No-till Cropping Systems in Oklahoma

No Till OKLAHOMA

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Oklahoma Cooperative Extension Service
Division of Agricultural Sciences and Natural Resources
Oklahoma State University

Foreword

Pre-statehood maps of what is now Oklahoma show a patchwork of territories and unassigned areas. These lands were coveted by the pressing population of European-Americans who would soon dramatically change the face of the yet unborn state. A new and different patchwork developed as settlers tilled and planted. For two decades, beginning in the early 1890s, acres planted of cotton and wheat doubled every couple of years with "king cotton" growing the fastest. Potential problems related to typical agronomic practices of the day coupled with the often fragile soils of our state became apparent to scientists at the fledgling Oklahoma Agricultural and Mechanical College in Stillwater. In his book *Agriculture* (an edition of the *OSU Centennial History Series*), Donald Green photocopied a set of class notes taken by Jessie Thatcher in the mid 1890s. Some of the excerpts indicate that Oklahoma A&M was already passing early conservation tillage on to students. Ms. Thatcher wrote, "The productiveness of the soil depends more upon the condition, than upon the quantity of the elementary substances in it." Her notes went on to say, "The crop (residue) itself if applied as a fertilizer could have much the same effect as the application of manure produced by feeding the crop to animals. Shading the soil by growing crops, such as, clover or grass, or covering it with straw or leaves will increase the fertility of the soil and make the land more productive."

The State of Oklahoma has come a long way since those pre-statehood years. So too has the little Land Grant college in Stillwater and the science it develops and extends to the people of the state. Conservation tillage and agronomic practices have evolved since those early days, with the Oklahoma State University's Division of Agricultural Sciences and Natural Resources assuming the role of scientific leader in changing practices that once led to the tragic Dust Bowl. The Division continues to partner with other agencies and many of the producers in the state to develop, test, and demonstrate tillage and other agronomic practices to better conserve the soil, its moisture, and nutrients. More recently, changes in government programs, plant genetics, low impact practices, farm equipment, and growth of biofuels open the potential for new and dynamic cropping systems. Often, conservation tillage (minimum till, no-till, etc.) practices can be employed to improve the success of these cropping systems and help assure the sustainability of the land.

OSU scientists and their colleagues around the country, along with producers, have tested and revised many conservation tillage practices. This circular is designed to help those producers think about how such practices might fit into their cropping systems. It provides the basics for those producers, as well as some insights for producers already employing an array of conservation tillage methods. This circular should not be the end of your investigation into conservation tillage practices for your operation, but rather the starting point to seek out more information from your local Cooperative Extension educators, other federal and state agency personnel, OSU scientists, and your fellow producers.

The land so coveted by early producers and its soil remains an important and dynamic force in our economy. It is imperative that today's producers and landowners employ the best management practices for the economic viability of their operations and the sustainability of this valuable resource. We trust that *No-till Cropping Systems in Oklahoma* will prove an important resource in that process. The contents of this circular are made possible through the Oklahoma Cooperative Extension Service, Oklahoma Agricultural Experiment Station, Oklahoma Natural Resources Conservation Service, and Oklahoma Conservation Commission. Funding support for this printing comes from the Oklahoma Natural Resources Conservation Service, Conservation Innovation Grants Program, the EPA 319 Program and Southern SARE.

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This publication is designed to assist individuals interested in a no-till cropping system in making decisions that affect the production of their operation. We wish to thank the following individuals for their contributions toward this publication.

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Introduction

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No-till Anxiety: Getting Started

Many producers have probably considered switching to a no-till production system at one time or another, but have felt anxiety about switching from their conventional tillage practices. It's natural for anyone who has farmed for any length of time to feel anxious about trying a new system. For a producer to establish and learn a new system, it may seem daunting, but it can be done with careful planning and surrounding yourself with knowledgeable people. Following are a few obvious benefits of no-till and some general suggestions if considering a switch to no-till.

> *"With fuel and machinery costs increasing at the rates they have the past 10 years, I can't believe that there is anyone that hasn't tried no-till."*
>
> **Greg Leonard**
> **Afton, OK**

The biggest attribute of no-till is the long-term productivity of your soil. When a soil is tilled, it loses a key ingredient, carbon. Soil carbon makes up more than half of the soil organic matter. Soil organic matter is a critical determinant in water-holding capacity, biological activity, aggregate stability and overall soil productivity. Soil organic matter has continued to decrease during the past several decades due to intensive tillage. In the western part of Oklahoma, organic matter levels in soils prior to tillage were as high as 4 to 6 percent. Today, it is hard to find a conventional tilled soil with organic matter greater than 2 percent.

Research has indicated no-till increases organic matter in the top three inches of the soil and will tend to conserve more moisture compared to conventional tillage systems. This moisture savings is the second most important benefit of no-till. No-till and the maintenance of surface residue slows the rate of evaporation from the soil surface. It has been estimated in conventional tillage systems with little or no surface residue, that precipitation storage efficiency is 20 percent. For example, if you receive 10 inches of rain during your fallow period, you conserve only 2 inches as soil moisture. In contrast, precipitation storage efficiency estimates are 40 percent in no-till. Therefore, you can conserve twice as much moisture in a no-till system when compared to a conventional till system, depending on rainfall patterns. There are numerous other benefits to no-till, such as reduced wind and water erosion, time savings, fuel savings, decreased soil compaction, and reduced labor requirements. Greater detail about the benefits of no-till can be found in later chapters.

Finding a knowledgeable no-till producer in your area is important. They have worked through some of the same problems you will probably encounter. Extension educators and Natural Resource Conservation Service district specialists are also available for consultation. Keep asking until you find a suitable answer. When making a transition to a no-till system, you often hear about slight yield reductions in the first three to five years. This is often management related and can be overcome by making adjustments to equipment, fertility, herbicide/pesticide programs, etc. This is a perfect example of learning from the mistakes of others. Fortunately, unlike in the past, there are now many experienced people throughout the state who are willing to help.

> *"What would the neighbors think? Am I just too lazy to be on a tractor all summer?"*
> **James Wuerflein**
> **Kremlin, OK**

Remember there are no dumb questions and that thinking outside the conventional box can be useful.

When switching to a no-till system, be prepared to make mistakes and perhaps be criticized. There may be comments such as "What in the world is he doing?" and the list could go on and on. However, the successful implementation of no-till can be well worth it–stay the course, follow the general guidance provided in the following chapters and learn from experienced producers in your area. In some parts of the world, and even in the U.S., no-till production systems are the norm — not the exception. The soils and environment in Oklahoma are well suited to positively respond to no-till. The key is to develop a no-till "system" that will fit your farm business plan. It will also allow for the improvements in soil health, ultimately improving productivity and dramatically decreasing the negative impacts of conventional tillage.

Finally, when switching to no-till, have a well thought-out plan that encompasses the following — soil testing, crop rotation, pest management, and other farm enterprises such as grazing. Be dedicated and committed to no-till. If you go into no-till with an "I think it is going to fail" attitude, it probably will. Always remember that no one production system is appropriate for everybody. We hope the information in this circular will help you establish a successful and profitable no-till cropping system. Use your apprehension to your benefit, which means finding answers to your questions.

> *"It is a trial and error endeavor, just when you think you have it figured out…something else happens, weather, weeds, insects, etc. Once you decide to do it, stick with it, be flexible and learn all you can from different sources."*
> **David Shultz**
> **Altus, OK**

Chapter 2

Soil Health and No-till

Steve Alspach
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What is "Soil Health?"

Since tillage began, crop producers have been aware of important soil properties affecting plant growth and yield. The term tilth evolved from an old English term meaning tillage and included many of these properties in one term. A soil was often referred to as having 'good tilth' if it had stable aggregates, high organic matter content, was easy to till, did not readily crust, made a good seedbed, took in water rapidly, and had low bulk density. Soils with poor tilth crusted easily, were hard, resistant to tilling, had low organic matter, and were difficult to prepare for planting. Thus, tilth refers to "the physical condition of the soil in relation to plant growth" (Brady and Weil, 2002). In the last few years, the term 'soil health' has replaced 'tilth.' Soil health includes the properties mentioned above, but also includes soil temperature, water content, soil faunal populations, pH, fertility, and nutrient cycling.

USDA's Natural Resources Conservation Service defines soil health as 'the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.

Soil Health

Good soil qualities are enhanced with no-till practices. With time, favorable changes occur that affect:

- Organic matter content
- Water infiltration
- Structure
- Temperature
- Bulk density
- Soil organism populations
- Hydraulic connectivity
- Nutrient cycling

In short, the capacity of the soil to function.' There are two aspects of the definition: inherent soil properties and dynamic soil properties. The dynamic properties of the soil are the properties we, as land managers, can influence to allow soils to better:

- accept, hold, and release nutrients and other chemical constituents;

> *"Remember, it is hard not to go get a plow when things look like a wreck and your neighbors are talking about you, but if you plow, you will mess up soil structure and earthworm activity."*
>
> **David Shultz**
> **Altus, OK**

Photo courtesy of USDA

Figure 1. Soybeans double-cropped into wheat stubble, Kay County, Oklahoma.

- accept, hold, and release water to plants, streams, and groundwater;
- maintain suitable soil biotic habitat; and
- respond to management and resist degradation.

Soil Health Concepts

There are four key soil health concepts to remember when trying to develop a healthy soil. They are:

- Disturb the soil as little as possible;
- Increase diversity by using crop rotation;
- Keep living roots in the soil as many days as possible throughout the year; and
- Keep the soil covered as much as possible.

> *"Long term no-till leads to improved soil tilth and structure, soil health, water infiltration, and raising organic matter percentage."*
>
> **James Wuerflein**
> **Kremlin, OK**

Disturbances such as tillage introduces an abundance of oxygen to the soil that accelerates the action of bacteria that process organic matter. This leads to rapid oxidation of organic matter (OM) and an overall loss of OM in the soil as it is decayed and released into the atmosphere as carbon dioxide (CO_2). Conventional tillage systems that disturb the soil multiple times a year cause the soil biological system to be dominated by a bacterial community. Removing tillage and minimizing disturbance allows the fungal, micro-arthropod, protozoa, nematode and earthworm populations to come into balance with their environment and produce a more diverse biological community. Processing of OM becomes more consistent throughout the year and OM levels will actually begin to increase.

Crop rotation increases the diversity of residues in and on the soil and creates breaks in disease and pest cycles. Growing the same crop year after year after year has led to an increase in weeds, diseases and other pests as the same residues and timing cycles are present each year. A crop rotation that uses multiple crops with a mix of grasses and broadleaf crops grown during different seasons (i.e. fall planted vs. spring planted) allows the land manager to break those cycles and gives them better opportunity to control pests.

Living roots exude sugars created in the photosynthetic process. These exuded sugars are an energy source for organisms living in the soil. Therefore, keeping live roots in the soil as much as possible stabilizes the biological community and allows for more consistent residue processing and mineralization of nutrients for use by plants. Keeping living roots in the soil as much as possible can be enhanced by using cover crops during fallow periods.

Keeping the soil surface covered with residue serves many beneficial functions. The key benefit is protecting the soil from the erosive forces of wind and water, thereby reducing or preventing soil erosion. The residue absorbs the energy of raindrops and prevents soil aggregates from being dispersed and forming a crust at the soil surface. A crusted soil has reduced infiltration, which leads to runoff and water erosion. The shadowing effect of the residue allows for lower soil temperatures, which in turn, lowers evaporation of water from the soil. This shadowing also lowers the amount of sunlight hitting the soil surface, resulting in lower germination rates of weed seeds found in the soil. Therefore, the residue can have a significant weed control outcome.

Organic Matter

Organic matter (OM) increases are due in part to ceasing tillage, but can be enhanced with the use of cover crops in a management system. Tillage introduces an abundance of oxygen to the soil, accelerating the action of microorganisms that mineralize organic matter. The simple act of ceasing tillage brings the oxygen supply back in balance and creates an environment where organic matter can increase (Derpsh, 2005). Roots in the soil and crop residue on the surface supply the raw materials for stable organic matter. Even though the bulk of the residues are consumed during respiration by decomposers, a small fraction is converted into soil OM. Cover crops provide a living cover during the typical fallow period and can be used to ensure the soil surface is protected from erosion, balance the C:N ratio and increase OM in the soil.

The increase in OM influences the water-holding capacity, aggregate stability, nutrient cycling, and nitrogen demand of the soil. Water-holding capacity in soil is largely the product of surface area, where a combination of adhesion and cohesion holds water as a film on the surface of the soil particles. The surface area-to-weight ratio of OM is much larger than mineral particles, so OM holds a large amount of water for its weight. Small increases in OM significantly increase its water-holding capacity. Organic matter functions as glue for soil aggregates and structural units (blocks, prisms, or granules) and increases aggregation and structural strength.

Over time, the soil regains the strength to support vehicles, equipment, and livestock even when wet. Soil OM also functions as a reservoir for nutrients. As soil organisms feed on old OM, they release available nutrients back into the system. Creating conditions where OM can increase also creates a new demand for nitrogen, since nitrogen is a necessary component of OM. Soil organisms need nitrogen to decompose plant residue and incorporate it into OM. This nitrogen is not lost, but is 'banked' until soil organisms mineralize it and cycles the nitrates to feed crops in future years. Many producers report that this new nitrogen demand is temporary and continues about three to ten years, depending on crop rotation.

Carbon is the most important nutrient in the ecosystem. It makes up the bulk of dry matter in all organisms. While plants get carbon from the air (CO_2), all other life depends on the consumption of plant-derived carbon-based foods for energy and structural components. Organisms that live in the soil depend on plant residues, roots, and soil OM for the carbon to live and carry on various beneficial functions below ground. A large amount of soil OM is an indicator of a properly functioning ecosystem. If topsoil (the top seven inches) has 3 percent organic matter, it will have about 4,800 tons of organic matter in 160 acres. In an undisturbed soil, some organisms are always creating soil OM, while others are decomposing OM, but the trend is increasing OM and feeding the dynamic food-web of underground organisms.

Soil Organisms

Earthworm, fungi, bacteria, and other invertebrate populations generally increase with no-till. With many years of tillage and a single crop, the population of soil organisms decreases and becomes unbalanced. This can aggravate the pest problems and prevent maintenance of soil structure and OM. No-till creates a stable environment, allowing populations to increase and reorganize. Populations typically build back towards the full diversity of organisms that were 'burned off' with conventional tillage. Approximately 5,000 pounds of soil organisms per acre is not uncommon.

Earthworms create stable macropores, consume and recycle organic materials, and help form stable aggregates (Figure 2). Several species will inhabit a soil, each having a particular season of activity and zone of habitation. Some species come to the surface and others do not. Some are mostly horizontal burrowers and others form long vertical burrows. Plant roots tend to prefer earthworm casts and burrows for growth. The burrows usually have a higher bacterial population and higher available nitrogen. Exudates from worms help glue the casts together into a stable granular structure (Tugel and Lewandowski, 2000). Earthworms will tend to move into fields after conversion to no-till from adjacent fence rows or pastures.

Figure 2. Earthworms under no-till corn in Reinach silt loam, Kay County, Oklahoma.

Soil fungi carry out several functions. One of the most important is the exudation of glomalin, an organic glue important to stable aggregates (Wright, 1996). Other fungi live in a symbiotic relationship with the plants providing additional water, phosphorus, and zinc for a supply of energy. A wide variety of bacteria is responsible for nutrient cycling in the soil. Bacteria, fungi, and nematodes finally cycle the vast majority of nutrients the plant uses from crop residues back to the plant. Nematodes carry out a variety of functions, including nutrient cycling and control of harmful organisms (Tugel and Lewandowski, 2000).

The diversity and population of soil organisms increases with time. As diversity increases, the proportion of beneficial organisms increases relative to harmful ones. For instance, predatory nematodes and fungi become more abundant relative to disease-causing nematodes. The organisms visible to the naked eye serve as a proxy for the ones not seen. Thus, an increase in earthworms, insects, other worms, burrows, fungal mycelia, egg cases, etc. indicate a corresponding increase in smaller organisms.

Permeability, Macropores, and Connectivity

Soils that have never been cultivated tend to have many large pores that allow rapid movement of water and gasses into and out of the soil. These macropores are the result of earthworms, insects, burrowing insects and mammals, and old root channels from woody plants and forbs. The shrinking and swelling of the soil during wet and dry cycles creates stable cracks that serve as important macropores in loamy and clayey soils.

Most conventionally tilled soils have lost nearly all of the macropores, resulting from the action of plants and animals. Single crop rotation and frequent tillage destroy residue, earthworm habitat, and macropores. Frequent tillage prevents the formation of new pores. Tillage with conventional tools also destroys the continuity of pores from the surface to the deep subsoil. These pores are destroyed, smeared shut, or compacted during such operations.

Macropores allow rapid and deep penetration of water into the soil. Water stored in the subsoil is protected from wind and sun but is available for plants. Rapid infiltration of water also allows more water intake during precipitation.

Gas exchange at the surface is important but often not appreciated. During rapid plant growth, plant roots and soil organisms release large amounts of carbon dioxide and require large amounts of oxygen. A network of large pores allows rapid diffusion of oxygen into, and carbon dioxide out of the soil. If gas exchange is restricted by a compacted or water saturated soil, plant growth may stop.

No-till systems facilitate the formation of large pores by allowing worm populations to recover. They also enhance the connectivity of the pores by not cutting pores with horizontal tillage or plowing. Deep pores connected to the surface allow rapid and deep intake of water and oxygen. Pores created by plants and animals last for several years, so porosity increases yearly as previous years' pores continue to operate. Crop rotations are an important part of increasing the porosity of a soil. For instance, a crop with a deep taproot will leave behind large pores for several years.

Water Content

For any soil, the goal of a producer is to capture as much water as possible, store that water for a crop, and deliver it back to the crop for optimum yield. As the soil improves, the increase in infiltration rate, permeability, and porosity allows more rain to get in the soil before it runs off the surface.

