1997

Ridge, Moldboard, Chisel, and No-Till Effects on Tile Water Quality beneath Two Cropping Systems

Rameshwar S. Kanwar
Iowa State University, rskanwar@iastate.edu

Thomas S. Colvin
United States Department of Agriculture

Douglas L. Karlen
United States Department of Agriculture

Follow this and additional works at: https://lib.dr.iastate.edu/abe_eng_pubs
Part of the Agriculture Commons, Bioresource and Agricultural Engineering Commons, Hydrology Commons, and the Water Resource Management Commons

The complete bibliographic information for this item can be found at https://lib.dr.iastate.edu/abe_eng_pubs/684. For information on how to cite this item, please visit http://lib.dr.iastate.edu/howtocite.html.
Ridge, Moldboard, Chisel, and No-Till Effects on Tile Water Quality beneath Two Cropping Systems

Abstract
Soil conservation tillage systems, including ridge-tillage, often reduce surface water contamination by pesticides because soil erosion and surface runoff are reduced. However, the effects on losses through subsurface drainage tile are somewhat uncertain. Our field study quantified the effects of four tillage practices in continuous corn (Zea mays L.) and corn-soybean [Glycine max (L.) Merr] rotations on herbicide and nitrate N losses in tile drainage water. Fertilizer and pesticide application methods were uniform for ridge, moldboard, chisel, and no-till systems. Pesticide and nitrate N leaching losses were significantly affected by crop rotation. Tillage practice had little influence on nitrate N and pesticide losses to the subsurface drainage water within a corn-soybean rotation. However, ridge-till and no-till resulted in larger losses of atrazine than the moldboard plow and chisel based systems under continuous corn. Tillage system did not affect the timings of peak tile flow occurrences, although peak tile flow volume was affected by tillage, presumably because each system had its own macropore system related to preservation or annual destruction of biopores by tillage. Corn yields were significantly higher under corn-soybean rotation than with continuous-corn for all tillage practices. These results indicate that continuous corn production is not an environmentally sustainable practice for this area because it resulted in higher nitrate N leaching losses to groundwater, received higher N-applications, and resulted in lower corn yields than the corn-soybean rotation. The results also reinforce the need for studies on chemical placement, rate, and timing for various tillage practices to reduce tile drainage losses of agricultural chemicals.

Disciplines
Agriculture | Bioresource and Agricultural Engineering | Hydrology | Water Resource Management

Comments

Rights
Works produced by employees of the U.S. Government as part of their official duties are not copyrighted within the U.S. The content of this document is not copyrighted.
Research Application Summaries
Soil and Water Quality

Ridge, Moldboard, Chisel, and No-Till Effects on Tile Water Quality beneath Two Cropping Systems
R. S. Kanwar, T. S. Colvin, and D. L. Karlen

Problem
Pesticide and nitrate losses into groundwater aquifers from some soil and crop management practices are decreasing the water quality.

Literature Summary
Agricultural chemicals applied on or near the soil surface can be rapidly transported to deeper soil depths and into shallow groundwater. One process through which this occurs is movement through tile drainage water. The type of tillage and cropping system used can influence the amount of these materials that can be lost from agricultural fields. However, the effects of these practices, especially at the field scale are not well understood. A better understanding of soil management practices is therefore needed to protect surface and groundwater quality.

Chemical leaching losses can be minimized by using practices like banding of herbicides and multiple N applications to decrease herbicide and nitrate concentrations in the soil water, but it is difficult to control the volume of tile drainage water. One exception is that ridge-till and no-till practices can be used to increase the amount of crop residue left on the soil surface. This influences rainfall partitioning between surface runoff and subsurface drainage, which can increase agrichemical movement with subsurface drainage as surface runoff would be decreased.

Ridge-till can increase crop yield on poorly drained soils by creating ridges that are warmer and drier than soils that are not tilled. Ridge-till can also have economic advantages because it combines tillage and herbicides to control weeds. Comparison between ridge-till and other conservation tillage practices is needed to determine the effects of these practices on drainage water quality. The main objective for this study was to quantify the effects of four tillage practices in continuous corn and corn-soybean rotations on herbicide and nitrate N loss to tile drainage water.

Study Description
This study was conducted at Iowa State University’s Northeast Research Center near Nashua, on the Kenyon-Clyde-Floyd soil association. The site has 36 1-acre plots that have had a subsurface drainage system installed for more than 14 yr. Tile lines are spaced 95 ft apart at an approximate depth of 4 ft. Each plot has tile lines along the edge and one in the middle that has been intercepted and connected to an individual sump to measure the volume of water flow. Approximately 0.2% of the tile drainage water is collected every time water is pumped for nitrate N and herbicide analyses.

