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BEST MANAGEMENT PRACTICES

CHAPTER 11

Soil Tillage

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Historically, tillage was used to manage residues, diseases, insects, weeds, excess water, and soil compaction with little consideration given to its impact on soil health, water quality, and erosion. The extreme drought during the 1930s helped change this perception. Tillage was and is still used to prepare a seedbed. Today, innovations in production tools (e.g., planters, herbicides, and genetically modified crops) provide an opportunity to replace moldboard plows (Fig. 11.1) with conservation-tillage systems. Alternate tillage systems are listed in Table 11.1.

Figure 11.1 Moldboard plowing wheat stubble in South Dakota.
(Photo courtesy of Howard Woodard, SDSU)

Table 11.1 Tillage systems for corn production:

1. Clean-till, <30% residue cover
   - Moldboard plow.
   - Chisel/disk.
   - Not considered a Best Management Practice (BMP).
2. Conservation-till, >30% residue
   - Chisel plow followed by a disk.
3. Ridge-till, >30% residue cover
   - Requires special equipment for ridge-building.
4. No-till or strip-till, >30% residue
   - Requires special equipment and a residue-management plan.

Different Tillage Systems

When considering tillage systems, it is important to consider that compaction can be caused by all systems as well as by grain wagons, combines, and trucks driving across the field. Field traffic should be minimized to minimize compaction. Excessive tillage can increase soil crusting and compaction. Moldboard plowing or excessive tillage is not considered a Best Management Practice (BMP) for South Dakota production systems because of erosion and compaction risks. Additional information on compaction is provided in Chapter 14.

Clean-till

Clean-tillage involves inverting the soil so that most of the residue is buried. Moldboard plowing followed by preplant disking is a common clean-till procedure. Because crop residue is mostly buried, the soil surface is exposed to wind and rain, increasing the potential for erosion and a loss of soil moisture. Of the tillage systems discussed, clean-tillage carries the greatest wind and water erosion risks. Clean-tillage is not considered a conservation tillage system. The advantages and disadvantages of clean-till systems are shown in Table 11.2. Clean-tillage may be best-suited for bottomland or poorly drained soils because it speeds soil heating and reduces soil water content, and water erosion risks are low. However, moldboard plowing can result in a plow pan that can restrict plant root growth. The use of deep rippers to overcome a plow-pan problem will provide only temporary relief.

Table 11.2 Advantages and disadvantages of clean-till:

Advantages	Disadvantages
Suited for many soils	High erosion risk
Well-tilled seedbed	Compaction
Pest control	Fuel and labor
Soil warmer	Soil-moisture loss
Mixed nutrients	Increased runoff

Conservation-till

Conservation-tillage systems leave at least 30% or more crop residue on the soil surface following planting. Directions for calculating residue were prepared by McCarthy et al. (1993). There are a number of implements that can be used in conservation-till. The most common conservation tillage-systems are spring disking and chisel plowing (Fig. 11.2). Different systems provide different amounts of surface residue. Advantages and disadvantages are provided in Table 11.3.

Figure 11.2 Chisel plowing wheat stubble. (Photo courtesy of USDA-NRCS)

Increasing the residue on the soil surface decreases the potential for erosion and soil water loss. Crop residues create a barrier between the soil, water, and wind that reduces erosion. The amount of residue left on the soil surface is directly related to available water, and the length of time needed for the soil to warm. The amount of residue remaining on the soil surface can be increased by:

1. Including a high-residue-producing crop in the rotation.
2. Conducting tillage operations in the spring.
3. Reducing the number of tillage passes.
4. Using cover crops.
5. Driving slower during tillage.
6. Setting chisels and disks to a shallower soil depth.
7. Using straight shanks and sweeps rather than curved implements.

Table 11.3 Advantages and disadvantages of conservation-till:

Advantages	Disadvantages
Reduced erosion	May require stalk chopping
Reduced cost	Increased compaction
Mixes nutrients	Can delay planting
Increased water infiltration	
Increased snow catch	

Ridge-tillage

Ridge-tillage is a conservation-tillage system where crops are grown on permanent beds (or "ridges"). With ridge-tillage, the planter must be able to cut residue, penetrate the soil to the desired depth, and in many situations, clear the ridge of the previous years' crop residues (e.g., stalks and rootballs). Following planting, cultivators are used to control weeds, and rebuild and shape the ridges. Ridge-tillage is well-suited to relatively flat landscapes and is often furrow irrigated in arid climates. Advantages and disadvantages are provided in Table 11.4.