Crop residues on the surface create an effective barrier that prevents crusting from falling rain drops and slows water as it runs off the surface. This allows for more infiltration, especially into the macropores that are developing and increasing in number each year (Figure 3). Those same residues shade and insulate the surface from wind and sun, reducing evaporation from the soil, which is the major loss during fallow periods. The water saved is available for crop production and a higher moisture content in the surface layer allows more activity in the soil microorganism community that supports plant growth. The soil dries out less often and the soil organisms operate (nutrient cycling) for a longer portion of the year.

Figure 3. Corn residue on Brewer silty clay loam, Kay County, Oklahoma.

Temperature

In Oklahoma, cold soils are not often a problem, but hot soil is common. Soil temperatures at the surface in summer are commonly 100 F one inch below the surface. The soil heats, dries out, and plant and animal activity ceases. In no-till fields, the soil temperature just one inch below the surface will be 25 F lower than an adjacent tilled field. In addition, fields with an actively growing cover crop have been observed to have soil temperatures 8 to 12 degrees cooler than a no-till field with stubble only. Typically, these cooler soils have much higher water content. The crop residues shading the surface have a dual

Figure 4. Wheat residue on dryland no-till, Cimarron County, Oklahoma.

benefit of lowering temperature and increasing soil moisture (Figure 4). Plant roots begin to utilize the inter-row zone that they previously avoided due to heat and dryness. Nutrient availability is higher because the soil fauna are active longer than in a tilled field.

Structure, Aggregate Size, and Strength

Tillage does not create soil structure; it destroys structure and creates clods. Often we spend the fallow period trying to break up those clods for planting. The structure of topsoil in tilled fields is artificially created through numerous trips with plows, disks, harrows, etc. After a rain, it collapses into massive clods and often forms a crust. No-till allows a naturally granular structure to reform. This occurs first at the very top of the soil (Figure 5).

The natural structure that prairie soils have at the surface is a product of plant roots, earthworms, soil fungi, and wet/dry cycles. Earthworms eat soil and their casts form the basic structure of the surface soil. Worm exudates and glomalin from soil fungi are the glues that hold aggregates together. The change from artificial soil structure created by tillage to a naturally granular structure (Figure 6) does not happen overnight. The structure that does form is not destroyed and lasts for years. As surface aggregates replace the powder-fine surface commonly found in tilled fields, the size of the surface aggregates increases toward the size of the aggregates in the subsoil. Water moves from the surface to the subsoil more easily when there is a consistent aggregate size.

The product of reforming soil structure and strength is counter-intuitive to those who are used to clean-tilled fields. The aggregates gain strength to hold up tractors and vehicles, while the density decreases and porosity increases. Conditions approach those of a native prairie that is firm to drive on, but is very porous.

Figure 5. Worm casts and crop residue, Tabler silt loam, Kay County, Oklahoma.

Figure 6. Granular structure forming on soil surface, Tabler silt loam, Kay County, Oklahoma.

Density

A healthy soil should be about 50 percent solid matter, and 50 percent pore space available to hold roots, water, and air. Compaction resulting from conventional tillage reduces the pore space by packing soil particles tightly together. Compaction results in less available water, lower permeability, and oxygen-starved soils. It can prohibit plant roots from entering the subsoil, effectively turning a deep soil into a very shallow soil. Compaction (or high bulk density) increases the energy a plant must expend to grow roots through compact soil. Roots tend to be shorter, fatter, and explore less soil (Nadian et al., 1997). Compaction lowers yields by reducing the soil available to the plant and causing the plant to expend extra energy to grow roots rather than put the energy into yield. Roots growing horizontally at the bottom of the tillage layer are a definite symptom of compaction.

A soil with a penetration resistance of 300 pounds per square inch (psi) will stop the root growth of most plants. In Oklahoma, some tilled fields resist penetration at 300 psi at some depth within nine inches of the surface when they are moist. A producer can diagnose the depth, severity, and pattern of dense layers quickly with a soil compaction tester, a three foot piece of steel ¼-inch round stock with a T handle or a commercial product with a pressure meter (such as the Dickey-John Tester, Figure 7).

No-till simultaneously decreases density and reverses compaction by not interfering with the processes previously mentioned. The action of roots; earthworms; and wet/dry and freeze/thaw periods reverse compaction in loamy and clayey soils (Figure 8). The benefits from these soil-forming

Figure 7. Using a density tester to locate compacted zones in soil.

processes begin and accumulate year by year when tillage ceases. Biological reduction of compaction can be achieved with the use of aggressively rooting plants, such as forage radishes or sunflowers, grown in a cover crop mix. Radishes have a very strong taproot that is able to penetrate compacted soil layers and reach into the subsoil. After the radishes decay, a large macropore exists that allows rapid water infiltration and an avenue for root development of future crops.

Figure 8. Density of corn roots in no-till, Reinach silt loam, Kay County, Oklahoma.

Sandy soils react differently to compaction. Many of these soils have the perfect proportion of sand and clay to be compacted to a high density. Some soils may not have enough clay to swell when they are wet. Natural processes that keep sandy soils from packing are relatively large soil animals (i.e. gophers) and a more diverse population of plants with coarse roots. A strategy for decreasing compaction on sands may require more diverse crop rotations and toleration of a population of burrowing animals.

Tillage Planes and Hydraulic Boundaries

Closely related to high density are the boundaries created by normal tillage tools (disks, sweeps, and plows). As these tools move through the surface, they push down with enough weight to compact and smear the cut surface they create. Most producers perform tillage when the moisture content allows maximum compaction. Over time, a soil will accumulate several density layers at different depths. This platy structure and the compact boundaries are very effective at stopping roots and water and air infiltration. Note the horizontal roots at this boundary (Figure 9).

The processes that reverse compaction also operate to reverse tillage planes. Cracks, pores, animals, and roots begin to break up tillage planes when tillage ceases and can change the horizontal plates to a more natural structure. In loamy and clayey soils in Oklahoma, as the tillage planes disappear, roots begin to enter the subsoil and grow to surprising depths. The clayey subsoil did not limit the roots; the packed boundary at the bottom of the tillage layer did.

Figure 9. Roots growing horizontally on bottom of tillage pan.

Erosion by Wind and Water

The rate of erosion by wind and water falls dramatically with no-till. Crop residue covering the surface protects the soil surface from the energy of wind and rain. The residue dissipates the kinetic energy of raindrops and wind. Soil particles are not detached and are not available for transport off the field. The additional aggregate stability resulting from organic 'glues' also help protect soil from erosion.

Keeping the soil covered is a primary concern in maintaining a healthy soil. Many low-residue crops, such a soybeans, leave very little protection on the soil surface. Cover crops are an excellent management tool for establishing the protective residue layer needed to maintain a healthy soil.

Conclusion

No-till enables rapid increases in soil health simply by working with soil forming processes rather than against them. These increases can be accelerated by using cover crops in the management system. The product of improved soil health is a soil that is more productive because it is more able to provide for plant needs, which in general are water, nutrients, and oxygen. Biological activity and nutrient cycling is high. Macropores are created and maintained. Root density and depth of rooting increases. Plants have access to more volume of the soil, and the water and nutrients present there.

Improvements are not instantaneous, but the changes do begin immediately, and producers see signs in the first year. However, the soil goes through several phases and patience is important, especially in the first five years. Producers have observed that improvement continues for more than 20 years, depending on the soil, climate, and rotation used. Producers need a more adaptable management approach than in a tilled system.

It is important to note that none of these components operates independently. Soil health increase occurs simultaneously in many components, and improvement in one component affects the whole system. For instance, increased residue cover lowers soil temperature, lowers evaporation, increases water content, lowers erosion, supports the soil organism community, and leads to increased nutrient cycling.

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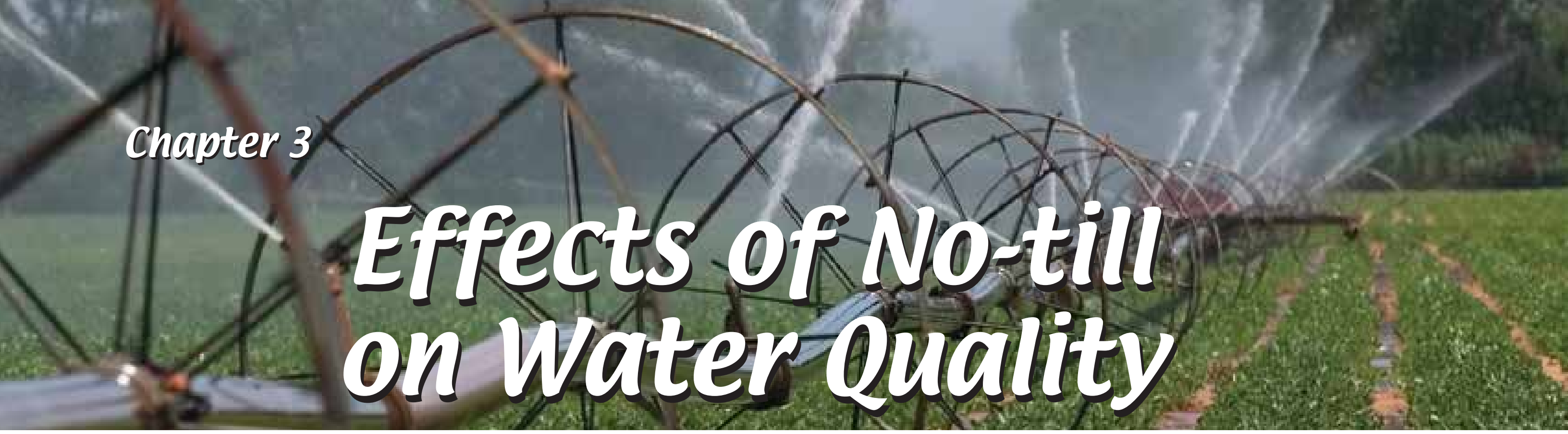

Chapter 3

Effects of No-till on Water Quality

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Oklahoma agriculture plays a significant role in the quality of the water found in our streams, rivers, and reservoirs simply because agricultural land represents a large portion of Oklahoma. Cropland agriculture can contribute to poor water quality because of sediment, nutrients, and pesticides lost from these lands to the surface water. No-till management is the most effective way to reduce these negative impacts of crop production on water quality.

The most obvious and immediate benefit comes from the dramatic reduction in erosion. Even under conservation tillage, it is easy to erode two to five tons of soil annually from a cropland field. A portion of this sediment reaches surface water. To put this in perspective, if five tons per acre per year of soil were eroded from a 160-acre field into a 1-acre pond, the depth of the pond would decrease by approximately 5 inches per year. Removing tillage and maintaining continuous residue cover can easily reduce this rate of erosion to a fraction of a ton per year.

With this reduction in erosion, a reduction in other common pollutants from agriculture is also achieved. The most well studied of which is the reduction in phosphorus transport to surface waters. Phosphorus is insoluble relative to other nutrients such as nitrogen. Most phosphorus that is lost from cropland soil to surface waters is attached to eroded clay particles. Therefore, no-till can dramatically reduce phosphorus loses to surface water. However, when phosphorus is applied in excess of crop requirement, it will accumulate near the soil surface. Excess accumulation can cause water quality problems even under no-till. This will generally only occur when manures or other organic nutrient sources are used for long periods of time. Care should be taken that excess phosphorus is not applied regardless of its source.

Nitrogen is a mobile nutrient, and therefore does not have to be transported with sediment to surface waters. This makes its management with respect to environmental quality more challenging than phosphorus. With no-till management, much of the nitrogen is surface applied. When this is done prior to a rainfall event to prevent NH_3 volatilization, we are increasing the potential for off-site loss to the environment. Therefore, care should always be taken to select the appropriate N rate without applying excess nitrogen. Another option to reduce the potential for N loss to surface waters is to inject liquid or gas N with low disturbance applicators. This places the N below the soil surface, where it is protected from losses to runoff and NH_3 volatilization.

"Saving more water in the soil allows you to withstand the dry spells longer…less runoff erosion…if you rely on runoff to fill your ponds for livestock (or fishing) you had better pray for floods."

James Wuerflein
Kremlin, OK

Water Quality

Water quality improvement is the biggest benefit of a no-till production program resulting from:

- Reduced run-off
- Reduced sediment loss
- Greater soil retention of herbicides and fertilizers

In its natural state, soil serves as a water filter, which removes many contaminates. However, under conventional tillage its capacity to filter water is reduced due to surface crusting, which limits water infiltration. Removing tillage allows natural processes to occur that improve soil structure, which in turn improves water infiltration rates. This allows the soil to regain its function as a filter, and thereby reduces contaminates as they move into groundwater instead of being washed to the nearest surface water body. This being said, it is always important to remember that everything humans do can impact the environment. There is no doubt that the benefits of no-till far outweigh the potential harmful consequences such as an increase in the potential for pesticide contamination. However, always keep in mind that when agricultural inputs are applied in excess of that required for profitable production, they can result in unwarranted harm to water, and in some cases, air quality. Sound soil fertility management can further improve the effectiveness of no-till in protecting the quality of Oklahoma's water supply.

Chapter 4

No-Till Equipment

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Once the decision has been made to start no-till, planting the crop seems to be a major concern. Obtaining good stands in no-till conditions requires planters and drills that can penetrate firm soil and cut or move heavy surface residues without plugging. Planting seed at a uniform depth and in firm contact with moist soil assures a good stand (Figure 1). There are many planters and drills on the market that can accomplish this task. There are also some older seeders available that perform quite well with the proper adjustments and/or attachments.

Figure 1. No-till corn in wheat residue.

Seeding Equipment

No-till seeding of crops differs from conventional tillage with respect to the equipment needed. Considerations include:

- Row spacing
- Types of openers
- Press wheels
- Depth control
- Residue management
- Topography of fields

No-Till Drills

No-till seeding of corn and other drilled crops differs from conventional till in many ways. More residue must be cut or moved out of the path of the opener. This is a challenge for the narrow 6- to 12-inch row spacing used for grain drills, and some of the solutions used for row crop planters are simply too expensive or the attachments are too large to be used on drills. On the positive side, soil moisture is usually closer to the surface in no-till than in conventional till. This means that seeding depths can often be shallower with no-till, provided the seeding depth is still sufficient for adequate early season plant growth. Also, heavy residue slows the rate of soil drying and reduces the tendency of the soil to crust before the plant emerges.

Figure 2. A no-till drill ready to seed into wheat stubble.

Figure 3. No-till drilling soybeans into milo stubble.

Component/Design Features

When looking at no-till drills there are some items that are worth comparing. Row spacing, types of openers, linkage, press wheels, and depth control are just a few of these. Consider all crops that will be seeded with the drill and choose the best options for your environment (Figure 3).

Row Spacing

The standard row spacing for most drills is 7.5 inches. For wheat, this row spacing tends to be much wider than the theoretically ideal square plant zone (equal distance in all directions to nearest plant). A bushel of wheat typically contains between 800,000 and 1,000,000 seeds, so achieving the square plant zone would require approximately 2-inch row spacing at a 1.5 bushels per acre rate. The concept of ultra-narrow row openers has been investigated in Oklahoma. A research study compared 3-, 6-, and 9-inch row spacings for two years at several locations. The study predicted a yield increase of about eight percent and nine percent for 6-inch and 3-inch rows compared with 9-inch rows. The yield response to the narrower rows occurred in both cheat-free and cheat-infested fields. The study concluded that the optimum row spacing for seeding rates commonly used in Oklahoma was about 6.6 inches. Thus, 6-inch and 7.5-inch row widths appear to be appropriate for wheat in Oklahoma.

For producers whose primary use of a no-till drill is soybeans and grain sorghum, a 10-inch spacing may be the most economical compromise, if wheat acreage is low. Grain sorghum growers who use seeding rates in the range of 30,000 to 60,000 seeds per acre can block half of the openers in the raised position to achieve satisfactory (12- to 20-inch) row spacing while eliminating unnecessary opener wear. The same technique can also be used for soybeans.

Naturally there is added cost of narrow row spacing on drills. A drill with 7.5-inch spacing has a third more openers than a drill with 10-inch spacing. However, the narrower row spacing may provide better weed control by allowing the crop to canopy sooner.

Types of Drills

The type of seed slot openers typically categorizes drills. There are three primary types of openers used in Oklahoma. They are the single-disk, double-disk, and hoe.

Single Disk Openers

For conventional tillage, single-disk openers were the standard grain drill in Oklahoma for more than 50 years. These openers usually consisted of a single concave 13-inch disk suspended by a simple swing arm. Depth control was acceptable in conventional tillage seedbeds without using an attached press wheel for depth control. Although these single disk drills are still available, the market for conventional till to reduced till drills has been largely captured by double disk openers during the last two decades.

No-till single-disk openers are available from several manufacturers (Figure 4). Designed for no-till, these openers are equipped with large (16- to 22-inch), heavy, flat disks with a heavy duty disk hub and bearing. These openers use a swing arm suspension, with depth controlled by a gauge wheel

Figure 4. A single disk opener on a Flexi-Coil air seeder. Note the tilted opener disk.

Figure 5. A single-disk opener operating in wheat stubble.

Figure 6. A Sunflower no-till drill with parallel linkage system.

beside the opener. A narrow press wheel is typically operated directly in the seed furrow to create seed-to-soil contact and a furrow closing wheel typically follows (Figure 5). Although the single disk is subject to hairpinning when planting in tough residue, these openers can place seed at the desired depth with minimal disturbance of crop residues. They may be equipped with hydraulic down force adjustment (sometimes called "active" down force). The hydraulic down force system keeps a nearly constant force on the opener to maintain more consistent depth control over rolling terrain.

Double Disk Openers

Double disk openers usually have a press wheel attached directly behind the opener for depth control, seed-to-soil contact, and furrow closing. Double disk openers move less soil laterally than the concave single disk drill, allowing them to operate at higher speeds than the concave single disk. However, they have more lateral soil movement than the newer single disk no-till drills.

