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CONSERVATION TILLAGE SERIES
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Crop Rotations and Conservation Tillage

Crop rotations increase crop yields by improving soil conditions and reducing weed and insect populations. Rotations also help producers use conservation tillage successfully. A well-planned crop-rotation system can help producers avoid many of the problems associated with conservation tillage, such as increased soil compaction, perennial weeds, plant diseases, and slow early season growth. This publication reviews the effects of crop rotations on conservation-tillage crop production and provides examples of successful rotations used by crop producers in Pennsylvania.

GENERAL EFFECTS OF CROP ROTATIONS

Crop rotations have many benefits that can influence the success of crop-production enterprises, even under conventional tillage programs. These advantages can be substantial and provide a foundation for a profitable cropping system that lends itself to conservation tillage.

The yield benefits of crop rotations are often overlooked. For example, corn following soybeans will often yield 5 to 20 percent more than continuous corn on the same farm. Corn following a hay crop will yield as much as or more than corn following soybeans. The effects of crop rotations on the grain yield of corn in a crop rotation study at Penn State are shown in Table 1. Yield responses to crop rotation of 15 percent for soybeans and 10 percent for wheat are common. Crop rotations also can decrease the cost of crop production.

Crops can be produced with fewer inputs when grown in rotation. Corn following soybeans, for example, can be produced with about 40 pounds per acre less nitrogen fertilizer and without a soil insecticide, which often is needed to control corn rootworm larvae in continuous corn. Therefore, corn planted after soybeans will cost producers about $25 per acre less than continuous corn. Because of the narrow profit margins in crop production, these yield increases and reduced production costs can have a great effect on overall profit.

Crop rotations are essential to help control many of the crop-disease problems that occur in Pennsylvania. Diseases such as gray leaf spot in corn, take-all in wheat, and sclerotinia in soybeans can be partially controlled with crop rotation. Where these problems occur, crop rotations must be considered carefully in the profitability analysis. For some crops, such as alfalfa, continuous cropping is almost impossible because of autotoxicity, a phenomenon that occurs when toxic compounds produced by the previous alfalfa crop inhibit new alfalfa seedling germination.

Table 1. Average corn yields as affected by crop rotation over a twenty-year period (1969-1989) at Rock Springs, Pennsylvania.

Crop rotation	Corn yield (bu/A)
Continuous corn	139
Corn/soybeans	145
Corn/two-year alfalfa	154
Corn/corn/three-year alfalfa	153[a]
Corn/corn/three-year alfalfa	148[b]

[a]First-year corn yield
[b]Second-year corn yield

Rotations also can help control insects and weeds. Because western corn rootworm larvae cannot tolerate the rotation to alfalfa, this rotation can be an effective way to control this pest in corn. Most perennial weeds are susceptible to late-summer or fall herbicide applications. Rotation to a small grain can provide an opportunity to control these weeds. A recent study demonstrated how a combination of crop rotation and fall herbicide applications could control hemp dogbane to a greater degree than late-spring herbicide applications alone (Table 2).

Another benefit of crop rotation that contributes to yield enhancement is improvement of soil physical properties such as tilth and bulk density. When a hay crop is plowed under, for example, the soil will be loose and have a good granular structure and tilth. These improved soil properties result from the protection of the soil from raindrops, the proliferation of fine roots throughout the soil, and the formation of humus in the soil from decomposing plant roots.

A well-planned rotation can contribute to more efficient use of plant nutrients. In a three-year corn/alfalfa rotation, for example, manure can be applied during the corn rotation, resulting in efficient use of the N and often a buildup of P and K levels. During the alfalfa phase of the rotation, when manure is not applied, the forage crop will utilize the soil P and K levels that were built up during the corn phase of the rotation. This combination of nutrient management and crop rotation can reduce or eliminate the need for purchased fertilizer.

Timeliness is another factor that is overlooked as a benefit of rotation. A good crop mix can spread the workload during planting season over several weeks and help producers avoid the costly effects of late planting that are common with some crops, such as corn. Consider the case of a 1,000-acre grain operation. If it takes this operation an average of six weeks to plant its acreage and only corn is planted starting May 1, then one-third of the crop will be planted in June, when the yield potential has dropped to about 75 to 80 percent of the potential. If one-third of the acreage is devoted to soybeans rather than corn, then the corn should be planted by the end of May, and soybeans can be planted in the first two weeks of June. In the corn and soybean system, all of the acres of both crops will be planted in situations that should result in 90 percent or more of their yield potential.

For crop rotations to be profitable, however, rotational crops must have enough profit potential to pay for the additional machinery, labor, and storage costs that they require. For example, it is difficult for grain producers to utilize long hay rotations with row crops because of the large amount of labor required for haymaking. It also can be difficult to justify small acreages of crops in rotation, such as wheat or oats, that may require specialized harvesting equipment in regions where grain heads for combines are not common. Nevertheless, sound crop rotations are often the foundation of a profitable cropping system. There are some initial costs for implementing crop rotations, such as extra equipment, but in the final analysis these costs may be more than overcome by the reduced inputs, timeliness, and higher yields.