Table 11.4 Advantages and disadvantages of ridge-till:

Advantages	Disadvantages
Reduced erosion	Crusting in light textured soils
Saves water	Must match wheel spacing
Lower fuel costs	Not suited to rotation that includes alfalfa or small grains
Increased snow catch	High labor requirement
	Requires ridge maintenance

In ridge-tillage, crop residue and organic matter tend to accumulate between the ridges. If mechanical cultivation and ridge-building take place during the growing season, these materials are generally mixed into the upper portion of the soil profile. Relative to conventional-tillage, ridge-tillage generally increases water infiltration and reduces surface runoff. Banding the fertilizer into the ridge can reduce nitrogen leaching. Herbicides may be applied to the ridge, with cultivation used between the rows for weed control. Two disadvantages of ridge-tillage are 1) specially designed equipment is needed, and 2) it is labor intensive.

Figure 11.3 Corn in a ridge-tillage system. (Photo courtesy of Lynn Betts, USDA-NRCS)

In ridge-tillage, it is recommended that the soil samples for nutrient analysis be collected halfway between the center of the row and the crop row. When applying fertilizers into the ridge, care should be taken to minimize direct contact with the seed. For sandy soils, the amount of N plus K_2O applied with the seed should not exceed 5 lbs/acre. This limit increases to 10 lbs/acre for fine-textured (clay) soils. The effectiveness of P and K applications is often improved by banding.

Strip-tillage

Strip-tillage is a conservation-tillage system where the seedbed (8- to 10-inches wide) is tilled and cleared of residue and the rest of the area is not disturbed (Fig. 11.4). Strip-till systems prepare a seedbed that is relatively free of residue, even in a corn-following-corn rotation. The spreading of residue at harvest can reduce residue interference at planting. Strip-tillage may be conducted in the fall or spring. Spring strip-till uses a tillage tool that tills strips ahead of the seed openers on the planter. If strips are prepared in a separate operation: 1) it can be challenging to consistently follow the strip with the planter, and 2) it is recommended to follow the same direction with the planter. Failing to follow the strips with the planter can affect fertilizer placement with respect to the seed.

Figure 11.4 Strip-tilled corn in South Dakota. In this image strip-tillage was conducted down a slope. The strip can provide a conduit for water transport. (Photo courtesy of Dwayne Beck)

If P or K fertilizers are needed, they can be fall banded into the strips. As with any tillage system, N fertilizer should not be fall-applied until soil temperatures are below 50°F. Starter fertilizer can be used; however, the total amount of N + K_2O applied in contact with the seed should not exceed 5 pounds in a sandy soil and 10 pounds in fine-textured soils. Many producers have problems when attempting to plant into fall-created strips in rolling terrain. Plant growth can be compromised if the seed rows are too close or too far away from the fertilizer band.

Soil in the strip-tilled systems tends to warm faster than areas where residue is present. Strip-tillage does not eliminate erosion and, following rainfall, erosion can occur down the strip. Contour strip-tillage should be considered in high-slope situations. In some strip-till systems, when strips are tilled in the fall or spring, fertilizer is applied in a band.

No-tillage

Properly managed no-till systems leave the most residue on the soil surface (Fig. 11.5). This residue conserves soil water and can increase yields and profitability. Compared with other systems, no-tillage has higher water infiltration rates and less potential for erosion. Lower erosion losses are attributed to increased water infiltration and reduced runoff, resulting from the development of macropores (old root and earthworm channels). Considering the potential conservation and production benefits, no-tillage should be strongly considered by South Dakota producers. Advantages and disadvantages are provided in

Table 11.5.

No-tillage requires the optimization of planting and residue-management systems (Fig. 11.6). A common misconception is that residue managers can compensate for nonuniform residue distribution. Residue management begins at harvest. Using stripper headers for harvesting wheat and other crops allows straw to remain upright and attached, and prevents residue from being moved by wind or water. In corn, this is accomplished by adjusting the combine to keep the stalk intact and upright. Uniformly spreading chaff is particularly difficult when using large headers. Straw and plant stems that are chopped into small pieces are difficult to distribute uniformly and have a tendency to be moved into piles by wind or water.