Double disk openers may be suspended by a swing arm, parallel arms, or a strut and swing arm combination (Figures 6, 7, and 8). Down force may be applied by springs, hydraulics, or a combination of the two. Most double disk openers that are intended for no-till have the disks offset slightly (0.5 to 1.5 inches), so only the leading disk edge cuts residue. In some cases, the trailing disk is a smaller diameter than the leading disk. The leading disk may also be notched, which should help cut residue better (Figure 9).

Coulter/double-disk combinations are a popular style of no-till drill, sometimes known as the "fluff-and-plant" system (Figure 10). These machines use coulters (usually rippled or wavy) aligned to run directly in the path of the double-disk openers. The coulters cut the residue and till the soil in front of the opener. Depth of the coulters

Figure 7. A Great Plains no-till drill with parallel linkage system.

Figure 8. A Great Plains no-till drill with a swing arm linkage system.

and speed of operation have a major impact on the function of this concept. The addition of the coulters will cause more soil and residue disturbance than single disk and double disk no-till drills operating without coulters.

Figure 9. A double disk opener on a no-till drill with staggered disks and a notched leading blade.

Figure 10. Tillage action of coulters on a no-till drill.

Figure 11. A Great Plains no-till drill operating in milo stubble.

Hoe Openers

Hoe openers generally require much less down force to penetrate firm soil, and they usually move more soil laterally than disk openers. A hoe tends to lift the residue and allow it to fall to the side, whereas disk openers tend to push residue into the soil as they cut it. These features have made hoe drills more popular in western Oklahoma than in the east (Figure 12). The challenge of planting in dry conditions is to place the seed into moist soil without covering it too deeply. The hoe opener, operated on

Figure 12. A Haybuster no-till hoe drill. Note the under frame clearance for residue flow.

relatively wide spacing (10 to 14 inches), can move a layer of dry soil into a ridge between the rows. This can allow the seed to be placed 4 inches below the original soil surface, while covering the seed with about 2.5 inches of soil.

Hoe openers are usually used with gangs of "full press" wheels, which can carry much of the drill or air seeder frame weight. Full press wheels can apply heavy down force, forming well-defined furrows and ridges on the soil surface.

Though the hoe opener may require less down force for soil penetration, it will pull harder than most disk type no-till drills. Also the greater lateral soil movement created by hoe openers tends to limit the maximum speed of operation. At high speeds, the second (and third) ranks of openers tend to cover the front rank with additional soil. This may produce a noticeable stand reduction produced by the front rank. Attachments have been marketed to limit lateral soil movement from the rear rank.

On hoe drills, the openers are usually attached to the frame via a swing arm. There are a few examples of hoe openers having depth control/press wheels. With hoe-type air seeders, the opener is often rigidly attached to the seeder frame (the opener may be equipped with a spring linkage for shank protection). Such seeders rely on good frame flexibility to allow the machine to comply with lateral terrain features. Floating hitches, used with support wheels in front of the main frame, allow the frame to follow the ground independently from the tractor. Hoe openers may be selected to apply seed in narrow or wider bands and dual place fertilizer.

Older-model hoe drills do not function well in heavy residue. There are typically three dimensions that dictate how well a hoe drill will operate in residue: clearance, rank spacing, and spacing between openers on a rank. Increasing any of these dimensions improves the operation characteristics of hoe drills in no-till systems. Current hoe drills have much greater clearance than previous generation hoe drills. Three-rank hoe drills are available with

26-inch vertical clearance and 20-inch longitudinal spacing between ranks. Coulters are available on some models for operation in very heavy residue.

Depth Control

Depth control is a concern with any seeding system. A survey of conventional grain drills conducted in 1994 by Oklahoma State University researchers indicated a strong tendency for farmers to plant wheat much deeper than they intended. Only about 20 percent of producers were at or near the intended depth, and 68 percent of the fields were planted too deep. Excessive depth delayed emergence and reduced stands. In more than half of the fields examined, emergence was less than 60 percent. Kansas State University research in no-till wheat indicated that each half-inch of excess depth reduced the stand by six to 22 percent, depending on location.

> *"Start with the right equipment, talk to experienced no-tillers, check your planter settings, and constantly adapt, adapt, adapt!"*
>
> **Larry Davis**
> **Miami, OK**

It is critical that depth be checked, especially when changing fields or planting conditions. This can be time consuming, especially in grain sorghum, where the seeds are small and more widely spaced than wheat. The objective is to place the seed in contact with moist soil, with an acceptably shallow covering depth. Because soil moisture varies with both location in a field and the time of planting, depth is usually a compromise between the need to place the seed into moisture and the need to plant shallow for quick and uniform emergence.

With most disk-type openers, the two primary adjustments affecting depth are a) the down-force applied to the opener, and b) the relative position of the disk and the depth-control wheel. Understanding how these two adjustments affect depth control is important. The down-force applied to the opener is balanced by the up-force of the soil on the disk itself and on the depth control wheel. In some cases, a seed firming wheel or runner also applies force to the soil.

As the opener moves through the field, the force on the disk changes in response to soil hardness and residue conditions. Any down-force not used to make the disk penetrate to the desired depth is fed into the depth control wheel. No-till seedbeds usually require more down-force for disk penetration. If an opener is planting too shallow, check to see if the depth control wheel (in some cases the press wheel) is carrying a load. If the depth control wheel is not supporting down-force, depth will not be increased by raising the wheel. The solution is more down-force. Conversely, when moving a drill from firm soil to looser conditions, down-force should be reduced to prolong the life of the opener suspension, the depth control tire, and the bearing. In general, use just enough down-force to consistently force the disk to the desired depth, with enough left over to let the press wheel do its job. Depending on the drill, down-force may be adjusted by changing spring preload, hydraulic pressure, or even the operating height of the drill frame. Check the operator's manual for specific instructions on depth and down-force adjustment. Also, many disk openers have more than one style of down-force springs available. Heavier springs are used for reduced or no-till seedbeds.

Residue Management

There are two basic options with residue management. One option is to cut through the standing residue and leave as much as possible still standing. Another option is to use coulters to mulch the residue ahead of the openers. If the residue is left standing, the risk of hair-pinning into the seed trench is possible.

Naturally, residue disturbance is a function of opener spacing, but the following generalities can be made regarding opener design. Residue disturbance is least with single disk openers. Double disk openers disturb more residue than single disk openers, but still leave a substantial amount of residue attached and standing (Figure 13). Drills with coul-

Figure 13. The area on the left was seeded with a single disk opener drill and the area on the right was planted with a double disk drill equipped with coulters.

Figure 14A. A single disk Flexi-Coil air seeder.

Figure 14B. A single disk Flexi-Coil air seeder.

Figure 15. No-till planting of corn in milo stubble.

Figure 16. No-till planting of soybeans in milo stubble.

ters will leave very little residue attached and standing, but the surface generally has ample residue to protect the soil from erosion.

Air Seeders

Air Seeders are now available with both disk and hoe openers, plus sweep and paired-row openers (Figures 14A and 14B). Using air to convey the seed (and fertilizer) from a central tank offers at least three basic advantages over conventional grain drills. First, the central hopper of an air seeder eases filling. Secondly, wings can be folded vertically for road transport like a tillage tool. These two advantages become more important as the width of the seeder increases. The third major advantage is the ability of the air seeder to transport seed horizontally under the soil. This allows one opener, such as a small sweep, to seed multiple rows of seed. It also facilitates the concept of the paired row.

A wide variety of openers are available for air seeders. Knife-type openers cut a narrow slot for seed placement with minimal soil disturbance, while sweep-type openers accomplish some mechanical weed control at seeding time. Double-shoot openers use separate tubes for seed and fertilizer, allowing a heavy rate of nitrogen to be placed a safe distance from the seed. Openers are available to dual place dry, liquid, and even anhydrous ammonia fertilizer with the seed. Some air seeder openers split the seed stream into two rows, 3 to 7 inches apart, and place the fertilizer between the seed rows. The paired row concept is intended to give the crop preferential access to the fertilizer.

Topographical Conditions

Tillage tends to even out or "level" a field. Conversely, for reduced and no-till farming, unevenness is often more extreme and may increase with time. Erosion may be a major cause, especially for steep slopes, but terraces and contour farming are also causes of topography variations. With larger machinery and farming more marginal land, there is a greater requirement for machine flexibility. Most new planters have flex linkages that allows each row to move up and down independently of each other. This feature allows the planters to accommodate the soil unevenness. Flexing of the frame will be required for wide planters or uneven topography.

Planting on the contour often requires sharp turns. The distance from front to back (coulters to opener and press wheels) determines how well the planter will follow the row. The shorter front-to-back distance, the better the planter will stay on the row. Pull-type planters will follow curves better than mounted planters, but keeping spacing on steep side slopes may be a greater challenge.

No-Till Row Crop Planters

Row crop planters can be used to obtain good stands in no-till conditions even if the planter was not originally equipped for no-till. Most late model planters are heavy enough to be set up for no-till. They may require additional, or heavier, down-force springs to help penetrate firmer seedbeds. Coulters to slice through heavy residues or row cleaners that move residue from the seed slot may also be needed. Selecting the correct optional equipment and a good knowledge of planter adjustment are important for best planting in heavy residue and firm soil. If the planter is adjusted properly, it can operate in most no-till conditions without coulters or row cleaners.

Adjustments

For optimum planter performance, the frame should be leveled. Leveling the planter allows the row unit to stay parallel to the soil surface throughout its full range of motion. When a planter is level, the row unit will operate parallel to the ground. If the planter is not level, it will be more difficult to 'fine tune' the adjustment for operating in crop stubble. Making adjustments at the drawbar typically levels pull-type planters. Leveling of mounted planters is accomplished by adjusting the third link, while adjusting the carrying wheels levels semi-mounted planters.

Seed Metering

A well-controlled and evenly distributed plant population is essential for high yields. The metering mechanism should drop the same number of seeds per unit length regardless of variation in seed size and shape, travel speed, and slopes. Planter plates with individual openings for each seed are much more precise in spacing than feed cups used on drills. The spacing should be the same in all rows. Changing seeding rate (number of seeds per acre) should be simple. Plateless seed mechanisms are helpful in achieving uniform spacing with unsized seeds, especially for corn. A survey of planters in Nebraska showed a decrease in spacing uniformity when coulter-driven planters were used in tilled fields and when press wheel-driven units were used with less tillage.

Seed Depth Uniformity

A planter should place seed at a uniform depth regardless of soil or residue conditions. Tillage tends to mask soil variations, which help improve uniform seed placement on old style planters. In no-till and reduced-till planting systems, the variations in soil conditions will usually be greater than with conventional tillage. Variations in soil texture are common, especially in alluvial soils, where they may range from clay to sandy soil in the same field. Surface residue retards soil drying so uniform residue conditions are especially important for no-till planting. Obtaining uniform residue spreading with wide combine platforms is especially challenging, but large spreaders and some straw choppers generally improve residue uniformity.

> ***"You must be willing to commit to no-till and buy a drill made for no-tilling. You can add attachments and make a normal planter work in normal conditions."***
>
> **Greg Leonard**
> **Afton, OK**

Variations in soil conditions make design of a planter that will perform equally well under all conditions difficult. New planters with depth gauge wheels at the side of each opener can drop seed at a uniform depth under a wide range of soil texture and moisture conditions. This feature, plus heavier weight and heavy-duty coulters enable accurate seed placement in difficult soil and residue conditions.

Press wheel or coulter controlled depths are generally more variable than gauge wheels beside the opener. Press wheels are adjacent to the opener rather than leading or following the opener as with press wheels or coulters.

Openers

The primary items of interest on row crop planters are the slot openers and presswheels. The opener forms a slot or groove in the soil for seed placement and one or more press wheels compact soil around the seed. Openers on row crop planters are typically double disks or runners. Because runner openers require looser soil for adequate penetration, the fluted coulter may be required. Double disk openers will usually penetrate following a coulter that has cut residue and penetrated firm soil.

Openers shape a groove for the seed and provide a bed for seed-to-soil contact. The runner opener shapes a sharp 'V' groove, which centers the seed. The double disk alone provides a less accurate flat or slightly raised center seed slot. Some double disks also have a small chisel or runner in the center to shape a rounded or 'V' groove. The shape of the seed opening is probably not as important as depth control, which provides seed placement in firm contact with moist soil.

Double disks and runners may press residues and dry soil into the seed opening which can delay germination and emergence. In a reduced tillage condition, buried residue and large soil clods can be serious detriments to obtaining good seed-to-soil contact for all planters.

Attachments

Though adjustments are probably the most critical item affecting row crop planter performance, there are several attachments that can help improve performance. These attachments help planters operate in heavy crop residue and improve seed-to-soil contact.

Coulters

Coulters are used to cut residue and penetrate firm soil planting conditions (Figure 17). The amount, condition, and distribution of previous crop residue as well as soil conditions affect proper operation of the coulter. Fresh, damp, wheat straw is tough and difficult to cut. Dry, decayed straw can be cut easily with sharp coulters.

Sod crops, such as grass or alfalfa, or stubble grazed by livestock on wet soil may result in very firm soil, especially when dry. Coulters in front of the planting units are essential to cut through sod and firm soil. In other conditions, such as moist soil and little residue or following soybeans, the same soil may be quite soft and easily penetrated. Some coulter units are adjustable for down pressure and some have provisions for adding weight to increase penetration and cutting capability. When the soil is firm and dry, these features may be essential to ensure penetration.

Figure 17. A bubble coulter on an older John Deere planter.

Many types of coulters are available to cut residue and penetrate the soil. Each have advantages and disadvantages, so choosing one can be confusing. Large diameter coulters will mount residue but require more weight (or down pressure) to cut residue and penetrate soil.

Smooth or rippled coulters are preferred for cutting residues. Coulters with a smooth surface can be rolled to ensure a sharp edge for cutting heavy, tough residue. The rippled coulter with a smooth edge cuts well, loosens a narrow band of soil, and helps the coulter rotate.

Fluted and wavy coulters are available in a variety of widths and designs. They are ideal for tilling a narrow strip of soil ahead of the row opener. In some soil conditions this tillage may be required, but most often for spring planting the soil is soft and crumbly and requires little or no tillage. The need for tillage is partly dependent on the opener type and weight of the row units. The amount of tillage that fluted or wavy coulters provide is dependent on coulter width and number of waves. Wider coulters and less waves typically means the coulter will till the soil more. Wider coulters usually require more weight for cutting and penetration.

Row Cleaners

Row cleaners can be used on disk-opener type planters to move residue from in front of the opening disks and gauge wheels. Moving the residue means that the opener no longer needs to cut through it. This should increase the life of the opener disks by reducing wear.

Moving residue also provides gauge wheels a smoother operating surface, which allows more uniform depth control. Row cleaners can provide earlier emergence when planting crops in early spring. By moving residue off the seed slot, the soil in the row warms more quickly since it is a darker color than the residue covered soil between the rows. For later planted crops this is probably not an issue.

Row cleaners also have some disadvantages. If preplant herbicides are broadcast on the field, row cleaners can move them out of the row with crop residue. This can be disastrous. Row cleaners can have some problems operating in wet wheat straw and fields with heavy weeds. When these conditions exist, row cleaners tend to clog and stop turning.

Types of row cleaners vary widely (Figures 18, 19, and 20). They typically consist of concave disks or spoke wheels, and may also have some type of a coulter mounted with them. In general, the disk type row cleaners move more soil than the spoke type. The disk type row cleaners are adequate for some no-till applications, but the spoke type units work better in more conditions.

Figure 18. A spoke-type row cleaner on a Kinze planter.

Figure 19. A combination coulter/row cleaner.

Figure 20. A 'saw' or 'shark tooth' type row cleaner.

Press Wheels

There are many current options for press wheels when ordering a planter or retrofitting an older planter (Figure 21). These range from cast iron to plastic in construction. Though many options exist, proper adjustment is still a necessity. Remember the primary function of press wheels is to provide good seed-to-soil contact for uniform emergence. When properly adjusted, factory press wheels generally provide adequate seed-to-soil contact. However in some no-till conditions where the soil may be wet, obtaining good seed-to-soil contact is challenging. The side walls of the seed trench may be smeared or compacted. Some of the spoke type press wheels, used with a seed firmer, can break up the tight soil around the seed to create a better environment for early season root development (Figure 22). The seed firmer becomes a key component in this arrangement because it provides most of the seed-to-soil contact.

Figure 21. A spike closing wheel used with a standard John Deere closing wheel.

Figure 22. Spoked closing wheels on a John Deere planter.

Seed Firming Devices

Several companies are offering devices to firm the seed in the slot (Figure 23). These may be plastic rods or small wheels that operate in the furrow or small closing disks that force the sidewall closed. The devices are intended to improve seed-to-soil contact, reduce seed bounce, and ensure the seed is placed in the bottom of the furrow. While all these items typically work well, experience in Oklahoma has found the conditions most needed are where some of these do not perform well. Wetter soils with higher clay content tend to stick to small wheels operating in the seed furrow, reducing their ability to operate as designed. Plastic seed firming devices that slide in the seed furrow seem to be more effective. Research in Kansas has indicated the plastic devices help stand establishment to a certain degree.

Figure 23. A Keaton seed firmer on a John Deere planter.

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This material was adapted from the Chapter 11 – Seeding Equipment for No-till, *Kansas No-till Handbook*, Kansas State University. November, 1999.

Photos courtesy of Randy Taylor, Oklahoma State University

Chapter 5

Sprayers for No-till Crop Production

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No-till requires some adjustments in pesticide application equipment compared to intensive tillage systems. Because soil incorporation of herbicides can destroy crop residue, no-till systems typically use contact herbicides and/or residual herbicides that are carried into the soil by rainfall or irrigation. Applying herbicides in heavy residue does not require additional active ingredients, but may require higher spray volumes for coverage and penetration of crop residue. The use of herbicide resistant crops has reduced the need for many soil-incorporated herbicides and increased the amount of foliar or postemergence herbicides.

