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Tillage Best Management Practices for Small Grain Production in the Upper Minnesota River Basin

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Introduction

Management of crop residues with reduced tillage is the most cost-effective method of controlling sediment losses and reducing farming impacts on water quality. Crop residues can also help reduce wind erosion and can enhance snow entrapment. One of the primary water quality concerns for the Minnesota River and its tributaries is sediment, which contributes increased phosphorus (P) to the system. This increased P stimulates algae growth, which is followed by an increased biological oxygen demand when the algae die and decompose. This can deplete dissolved oxygen levels, resulting in game fish stress or kill.

In addition to affecting sediment loss, tillage influences many interacting physical, chemical, and biological properties of soils that can have major impacts on crop production. These properties include temperature, moisture, aeration, bulk density, structure, nutrient distribution, organic matter levels, and microbial populations. Various crops respond to these changes differently. The range of these changes can be amplified by extremes in tillage reduction associated with some residue management alternatives. Small grain is insensitive to temperature changes but may respond to changes in the seed furrow environment and to differing weed species present.

Small grain is a prominent part of the agriculture in the upper Minnesota River basin. Following is a discussion of residue management tillage system effects on small grain production.

Factors To Consider When Making A Tillage Decision

• Soil Characteristics

On soils classified highly erodible land (HEL) the general requirement is 30% residue cover after planting. On non-HEL soils the steepness and length of the slopes will indicate the potential for significant erosion. A second soil factor that must be considered is internal drainage. Poorly drained soils warm up more slowly than well-drained soils, so may require more tillage. Tile drainage may improve this situation, but in some cases this may not be enough to insure consistent success with little or no tillage. A third factor is soil fertility level. Having a high level of fertility is necessary if reduced tillage systems are to perform well. Low fertility conditions offer too many obstacles and generally limit yields in reduced tillage systems. It is important to effectively control sediment at high soil test P levels. Research has shown that this can be done effecectively with crop residues in conjunction with other conservation techniques.

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• Crop Rotation

The amount of residue present in a field depends on the crop rotation and the level of production. Corn generates more residue than small grains or soybeans; thus it is easier to maintain higher residue levels with a variety of tillage systems. The durability of the residue is also crop dependent. Soybean residue is classified as "fragile," or in other words is easily destroyed. Corn and small grain residues, on the other hand, are classified as "non-fragile."

Spring wheat and soybeans appear to be a viable crop rotation in a no-till system for Minnesota conditions. Other crops that fit well in a small grain rotation are sunflowers, sugar beets, and field beans. Maintaining a sufficient residue cover may be a problem following these crops. Soybean yields after small grain have generally not been affected by tillage. With more intensive tillage systems, crop sequence becomes less important. In summary, both the crops in the rotation and the sequence of the crops are important in tillage management.

• Residue Management

Tillage for small grain production requires the management of residue to allow for effective stand establishment. Planting when surface crop residues are relatively dry and are cut more easily with coulters is advisable. Experience has shown that planting in the direction of stubble orientation reduces the effectiveness of coulters and disc openers. Small grain residue pushed into the seed furrow by coulters "cradles" the seed and often results in stand loss and delayed emergence. This is primarily because of slower absorption of soil water due to poor seed-to-soil contact and allelopathic inhibition. Small grains are not as temperature sensitive as corn, so residue effects are mainly due to in-furrow seed-soil contact or phytotoxicity.

• Fertilizer Management

Do not surface-apply urea sources of nitrogen (N) without incorporation unless air temperatures are cool or rain is imminent. Urea left on the surface in proximity to residue has a high potential of volatilization losses. With residue management tillage systems, less N is released from soil organic matter due to less physical disturbance. In addition, soil organic matter may increase under some reduced tillage systems, and this will act as a sink for nitrogen. Anhydrous ammonia has been the most consistent source of N. Drill-applied diammonium phosphate (18-46-0) places N and P below the soil surface and close to the seed. This has been very effective in the western Minnesota River basin with calcareous soils that can tie up P. In addition to being a very efficient method of P fertilizer application, it also minimizes the risk of erosive losses of P.

• Disease Management

The effects of tillage on the development and severity of crop diseases are variable, depending on the disease, the specific type of tillage system used, and the effectiveness of the other disease management practices used. Conservation tillage usually reduces soil temperatures, conserves soil moisture, and leaves crop residue on the soil surface. Of particular concern are crop diseases that are favored by cool, wet soils. Diseases most troublesome in high-residue tillage systems are those that have inoculum associated with crop residues left on the soil surface. In many cases the diseases are most noticeable when monoculture cropping is practiced. Diseases of most concern are scab and tan spot, both of which are associated with plant residue. However, in addition to the disease inoculant supplied by residue, the proper environment and susceptible varieties must be present for economic infestations.

