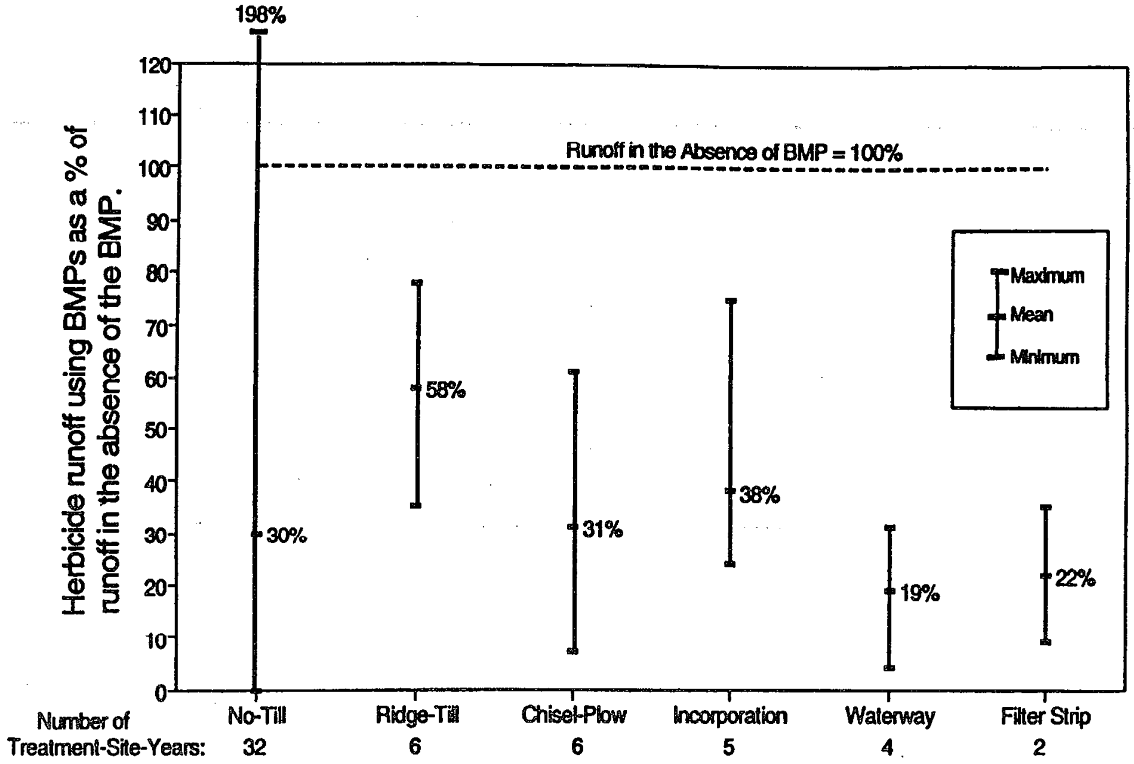

Figure 9. Summary of studies comparing herbicide runoff with BMPs to runoff without BMPs. Note: due to the difference in the number of studies and years of each BMP, only general comparisons between practices should be made.

Other Best Management Practices

Field practices which increase water infiltration can reduce herbicide runoff. Studies on reduced soil compaction and improved internal field drainage by drainage tile have shown reduced herbicide runoff (3, 20).

Herbicide application timing can also affect the probability of product runoff. Application to wet soils has resulted in greater runoff than application to dry soils. Application when heavy rainfall in imminent should be avoided. Long-term rainfall records may be useful to guide application timing and rates, using lower rates when runoff producing rains are more likely. Pesticide formulation changes may also reduce environmental impacts (21). Techniques such as pesticide encapsulation are being studied to determine if leaching and runoff can be reduced (22, 23). Increasing the use of crop rotation can reduce pesticide runoff risk by increasing the amount of crop residue present and improving soil structure and water infiltration. Crop rotation usually reduces reliance on any one herbicide, reducing the total acres treated in any watershed.

Summary

Over 140 reports and papers from the published literature were reviewed. The goal of this effort is to assess which management systems would be effective field BMPs to manage surface water runoff an associated soil erosion and herbicide movement.

Based on this review, the following observations can be drawn:

- Conservation tillage systems are sound field BMPs to reduce soil erosion (Figures 2 and 5).

- The no-tillage practice is an excellent BMP .

- All conservation tillage practices (i.e., no-till, ridge-till, and mulch-till) reduced herbicide movement from the treated field on highly-erodible land when compared to fields prepared with the moldboard plow.

- The average reduction herbicide runoff ranged from 70 percent in no-till practices to 42 percent for ridge-till practices (Figure 9).

- The conservation tillage practices appear to provide similar reductions for all products (i.e., alachor, atrazine, cyanazine, metolachlor, and simazine).

- The use of filter strips and grass waterways holds promise as excellent BMPs. Herbicide reductions averaged 81 and 78 percent, respectively (Figures 8 and 9).

- The amount of herbicide runoff with field BMPs in place will vary from year-to-year (Figures 1 and 4, Table 2).

- It is not possible to predict exactly how much herbicide runoff reduction each BMP will produce in a given year and location due to variations in weather, soil, crop rotations, and field topography.

- Conventional moldboard tillage followed by soil incorporation of the herbicide provides herbicide runoff reduction (Figure 7) when crop production is not on highly-erodible soil.

- Due to the difference in the number of studies for each field BMP, only general comparisons among the practices should be made.

- The field BMPs, such as conservation tillage practices, filter strips, and grass waterways provide improved erosion and herbicide control.

Research continues to determine the impact of BMPs on other concerns such as ground water quality. For a full discussion of surface water BMPs with a complete literature review and discussion of impacts on other environmental concerns, refer to the publication, "Best Management Practices to Reduce Runoff of Pesticides into Surface Water: A Review and Analysis of Supporting Research."

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