Proper equipment adjustment and product selection is critical for satisfactory performance. Inaccurate pesticide application is expensive. It can result in wasted pesticide, marginal pest control, and excessive carryover contributing to water contamination and/or crop damage. Better application equipment and new techniques that allow for smaller dosages of crop protection products and reduce drift and residue have become increasingly important in minimizing harmful effects of crop protection products on the environment.

Sprayers for No-till Crop Production

Optimal use of sprayers for No-till crop production requires:

- Understanding proper equipment types for specific applications
- Understanding variables affecting application rates
- Performing accurate calibrations to determine chemical application
- Calculating the gallons of spray to be applied per acre

Low-Pressure Field Sprayers

Sprayers are available in various types and sizes, each designed for a specific application. For applying crop protection products in agriculture, applicators use low-pressure sprayers more than any other kind of application equipment. Tractor-mounted, pull-type, and self-propelled low-pressure sprayers are available in many models and for a wide range in cost. Spray pressures typically range from 15 to 70 pounds per square inch (psi) and application rates can vary from less than 5 to 30 gallons per acre (GPA). All low-pressure sprayers have several basic components: a pump, tank, agitation system, flow-control assembly, and a distribution system. At the end of the distribution system is the spray nozzle.

Keep spray equipment in good condition; calibrate frequently, and operate as recommended for specific field conditions. Manufacturers' manuals include tables to show application rates in GPA for various nozzles, pressures, nozzle spacing, and ground speeds under ideal conditions. Use this information to adjust the sprayer; then calibrate and fine-tune the sprayer for accurate application.

Nozzle Types

Selecting the correct type and size of spray nozzle is essential for each application. The nozzle determines the amount of spray applied to an area, the uniformity of the application, the coverage of the sprayed surface, and the amount of drift. Although nozzles have been developed for practically every kind of spray application, only a few types - extended range flat-fans (Figure 1), Turbo flooding flat-fans, Turbo flat-fans, venturi flat-fans, and drift reduction pre-orifice flat-fans are commonly used in the application of crop protection products.

Figure 1. Flat fan nozzle.

An emphasis in nozzle design during the past few years has resulted in a vast improvement in spray quality. You can minimize drift by selecting nozzles that give the largest droplet size while providing adequate coverage at the intended application rate and pressure.

Spray nozzle assemblies consist of a body, cap, check valve, and nozzle tip (Figure 2). Various types of bodies and caps (including color-coded versions) and multiple nozzle bodies are available with threads as well as quick-attaching adapters. Nozzle tips are interchangeable in the nozzle cap and are available in a wide variety of materials, including hardened stainless steel, stainless steel, brass, ceramic, and various types of plastic. Hardened stainless steel and ceramic are the most wear-resistant materials, but they are also the most expensive. Stainless steel tips have excellent wear resistance with either corrosive or abrasive materials. Plastic tips are resistant to corrosion and abrasion, and are proving to be very economical tips for applying crop protection products. Brass tips have been very common, but they wear rapidly when used to apply abrasive materials, such as wettable powders, and are corroded by some liquid fertilizers. Other types should be considered for more extensive use. See Table 1 for information about nozzle nomenclature.

Figure 2. Spray nozzle assemblies consist of a body, cap, check valve, and nozzle tip.

Table 1. ASABE Standard S-572.

Spray Quality Categories	
Category	*Color*
Very Fine (VF)	Red
Fine (F)	Orange
Medium (M)	Yellow
Coarse (C)	Blue
Very Coarse (VC)	Green
Extra Coarse (EC)	White

Variables Affecting Application Rate/Volume (GPA)

Three variables affect the amount of spray material applied per acre: (1) the nozzle flow rate, (2) the ground speed of the sprayer, and (3) the width sprayed per nozzle. To calibrate and operate a sprayer properly, you must understand how each of these variables affects sprayer output.

The nozzle flow rate varies with the size of the tip, the nozzle pressure, and the density of the spray liquid. Installing a nozzle tip with a larger orifice, increasing the pressure, and decreasing the density of the spray liquid all increase the flow rate. To increase the nozzle output, you must multiply the pressure by the square of the desired increase in flow rate. In other words, doubling the pressure will not double the nozzle flow rate. To double the flow rate, you must increase the pressure four times. For example, to double the flow rate of a nozzle from 0.2 gallons per minute at 10 psi to 0.4 gallons per minute, the pressure must be increased to 40 psi (4 x 10).

Pressure changes should not be used to make major adjustments in the application rate. To obtain a uniform spray pattern and minimize drift, you should maintain the operating pressure within the recommended range for each nozzle. The pressure can be changed, however, to correct for minor variations in flow rate resulting from nozzle wear.

The spray application rate varies inversely with the ground speed. Doubling the ground speed (MPH) of the sprayer reduces the application rate (GPA) by one-half. For example, a sprayer applying 20 GPA at 4 MPH would apply 10 GPA if the speed were increased to 8 MPH while the pressure remained constant.

Many low-pressure field sprayers have a metering control system that maintains a constant application rate while operating over a range of travel speeds. All metering systems now in use, such as ground-driven piston pumps, electronic feedback control systems, and various centrifugal pump arrangements, vary the nozzle pressure to compensate for changes in travel speed, keeping the application rate constant. Although all the systems work over a wide range of travel speeds, the spray nozzle limits the range of speeds at which precise application can be obtained. Because of the possibilities for dramatic pressure increases while using such systems, a serious potential for spray drift could occur through a fixed orifice nozzle.

To regulate the flow in proportion to travel speed, the rate of increase in nozzle pressure must vary with the square of the rate of increase in speed. For example, if the sprayer is traveling at 4 MPH at a nozzle pressure of 30 psi, increasing the speed to 8 MPH will require increasing the nozzle pressure to 120 psi to maintain the same flow volume. Remember, a fourfold change in pressure drastically reduces the droplet size, which may result in increased drift. The pattern width and distribution pattern may also be affected. For uniform application, the travel speed should be held as nearly constant as possible, even when using controlled metering systems.

To apply crop protection products accurately, you must maintain the proper ground speed. Do not rely on a conventional speedometer as an accurate indicator of speed. Slippage of the drive wheels can result in speedometer errors exceeding 20 percent. Electronic wheel speed sensors, radar guns, and GPS give more accurate readings since they do not depend on the drive wheels for speed measurements. Changes in tire size also affect speedometer readings, and the accuracy of all speedometers should be checked periodically.

The effective width sprayed per nozzle also affects the spray application rate. Doubling the effective width sprayed per nozzle decreases the gallons per acre (GPA) applied by one-half. For example, if applying 20 GPA with flat-fan nozzles on 20-inch spacings, changing to flooding nozzles with the same flow rate on 40-inch spacings will decrease the application rate from 20 GPA to 10 GPA.

Calibration

Accurate calibration is the only way to know how much chemical is applied. Even with the widespread use of electronics to monitor and control the application of crop protection products today, a thorough sprayer calibration procedure is essential to ensure against misapplication. Failure to calibrate a sprayer can injure the crop, cause potential pollution, and waste money. In addition to calibrating the sprayer at the start of the season, recalibrate regularly. Abrasive pesticide formulations can wear nozzle tips resulting in increased nozzle flow rate and the development of poor spray patterns.

To obtain uniform coverage, you must consider the spray angle, spacing, and height of the nozzle. The height must be readjusted for uniform coverage with various spray angles and nozzle spacings. Do not use nozzles with different spray angles on the same boom for broadcast spraying. Be sure the nozzle tips are clean. If necessary, clean with a soft bristle brush. A nail, wire, or pocket knife can damage the tip and ruin the uniformity of the spray pattern. While the sprayer is running, observe each spray tip for any distortions in the patterns.

Worn or partially plugged nozzles produce nonuniform patterns. Misalignment of nozzle tips is a common cause of uneven coverage. The boom must be level at all times to maintain uniform coverage. Skips and uneven coverage will result if one end of the boom is allowed to droop. A good method for determining the exact nozzle height to produce the most uniform coverage is to spray water on a warm surface, such as a road, and observe the drying rate. Streaks in the spray pattern should be obvious. Replace nozzles that not performing correctly.

Once the sprayer is operating properly, you are ready to calibrate. There are many methods for calibrating low-pressure sprayers, but they all involve the use of the variables discussed in the following section. Any technique for calibration that provides accurate and uniform application is acceptable. No single method is best for everyone.

The calibration method described below has four advantages. First, it allows you to select the number of gallons to apply per acre and to complete most of the calibration before going to the field. Second, it provides a simple means for frequently adjusting the calibration to compensate for changes due to nozzle wear. Third, it can be used for broadcast, band, directed, and row crop spraying. This method requires knowledge of nozzle types and sizes and the recommended operating pressure ranges for each type of nozzle used. Finally, when using the method below, the applicator will have a better understanding of how each variable will affect the application rate. As each of the variables change, the influence on the rate (gallons per acre) is apparent.

The gallons of spray applied per acre can be determined by using the following equation:

$$\text{(Equation 1) GPA} = \frac{\text{GPM x 5,940}}{\text{MPH X W}}$$

GPA = gallons per acre or desired output
GPM = output per nozzle in gallons per minute
MPH = ground speed in miles per hour
W = effective width sprayed per nozzle in inches
5,940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre

The size of the nozzle tip will depend on the application rate (GPA), ground speed (MPH), and effective width sprayed (W) planned. Some manufacturers advertise "gallon-per-acre" nozzles, but this rating is useful only for standard conditions (usually 30 psi, 4 MPH, and 20-inch spacing). The gallons-per-acre rating is useless if any one of the conditions varies from the standard.

Most applications will begin with reading the label to decide what carrier volume (GPA) is recommended with the chosen product. With a selected GPA, a more exact method for choosing the correct nozzle tip is to determine the gallons per minute (GPM) required for the conditions. Then select nozzles that provide this flow rate when operated within the recommended pressure range. By following the five steps described below, the nozzles required for each application can be selected well ahead of the spraying season.

Step 1. From the label information, select the spray application rate in gallons per acre (GPA). Pesticide labels recommend ranges for various types of equipment. The spray application rate is the gallons of carrier (water, fertilizer, etc.) and pesticide applied per treated acre.

Step 2. Select or measure an appropriate ground speed in miles per hour (MPH) according to existing field conditions. Do not rely on speedometers as an accurate measure of speed. Slippage and variation in tire sizes can result in speedometer errors of 20 percent or more. If you do not know the actual ground speed, you can easily measure it. (Instructions for measuring ground speed are given below.)

Step 3. Determine the effective width sprayed per nozzle (W) in inches.

For broadcasting spraying, W = the nozzle spacing
For band spraying, W = the band width
For row-crop applications, such as spraying from drop pipes or directed spraying,

$$W = \frac{\text{row spacing (or band width)}}{\text{number of nozzles per row (or band)}}$$

Step 4. Determine the flow rate required from each nozzle in gallons per minute (GPM) by using a nozzle catalog, tables, or the following equation. Using Equation 2 allows the applicator to determine flow rates for each application scenario needed for the application season. This can be done before the application season begins, thus not interfering with critical time available during the application time.

$$\text{(Equation 2)} \quad \frac{\text{GPA x MPH x W}}{\text{GPM}} = 5{,}940$$

GPM = gallons per minute of output required from each nozzle
GPA = gallons per acre from Step 1
MPH = miles per hour from Step 2
W = inches sprayed per nozzle from Step 3
5,940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre

Step 5. Select a nozzle that will give the flow rate determined in Step 4 when the nozzle is operated within the recommended pressure range. You should obtain a catalog of available nozzle tips or view on-line. These catalogs and on-line information can be obtained free of charge from equipment dealers or nozzle manufacturers. If you decide to use nozzles you already have, return to Step 2 and select a speed that allows operation within the recommended pressure range.

Herbicide Band Applications for Cost-Effective Weed Control

Band applications of herbicides can reduce costs for postemergent and preemergent weed control treatments. In band applications, the treated acre is the acres actually sprayed, and depending on the row spacing and the band width, is some fraction of the total field acres. Remember, herbicides are applied in bands at the same rate of active ingredients per treated acre as in broadcast applications. Treating a field with 30-inch rows in 15-inch bands has the effect of reducing the herbicide cost by one-half.

When banding soil-applied herbicides to control weeds in row crops, use spray tips designed for band application. They are commonly referred to as 'even flat spray' tips and are designated in the nozzle nomenclature with the letter 'E.' Even flat spray tips are designed to apply a uniform pattern on the target across the width of the angle with no overlap required. Extended range flat spray tips on the other hand are designed to apply a tapered edge pattern, and thus would not uniformly cover the targeted band width requiring 50 to 60 percent overlap (25 to 30 percent on each edge). For even spray tips, the nozzle spray angle and height above the target will determine the spray width.

Band applications can also be used to apply postemergence materials. To obtain thorough coverage to all plant material, it may be necessary to direct the spray in a multi-nozzle arrangement around and over the top of the plant. Special band-application row kits or drops are available for this purpose. Special attention should be given when using a multiple nozzle kit to properly calibrate for the correct nozzle orifice size.

Now that you have selected and installed the proper nozzle tips (Steps 1 to 5) you are ready to complete the calibration of your sprayer (Steps 6 to 10 below). Check the calibration every few days during the season or when changing the crop protection products being applied. New nozzles do not lessen the need to calibrate because some nozzles 'wear in,' increasing their flow rate more rapidly during the first few hours of use. New nozzles can also come from the factory with flow or pattern defects. The electronics component of the spray system does not necessarily alert you to these problems. Once you have learned the following method, you can check application rates quickly and easily.

Step 6. Determine the required flow rate for each nozzle in ounces per minute (OPM). To convert GPM (Step 4) to OPM, use the following equation:

(Equation 3)

$$\text{OPM} = \text{GPM} \times 128 \text{ (1 gallon = 128 ounces)}$$

Step 7. Collect the output from one of the nozzles in a container marked in ounces. Adjust the pressure until the ounces per minute (OPM) collected is the same as the amount determined in Step 6. Check several other or all of the nozzles to determine if their outputs fall within five to 10 percent of the desired OPM.

If it becomes impossible to obtain the desired output within the recommended range of operating pressures, select larger or smaller nozzle tips or a new ground speed, then recalibrate. It is important for spray nozzles to be operated within the recommended pressure range. The range of operating pressures is indicated at the nozzle tip. Line losses, nozzle check valves, etc., may require the main pressure gauge at the boom or at the controls to read much higher.

Step 8. Determine the amount of pesticide needed for each tank or for the acreage to be sprayed. Add the pesticide to a partially filled tank of carrier (water, fertilizer, etc.). Then add carrier to the desired level with continuous agitation.

Step 9. Operate the sprayer in the field at the ground speed measured in Step 2 and at the pressure you determined in Step 7. The application rate selected in Step 1 will be spraying. After spraying a known number of acres, check the liquid level in the tank to verify that the application rate is correct.

Step 10. Check the nozzle flow rate frequently. Adjust the pressure to compensate for small changes in nozzle output due to nozzle wear or variations in other spraying components. Replace the nozzle tips and recalibrate when the output has changed five to 10 percent or more from that of a new nozzle, or when the pattern has become uneven.

To apply crop protection products accurately, proper ground speed must be maintained. Because speedometers do not always provide an accurate measure of speed, check the accuracy of the speedometer with an electronic kit or radar gun. If the sprayer does not have a speedometer, or if the speedometer is not accurate, measure the speed at all of the settings planned in the field. By measuring and recording the ground speed at several gear and throttle settings, remeasuring speed each time you change settings will be unnecessary.

To measure ground speed, lay out a known distance in the field you intend to spray or in another field with similar surface conditions. Suggested distances are 100 feet for speeds up to 5 MPH, 200 feet for speeds from 5 to 10 MPH, and at least 300 feet for speeds above 10 MPH. At the engine throttle setting and in the gear you plan to use during spraying with a half-loaded sprayer, determine the travel time between the measured stakes in each direction. Average these speeds and use the following equation to determine ground speed.

$$\text{Speed (MPH)} = \frac{\text{distance (feet)} \times 60}{\text{time (seconds)} \times 88}$$

1 MPH = 88 feet per 60 seconds

Once speed is decided, record the throttle setting and drive gear used.

Droplet Size Considerations

Droplet size will influence coverage and drift. The nozzles typically used to apply herbicides produce droplets that vary greatly in size (Figure 3). Large droplets, which will help mitigate spray drift, may not provide good coverage. Very small droplets lack the momentum needed toward the target and are prone to drift under windy conditions. The range of droplets from a nozzle is also affected by liquid flow rate (size of nozzle orifice), liquid pressure, and physical changes to nozzle geometry and operation.

