Conservation Tillage and Water Quality

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INTRODUCTION

Conservation tillage (CT) systems have become increasingly popular because they offer the grower an opportunity to save time and fuel without a reduction in yield. The systems are also popular with resource managers because of their potential to protect and preserve the quality of surface and ground water. Because of this, CT is being looked to as an ideal best management practice (BMP); however, to achieve water quality production as well as production benefits, different management is required. For example, no-till may dramatically reduce erosion rates but increase phosphorus (P) concentration in the runoff.

Before individual CT systems can be evaluated, an identification of various accepted CT systems is in order. There are probably as many different CT systems as growers, and while terminology varies widely, the generally accepted systems include chisel plow (CH), till-plant (TP) and no-till (NT) with the standard of comparison being the conventional (CN) system.

SURFACE WATER

Runoff and Erosion

Contaminants are transported dissolved in the runoff water or adsorbed to the sediment. The effect that CT systems have on these two important transport mechanisms determines their ultimate impact on water quality. Studies have shown that CT systems are highly effective in reducing soil loss relative to the CN system. The effectiveness of NT in reducing sediment concentrations and soil loss, relative to other CT systems, has been mostly ascribed to increased residue cover (Laflenand Colvin, 1981). However, the success of the NT system in reducing runoff volumes has been variable. The majority of studies (such as McGregor and Greer, 1982) have shown reduced runoff with NT; however, a limited number report little or no reduction (Mueller et al., 1984). The CH and TP systems may also substantially reduce soil loss compared to CN tillage (Johnson and Moldenhauer, 1979). Relative to CN tillage, CH and TP svstems have reduced both sediment concentrations and runoff volumes. Several studies have reported that soil loss reductions for the CH system were similar to those for NT (Griffith et al., 1977). Laflen et al. (1978) found the CH and TP systems to be less effectivethan NT but more effective than CN tillage in reducing soil loss.

Most scientists agree that relative to CN tillage, all the CT systems do a good job in reducing soil loss. While less firm in their conviction, most scientists also agree that CT systems generally reduce runoff. The inconsistency among studies as to the effect of CT on runoff data relates primarily to NT.

Phosphorus Loss

Phosphorus availability most often limits biological productivity in surface waters (Schindler, 1977). Consequently, increased input of available P in fresh water lakes and streams will often result in concomitantly increased growth of aquatic weeds and algae. Thus, reducing the amount of available P in runoff is a logical means of reducing the impact of agriculture on accelerated rates of eutrophication.

Maintenance of crop residues may limit fertilizer placement options and thus affect nutrient concentrations and losses (Baker and Laflen, 1983). Total P losses have generally been found to decrease due to soil loss reductions with CT systems (Mueller et al., 1984). However, studies have also indicated that concentrations and losses of dissolved P can substantially increase when CT is used (McDowell and McGregor, 1980; Johnson et al., 1979). Investigators generally attribute such increases to unincorporated fertilizer P and to a release of P from crop residues (Timmons et al., 1973; Wendt and Corey, 1980). In a study by Mueller et al. (1984) in which fertilizer was banded, concentrations and losses of dissolved P from CT treatments were similar to those from conventionally tilled plots, and concentrations and losses of algae-available P were reduced by CT. These researchers also demonstrated a dramatic increase in P loss relative to CN when manure was applied to NT and most of the runoff P occurred in the dissolved form. Andraski et al. (1985) later confirmed the ability of CT systems to reduce dissolved P load over CN tillage provided the fertilizer is banded (incorporated).

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Total P loss is decreased with CT systems due to reduced soil loss. The effect of CT on dissolved P loss depends on whether or not the fertilizer or manure is soil incorporated. Generally, when the material is incorporated, the P loss is reduced; when the material is not incorporated, significant increases in P loss can occur. The controversy appears to focus on NT because the materials are not incorporated into the soil. However, with some modification such problems can be circumvented. For example, manure application on NT is not a recommended practice from either a production or a water quality stand-point. The application of manure to an already high residue system only increases the probability of production problems and virtually ensures water quality degradation. A light incorporation of the manure reduces the potential for weed, temperature and planting problems and dramatically lowers P loss.

Pesticide Loss

Conservation tillage systems may have a detrimental effect on surface water quality due to increased runoff losses of pesticides. Reasons for this concern stem largely from the increased use of and reliance on chemicals for weed and insect control with CT systems.

Atrazine and alachlor are two widely used herbicides. Several researchers have monitored runoff losses of these compounds from agricultural land under a variety of conditions (Hall et al., 1983).

Ritter et al. (1974) reported that atrazine runoff from a TP watershed over a two-year period was only 24% of that from CN. No-till watersheds in Ohio showed reductions in atrazine runoff losses as compared to CN watersheds, while average loss for all watersheds was < 2% of the active ingredient applied (Triplett et al., 1978). Baker et al. (1982) compared six tillage systems on three Iowa soils and found reduced alachlor losses due to decreased runoff and erosion with CT systems. However, this reduction was diminished by higher herbicide concentrations in runoff water and sediment from these systems. Baker and Johnson (1979) compared CN, TP and CH systems with respect to both atrazine and alachlor runoff losses on six small watersheds. Again, decreased runoff and erosion with CT systems relative to CN tillage resulted in decreased herbicide losses, while concentrations of the compounds in sediment and/or runoff water were sometimes higher for CT systems.