• Seeding Equipment

Controversy exists over what type of seed openers (disk vs. hoe vs. sweep) deal with small grain residue most effectively. Generally, hoe openers work better in drier soil. Hoe-type openers operate below residue, making "in furrow" residue less probable. Sweep or air seeders, placing seeds below sweeps, also reduce the probability of intimate contact of seed with crop residue. Depth control is the challenge with sweep seeders. Press wheels should also be used for good stand establishment under dry conditions. Disk-type openers require the most caution in this respect, but work better under wet conditions. If considering no-till small grain production, it is essential to use a properly designed, heavy duty drill that can cut through the residue, place seed in contact with the soil without incorporating residue, and firm the soil over the seed. Selecting a drill with fertilizer capability is also important.

Summary

Various factors including soil characteristics, crop rotation, residue management, disease problems, seeding equipment, and management ability must be considered when selecting a residue management system including small grains. In rotations with moderate amounts of residue, many systems will work on a variety of soils. With higher residue levels, the importance of proper residue management and heavy duty reduced tillage drills will ensure proper seed-to-soil contact without significant residue in contact with the seed. In the upper Minnesota River basin, higher levels of residue may contribute to increased soil moisture and subsequent yield increases in dry years. Crop rotation is a major factor in minimizing the disease problems in small grains.

Yield Results from Tillage Research

Spring and Winter Wheat

The results of studies in Douglas, Norman, and Becker Counties are shown in table 1. In these studies tillage plots were split, with winter and spring wheat planted into barley stubble.

On average, spring wheat yields following barley were not affected by tillage. Only in one site year (1986 in Becker County) did tillage significantly affect spring wheat yields. A bindweed problem at this site was the likely cause. At most sites an increase in foxtail (pigeon weed) was associated with chisel and no-till systems.

Table 1. The effect of tillage on spring and winter wheat yields (bu/A) following barley.

	Spring Wheat			Winter Wheat		
Year	NT	Chs	Mldbd	NT	Chs	Mldbd
1987[1]	34a[4]	33a	39a	38a	37a	33a
1986[2]	27a	31a	35a	51a	47a	53a
1987[2]	47a	41a	42a	35a	44b	42b
1988[2]	30a	26a	24a	21a	13b	19b
1986[3]	24a	25a	30b	30a	38b	35b
Avg.	**33**	**31**	**34**	**35**	**36**	**35**

1. Douglas County, Barnes loam-Langhei loam soils
2. Norman County, Fargo silty clay-Hegne silty clay soil
3. Becker County, Hamerly clay loam-Winger silty clay loam soils
4. Data followed by the same letter in the same row for a given wheat type are not significantly different at the 10% level.

Table 2. The effect of tillage on spring wheat yields (bu/A) and protein content (%) following soybeans in Ottertail County.

	Yield				Protein			
Year	NT	Spr Disc	Chs	Prplw	NT	Spr Disc	Chs	Prplw
1992[1]	56a[7]	56a			13.0a	14.0b		
1992[2]	47a		49a		13.6a		13.7a	
1993[3]	43a		45a		14.4a		15.3a	
1993[4]	48a		53a		13.8a		14.0a	
1994[5]	45a		51b	46a	13.8a		13.6a	14.2a
Avg.[6]	**46**		**50**		**13.9**		**14.2**	

1. Chappet, Chappet-Sisseton, and Friberg loam soils
2. Sandberg loamy sand soil
3. Formdale-Buse, Formdale-Langhei, and Aazdahl clay loam soils
4. Fordum fine sandy loam, Sandberg loamy sand, and Langhei loam soils
5. Barnes-Langhei, Langhei-Barnes, and Lake Park loam soils
6. Only the four years in common are averaged to compare the no-till and chisel plowing tillage systems
7. Data followed by the same letter in the same row are not significantly different at the 10% level

Results of some recent studies near the headwaters of the Pomme de Terre River in Ottertail County are shown in table 2. Tillage affected spring wheat yields at only one site year out of five (in 1994). The yield reduction in 1994 was linked in part to stand reduction with the no-till system. The drill used had a single disk opener. At the other site years spring wheat yields following soybeans were not affected by tillage.

The Paraplow is a unique type of subsoiler which leaves surface residue minimally disturbed. Even though soils were very dense in the fall of 1993, subsoiling that fall reduced spring wheat yields the next year. Paraplowing reduced stand compared to a chisel plowing system. On average there was a 4 bu/acre yield reduction with the no-till system compared to the chisel plow-based system.

In a continuous wheat study on a Barnes loam near Morris (table 3) there were no significant effects of tillage on yield in the three years measured. Sometimes protein content can be used as an indicator of reduced N availability. For this reason it is presented in tables 2 and 3. Protein contents appeared to more affected by environment than by tillage system. Protein differences between tillage systems were very small.