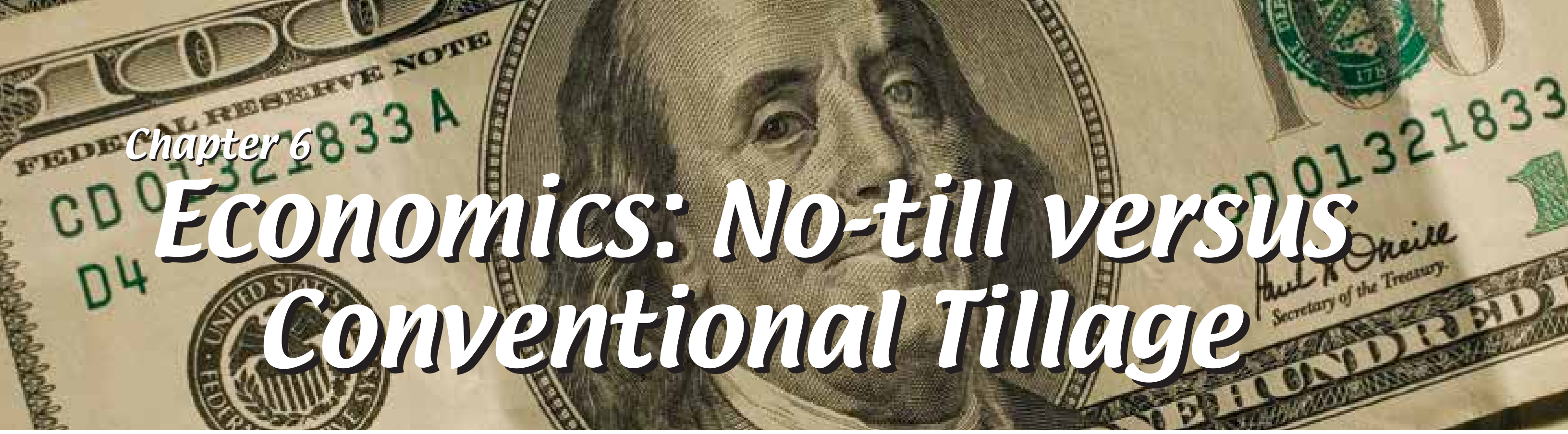
To help applicators select nozzles and use them at the most optimum droplet size range for a given situation, ASABE (American Society of Agricultural and Biological Engineers) has developed a classification system. According to this system, spray quality from a nozzle can be classified as: Very Fine; Fine, Medium, Coarse, Very Coarse, and Extremely Coarse (Table 1).

Figure 3. Different nozzles create droplet patterns used for a variety of purposes. (Refer to Table 1 for droplet size categories.)

Currently, medium to coarse spray droplets (approximately 300-500 microns) are recommended by nozzle manufacturers for application of herbicides. In fact, company labels may specify the droplet size suggested based on the above classification system. Contact herbicides may need to be on the smaller end of the range to achieve better surface coverage, while translocated materials are expected to work effectively at the upper end of the range. Since most nozzle sizes will span a range of droplets sizes, dependent on the operating pressure, it is important to select the nozzle type and pressure option that closely matches the 300 to 500 micron size recommended. To achieve this, calibration to determine needed flow rate or orifice size must be done in conjunction with matching pressure, nozzle type, orifice size, and speed to the desired droplet size. It will be necessary to add this step to the set-up of the sprayer to optimize the herbicide application for increased coverage and minimized drift.

Consulting the nozzle manufacturer's droplet sizing charts is essential. Websites and manufacturer's literature is available for additional help. Nozzle manufacturer's charts can help you determine what pressure to use for the nozzle type selected to produce the mid-fine to mid-medium quality spray.

Though sprayers have become more complex than their predecessors, there are a lot of similarities. The keys to successful sprayer operation are to select appropriate nozzles and calibrating for desired operating conditions. Following the simple tips presented here will enable accurate and effective chemical application.



Chapter 6

Economics: No-till versus Conventional Tillage

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Elsewhere in this handbook you will learn that adoption of no-till requires:

(1) an investment in a no-till drill (planter) or no-till air seeder or access to dependable and timely custom no-till planting;
(2) an investment in a sprayer or access to dependable and timely custom application of chemicals;
(3) an investment in a straw chopper for use on the combine so that residue may be chopped and distributed relatively evenly across the field (or access to dependable custom harvester who is willing and able to chop and distribute residue);
(4) an investment in learning how to farm without tilling; and
(5) for some farmers and landlords, an attitude adjustment.

> *"The no-till operation continues to have higher yields on average. We have split a farm in half, tilling one side and no-tilling the other side…the side that was no-tilled raised 10 to 15 bushels more per acre than the tilled side."*
>
> **C. Trojan**
> **Bison, OK**

The purpose of this section is to address the economics of no-till. Under what circumstances are these investments likely to be profitable? The most economical tillage system depends on a number of factors, and the most economical system for one farm may not be the most economical for an adjacent farm. Important factors to consider include:

Economics of No-Till

Situations that influence economics vary from farm to farm and depend on:

- Climate and soils
- Opportunities for crop rotations
- Available labor and cost
- Farm size

(1) soils;
(2) climate;
(3) the crops that can be produced and marketed in the region;
(4) feasible crop rotations (Bushong, et al. 2012);
(5) the cost or opportunity cost of labor;
(6) the relative cost of the alternative production systems, which depends on the quantity and prices of inputs such as herbicides and fuel, and the fixed cost of machines; and
(7) number of crop acres managed by the farmer.

No-till has thrived in regions in which the soils and climate conditions enable farmers who have no-till equipment and management skills to increase the number of harvested acres per year on the farm. For example, in some regions of the U.S., a no-till system enables the successful double cropping of soybeans or grain sorghum after wheat. The probability of a successful double crop with conventional tillage is not as great due to timing and loss of soil moisture. In some situations, no-till enables the cropping of land too steep for conventional tillage. In effect, a no-till system may enable the conversion of pastureland to cropland. In both of these situations, the appropriate economic comparison is not between no-till and conventional tillage. In the first case, it is between growing a crop and fallow. In the second case, it is between producing a crop and pasture. In both cases, no-till enables an increase in the number of harvested acres for a given farm size. The investment in no-till equipment and management skills may be weighed against the investment in additional land.

Adoption of no-till in Oklahoma has been relatively slower than in some regions of the U.S. because:

(1) in the main cropland areas, double cropping opportunities are limited;
(2) summer crops often fail;
(3) cropland used to produce pasture is often more valuable for producing forage than for producing other crops with no-till;
(4) for small farms that grow only continuous wheat and hope to produce grain, the potential economic benefit from switching to no-till has been minimal;
(5) historically, crop rotations have not been common; and
(6) alternative winter crops (barley, oats, rye) intended for grain harvest, have not been economically competitive with wheat.

Based on data reported in 2004 by the Conservation Technology Information Center (CTIC), no-till was used on less than 6 percent of Oklahoma annually cropped land. This adoption rate was less than one-quarter of the national average of 22.6 percent (CTIC, 2004; 2006; Vitale et al., 2011). The relatively slow rate of the adoption of no-till in Oklahoma is a function of the development of historical cropping patterns in response to the region's weather, climate, and soils. The vast majority of dryland crop acres in the state are seeded to continuous monoculture winter wheat. For example, from 1977 to 1996, an average of 81 percent of the dryland area cropped in the Southwest Oklahoma Agricultural Statistics District (district) (Caddo, Comanche, Cotton, Greer, Harmon, Jackson, Kiowa, and Tillman counties) was seeded to winter wheat (Figure 1) (USDA-NASS, 2010). In the decade 1997-2007, wheat was seeded on an average of 86 percent of the dryland area cropped in the district. Based on the revealed production patterns, it could be inferred that farmers expected wheat to be the most economical dryland production alternative in the district (Varner, et al. 2011).

The chart in Figure 2 illustrates the percentage of wheat, cotton, and grain sorghum planted area in the district that was not harvested during the decade 1998-2007. During that time, 34 percent of the land planted to dryland grain sorghum in the district was not harvested for grain. Similarly, 32 percent of the land planted to cotton was not harvested for lint. In 2000 and 2006, more than 70 percent of the area planted to dryland cotton was abandoned. In 2004, 2005, and 2007 less than 10 percent of the area planted to dryland cotton was abandoned. This variability in the proportion of area planted that was not harvested is a consequence of the district's highly variable weather and growing conditions. One advantage that wheat has relative to cotton is that wheat has multiple uses (Decker et al., 2009). Even though 36 percent of the wheat area planted from 1998 to 2007 in the district was not harvested for grain, it may have generated some income by producing forage for livestock.

Experiment station studies conducted in Oklahoma have found that when wheat is grown year after year in the same field, grain yield is often reduced when a substantial quantity of wheat residue from the previous wheat crop is retained on the surface (Daniel et al. 1956; Zingg and Whitfield 1957; Harper 1960; Davidson and Santelmann 1973; Heer and Krenzer 1989; Epplin et al. 1994; Epplin and Al-Sakkaf 1995; Decker et al. 2009). In continuous

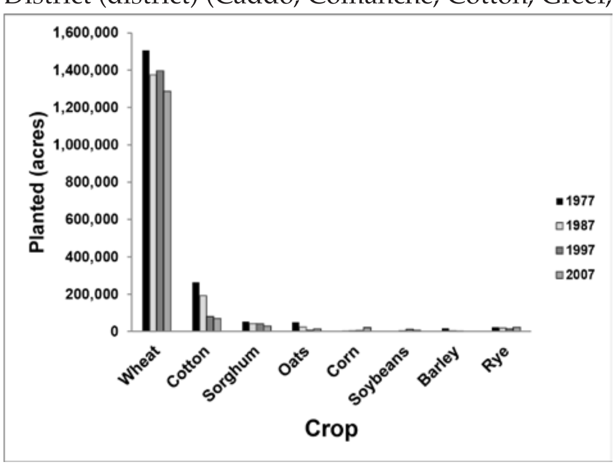

Figure 1. Land planted to dryland crops in the Southwest Oklahoma Agricultural Statistics District (Caddo, Comanche, Cotton, Greer, Harmon, Jackson, Kiowa, and Tillman counties) in 1977, 1987, 1997, and 2007 (acres).

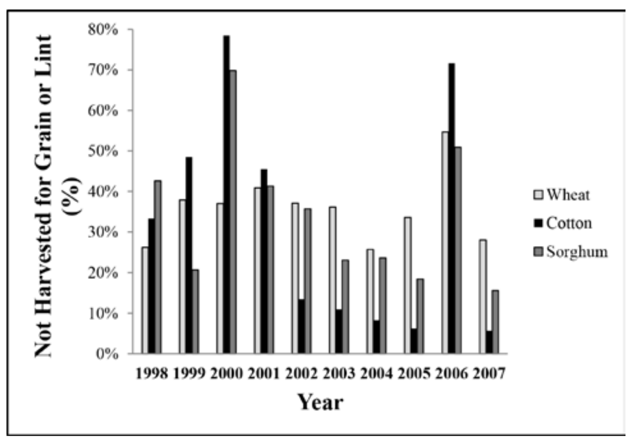

Figure 2. Proportion of area planted to wheat, cotton, and sorghum in the Southwest Oklahoma Agricultural Statistics District (Caddo, Comanche, Cotton, Greer, Harmon, Jackson, Kiowa, and Tillman counties) not harvested, 1998-2007.

Table 1. Field operations budgeted for tilled and no-till cotton, wheat, and grain sorghum.

		Systems					
		Tilled			*No-till*		
Field operations	*Month*	*Cotton*	*Wheat*	*Sorghum*	*Cotton*	*Wheat*	*Sorghum*
Chisel	March	x		x			
Disk	March	x		x			
Apply herbicide (glyphosate)	March				x		
Apply herbicide (glyphosate and s-metolachlor)	March						x
Chisel and apply fertilizer (82-0-0)	April			x			
Apply fertilizer (82-0-0) with no-till NH_3 applicator	April						x
Plant grain sorghum	April			x			
Plant grain sorghum with no-till planter	April						x
Apply herbicide (atrazine) 1/6th of the time	April			x			x
Apply herbicide (basagran) 1/6th of the time	May			x			
Apply fertilizer (82-0-0) chisel	May	x					
Apply herbicide (trifluralin)	May	x					
Cultivate	May	x					
Apply fertilizer (82-0-0) with no-till NH_3 applicator	May				x		
Plant cotton	May	x					
Plant cotton with no-till planter	May				x		
Apply herbicide (glyphosate)	May				x		
Harvest wheat grain	May		x			x	
Chisel	June		x				
Disk	June		x				
Apply herbicide (glyphosate and s-metolachlor)	June	x					
Apply herbicide (glyphosate)	June					x	
Apply herbicide (glyphosate)	June				x		
Disk	July		x				
Apply herbicide (glyphosate)	July					x	
Chisel and apply fertilizer (82-0-0)	August		x				
Apply fertilizer (82-0-0) with no-till NH_3 applicator	August					x	
Harvest grain sorghum	September			x			x
Apply herbicide (paraquat) 1/6th of the time	September						x
Plant wheat	October		x				
Plant wheat with no-till drill	October					x	
Apply defoliant (thidiazuronr-diuron)	October	x			x		
Harvest cotton	October	x			x		
Apply herbicide (sulfosulfuron) 1/6th of the time	November		x			x	
Rotary mow	November	x		x	x		x

wheat production systems, more disease inoculum is present on wheat residue left above the soil surface with no-till than with most alternative production systems. With a disease such as Take-all Root Rot, increased residue results in increased amounts of inoculum, because the fungus that causes take-all survives on the residue (Edwards et al. 2006; Decker et al. 2009). Foliar diseases such as Tan Spot and *Stagonospora* Glume Blotch are also more common in continuous wheat fields that have surface residue from the previous year's crop (Edwards et al. 2006). As a consequence, under Oklahoma conditions, the expected grain yield from no-till continuous wheat is lower than the expected grain yield from continuous wheat produced on soils with less surface residue at planting.

Altus Field Experiment

County educator Gary Strickland conducted a tillage experiment at the Southwest Research and Extension Center near Altus, Oklahoma from 2003 to 2008. Cotton, grain sorghum, and wheat were planted under both no-till and tillage systems. Field operations including tillage, fertilization, planting, and harvesting for each of the three crops and both tillage systems are listed in Table 1 (Varner, et al. 2011).

Average yields by year for each crop and tillage system are reported in Table 2. Since the wheat planted in 2003 was not harvested until 2004, only five years of data were available for wheat. Birds destroyed the 2003 grain sorghum plots, so those results are not included in the statistical analysis. All crops in the region suffered from limited precipitation during the 2006 growing season. During the time period from April through August of 2006, the plots received a total of 7.5 inches of precipitation. This amount was 51 percent of the April through August precipitation received during the other five years. The no-till grain sorghum plots were harvested in 2006 and produced 89 percent of the mean yield. However, as a result of the dry weather, the tilled plots were not harvested.

A representative farm approach was used to estimate production costs (Epplin et al., 1982; 1983). Decker et al. (2009) reported that a farm size of 2,560 acres, equivalent to four sections of land, was sufficient to achieve economies of size on Oklahoma wheat farms. Machinery complements were designed and production costs were estimated for a 2,560 acre farm. Enterprise budgets were prepared to determine the net return for each crop and each tillage system for each year for which yield data were produced.

Machines identified and selected for budgeting for the continuous cotton, continuous grain sorghum, and continuous wheat representative farms are listed in Tables 3, 4, and 5. Wheat is the dominant crop in the region, and most wheat in the region is custom harvested. Hence, custom harvesting was assumed for each of the three crops and the machinery complements do not include harvest machines.

Enterprise budgeting was used to compute expected net returns to land, labor, overhead, risk and management for each crop and each tillage system. Estimated revenue for each cropping system was determined by multiplying the respective yield for each system by the average price received during the 2003-2008 marketing years. Average annual crop prices received for cotton, wheat, and grain sorghum

Table 2. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems by year obtained at the Southwest Research and Extension Center, Altus, Oklahoma.

	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*Average*
Cotton Lint (lbs/acre)							
Tilled	248	359	679	0	732	205	371
No-Till	282	271	617	0	740	275	364
Cotton Seed (lbs/acre)							
Tilled	423	599	1203	0	1181	279	614
No-Till	497	447	1134	0	1169	397	607
Wheat Grain (bu/acre)							
Tilled	N/A	57	56	21	49	47	46
No-Till	N/A	68	51	0	49	53	44
Grain Sorghum (bu/acre)							
Tilled	†	47	86	0	43	31	41
No-Till	†	53	88	51	79	16	57

† The 2003 grain sorghum crop was destroyed by birds. Grain sorghum average yields do not include yields from 2003.

Table 3. Machinery complements budgeted for a 2,560 acre cotton farm.

Machine	*List price ($)*	*Machine width (ft)*	*Tilled*	*No-till*
95 hp tractor	$73,000		x	x
Sprayer	$34,000	90	x	x
Rotary mower	$23,000	20	x	
No-till NH_3 applicator	$37,967	30		x
135 hp tractor	$101,000			x
No-till planter	$83,000	40		x
Rotary mower	$23,000	20		x
155 hp tractor	$119,000		x	
Planter	$76,000	40	x	
Tandem disk	$29,000	20	x	
325 hp tractor	$200,000		x	
Chisel	$41,000	36	x	
NH_3 setup for chisel	$4,050		x	
Cultivator	$64,000	60	x	
Machinery labor (hrs/acre)			0.566	0.298
Average machinery investment ($/acre)			$157	$78

Table 4. Machinery complements budgeted for a 2,560 acre grain sorghum farm

Machine	*List price ($)*	*Machine width (ft)*	*Tilled*	*No-till*
95 hp tractor	$73,000		x	x
No-Till NH_3 Toolbar	$37,967	30		x
Sprayer	$34,000	90	x	x
Rotary Mower	$23,000	20	x	
135 hp tractor	$101,000			x
No-Till Planter	$83,000	40		x
Rotary Mower	$23,000	20		x
325 hp tractor	$200,000		x	
Chisel	$41,000	36	x	
NH_3 Setup For Cultivator	$4,050		x	
Cultivator	$64,000	60	x	
Tandem Disk	$43,000	30	x	
Planter	$76,000	40	x	
Machinery labor (hrs/acre)			0.385	0.273
Average machinery investment ($/acre)			$134	$77

from 2003-2008 were retrieved from the USDA's Oklahoma Agricultural Statistics 2009 annual report (USDA-NASS, 2009). Seed, fertilizer, and herbicide prices were obtained from dealers and distributors in the region. Custom harvesting rates were based on surveys conducted and reported by Doye and Sahs (2009).

For budgeting purposes, it was assumed that nitrogen was applied as anhydrous ammonia. Anhydrous ammonia costs less than alternative sources of nitrogen. A chisel plow equipped with anhydrous ammonia sweeps was budgeted for the tillage treatments and a no-till anhydrous ammonia applicator for the no-till treatments. Application of anhydrous ammonia is a soil disturbing operation and some may consider it to be inconsistent with no-till.