USING CROP ROTATIONS FOR CONSERVATION TILLAGE

A systematic crop rotation can improve the success of conservation tillage by eliminating many of the stress factors contributing to disappointments with reduced-tillage cropping systems. Some examples of practical crop rotations being used by crop producers in Pennsylvania can help illustrate this concept.

Continuous no-till corn fields can develop several challenging situations. Hard to control perennial weeds such as brambles and hemp dogbane can become established and are almost impossible to control with herbicides. Leaf diseases can build up innoculum levels in the residue and increase in severity with the length of the corn rotation. Heavy corn-residue levels contribute to cooler and wetter soils at planting and can interfere with seed placement, sometimes resulting in uneven stands. These factors, combined with possible toxic or allelopathic effects from the decomposing corn stover on young corn plants, often result in slow growth early in the season. Heavy residue interferes with the performance of some herbicides, occasionally resulting in poor control from preemergent herbicides. In addition, the lack of residual N in these fields means that N management is more critical, with some N needed at planting to avoid N deficiency early in the season. Finally, continuous corn crops are at a greater risk for rootworm damage, and where corn rootworm populations are high, a soil insecticide is justified. Despite these challenges, corn can be grown successfully no-till following corn, but it requires a higher level of management to anticipate many of these problems.

A recent Wisconsin study documented some of the effects of rotation and tillage on soil temperatures and corn yields (Table 3). Early season soil temperatures were especially reduced when corn was no-tilled following corn. The soil temperature reduction was more likely to result in slow early season growth and reduced yields in the continuous no-till corn system than in the continuous corn system where plowing was used. It is important to note that soil temperature differences among tillage systems have more of an effect on crop yields in shorter season areas than long season areas such as southeast Pennsylvania.

An alternative to continuous corn is the corn/hay rotation that is common on many Pennsylvania dairy farms. This rotation often includes corn following an alfalfa-grass sod. One challenge in this rotation is control of the existing sod. Sod control is best achieved with a fall application of herbicides such as Roundup and 2,4-D, but it requires some planning ahead. Killing the sod in the fall not only is good from a weed control standpoint, but also helps prevent heavy residue in the spring, which can contribute to cool, wet soils, slow growth, and uneven stands. Many of the problems associated with the continuous no-till corn will be eliminated in a rotation scheme where the sod is killed in the fall. Residue levels will be manageable; perennial weeds often will be eliminated; residual N levels will be high; the potential for insect problems will be low; and the soil structure usually will be excellent. This rotation is most successful when hay rotations are relatively short (i.e., three to four years), because few corn fields on

Table 2. Effect of herbicide-application timing on hemp dogbane control in no-till corn following winter wheat.

	1994	1995
	(% control in August)	
Fall applied Roundup[a]	74	90
June applied broadleaf[b]	56	67
Fall Roundup + June broadleaf	83	94
LSD (0.05)[c]	11	15

Note: the study was conducted in 1994 and 1995 in Dauphin County, Pennsylvania.
[a]Control values are an average of 1 or 2 quarts per acre applied in early September or early October.
[b]Control values are an average of several different post-broadleaf herbicide programs applied in early June (2,4-D, Banvel, Beacon+Banvel, or Marksman, for instance).
[c]LSD = least significant difference.

Table 3. Effects of tillage and crop rotation on residue cover, soil temperatures, and corn yields in a recent University of Wisconsin study.

Previous crop	Residue cover (%)[a] Plow	Residue cover (%)[a] No-till	Soil temperature (F)[b] Plow	Soil temperature (F)[b] No-till	Grain yield (bu/A) Plow	Grain yield (bu/A) No-till
Soybeans	2	31	65	63	173	176
Wheat	2	58	65	63	172	163
Corn	5	69	65	58	162	149

[a]At planting.
[b]Midday, in-row temperature at seed depth, averaged for seven days after planting.

the farm will be more than one or two years away from a perennial forage crop. These fields will still have good soil structure, some residual N available from the sod, and a reduced potential for insect problems.

Longer hay rotations result in lower hay yields; more potential damage from some insects that prefer grassy hayfields, such as wireworm, white grub, and common stalk borer; and corn yields that decline in the third and fourth year after hay. One alternative to long corn rotations between alfalfa seedings is to grow a soybean crop after two years of corn and follow it with two more years of corn. In this way, many of the negative effects of third- and fourth-year corn are avoided; the soybean crop provides opportunities for weed control; and the number of alfalfa fields established each year is reduced.