Table 3. Effect of tillage on spring wheat yields[1] (bu/A) and protein content1 (%) following wheat on a Barnes loam at Morris, MN.

	Yield[2]			Protein[3]		
Year	NT	Chs	Mldbrd	NT	Chs	Mldbrd
1987	54a[4]	54a	52a	10.9	10.9	11.6
1989	57a	50a	57a	14.9	15.1	14.7
1990	58a	58a	59a	12.5	12.7	12.6
Avg.	**56**	**54**	**56**	**12.8**	**12.9**	**13.0**

1. Average of 8 varieties at 120 lb. N/A as ammonium nitrate broadcast in early spring before any secondary tillage
2. Average of three replications
3. Analysis of samples from only one replication
4. Data followed by the same letter in the same row are not significantly different at the 10% level.

Traditionally there has been very little winter wheat grown in Minnesota. This is primarily due to the harshness of the winters. In some years lower prices (vs. spring wheat) and the lack of a suitable crop sequence may also be a factor. In most years, with a clean tillage system there will be substantial winter kill. This limits varietal selection to only the most winter hardy. In some instances this is at the expense of intrinsic yield potential, protein content, and disease resistance.

The studies in table 1 illustrate the potential for winter wheat production when stubble is managed for snow catch in an effort to insulate the soil. North Dakota research has shown that if 4 inches of snow are caught by stubble, winter wheat is protected to -30°F. In the three-year study at three locations, winter wheat yields were slightly higher than spring wheat and there was little effect of tillage. Disease management is more important with winter wheat, however.

Spring Barley

Data from six trials in northwestern Minnesota where barley was grown after soybeans with spring-applied urea showed no difference in yield or protein due to tillage (Table 4).

Summary

Success of reduced tillage approaches to small grain production have been higher when preceded by a low residue crop such as soybeans. Spring wheat and barley following soybeans have generally not been affected with most alternative tillage approaches. A no-till system resulted in more variability in yields (higher or lower than a moldboard plowing system). No tillage sometimes posed challenges in stand establishment, N management, and weed control.
By catching snow with barley stubble, no-till systems allow winter wheat to be grown in Minnesota with less "overwintering" risk. Winter and spring wheat resulted in comparable yields, although performance was more variable for winter wheat. This provides an opportunity for growers to reduce their labor during peak labor demand periods (spring and fall). It also allows for more flexibility to accommodate variations in weather.

Table 4. Effect of tillage on barley yields (bu/A) and protein content (%) following soybeans.

	Yield			Protein		
Year	NTI	Chs	Mldbrd	NT	Chs	Mldbd
1986[1]	63a[5]	63a	62a	11.2a	11.4a	11.2a
1986[2]	20a	20a	18a	12.9a	12.9a	13.5a
1987[2]	55a	59a	57a	10.8a	11.1a	11.3a
1988[2]	62a	60a	56a	13.5a	13.7a	13.0a
1988[3]	71a	76a	75a			
1989[1]	58b	61ab	65a	10.6a	11.5a	11.6a
1994[4]	58a	54a		13.3a	13.9a	
Avg.[6]	**55**	**57**	**56**	**11.8**	**12.1**	**12.1**

1. Douglas County, Barnes-Langhei loam soils
2. Norman County, Fargo and Hegne silty clay soils
3. Becker County, Hamerly clay loam and Winger silty clay loam soils
4. Ottertail County, Formdale-Buse, Formdale-Langhei, and Aazdahl clay loam soils. At this site, barley followed wheat.
5. Data followed by the same letter in the same row are not significantly different at the 10% level.
6. Only the years in common are averaged to compare the no-till, chisel plow, and moldboard plow tillage systems.

Managing Crop Residue With Tillage

Tillage passes with different implements can be used very effectively to create various levels of residue remaining on the soil surface. Four tillage systems shown below are categorized in the following tables 5-8 according to the residue management/yield performance indicators also shown below:

Tillage Systems

Moldboard Plow: Fall moldboard plowing followed by one or two secondary spring tillage operations before seeding.

Chisel Plow: Fall chisel plowing plus secondary spring tillage before seeding. Special attention should be paid to use of proper shaped/width shovels and implement speed in order to maintain proper residue cover.

Spring Disc/Field Cultivator: One or two passes in the spring prior to seeding.

No-till: All seedbed preparation is performed by the drill.

Residue Management/Yield Performance Indicators

1) ***Inadequate Residue to Minimize Erosion*** (less than 30 percent of soil surface covered after planting). Where erosion is not a concern, fall moldboard plowing may be the best practice.