The budgets that include total revenue, total operating costs, machinery fixed costs, and net returns to land, labor, overhead, risk, and management for each crop and both production systems are reported in Table 6. The average annual net return from no-till wheat was $84/acre followed in order by tilled wheat at $80/acre, no-till grain sorghum at $50/acre, no-till cotton at $32/acre, tilled cotton at -$4/acre, and tilled grain sorghum at -$19/acre. These greater net returns for wheat than sorghum or cot-

Table 5. Machinery complements budgeted for a 2,560 acre wheat farm.

Machine	*List price ($)*	*Machine width (ft)*	*Tilled*	*No-till*
95 hp tractor	$73,000			x
Sprayer	$34,000	90		x
155 hp tractor	$119,000		x	
Tandem Disk	$29,000	20	x	
Sprayer	$34,000	90	x	
215 hp tractor	$151,000			x
No-till NH_3 applicator	$46,783	40		x
No-till air seeder	$141,348	36		x
325 hp tractor	$200,000		x	
Chisel	$41,000	36	x	
NH_3 setup for chisel	$4,050		x	
Air seeder	$126,987	43	x	
Machinery labor (hrs/acre)			0.440	0.202
Average machinery investment ($/acre)			$142	$100

ton could explain why the vast majority of cropland in the district is seeded to continuous wheat. The estimated advantage for no-till wheat relative to tilled wheat may be insufficient to entice growers to change machinery and invest in learning a new system.

Net returns for each crop and production system by year are reported in Table 7. Wheat in both tillage systems provided positive net returns in four of the five years and was more consistent at producing positive net returns than either cotton or grain sorghum. Cotton no-till produced positive net returns in only two of six years. Grain sorghum no-till produced positive net returns in four of five years. In three of the five years for which both no-till cotton and no-till grain sorghum data were available, no-till cotton produced greater net returns than no-till grain sorghum. However on average, the net returns for no-till grain sorghum exceeded those for no-till cotton by $18/acre.

The findings illustrate the economics of no-till relative to tillage differs across crops. The expected economic benefits of no-till relative to tillage are substantially greater for sorghum than for wheat. This is a result of several factors. First, the yield of no-till sorghum was significantly greater than the yield of tilled sorghum and added 39 percent to revenue. Wheat no-till did not produce significantly more revenue. Second, machinery fixed costs savings are relatively greater for cotton and sorghum that require a no-till planter relative to wheat that requires a no-till drill or air seeder. The budgeted no-till seeder is priced at $14,000 more than a conventional seeder whereas the no-till planter is priced at only $7,000 more than a conventional planter.

One benefit that no-till had for each crop relative to tillage was that no-till required less machinery time in the field. The estimated pre-harvest machinery labor in hours per acre for cotton, wheat and grain sorghum, respectively, for each tillage system are reported in Tables 3, 4, and 5. These estimates do not include harvest labor, since custom harvest is assumed. Tilled cotton required an estimated 1,448 hours per year of machinery labor to farm the 2,560 acres. While no-till cotton required an estimated 762 hours per year of machinery labor for the same farm size, which is a savings of 686 hours year. Wheat no-till had an estimated labor savings of 609 hours per year on the 2,560 acres wheat farm, and no-till grain sorghum had an estimated labor savings of 287 hours per year. If the labor saved by switching to no-till can be used productively elsewhere or if the labor saved enables the producer to farm more land, no-till could be the better alternative.

These expected differences in net returns between no-till and tillage provide an incentive for cotton and grain sorghum producers to adopt no-till for cotton and grain sorghum. However, the incentive to adopt no-till for continuous wheat for grain is small. By these measures, the rate of adoption for wheat producers could be expected to be slower. However, no-till wheat will require less machinery time per acre and for producers who have alternative uses for their labor, no-till may be the preferred alternative. The value of the labor saved by no-till could explain why some wheat producers have adopted no-till and others have not done so.

Survey of Western Great Plains Wheat Producers

Vitale (2013) summarized crop production data obtained from 141 farmers through four complete

Table 6. Costs and returns estimates for a 2,560 acre farm ($/acre) (2003-2008 prices).

	Tilled systems			*No-till systems*		
	Cotton	*Wheat*	*Sorghum*	*Cotton*	*Wheat*	*Sorghum*
Revenue based on overall mean yield:						
Wheat ($4.63/bu)		209			202	
Cotton						
Lint ($0.50/lb)	185			182		
Seed ($0.04/lb)	30			36		
Grain Sorghum ($2.80/bu)			114			159
Total Revenue	215	209	114	217	202	159
Operating Inputs:						
Wheat Seed		15			15	
Cotton Seed (glyphosate-tolerant)	36			36		
Grain Sorghum Seed (treated)			4			4
Fertilizers						
anhydrous ammonia	24	30	24	24	30	24
Herbicides						
glyphosate (4 lbs/gal a.i.)				3	6	3
glyphosate (5.5 lbs/gal a.i.)	7			15		
s-metolachlor	15		23			10
paraquat						3
atrazine			1			1
trifluralin	4					
basagran			3			
sulfosulfuron		2			2	
Defoliant						
thidiazuron-diuron	13			13		
Adjuvants						
nonionic surfactant	3			7		
crop oil concentrate			1			1
Grain Harvest and Hauling		32	32		31	39
Cotton Harvest	37			36		
Cotton Ginning	25			25		
Machinery Fuel, Lube, and Repair	17	19	15	7	10	6
Total Operating Costs	183	99	104	166	96	91
Machinery Fixed Costs:						
Interest (8.00%)	13	11	11	6	8	6
Taxes (1.00%)	3	2	2	1	2	1
Insurance (0.60%)	1	1	1			1
Depreciation	20	16	15	11	11	10
Total Fixed Costs	36	30	29	20	21	18
Total Costs	219	130	133	186	117	109
Net Returns to Labor, Land, Overhead, & Management	-4	80	-19	32	84	50

Table 7. Net returns to land, labor, overhead, risk, and management from cotton, wheat, and grain sorghum for tilled and no-till production systems by year for a 2,560 acre farm ($/acre).

	2003	*2004*	*2005*	*2006*	*2007*	*2008*	*Average†*
Cotton							
Tilled	-54	-5	140	-144	121	-76	-3
No-Till	-6	-13	146	-111	194	-13	33
Wheat							
Tilled	N/A	129	113	-22	96	87	80
No-Till	N/A	187	104	-83	108	124	88
Grain Sorghum							
Tilled	N/A	-1	91	-95	-31	-49	-17
No-Till	N/A	33	117	49	98	-44	51

† Average net returns in Table 8 differ from mean net returns in Table 7 due to rounding error in yields and harvesting cost. For the budgets in Table 7, the mean yield across years was used to calculate the grain harvest and hauling, cotton harvest, and cotton ginning costs. Each of these costs is a function of yield. In Table 8 the year specific yield was used to calculate the grain harvest and hauling, cotton harvest, and cotton ginning costs.

cropping seasons from 2002 through 2005. The farms were located in Colorado, Kansas, Nebraska, Oklahoma, Texas, and Wyoming. Farms that exhibited the greatest level of flexibility in terms of crops grown, tillage systems used, and insecticide use, produced the greatest net returns per acre. Theoretically, farm managers with fewer constraints will have more opportunities to engage in profitable endeavors. Farms with equipment enabling production with either conventional tillage or no-till, are open to use insecticide when warranted and have the flexibility to grow a variety of crops in response to changing conditions have an advantage over farms tied to a single crop with a single production method.

To the extent that climate and soils permit, farms that have traditionally produced only wheat may benefit by identifying and implementing economically viable cropping alternatives. When considering replacing existing machinery, farms that are constrained by available machines to a single tillage system may benefit by investing in a complement of machines that can be used in both no-till and conventional tillage environments.

Checklist

The following questions may be useful to assist with determining whether no-till may be an economical alternative for your farm situation.

1. *Do you currently, or do you plan to use a crop rotation?*
   If Yes: consider no-till. Weeds and diseases are difficult to manage under no-till for continuous monoculture wheat for grain, and the presence of weeds and diseases rob yields.
2. *Do you plan to double crop by planting grain sorghum or soybeans immediately after wheat harvest, or do you plan to grow summer crops?*
   If Yes: consider no-till.
3. *Would a no-till drill/planter permit you to crop fertile pasture land that is currently not cropped because of potential for erosion?*
   If Yes: consider no-till.
4. *Do you have the opportunity to use the potential labor savings (0.25 to 0.75 hours per acre) either to farm additional land, or to earn additional income from an alternative use for your labor?*
   If Yes: consider no-till.
5. *Are you planning to replace your grain drill?*
   If Yes: consider purchasing a machine that has the flexibility to seed into a variety of soil conditions including no-till.

If the answer is yes to one or more of the above questions, then farm-specific economic analysis could be used to determine if no-till is likely to be an economical choice for your farm. The economics of no-till are farm and farm situation specific.

The Oklahoma Cooperative Extension Service has a program specifically designed to assist farm families in the process of considering a change in the farm business. The Intensive Financial Management and Planning Support (IFMAPS) program provides specially trained financial specialists to work one-on-one with Oklahoma farm families to develop sound financial plans in a confidential manner. Specialists arrange a mutually convenient time and place (often the producer's home) to meet. To determine if a change in tillage system is likely to be economical for your farm, contact your county Extension office, or call 800-522-3755 and ask to participate in the IF-MAPS program.

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Chapter 7

Soil Fertility and pH Management for No-till

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A successful no-till production system starts with proper management of soil pH and fertility. The acidification process and nutrient distribution in a no-till soil are somewhat different from those of a conventional tillage system due to limited mixing of soils under no-till. Therefore, prior to adopting a no-till system, soil pH and nutrient levels should be tested and proper adjustments should be made to be successful.

> **Soil Fertility and pH Management**
>
> Soil Testing is important to monitor levels of:
>
> - Nitrogen
> - Phosphorus
> - Potassium
> - Soil Acidity

Soil Testing: the Right First Step

It is possible to apply unneeded fertilizer or animal manure if the nutrient status of a field is unknown. This not only costs more money, but the excess nutrients applied may also enter water supplies and cause environmental problems. It is especially important to have a soil test done when fertilizer prices are high. On the other hand, applying inadequate fertilizer could reduce yields, decreasing profits. Soil testing helps determine the nutrient status of the soil. Fine-tuning nutrient management will result in more efficient fertilizer use, which can increase yields, reduce costs, and potentially reduce environmental pollution.

Careful soil sampling is essential for an accurate fertilizer recommendation. A sample must reflect the overall or average fertility of a field, so subsequent analyses, interpretations, and fertilizations accurately represent the nutrient status of the soil. Soil fertility varies by location, slope, and past management. Consider each of the following steps to obtain a good soil sample (Figure 1):

1. **Area:** A composite soil sample should represent a uniform field area. Each such area should have a similar crop and fertilizer history. A soil survey map may be helpful in identifying sampling area. Exclude small areas within a field that are obviously different. These can be sampled separately if they are large enough to warrant special treatment. One sample in general should represent no more than 40 irrigated acres or 80 dryland acres.
2. **Procedure:** Follow a random zig-zag pattern to get a minimum of 15 to 20 cores from the sample area. Mix these subsamples thoroughly and save one pint for analysis. Fewer subsamples taken in a given area results in less accuracy when evaluating the nutrient status of the soil.
3. **Depth:** Take the sample to tillage depth or about 6 inches, for routine fertility analysis.
4. **Time:** Typically, the best time to soil test is before each cropping season. Be sure to allow enough time for analysis and fertilizer recommendation. It generally takes less than two weeks (in Oklahoma) to have a sample tested.
5. **Handling:** OSU soil sample bags, probe, and other information related to soil testing are available at your local county Extension office. County Extension educators will mail your samples to the OSU Soil, Water, and Forage Analytical Laboratory and assist you in interpreting test results.

A routine soil test including pH, nitrate/nitrogen, plant available phosphorous, and potassium is needed for most crops, but secondary and micronutrient analyses may also be important for a successful crop production. Soil tests will provide you with reliable recommendations on lime and nutrients.

Photo courtesy Hailin Zhang

Figure 1. The proper procedures for getting a representative soil sample.

Soil pH Management

Soil acidity is a common problem limiting crop yields in central and eastern Oklahoma. The problem is corrected by adding lime to the soil in amounts ranging from one-half ton to as much as four tons of effective calcium carbonate lime per acre. Special lime formulations, like liquid lime, are only as good as the actual lime that is in them. Soil testing or having a test strip of lime is a good way of telling whether lime will help crop production. If the pH is low, lime should be applied to bring the pH to a normal range. The pH of soil in continuous no-till fields should be checked every two years. When lime is needed, the same amount of lime as recommended for conventional practices should be applied, but it may take longer to correct soil acidity in the lower portion of the rooting zone under no-till than conventional tillage system. Furthermore, nitrogen applied to the soil surface under no-till can produce very acidic conditions in the surface layer. This acidic soil not only affects crop growth directly but also affects pesticide activity. When N is always surface applied, a 3-inch soil sample should be collected every five to eight years to document surface pH.

Intensive crop production has driven pH down in many parts of the state (Figure 2). Aluminum toxicity and the deficiency of some nutrients are associated with high acidity or low pH. Therefore, it is critical to consider liming when switching to a no-till system. The lime recommendation is provided with a soil test. The typical ranges of pH for common Oklahoma crops are shown in Table 1.

Fertilizer Recommendation Guide

Apply fertilizer according to the needs indicated by a recent soil test and avoid over- or under-applying needed nutrients.

Nitrogen Management

Crop residue covering the soil surface under continuous no-till increases water infiltration, reduces runoff, and decreases water losses from evaporation. This same residue, however, may also increase

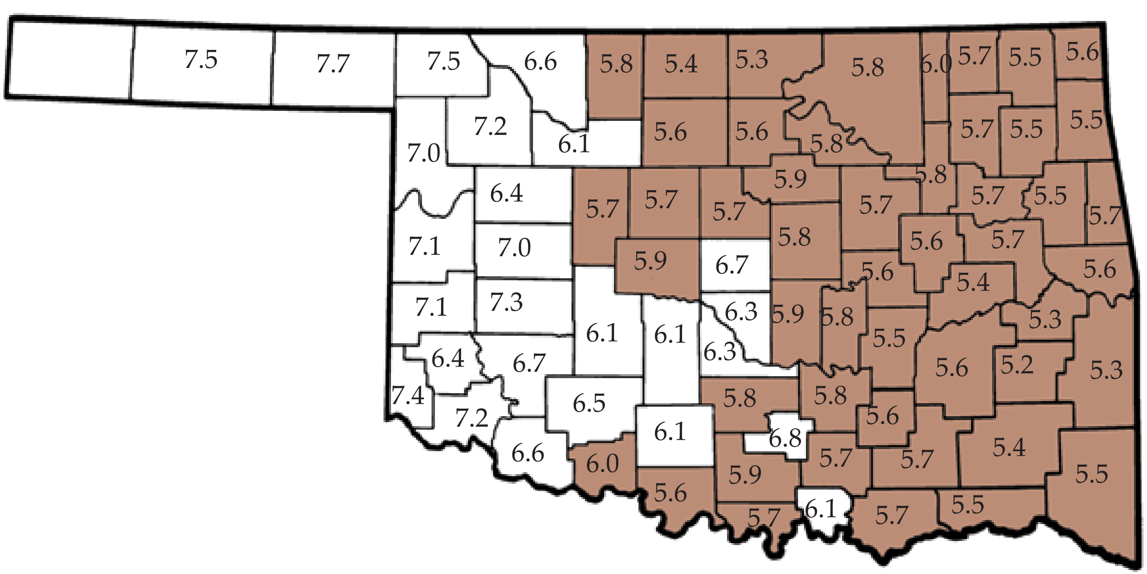

Figure 2. Median soil pH in Oklahoma cropland soils. Fifty percent of samples had pH less than the median value in each county.

Table 1. Soil pH Preference of Selected Crops.

Legumes	*pH Range*
Cowpeas, crimson clover, mungbeans, vetch	5.5-7.0
Peanuts, soybeans	5.8-7.0
Alsike, red, and white (ladino) clovers, arrowleaf clover	6.0-7.0
Alfalfa, sweet clover	6.2-7.5
Nonlegumes	*pH Range*
Bluestem, fescue, native hay, weeping lovegrass	4.5-7.0
Buckwheat	5.0-6.5
Corn, oats, orchardgrass, ryegrass, sorghum, sudangrass, winter wheat	5.5-7.0
Bermudagrass	5.7-7.0
Barley	6.5-7.0
Cotton	5.7-7.0

nitrogen (N) loss due to volatilization if N fertilizers are broadcast over the surface of residue. However, placing N fertilizer just below the soil surface with a coulter can effectively reduce volatilization loss.

Additionally, some N may be temporarily used by microorganisms as they decompose crop residue with a high C:N ratio. This may reduce N available to plants during the early stage of plant growth, but applying 1/3 to 1/2 of the total N preplant, preferably injected into the soil, should avoid residue decay-induced N deficiency. Ultimately, if managed properly, the amount of N needed for no-till should be similar to that for conventional tillage system. When applying UAN (28 or 32-0-0) with a sprayer, it is recommended that streamer nozzles be used to limit contact with residue.

The sensor-based N management strategy developed by Oklahoma State University has proven to be practical and efficient. If used correctly, it can increase nitrogen use efficiency (NUE) by 10 to 20 percent and increase profits by $10 per acre in addition to the environmental benefits. The sensor-based N management uses a 'Nitrogen Rich Strip' and a GreenSeeker® sensor to predict site-specific yield goals and prescribe the right amount of top dress N at an appropriate growth stage in the season. It addresses the point-to-point variability within a field (spatial variability) and year-to-year variability over time (temporal variability). The sensor-based N management technology has been calibrated for wheat, corn, sorghum, canola, and many other crops. Several states and foreign countries are currently using this new invention for crop production. More information about this crop-sensing-based technology to improve N use efficiency can be found at www.nue.okstate.edu.