On grain farms, corn/soybean rotations are nearly as successful for reduced tillage as a short corn/hay rotation. Soybean stubble fields often have excellent soil structure and no heavy residue, which makes them excellent candidates for no-till corn planting. These fields dry out and warm up relatively early and are an excellent seedbed for no-till planters. Timeliness considerations, as well as the reduced N and insecticide requirements of corn following soybeans, increase the profit potential for reduced tillage. Some no-till growers successfully use a corn and soybean rotation during the grain-crop phase of a four-year grain/hay rotation, and this rotation helps reduce insecticide and nitrogen inputs. On some soil types, the lack of soybean residue occasionally results in some overwinter erosion or some hard soils in the spring. In addition, some perennial weeds, such as hemp dogbane, may persist through both the corn and soybean weed control programs and increase over time.

Ohio researchers found that on some poorly drained soils, yields of continuous corn declined under no-tillage, but when a corn/soybean or corn/oat/hay rotation was used, no-till corn yields were similar to plowed corn yields (Table 4). Consequently, soil characteristics partly determine whether crop rotation will benefit a no-till corn crop. Generally, these benefits will increase as soils become heavier and less well drained.

Adding an occasional wheat crop to a reduced-tillage corn/soybean rotation can increase the crop diversity and reduce weed problems that develop over time. Wheat following soybeans is an excellent alternative, provided the soybeans can be harvested early enough to allow timely planting of the wheat. An earlier-maturing soybean may be necessary to achieve an early harvest. No-tilling wheat into soybean stubble works well, because it helps producers avoid planting delays due to seedbed preparation and because the soybean stubble provides a good, disease-free seedling environment. Planting the wheat into soybean stubble also would help prevent head scab, which could be more prevalent if wheat were no-tilled into cornstalk residue.

One challenge with this rotation is that the wheat sometimes leaves the soil hard or compacted, limiting the potential of the succeeding no-till corn crop. Little research data are available to address this problem, but some growers are trying to alleviate the situation by double cropping with buckwheat following wheat, using a fall herbicide treatment to kill any existing weeds and create an overwinter dead mulch, or by incorporating some tillage in their program at this point in the rotation.

Interseeding red clover or sweet clover into the wheat in the spring can provide a green manure or possibly a forage crop before rotation back to corn. The taproot of these clover crops also helps to alleviate any soil compaction problems in the field. Consider using high-quality clover seed for interseeding, since low-quality seed may contain weed seeds that could cause more problems in the future. In some areas, soybeans can be double cropped after the wheat harvest.

Table 4. Effects of rotation and soil type on corn yields.

Soil	Rotation	Yield (bu/A) No-till	Yield (bu/A) Plow
Wooster silt loam	Continuous corn	130	116
(well drained)	Corn/soybeans	132	118
	Corn/oats/hay	146	134
Hoytville silty clay loam	Continuous corn	112	125
(poorly drained)	Corn/soybeans	129	129
	Corn/oats/hay	127	133

Source: Ohio State University.

Continuous corn silage is another example of how a minor change in rotation can maintain soil productivity. In some situations, it is necessary to continuously grow corn for silage. The lack of residue and the potential for soil compaction in this rotation make continuous no-tillage a challenge. Many producers have found that they are able to maintain productivity by seeding a rye crop following silage harvest. The rye helps loosen the soil over the winter, takes up excess nutrients left over from the corn crop, and helps reduce runoff, which is especially important when manure is applied to the field over the winter. In this rotation, the management of the rye is critical for success. An early burn down of the rye in spring helps limit the amount of residue on the field and reduces the field's attractiveness to insects. Limiting the amount of residue helps fields dry out faster in spring and minimizes the potential for tie up of the herbicide on the residue. Also, it helps prevent the allelopathic effects of the rye on the corn, which sometimes occur in cool, wet conditions. Harvesting the rye for ryelage also is an alternative, provided harvesting can be done on a timely basis so that corn planting is not delayed unnecessarily.

Well-planned rotations enhance the effectiveness of reduced-tillage forage-crop establishment. When seeding many small-seed forage crops, good seed-to-soil contact is essential. Avoiding situations where heavy residue may interfere with seed placement is a key to success. For example, no-till alfalfa establishment works well following corn silage for spring seedings and following a small grain for fall seedings. Consequently, planning to harvest corn silage in the third year of a three-year corn/alfalfa rotation could help improve the potential success of a no-till alfalfa seeding.

Alfalfa also can be effectively no-tilled in the late summer following a spring-seeded, sorghum-sudangrass crop. The sorghum-sudangrass is vigorous, competes well with existing weeds, and leaves the soil with good structure. These situations help reduce pest problems, which can occur when alfalfa is no-tilled into a killed grass sod.

Crop rotations play an important role in the success of most crop production enterprises, but rotations are especially important for conservation-tillage crop production. With carefully planned crop rotations, the advantages of no-till crop production can be extended to soil types or situations where success is difficult. Some producers have demonstrated that combining the timeliness and reduced-labor benefits of no-till with the yield advantages and reduced inputs associated with a good crop rotation significantly increases profits associated with crop production. Making these crop rotations work effectively takes advance planning and occasionally some initial investments in machinery or herbicides that otherwise would not be necessary. Crop rotation should be considered an essential part of a successful reduced-tillage cropping program in Pennsylvania.

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