2) ***Recommended with Good Management***
No yield penalty is expected if the farmer observes all relevant recommended management practices for high residue systems.

3) ***Excellent Management Required.***
Slight yield penalty is possible, even if all recommended management practices are observed. Above average crop management will be needed to ensure good performance.

4) ***Reduced Yield Potential.***
The potential exists for substantially reduced yields, especially on poorly drained soils in wet years.

A number of tables have been developed which estimate residue management/yield performance of various crop rotations involving corn, soybeans, and/or small grains. Continuous corn and corn-soybean sequences are discussed in other publications. In those publications the Minnesota River Basin was divided into high annual rainfall (> 28 inches) and low rainfall (< 28 inches) areas. This north-south line is approximately halfway between Highways 71 and 15. Since most small grain is grown in the low rainfall segment of the Minnesota River Basin, indices were developed only for that section of the basin. In each crop sequence, separate indices were developed for glacial till (deposited in place by melting glacier, poorly sorted) and lacustrine (deposited in glacial lakes, well sorted) soils.

Table 5. Matrix of residue management/yield performance indicators for corn following small grain on glacial till and lacustrine soils under low annual rainfall (< 28 inches) conditions in the Minnesota River Basin.

Tillage System	Glacial Till	Lacustrine
Moldboard plow	1	1
Chisel plow	2	2
Spring Disc/Field Cult.	2	3
No-Till	3	4

Table 6. Matrix of residue management/yield performance indicators for small grain following soybeans on glacial till and lacustrine soils under low annual rainfall (< 28 inches) conditions in the Minnesota River Basin.

Tillage System	Glacial Till	Lacustrine
Moldboard plow	1	1
Chisel plow	1	1
Spring Disc/Field Cult.	2	2
No-Till	2	3

Table 7. Matrix of residue management/yield performance indicators for soybeans following small grain on glacial till and lacustrine soils under low annual rainfall (< 28 inches) conditions in the Minnesota River Basin.

Tillage System	Glacial Till	Lacustrine
Moldboard plow	1	1
Chisel plow	2	2
Spring Disc/Field Cult.	2	3
No-Till	2	3

Table 8. Matrix of residue management/yield performance indicators for small grain following small grain[1] on glacial till and lacustrine soils under low annual rainfall (< 28 inches) conditions in the Minnesota River Basin.

Tillage System	Glacial Till	Lacustrine
Moldboard plow	1	1
Chisel plow	2	2
Spring Disc/Field Cult.	2	3
No-Till	3	4

[1]In order to minimize residue-borne diseases, barley, oats, or wheat should not follow themselves in rotation. The use of various small grains in rotation will minimize this problem, but producers must be aware of diseases that are common to more than one crop.

Discussion

Moldboard Plow: This system generally results in high yields but leaves inadequate surface residue to minimize soil erosion. For this reason it should not be used except on level soils where erosion is not a concern, to alleviate surface soil compaction, to incorporate P and K fertilizer, or to incorporate manure.

Chisel Plow: This tillage system generally results in high yields but care must be taken to insure adequate surface residue cover. In most cases straight chisel shanks should be used to achieve 30 percent residue cover. For small grain following soybeans this system will result in less than 30 percent cover, so it is not recommended.

Spring Disc/Field Cultivate: On glacial till soils this tillage system will result in good yields and will leave adequate residue if the implement is properly set. On lacustrine soils this system will probably result in some yield loss due to delayed planting for small grain following soybean. It will also require a high level of management on other crop sequences with higher residue production.

No-till: On glacial till soils this system will work well for small grain following soybeans or soybeans following small grains. For corn following small grain or small grain following small grain, some yield loss would probably result. On the lacustrine soils the no till system will likely result in yield loss (even with good management) for small grain following soybean or soybean following small grain due to delayed planting. For the other crop sequences substantial yield loss would occur.

This set of publications was the result of a joint effort between Minnesota Extension Service, Minnesota Agricultural Experiment Station, and Minnesota Pollution Control Agency. This information was first presented February of 1995 at the Sediment Control Solutions Conferences in Mankato and Montevideo, MN.

To order other publications in this series, contact your Minnesota County Extension Office or, outside of Minnesota, contact the Distribution Center at (612) 625-8173. Titles in this series include:

- *Sediment Problems and Solutions for the Minnesota River* (FO-6671).
- *Tillage Best Management Practices for Continuous Corn in the Minnesota River Basin* (FO-6672).
- *Description of the Minnesota River Basin and Recommendations of Residue Management Systems for Sediment Control* (FO-6673).
- *Economic Comparison of Incremental Changes in Tillage Systems in the Minnesota River Basin* (FO-6675).
- *Tillage Best Management Practices for Corn-Soybean Rotations in the Minnesota River Basin* (FO-6676).

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