Phosphorous Management

The method used to determine phosphorus (P) availability in soil is called Mehlich 3. It is expressed using an index. An index of 65 is desired for all crops, which is considered 100 percent sufficient. A soil test with 40 percent sufficiency means 40 percent of plant phosphorus needs will be supplied by the soil. The remainder must be provided by adding fertilizer. If no phosphorus is added, the yield will only be 40 percent of the potential yield. If P is deficient, apply adequate amount of fertilizers before switching to a no-till system. Similar to conventional till, banding P fertilizers is advantageous over broadcasting in a no-till system. In fact, banding may be even more advantageous in a no-till system because P movement in the soil is very slow. Furthermore, P applied on the surface may be subject to erosion or runoff loss more easily than when (or if) it is band applied.

Research has shown that no-till crops responded to starter fertilizers containing both N and P very well even in soils with high soil test P levels. This is probably because no-till soils with increased residue cover are cooler and wetter early in the growing season than conventionally tilled soils, which may decrease soil P availability.

Potassium Management

Like phosphorus, potassium (K) soil test estimates K availability in the soil and the test indicates a certain percent sufficiency. The optimum level will vary with crops, soil type, and other soil related factors, but an index of 250 is considered adequate for all crops except for alfalfa. Alfalfa requires 350 to have an adequate K supply from the soil. Potassium can be either surface or band applied. However, the amount of K and N in the starter (banding) is determined by the distance between fertilizer band and the seed, since both nutrients contribute to the salt index. Some crops are more sensitive to salt injury than others. Soluble fertilizers placed in a band may cause germination and/or seedling injury if rates are too high. In general, the salt index (applied N + K_2O) should not exceed 30 pounds per acre for wheat and 7 pounds per acre for corn. In extremely arid regions and/or where rapid drying takes place, salt rates less than these can adversely affect wheat and corn seed germination.

Summary

- Soil test at the beginning and on a regular basis.
- Lime to adjust soil pH before switching to no-till practices. Once in no-till, monitor surface pH frequently and lime to maintain proper pH if needed.
- Residue can reduce N efficacy and tie up N during decay. Adjustment may be needed on N fertilization.
- Base P and K fertilization rates on regular soil test recommendations.
- Pay attention to salt index when band-applying fertilizers.

Chapter 8

Weed Management

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Introduction

Switching from a conventional tillage weed control system to a no-till weed control system is similar to a mechanic losing their open-end adjustable wrench (i.e. Crescent® wrench). The open-end adjustable wrench is the wrench of choice for many jobs and losing it can make your toolbox look bare if you come upon a job where it would be particularly useful. Likewise, tillage is a reliable method to combat weed populations regardless of the species and regardless of what chemical control options exist. But there are many other tools in our weed management toolbox including cultural and chemical control practices. Reliance on these methods will increase in no-till crop production systems where conventional tillage is lost as a weed management tool.

Major considerations to examine when switching from a conventional to a no-till system are the potential for shifts in weed populations. A shift can occur in just one or two seasons after implementing no-till practices and the weeds you are used to dealing with in a conventional system may change once you implement no-till. Increases in and build-up of perennial weeds is most notable. There is also potential for increases in small seeded annual and biennials weeds (Ross and Lembi 2009). But cultural and chemical control practices can be used to effectively manage these weeds in a no-till system.

> **Successful weed control for no-till production systems will ensure:**
>
> - A healthy, actively growing crop.
> - Timely applications of an appropriate herbicide.

Cultural Control Practices

A Healthy Crop is a Competitive Crop

Cultural weed management should not be overlooked when planning for a crop. Too often, producers forget the basics of 'crop health,' which leads to weed problems. The best weed control tool we have is a healthy, actively growing crop. Therefore, getting a no-till system off to a good start, in terms of proper adjustment of soil pH and nutrients, will benefit the health of a crop and also improve weed management success. A healthy crop is more likely to out-compete weeds than a crop lacking proper fertility.

Small Changes May Drastically Ease Weed Control

Narrower row spacing and higher seeding rates result in quicker canopy closure and a denser crop canopy, which enables the crop to shade out weeds. Likewise, planting into good soil moisture, at uniform depths across the field, and closing the seed furrows ensures uniform crop emergence. This also lessens the chances of herbicide injury to the crop. These factors improve crop competitiveness and weed control.

Crop Rotations Complement Weed Control Strategies

Crop rotations work by allowing the use of a different suite of weed control chemistry in alternating seasons or years to improve the spectrum of weeds that can be effectively managed. For example, a summer rotational crop will help control populations of winter annual grasses that may have been problematic in winter wheat production. Similarly, rotating to a summer broadleaf crop may help address the control of summer annual grasses that may infest corn or grain sorghum planned the following year.

Winter rotations should also be a consideration. Canola has gained ground in Oklahoma and canola rotations with winter wheat can significantly improve control of weedy grasses which are difficult to control in wheat. In no-till production, the more diversified you can make your rotations the more able you will be to address existing and emerging weed problems.

Cover Crops for Weed Control

Cover crops are another good strategy for weed management. Cover crops work to maintain soil cover during fallow periods, preventing erosion and conserving soil moisture. By choosing the right cover crop, you may also be able to graze it or cut it for hay before moving into the next season of production. Legume cover crops can add nitrogen back to the soil and all cover crops will increase the overall organic matter content of your soils. These factors improve soil conditions, allowing your crop to be competitive and aid in preventing weeds. Cover crops also occupy the space in your field while you are between crops, providing some level of weed control. See Table 1 for a summary of winter and summer cover crops and their reported weed control potentials. Keep in mind that a weed control potential listed as "fair" may be increased by using a mixed cover crop. Many cover crops, including foxtail millet, rye, sudangrass, and hairy vetch are allelopathic. Compounds which leach from their residues can suppress weeds (Creamer et al. 1996) in the next rotation. Sorghum and sunflower as summer crops can also leave allelopathic compounds in the soil, providing residual broadleaf weed control for a winter grain crop (Einhellig and Rasmussen 1989). For additional discussion of cover crops and their benefits in no-till systems see Chapter 12.

"Probably the greatest obstacle is weed control…it is hard when your fields look like they are full of trash, plus the neighbors want to know if you have quit farming… strange thing is the ones that gave me fits are now beginning to do the same thing!"

David Shultz
Altus, OK

Table 1. Summary of cover crops for utilization in Oklahoma. Weed control potential is given as good=80-99%, fair=60-79%, poor=60% or less. Each cover crop was evaluated based on two or more sources.

Cover Crop	*Allelopathic*	*N-fixing*	*Season*	*Weed Control Potential*
Cowpea	Yes	Yes	Summer	Good
Mungbean	Unknown	Yes	Summer	Good
Sudangrass	Yes	No	Summer	Good
Rye	Yes	No	Winter	Fair
Oats	Yes	No	Summer or Winter	Fair
Crimson clover	Yes	Yes	Winter	Poor
Soybean	No	Yes	Summer	Poor
Wheat	Yes	No	Winter	Poor
Hairy Vetch	Yes	Yes	Winter	Fair
Rapeseed	Yes	No	Winter	Good
Radish	Yes	No	Winter	Good
Buckwheat	Yes	No	Summer	Fair
Sorghum	Yes	No	Summer	Good
Sunflower	Yes	No	Summer	Good
Millet	No	No	Summer	Good

Chemical Control Practices

Burndown Programs For a Good Start

Planting a crop into an actively growing weed population is not a good practice. Significant crop competition occurs when crops and weeds emerge at the same time; however, the crop is damaged even more if the weeds are established prior to planting the crop. Using appropriate burndown herbicides prior to planting is essential for early-season weed management in no-till systems. Burndown applications are also prescribed to effectively terminate certain cover crops used in the no-till system. Too often rainfall, mechanical problems, or other issues delay burndown efforts and the crop is planted into actively growing weeds. This results in early-season weed competition and the use of more expensive and often, less efficacious herbicides for early in-season weed control. For a good start, burndown herbicide applications are a must for effective weed management in no-till systems.

Consider Soil Residual Herbicide Programs

The use of soil residual herbicides is another way to decrease the potential of early-season weed competition and help manage weeds, which are difficult to control with current postemergent herbicide options. If planned appropriately, these soil residual herbicides will diversify the herbicide chemistry in the field and delay weed resistance from developing. One downside to using residual herbicides is potential herbicide carryover into the following crop.

> *"All growers should be ready for a shift in their weed species the longer they leave a field in a no-till system…but also observe a great increase in their soils the longer it is no-tilled."*
>
> Greg Leonard
> Afton, OK

Herbicide Selection can Impact Crops Planted up to Three Years Later

Chemical carryover occurs when an herbicide applied during the crop season or the fallow period remains active in the soil long enough to impact the growth of the following crop(s). For this reason, one must consider not only the crop to plant, but also the herbicides that will be sprayed to control the major weed pests in the field. It is always important to read herbicide labels and determine rotational intervals prior to residual herbicide applications.

Timely Herbicide Applications are Critical

Early season weed interference can significantly lower crop yields and make chemical control of weeds much more difficult. To maximize your yield, weeds that emerge with the crop should be controlled during the third to fifth week after crop emergence. In order to achieve acceptable control, postemergent herbicides should be applied to small, actively growing weeds. The application timings should correspond to weed height ranges indicated on the herbicide labels. Consider purchasing your own sprayer if timely application from your commercial applicator has been a problem. Another consideration is to purchase one with a neighbor and share the cost.

Some Misperceptions to be Avoided

No-till Will Save me a lot of Money

Perhaps the most common misperception is, "changing to no-till will save a lot of money." Although changing to no-till should not increase your expenses drastically, the money you may save in fuel costs will likely be used in chemical weed control during both the crop and fallow periods. Time savings will be the greatest benefit from switching to a no-till management system.

Going No-till is Simple With the Use of Herbicide-resistant Crops

Herbicide-resistant crops (HRC) (i.e. Roundup Ready®, Liberty Link®, and Clearfield® crops) have made the conversion from conventional tillage to no-till production systems a lot easier, but there are still pitfalls to avoid. Several weeds in Oklahoma have become resistant to one or more of the

> *"The additions of herbicide-tolerant soybeans and corn have greatly aided in dealing with undesirable vegetation in the fields, but it still presents a challenge."*
>
> **Brent Rendel**
> **Miami, OK**

herbicides used in these HRC. Alternating herbicide modes of action may prevent or at least delay the development of herbicide resistance. Where resistance has already developed, rotating modes of action will help manage resistant weed populations. Avoid sole reliance on an herbicide resistant cropping system where the same mode of action is used application after application. It is important to incorporate other herbicide modes of action to compliment this program and have more activity on potential problematic weeds (e.g. Palmer amaranth, horseweed, Italian ryegrass, tall waterhemp, etc.).

Any Field can be Switched to No-till

Although this is a correct statement, one should also consider the expense it will take for each field. Fields with excessive weed pressure may be more trouble to convert to no-till. One should first concentrate on the cleaner fields before tackling the weediest areas. When the decision to convert a problematic field has been made, try to get perennials and other difficult weed populations under control for a couple of years prior to conversion to no-till.

Also, one should consider any herbicide resistant weeds you or your neighbors may have and whether or not these can be effectively managed in the no-till cropping system you are planning.

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Chapter 9

Disease Management

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Disease Management

Effective disease management requires understanding:

- The relationship between pathogen-host-environment that make-up the disease triangle
- Effects of reduced tillage and increased residue on plant diseases
- Genetic resistance
- Proper application of chemicals
- Cultural practices

There are many organisms (pathogens) that have the potential to cause plant disease, but it takes a combination of a pathogen along with a susceptible host and a favorable environment to result in disease. The combination of these three factors is known as the disease triangle (Figure 1), and unfortunately combinations of these three factors that are favorable for disease frequently occur with the cultivation of genetically similar crops covering large areas. In corn for example, epidemics of southern corn leaf blight swept across the corn-belt in the U.S. during the 1970s when corn hybrids were planted that all contained the same male-sterile trait. This trait was linked to susceptibility to the disease and when a favorable environment occurred, an epidemic resulted. An example closer to home is the 5 to 6 million acres of wheat that are typically planted in Oklahoma each year. Often, the majority of these acres are planted to one or two varieties with similar genetic backgrounds. For example, in the 2008-2009 growing season, approximately 48 percent of the wheat acreage in Oklahoma was planted to the wheat variety Jagger or varieties with Jagger in their pedigree. Such cultivation contributes to the corner of the disease triangle related to the presence of a susceptible host since Jagger and these other varieties were susceptible to wheat leaf rust.

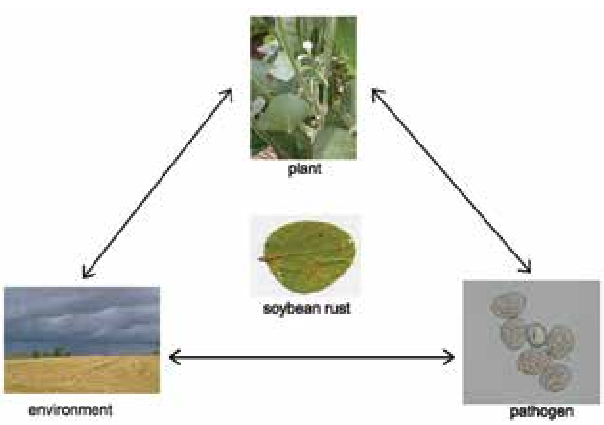

Figure 1. Disease triangle: A susceptible host plant, favorable environment, and the presence of the pathogen interact to produce disease. Soybean rust occurs during early reproductive growth stages, cloudy and rainy weather, and the presence of airborne spores.

Another corner of the disease triangle is related to the actual pathogens that cause plant disease. These pathogens represent several types of organisms including fungi, bacteria, viruses, and nematodes to name a few. The relationship between these pathogens and their hosts is often quite complex, and in many cases (for example wheat rusts), has coevolved over thousands of years. Some of these pathogens have an extremely narrow host range and are able to adapt quickly to genetic resistance incorporated into a new variety (again for example, wheat rusts). Others have an extremely broad host range and are able to infect and cause disease not only on several crops, but also on many weeds. A good example of this type of pathogen is the fungus *Sclerotium rolfsii*, which has been reported to have a host range of at least 500 plant species in 100 plant families.

The final corner of the disease triangle is related to the environment. It is in this corner where variation from year to year and from location to location can have a tremendous effect on presence of disease and its level of occurrence. With diseases such as leaf or stripe rust of wheat, there often is a susceptible variety and sufficient levels of the rust fungus (inoculum) to start the disease, but there also needs to be sufficient moisture/humidity and favorable temperature to allow the disease to develop and spread. Similarly, a foliar disease of soybean such as frogeye leaf spot is more of a problem in the southeastern U.S. where rainfall and humidity levels are higher than in Oklahoma.

Agriculture typically has employed tillage to bury or hasten the decomposition of crop residue in order to prepare a clean seed bed that is considered beneficial for proper seeding and crop establishment, and to manage residue-borne diseases. In contrast to clean tillage, reduced tillage leaves significant amounts of residue on or near the soil surface that has the benefits of increased soil moisture conservation, reduced energy use associated with tillage operations, and reduced soil erosion. However, reduced tillage and associated surface residues also can have the adverse effect of increasing some diseases by,

1) increasing levels of residue-borne disease inoculum, and
2) inducing changes in the environment that include cooler soil temperatures, increased soil moisture, and leaving soil undisturbed (Bockus and Shroyer, 1998).

"Positive point to no-till... less disease from crop rotation."

C. Trojan
Bison, OK

Table 1 describes the potential impact of increased wheat residue resulting from reduced tillage on subsequent wheat crops. As indicated in Table 1, wheat pathogens and the diseases they cause may be reduced, unaffected, or favored in reduced tillage systems. For example, the inoculum to initiate a disease such as tan spot of wheat (Figure 2)

Table 1. Effect of increased wheat residue* on the incidence and severity of various wheat diseases.

Disease	*Effect of increased residue* on incidence and severity of disease*	*Explanation for effect*
Tan spot (*Pyrenophora tritici-repentis*)	Increases disease	Increases pathogen inoculum
Septoria leaf blotch (*Septoria tritici*)	Increases disease	Increases pathogen inoculum
Stagonospora glume blotch (*Stagonospora nodorum*)	Increases disease	Increases pathogen inoculum
Powdery mildew (*Blumaria graminis* f. sp. *tritici*)	Increases disease	Increases pathogen inoculum
Take-all (*Gaeumannomyces graminis var. tritici*)	Increases disease	Increases pathogen inoculum
Aphid:barley yellow dwarf virus	Decreases disease	Fields with increased residue are less attractive to aphids
Strawbreaker [also called eyespot, foot rot] (*Pseudocercosporella herpotrichoides*)	Decreases disease	Related to modification of environment and inhibition of spore dispersal resulting in a reduction of infected plants
Other root rots including dryland root rot, common root rot, sharp eyespot, Pythium root rot	Increase or decrease, depending on the pathogen	Effect is through multiple factors including soil moisture, temperature, etc.

*In this table, "residue" indicates straw from a previous crop of wheat as opposed to residue from a rotated crop such as canola or legumes, which would be non-hosts for these pathogens and diseases of wheat.