Tillage treatments were fall moldboard plow, fall chisel plow, ridge-till and no-till. Continuous-corn and corn-soybean rotations were compared for all tillage.
treatments. Crops were planted in 3041-1 rows with a six row planter. Because the combine had a 90-in. wheel base, four of every six rows had a wheel track during the season. Continuous corn plots received 180 lb N/acre each year, while rotated corn received 150 lb N/acre as anhydrous ammonia injected between rows. Continuous-corn treatment received alachlor (2.0 lb a.i./acre) plus atrazine (2.5 lb a.i./acre) plus Counter for rootworm control. Corn in the corn-soybean rotation received alachlor (2.0 lb a.i./acre) plus cyanazine (2.5 lb a.i./acre) and no insecticide. Soybean plots received alachlor (2.0 lb a.i./acre) plus metribuzin.

Cultivation, even with the no-tillage treatment, was used to help with weed control. Drainage water samples were analyzed for alachlor, atrazine, cyanazine, metribuzin, and nitrate N.

Will adoption of ridge-tillage for continuous corn or corn-soybean rotations reduce nitrate N and pesticide loss to tile drainage water?

The years 1988 and 1989 were extremely dry, and the rainfall was well below normal. The years 1990 and 1991 were unusually wet, with total rainfall amounts of more than 41 and 38 in., respectively. The year 1992 had a dry spring and wet fall with a total rainfall of 29.2 in. These rainfall patterns caused all tile lines to flow through most of the growing seasons of 1990, 1991, and 1992. Tile flow had similar relationships among tillage systems in 1991 and 1992, indicating that tillage systems did not affect the total tile flow volumes. Larger tile flows occurred with continuous-corn than with the corn-soybean rotation. On the average, no-till and ridge-till systems had the highest peak tile flows for most growing season storms regardless of crop. Higher peak tile flows under the ridge-till and no-till probably occurred because macropores (worm or root holes and natural fractures) are not destroyed or disturbed by primary tillage.

With continuous corn, average subsurface drainage from no-till was significantly higher than from moldboard plow plots, but for the corn-soybean rotation, tile flows were not statistically different for various tillages. A different macro-pore system appears to be operative under each crop rotation and tillage treatment. Losses of nitrate N were much greater under continuous corn than under corn-soybean rotation. In 1991, they ranged from 26 to 68 lb/acre, while in 1990, the highest loss of 96 lb/acre was about 50% of the annual amount applied. Less nitrate N was lost from the corn-soybean rotation than from continuous corn because N application rates were lower and less frequent and yields were higher. Atrazine losses were greater than for cyanazine or metribuzin.

The rapid appearance of atrazine, alachlor, cyanazine, and metribuzin at high concentrations in subsurface drainage water shortly after rainfall suggests that preferential movement of these herbicides occurred in this silty soil overlaying loamy glacial till. Ridge-till and no-till practices, especially with continuous corn, appear to preserve a macropore network more than chisel or moldboard plowing. We conclude that, to reduce nitrate N and herbicide losses to drainage water, ridge-till and no-till practices should be used in combination with 2-yr corn-soybean rotation.
Ridge, Moldboard, Chisel, and No-Till Effects on Tile Water Quality

Soil conservation tillage systems, including ridge-tillage, have been studied to help develop better management practices for agrichemicals to deeper soil layers. This reduces the potential for leaching to groundwater.

Crop rotation can affect the timings of peak tile flow occurrences, although peak tile flow volume was often unknown because pesticide and N leaching are affected by many factors (Spalding et al., 1989; Johnson and Cruse, 1992; Clay et al., 1992, 1994; Lowery et al., 1993). The local hydrologic balance generally controls this volume, although some tillage practices (Kanwar and Baker, 1992; Hallberg, 1989; USGAO, 1991) can minimize chemical leaching losses by decreasing agrichemical movement.

Chemicals are often transported through soil and into shallow groundwater (Everts and Kanwar, 1994; Isensee et al., 1988; Merr, 1990; Kross, 1990; Hallberg, 1989; USGAO, 1991). The amount of subsurface drainage is one factor affecting these processes. The local hydrologic balance generally controls this volume. Agrichemical movement is primarily by mass flow. To develop soil and crop management systems that protect groundwater quality, various ground-water contamination mechanisms need better understanding.