In Pennsylvania, CN tillage combined with light incorporation of atrazine and strip cropping provided herbicide runoff control equivalent to CT (Hall et al., 1983). Baker and Laflen (1983) reported lower atrazine and alachlor losses when these compounds were incorporated rather than surface-applied. Runoff losses of atrazine and alachlor were 1.6 and 1.7%, respectively, when incorporated and 18.3 and 22.1%, respectively, when the compounds were surface-applied. Sauer and Daniel (1987) demonstrated that CT systems, especially NT and TP, could result in higher loss of some pesticides depending on time and intensity of rainfall. Intense rainfall soon after application resulted in higher atrazine loss with NT and TP relative to CN. Lowest pesticide loss occurred with the CH system regardless of conditions. In all cases, most (80%) of the atrazine loss was dissolved in the runoff, not attached to the sediment. For those compounds attached to the sediment, such as chlorpyrifos, CT systems resulted in dramatic reduction in loss when compared to CN.

Soil incorporation of pesticides reduces loss in the runoff; however, the most popular application method even for the CN is pre-emerge without incorporation. For compounds transported by the sediment, such as chlorpyrifos, CT dramatically reduces the loss because of the reduced sediment load. Reducing the loss of compounds transported in the runoff water, such as atrazine, can be accomplished only through a reduction in total runoff volume, and the BMP strategy should reflect this approach. Should reduction in runoff not be sufficient to reduce total pesticide loss with high residue systems such as NT, use of the CH system should be considered. This system has two distinct advantages: it appears to consistently reduce runoff volumes, and incorporation of the pesticides can be an inherent step in normal land preparation.

GROUND WATER

Contamination of groundwater by agricultural chemicals has become a national concern. This attention is appropriate because approximately 95% of all rural households depend on ground water for their drinking water supply. Concurrently, concern has been raised regarding the impact of CT on ground water quality. The effect of CT on ground water quality is not clear; in some situations research has demonstrated increased potential for contamination, while in others quite the opposite has been shown to occur. Generally, the contaminants of concern are nitrates and pesticides because P has been shown to be relatively resistant to leaching.

Nitrate Loss

Thomas et al. (1981) noted that., under Kentucky conditions, considerably more nitrogen (N) leached below 90 cm in a NT sod system than in a CN treatment.. These workers indicated that the leached N came largely from surface-applied ammonium nitrate and that there was a potential for greater leaching of N in CT systems than in CN systems. Their results are consistent with greater infiltration into a soil already at a higher moisture content and containing more continuous pores (Goss et al., 1978). Until recently, essentially all work showed that CT resulted in greater infiltration and it became accepted that greater leaching also occurred. However, recent work has shown that this assumption is not always correct. Kanwar et al. (1985), working on a loam soil in Iowa, observed much less leaching of N in NT as compared to CN. The following interpretation is offered to explain the discrepancy. In each case the majority of the drainage water is transported by large pores in the NT. In the Kentucky situation, this allowed the water containing the surface-applied fertilizer N to move deeper and faster into the soil, thus deeper N movement was observed. In the Iowa example, the nitrate was present in the soil profile where less interaction occurred with the water that moved in the large pores. Thus, less nitrate leaching was observed.

Pesticide Loss

Various researchers (such as Dick et al., 1986) have documented increased penetration of water and surface-applied chemicals under CT systems when compared to CN. Helling et al. (1988) and Isensee et al. (1988) reported that small amounts of surface-applied herbicides could be transported to depths greater than 1 m in NT fields. These authors also found preferential water flow to be an important method of transport on the soil studied, particularly when significant rainfall events occurred shortly after pesticide application.

Chlorpyrifos and carbofuran are the most commonly used insecticides on field corn. Chlorpyrifos has a strong affinity for soil colloids and has been found to resist leaching (Pike and Getzin, 1981). Carbofuran, on the other hand, is less adsorbed to the soil and thus is more mobile in the unsaturated zone (Felsot and Wilson, 1980). Several researchers have found carbofuran to be susceptible to leaching. Read and Gaul (1983) found carbofuran to leach past a depth of 45 cm in a sandy soil in 130 days with 43.5 cm of rainfall. In addition, carbofuran has been extensively detected in groundwater as a result of normal field use (Holden 1986). Fermanich and Daniel (1991) showed that twice as much carbofuran leached through the root zone of CN systems as through the root zone of NT systems, and it was postulated that greater decomposition and attenuation of carbofuran occurred under NT.

Research information is just becoming available on the effect of CT on ground water quality; however, preliminary results do indicate that management practices are important. For example, surface application of chemicals in a NT system appears to increase the probability of rapid transport through the soil profile. Should this prove to be the case, alternative CT systems such as CH may prove satisfactory because the tillage operation destroys the continuous pores responsible for the bulk of the transport.

SOUTHERN REGION AND ARKANSAS

The potential for increased use of CT in the southern region and in Arkansas is high. The variety of crops and the potential for double cropping provide numerous opportunities for integration of the CT concept. As growers and researchers in this region know, management changes are required to maintain present production levels. Maintaining water quality goals under these systems will also require adjustment and planning. Integration of proper timing and placement of fertilizer and manure with CT systems can ensure maintenance of water quality. However, the potential for increased pesticide loss under CT systems in the southern region is a problem. Runoff loss of herbicides is of particular concern because of the year-long weed pressure and the intensity of the storms that coincide with application. Innovative approaches require development and testing. For example, perhaps a winter cover crop that provides N credits can be incorporated into a CT system that leaves sufficient residue to reduce runoff during the critical period. Double cropping also offers some interesting opportunities to reduce pesticide input while maintaining residue cover.

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