Figure 11.5 No-till corn in South Dakota. (Photo courtesy of Howard Woodard, SDSU)

Table 11.5 Advantages and disadvantages of no-till:

Advantages	Disadvantages
Reduced erosion	Specialized equipment needed
Saves water	Nutrient stratification
Lower fuel costs	Reliance on herbicides
Increased snow catch	Cool spring temperatures
	May require more N

Residue managers work best in situations where residue is uniform. However, in situations when residue is not uniform, it is almost impossible to properly adjust residue managers. Single-disc fertilizer openers placed at the same depth and 2 to 3 inches to the side of the seed-opener path can serve a dual purpose, cutting residue and placing the sideband fertilizer. When compared with conservation tillage, no-till soils generally remain cooler in the spring. Cooler soil temperatures can slow nitrogen (N) and sulfur (S) mineralization. Placing nutrients such as N and S as a sideband improves early season plant vigor.

Figure 11.6 Planting corn in a no-till system. (Photo courtesy of Howard Woodard, SDSU)

The planter is the most important implement in a no-till system. Germination can be improved when seeds are covered with loose material and firmly planted at the right depth in warm, moist soil. The basic corn planter was designed for use in well-tilled seedbeds. Consequently, modifications are needed to assure optimal seed placement. Almost all row-crop planters have openers that utilize two discs to open the seed slot. The seed-opener discs are often arranged so that the blades touch evenly at the front and have discs of equal size. Some manufacturers offset these discs so that one disc leads the other. Wiper/depth wheels can limit the problem of mud being brought to the surface and interfering with seed-opener depth wheels.

South American openers use offset double-disc openers with discs of different sizes; this design results in a differing angular momentum between the blades that is thought to improve the slicing action. All disc openers require sharp blades; if they are not sharp, the residue can be pushed (hair-pinned) into the trench, resulting in uneven germination and growth. Hair-pinning is worse when residue is cut into short lengths and soil structure is poor. Continuous long-term no-till systems have less of a problem with this issue.

Once the seed is placed in the trench, it needs to be pressed into the soil and covered. In no-tillage systems, the best method is to separate the firming (seed pressing) and covering operations. Several companies make devices designed to press or lock the seed into the bottom of the trench. This speeds the rate at which the seed imbibes water and anchors it to the bottom of the trench. The lack of root penetration is often blamed on "sidewall" compaction, which can be traced to a poorly anchored seed. There are several companies that make aftermarket devices designed to press the seed into the bottom of the trench. In general, vertical wheels work better in most conditions; however, they are more expensive and harder to mount than the type that uses a sliding piece of plastic.

Once the seed is firmly pressed into the bottom of the trench, it needs to be covered. Standard closing systems on corn planters are designed to work in tilled seedbeds by packing the area under and around the seed, while leaving loose material above the seed. Standard rubber or cast-iron closing systems normally do not function well in no-till systems because they have difficulty properly closing the trench in well-structured or wet soils. If the soil over the seed is packed too firmly, the corn plant may set its growing point too shallow. This makes it prone to damage from herbicides and late frosts. If the soil covering the seed is too loose, the seed trench may dry too fast, leading to stand loss. Many companies (e.g., Martin®, May-Wes®, Exapta®, Yetter®) make attachments designed to loosen the soil in the seed trench and place it over the seed. One reason that strip-till may appear superior to no-till is that the seed is planted into loose soil created by the strip-tillage operation, which allows for optimal operation of standard closing wheels.

Other attachments needed for conversion of a standard planter to a no-till planter are fertilizer openers and residue managers. The best fertilizer opener designs are single-disc openers with a depth-gauging and/or wiping wheel. These openers cut the residue and place fertilizer 2 to 3 inches to the side of the seed. In fine-textured soils, most of the N and P can be band-applied using this approach. However, in irrigated or sandy fields, limit the amount of N applied to one-third to one-half of the seasonal N requirement.

The likelihood of planter plugging in heavy residue can be reduced by using residue managers that cut residue before it is moved and by replacing wide-depth wheels with narrow-depth wheels. Using a residue manager with a backswept design helps keep residue from wrapping. Cutting the residue allows the residue managers to split the mat of residue without tearing it apart, which is especially important under damp conditions. Cutting residue reduces soil disturbance because residue managers do not have to engage the soil, reducing problems with surface sealing or crusting, weed growth, and erosion.

There are many designs of residue managers. Test the ease of adjustment prior to selecting a residue manager. The bottom line with no-till seeding equipment is that while it does not have to be complex, it needs to work effectively. No-till systems are becoming increasingly popular. Additional information is available at www.sdnotill.com and at www.dakotalakes.com.

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