Tile drainage losses of agricultural chemicals are warmer than if soil is not tilled, crop yield on poorly drained soils is often increased. Ridge-till is drained soils is often increased. Ridge-till and no-till, have been studied to help develop better management practices for agrichemicals to deeper soil layers. This reduces the potential for leaching to groundwater. (Reeder, 1992). Ridge-till is

### Nitrogen Leaching

Nitrogen leaching is significant than the moldboard plow and chisel based systems under Project no. 3003. Kanwar et al., 1985, 1988, 1993). This rapid movement of chemicals is evidenced by preferential flow of solutes for all tillage practices. These results indicate that continuous corn production is not an environmentally sustainable practice because it resulted in higher nitrate N and pesticide losses to the groundwater (Everts and Kanwar, 1994; Isensee et al., 1988; Merr, 1990). The results also reinforce the need for studies on chemical placement, rate, and timing for various tillage practices to reduce tile drainage losses of agricultural chemicals. While conventional tillage destroys most of the root channeling, ridge-till is beneficial because soil erosion and surface runoff are reduced. However, ridge-till and no-till resulted in larger losses of atrazine and other pesticides and N, but their impact, especially at the field and watershed scales, are not thoroughly understood. One factor on which tillage has a profound effect is the amount of crop residue left on the soil surface. This influences partitioning agrichemical movement.

Placement of agrichemicals in soil zones that are favorable for root growth and where water does not accumulate may also reduce the potential for leaching to groundwater. While conventional tillage destroys most of the root channels and other preferential pathways for movement of water are warmer than if soil is not tilled, crop yield on poorly drained soils is often increased. Ridge-till is warmer than if soil is not tilled, crop yield on poorly drained soils is often increased. Ridge-till and no-till, have been studied to help develop better management practices for agrichemicals to deeper soil layers.

Various crop rotation systems can have a major impact on surface water and groundwater contamination by agrichemicals to deeper soil layers. This influences partitioning agrichemical movement. While conventional tillage destroys most of the root channels and other preferential pathways for movement of water, ridge-till is warmer than if soil is not tilled, crop yield on poorly drained soils is often increased.

Interest in ridge-tillage is increasing because, by controlling the number of continuous macropores which can be larger losses of atrazine and other pesticides and N, but their impact, especially at the field and watershed scales, are not thoroughly understood. One factor on which tillage has a profound effect is the amount of crop residue left on the soil surface. This influences partitioning agrichemical movement. Placement of agrichemicals in soil zones that are favorable for root growth and where water does not accumulate may also reduce the potential for leaching to groundwater. While conventional tillage destroys most of the root channels and other preferential pathways for movement of water, ridge-till is warmer than if soil is not tilled, crop yield on poorly drained soils is often increased.

Tillage practice and crop sequence can have a major impact on losses to the groundwater. These results indicate that continuous corn production is not an environmentally sustainable practice because it resulted in higher nitrate N and pesticide losses to the groundwater.
continuous corn treatments were replicated three times in a
have been in place since 1977. Corn-soybean rotation and
228
continuous-corn and corn-soybean rotations.

The ridge-till plots had the top of the ridge removed by the
planter, but ridges were reestablished at a height of 6 to 8 in.
plots were chiseled in the fall and cultivated in the spring.
tor tile flow on a continuous basis, each tile sump has a 110
volt effluent pump, water flow meter, and an orifice tube to
collect water samples for water quality analysis. The water
flow data. For water quality sampling, an orifice tube was
water samples for chemical analyses. The middle drainage
were intercepted and connected to individual sumps for
each of the two borders. Middle tile lines of all the plots
were installed about 4 ft deep at 954 spacing and had also
been in place for more than 14 yr. Each 1 -acre plot has a tile
measuring subsurface drainage (tile flow) and collecting
from cross contamination from all four sides as this tile
ally high water tables that vary from 2 to 5 ft below the sur-
tillage and cropping practices for 14 yr (Karlen et al., 1991)
Kenyon-Clyde-Floyd soil association. Generally, pre-
illinoisan glacial till units of 200 ft in depth overlie a car-
dolls), Kenyon silty-clay loam (fine loamy, mixed, mesic
Aquic Hapludolls), and Readlyn loam (fine-loamy, mixed,
mesic Aquic Hapludolls). These silty soils are moderately
SCS, 1977), have 3 to

tion when four tillage practices were imposed on 1-acre con-
tinuous corn and corn-soybean rotation plots.
A careful comparison between ridge-till and other con-
study was conducted at Iowa State University's
Northeast Research Center in Nashua. The soils at this site

Crop rotation, tillage, and chemical application practices
a 250-mC sample, then passing the
trade and company names

J. Prod. Agric.,

10, 1997

not imply endorsement

Milwaukee,

physiological maturity or

nitrate N.

Lachat Model AE ion analyzer' (Lachat Instruments,

Selective liquid chromatography. The minimum detection limit for herbicides in water
samples was 2 ppm (0.2 mgkg) a.i. Water samples were
eluted from cartridge with 2 mL of ethyl acetate that con-
herbicides of interest. The herbicides and surrogate were
 cartridges', which adsorbs organic compounds, including the
spectrophotometrically analyzed for nitrate N using a
when tile lines were flowing. After any major rain storm,

concentrations. Composite tile water samples for pesticides
analysis approximately three times per week when tile lines

within 60 d of pesticide application; during the remainder of

applicator knife was a standard knife about 0.75 to 1 in.
wide. All herbicides and insecticides were broadcast full-

knifed-in just before planting. The anhydrous ammonia
Metribuzin (0.4 lb a.i./acre). Anhydrous ammonia was
cide. Soybean plots received alachlor (2.0 lb adacre) plus
were refrigerated until analyzed in the lab. Drainage water
concentrations. Composite tile water samples for pesticides
were flowing to observe time base variations in the nitrate N

Corsoy 79 from 1982 through 1986, Elgin in 1987, Hardin
randomized complete block design on 36, 1-acre plots. Both

year. Corn hybrids include Pioneer' 3747 in 1985 and 1986,
Pioneer 3782 in 1987, and Golden Harvest H2343 from
tillage treatments resulted in different tile drainage.

With corn-soybean or soybean-corn rotation, this site. Larger tile flows were observed with continuous-tillage systems except ridge-till. A different macropore system appears to be operative under each crop rotation and equally important following the drought years of 1988 and 1989 may have left a large number of root and worm holes intact from previous years as macropores (worm or root holes and natural fractures) are not destroyed or disturbed. In solute transport experiments, Singh and Hanway, 1984) to determine N accumulation by the corn chopped, ground to pass a No. 34 (0.02 in. or 0.5-mm) stain.

Grain yields for each plot were measured with a modified commercial combine. To calculate N removal, grain samples in 1992 were ground and analyzed for N concentration using the Carlo-Erba Model NCS' 1500 (Haake Buchler Instruments, Patterson, N.J.) dry combustion analyzer. Total aerial biomass and N population (26 500 plantdacre

RESULTS AND DISCUSSION

<table>
<thead>
<tr>
<th>Rain (in.)</th>
<th>Rotation</th>
<th>Avg. CP</th>
<th>Avg. MF</th>
<th>Avg. SC</th>
<th>Avg. CP</th>
<th>Avg. MF</th>
<th>Avg. SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>41.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
<tr>
<td>38.3</td>
<td>continuous corn; ridge-tillage; NT</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
<td>38.3</td>
</tr>
</tbody>
</table>

Yearly average nitrate N concentrations were influenced by sampling date, tillage, and rotations. The years 1988 and 1989 were unusually wet, causing large volumes of preferential flow in 1990. More than 41 and 38 in., respectively. In 1992, spring was dry whereas in the same day that a major rainfall event occurred, indicating subsurface drainage under the corn-soybean rotation, however, moldboard plow treatment resulted in the lowest tile peak flow usually occurred within the first 0.5 h to about 6 h after the beginning of a major rainfall for all three years.
Fig. 1. Average daily tile flows under continuous corn in 1990 as a function of tillage (CP = chisel plow, MP = moldboard plow, RT = ridge-tillage, NT = no-tillage).

Fig. 2. Average daily tile flows under rotated corn in 1990 as a function of tillage (CP = chisel plow, MP = moldboard plow, RT = ridge-tillage, NT = no-tillage).

Fig. 3. Average daily nitrate N concentrations in tile flows under continuous corn in 1990 as a function of tillage (CP = chisel plow, MP = moldboard plow, RT = ridge-tillage, NT = netillage).

Fig. 4. Average daily nitrate N concentrations in tile flows under soybean-corn rotation in 1990 as a function of tillage (CP = chisel plow, MP = moldboard plow, RT = ridge-tillage, NT = netillage).
The 3-yr (1990 to 1992) average nitrate N concentrations in tile drainage water were significantly higher under continuous corn than under corn-soybean rotation for all tillage treatments (Table 1). This undoubtedly reflects the higher rate of N fertilization applied to the continuous corn plots. Average nitrate N concentrations in drainage water from the moldboard plow plots were significantly higher than from the no-till and ridge-till plots under continuous corn. Higher nitrate N concentrations in tile water from moldboard plowed plots than ridge-tillage or no-tillage treatments may have resulted from plowing and disking eliminating the macropore structure, resulting in conditions where water must pass through the soil profile according to the concepts of piston flow (matrix rather than preferential flow) (Kanwar, 1991). Lower nitrate N concentrations in tile water from no-till plots may have resulted from more water moving through macropores than the N fertilizer bound soil matrix or that less N was subjected to leaching because N mineralization rates may have been less in no-tillage than conventional tillage treatments. Of concern was the fact that in 1990, nitrate N concentrations in nearly all tile flow samples exceeded 10 ppm (the USEPA safe drinking water standard; USEPA, 1993) regardless of tillage practice and crop sequence.

Seasonal total nitrate N losses in drainage water ranged from 27 to 96 lb/acre for 1990 compared with 4 to 18 lb/acre in 1992 (Table 1). Losses of nitrate N were much greater under continuous corn than under corn-soybean rotation. Losses for 1991 ranged from 26 to 68 lb/acre. The highest nitrate N loss of 96 Ib/acre in 1990, about 50% of the amount applied, was from no-till plots under continuous corn. In 1991, the highest nitrate N loss of 68 Ib/acre was observed from chisel plow plots. Although nitrate N concentrations from continuous corn plots were greater under 0.2
0.15
h
E
P
2
0.1
2
G
v
3
0
0
0
-.
0.05
0
317x725
moldboard plow than under no-till, the total nitrate N losses through tile drainage water were greater under no-tillage and chisel plow systems because of a greater volume of water moving through the soil, although differences were not significant (Table 1). The nitrate N losses in 1992 were much lower than in earlier years because larger nitrate N losses were observed in two extremely wet years of 1990 and 1991. Statistically, there was no difference of nitrate N loss between tillage treatments within rotations. There is a large decrease in nitrate N loss when moving from continuous corn to corn-soybean rotation because N application rate on rotated corn was 150 Ib/acre, compared with a 2-yr total application of 360 Ib/acre under continuous corn. Uptake of residual N following the corn year by soybeans also contributed to lower losses of N with crop rotation. Also, the long-term effects of soil organic matter with rotations have to be evaluated for nitrate N leaching and sustainability of production systems as there is a possibility of differential N mineralization (or immobilization) among different tillages. Also, the sources of N in tile water includes soil organic matter, rain water, and applied N fertilizer.

The amount of atrazine losses to subsurface drain water were greater (although statistically nonsignificant) than with the other herbicide, alachlor, although there was difference in their application rates for different crop rotations (Fig. 5). Also, no-till and ridge-till had greater atrazine losses under continuous corn than moldboard plow and chisel plow systems but these differences were not statistically significant. Most of this leaching occurred in the first month after herbicide application (Kanwar et al., 1993 a). Weed et al. (1995) observed that for all years and tillages, 84% of alachlor, 70% of atrazine, and 82% of the metribuzen present in the soil profile were retained in the top 4 in. up to 48 d after application. This provided opportunity for the pond-
was significantly higher when grown in a rotation with soy-
also reflected in grain yields (Table 1).**

...the tillage systems than with moldboard plow and chisel... give higher cyanazine and metribuzin losses with rotated... potential flow can occur under no-till and ridge-till conditions,...

table 2. Tillage and crop rotation effect on aerial biomass accumulation (dry matter in tons per acre) and corn grain yield (bushels per acre at 15.5%

Factors          Rotation  
Tillage          CP    MP    RT  
CV(%)            ns  7.2  107  
Interaction      ns  24   96   
Yearly total N accumulation (Table 3) in the aerial biomass yield, grain yield, and N accumulation measurement...
Under these study conditions, continuous corn production resulted in higher nitrate N leaching into the tile lines, which led ultimately to surface water or groundwater resources. Ridge-till and no-till practices appear to preserve a macropore network better than chisel or moldboard plowing. Use of better chemical placement practices, which we did not evaluate in this study, may have the potential to correct some water quality problems associated with agricultural chemicals. Because no-till in continuous corn production performed most poorly (in terms of corn yields) in these studies, alternative practices should be incorporated into at least a 2-yr corn-soybean rotation to ensure the practices are both economically viable and environmentally benign. Economic acceptability of these systems will depend on the farmers' ability to reduce inputs, and hence costs, relative to the moldboard and chisel plow systems.