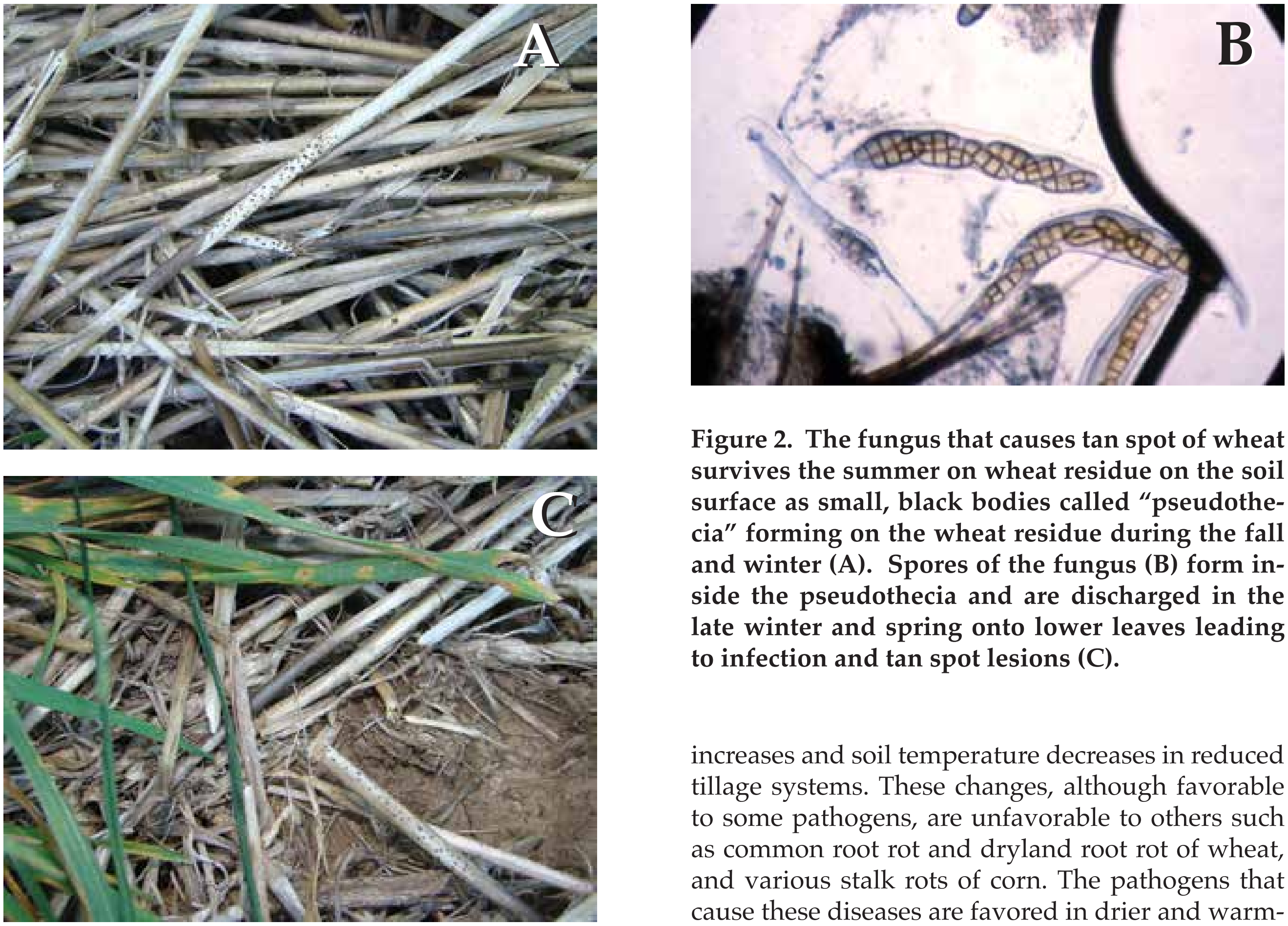

Figure 2. The fungus that causes tan spot of wheat survives the summer on wheat residue on the soil surface as small, black bodies called "pseudothecia" forming on the wheat residue during the fall and winter (A). Spores of the fungus (B) form inside the pseudothecia and are discharged in the late winter and spring onto lower leaves leading to infection and tan spot lesions (C).

comes directly from residue left on the soil surface. Hence, tan spot of wheat is a disease that would likely increase under reduced tillage systems. In fact, this occurred in the mid 1980s when there was an emphasis to switch to reduced tillage production along with the wide-spread cultivation of a wheat variety (TAM-101) highly susceptible to tan spot. Another similar example is take-all of wheat, where the pathogen (again, a fungus) survives in the upper root and crown tissue. If that residue is destroyed by clean tillage, the inoculum is also destroyed. However, if residue is left undisturbed, pathogen survival and resulting disease development increases. Take-all is also favored by reduced tillage because residue conserves soil moisture and decreases soil temperature both of which favor take-all. A few diseases, such as Rhizoctonia root rot on wheat, are favored in reduced tillage systems not only because the fungus causing this root rot survives on the residue, but also because of a reduction in soil disturbance. This allows the fungus to form a large growth mat that serves as a base from which infection of wheat plants can occur.

In contrast, there are a number of diseases that are reduced by decreased tillage. Again, this is often related to environmental conditions resulting from the increased residue. As described, soil moisture increases and soil temperature decreases in reduced tillage systems. These changes, although favorable to some pathogens, are unfavorable to others such as common root rot and dryland root rot of wheat, and various stalk rots of corn. The pathogens that cause these diseases are favored in drier and warmer environments and tend to cause the most damage under conditions of moisture stress. Another disease that decreases in incidence and severity with reduced tillage is foot rot (strawbreaker) of wheat. The pathogen that causes this disease survives on residue, which would seem to favor an increase in eyespot. However, this pathogen also requires cool temperatures and high humidity/free moisture to move from infected straw to young wheat plants. It is thought that increased residue reduces the density of the foliage that in turn leads to a less favorable environment for infection.

A similar scenario as described above for the effects of reduced tillage/increased residue on wheat diseases also applies to canola. Acreage planted to winter canola is increasing in Oklahoma in cropping systems traditionally planted to continuous wheat. While planting continuous canola is not recommended, rotation with wheat in a no-till system will increase levels of canola residue in the overall cropping system thereby increasing levels of inoculum of residue-borne disease available to infect canola. Canola residue is thicker and woodier than wheat and can remain intact for more than one season when disturbance in minimal. No-till and minimum till systems may or may not influence the prevalence and severity of common canola diseases (Table 2).

Table 2. Effect of canola residue on canola diseases in no-till cropping systems.

Disease	*Expected effect*	*Reason for effect*
Aster yellows (Aster yellows phytoplasma)	no effect	infection is from insects (leafhoppers)
Black leg (*Leptosphaeria maculans*)	increased disease	increased pathogen levels on residue
Black rot (*Xanthomonas campestris*)	increased disease	increased pathogen levels on residue
Powdery mildew (*Erysiphe* spp.)	no effect	infection is from airborne spores
Sclerotinia stem rot (*Sclerotinia sclerotiorum* and *S. minor*)	no effect	infection is from soilborne inoculum (sclerotia)

Black leg disease, caused by the fungus *Leptosphaeria maculans*, causes cankers on the lower stems of canola and is capable of reducing yield by up to 50 percent. The fungus survives on canola stubble where it undergoes sexual recombination each year, producing airborne ascospores that infect canola leaves and complete the disease cycle (Figure 3). Not only are ascospores infective, but this genetic recombination produces new strains or "races" of the pathogen capable of overcoming black leg-resistance in canola cultivars. New races causing resistance breakdown have occurred in spring canola cultivars in Australia and Canada, and in winter canola cultivars in Europe. Ascospores have been released from canola stubble for more than one and a half years in Kentucky and for more than two years in Australia. Therefore minimum tillage practices that leave residue standing favor disease development.

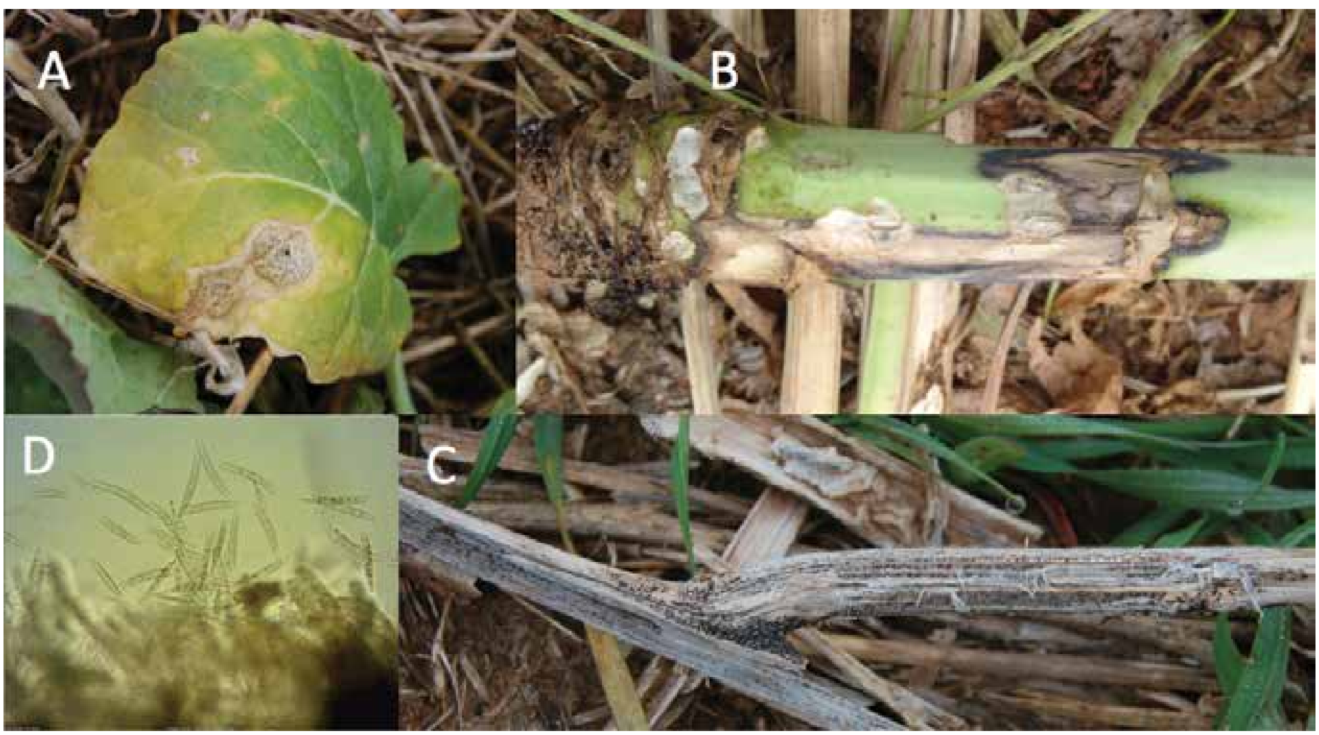

Photo courtesy Bob Hunger.

Figure 3. Black leg disease of canola is a damaging canola disease that arises from spores produced on crop. A) The leaf spot phase of black leg is caused by ascospores produced on canola residue. B) Stem cankers produced on lower stems may girdle the plant prior to maturity. C) Canola residue with fruiting bodies of the black leg fungus. D) Ascospores produced on canola stubble.

Reduced tillage also favors survival of black rot, a bacterial disease of Brassica crops such as canola. The bacterium survives longer on infested residue on the soil surface than in buried residue or in soil. While black rot has been of minor importance in canola, there may be an interaction between black rot and freeze damage in the spring that kills plants before harvest.

Tillage is unlikely to affect levels of other canola diseases. Powdery mildew arises primarily from airborne spores and is of minor importance. Sclerotinia stem rot, another disease of canola capable of causing severe yield loss, is produced by seed-like fungal structures called sclerotia that can survive in soil for many years. Levels of this disease are more likely to be influenced by canola cropping frequency and weather conditions during flowering than by tillage. Aster yellows is a virus-like disease spread by leafhoppers. The disease is most severe in poor canola stands where plants are more attractive to leaf hoppers. It is unlikely that the tillage system has a great influence on levels of leafhoppers available to spread the diseases except that canola stand establishment may be less than ideal in no-till systems, making plants more attractive to leaf hoppers.

Because canola is grown in rotation with wheat and perhaps other summer crops, disease responses to tillage system are not likely to pose insurmountable barriers to successful canola production. Black leg can currently be managed by growing varieties with resistance and/or by applying fungicides to control the leaf spot phase of the disease. Research in Oklahoma is ongoing to identify black leg-resistant varieties of winter canola and the benefits of fungicide application. Fortunately, diseases of canola do not attack wheat and vice versa making the wheat/canola rotation ideal for helping to break disease cycles.

In addition to the considerations related to the effects of reduced tillage and increased residue on plant diseases, the question of how to manage diseases in a reduced tillage system also arise. The answer to this question revolves around the same considerations that have been used over the years to manage diseases, and primarily involve use of genetic resistance, application of chemicals, and the use of cultural practices such as crop rotation. For many years, Oklahoma and other states have generated charts that compare the performance and disease reactions of various crop varieties (for example, see: http://wheat.okstate.edu/variety-testing/variety-characteristics/PSS-2142web2012.pdf). The disease reactions of varieties listed to various diseases are related to the genetics of each variety, and are helpful in selecting varieties for planting in different tillage systems once the effect of increased residue is known on a disease (see Table 1 for wheat and Table 2 for canola). Fungicides are a second approach to help control diseases in many commodities and are useful in both reduced and clean tillage systems. Finally, the use of various cultural practices may also be used to help control diseases that cause concern related to reduced tillage. For example, planting wheat later in the fall can reduce the incidence and severity of some diseases that are 'residue-borne' such as Cephalosporium stripe in wheat, but will have minimal or no effect on a disease such as tan spot of wheat. Another possible cultural control is the type of fertilizer used as demonstrated by the reduction in take-all of wheat following application of ammoniacal forms of nitrogen as compared to nitrate forms of nitrogen. However, the single most important cultural control to employ in management of diseases in reduced tillage operations is <u>rotation with an unrelated crop</u>. This type of rotation breaks the cycle of continuous residue of a given crop and nearly always significantly reduces the inoculum of a pathogen. This is most reliable if the rotation is during a two or three year period as compared to double cropping within the same season. There are a few instances where care must be taken. For example, a corn-wheat rotation would appear to fit this scenario quite well as these are quite unrelated hosts. However, in the Midwest, corn-wheat or corn-barley rotations can contribute to epidemics of head scab caused by Fusarium spp. because both crops are hosts for this pathogen. This, however, is the exception to the rule, and rotation with an unrelated crop generally will contribute greatly to the success of reduced tillage operations.

Summary

In summary, reduced tillage is attractive for a number of benefits including, conservation of energy and moisture, and reducing soil erosion. However, reduced tillage increases crop residue left on or near the soil surface, which can impact the incidence and severity of diseases primarily by maintaining pathogen populations in the increased residue, increasing soil moisture, decreasing soil temperature, and leaving soil undisturbed. Therefore, disease management programs that use disease resistant varieties, crop rotation, and fungicides when necessary should be considered for managing diseases that are likely to increase in reduced tillage operations.

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Chapter 10

Insect Management

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Oklahoma wheat producers are increasingly adopting conservation tillage practices such as no-till. As producers transition into conservation tillage, they may see shifts in the insect pest complex that infests their crops and will need to adjust their pest management strategies to account for them. Fortunately, control tactics are available regardless of the type of tillage used. What is important is to develop a management strategy based on fundamental principles of Integrated Pest Management (IPM).

How can conservation tillage affect insect pest populations? Tillage practices directly affect soil, which provides shelter and resources for many arthropods that live there, so tillage can affect insect populations as well:

1. Direct effects:
   a. Some insects live in or on the crop residue, or in the soil at some point in their lifecycle. Tillage can disturb these insects by killing them, by destroying the residue that the insects rely on for shelter, or by physically disturbing the soil habitat. For example, Hessian flies over-winter and over-summer as pupae on wheat stubble. If the wheat stubble is buried deep enough in the soil with tillage, emerging Hessian flies die in the soil.
   b. Some insects such as May/June beetles prefer to lay their eggs in fields that are covered with plant residue or weed seedlings, while others, such as the army cutworm, prefer bare soil.
   c. Soil temperatures are often cooler and soil moisture higher in fields with crop residue, which can affect the survival and development rate of insects that live in the soil. For example, Illinois researchers found that emergence of corn rootworm adults is delayed in no-till fields, and survival of rootworm eggs is actually increased in no-till because such fields tend to have less fluctuation in temperature during the winter.

Insect Management

Tillage systems greatly impact the insect populations present in the environment. Considerations should include an Integrated Pest Management Program for:

- Winter Wheat pests
- Corn/Sorghum pests
- Cotton pests
- Soybean pests

2. Indirect effects:
   a. Tillage can change the type and density of weeds that are present, which in turn can affect the populations of both beneficial and pest insects. Poor weed management can make a field more attractive to insects such as the black cutworm or the May/June beetle. Volunteer crops may serve as reservoirs for pests. Wheat curl mite populations, the vector of wheat streak mosaic virus, often build in volunteer wheat, and then move into the wheat crop once it emerges from the soil. On the positive side, the presence of wheat stubble in the soil has been shown to deter greenbugs from colonizing and building in numbers compared to tilled fields. In general, increased diversity in the physical environment from crop residue may also add stability and diversity to the agricultural ecosystem, including a more diverse population of beneficial insects.
   b. Crop rotations are often an important component for successful crop production with conservation tillage. Rotations can affect the potential insect pests that might occur. For example, continuous cultivation of the same crop may allow pests of that crop to build.

The lifecycle of some pests can be disrupted by rotating into a non-host crop for one or more years. Some insects are pests of several crops and can cause problems if the crop rotation sequence is favorable for them. In general, crop rotations benefit crop production using conservation tillage, but producers should become aware of the pests associated with the rotation program they implement.

With a couple of exceptions, effective management tactics are available to control insect pests regardless of the tillage system. In fact, most control recommendations are not contingent on the type of tillage system in place. Tillage can be an effective management tactic for some insects, thus by removing it as a potential tool, other tactics need to be identified and used to compensate for that loss. Some tactics that are important for managing insect pests of small grains include:

- Biological control
- Crop rotation
- Planting date selection
- Resistant varieties
- Weed control
- Chemical control

The following section will discuss some of the more important insect and mite pests of individual crops as they relate to conservation tillage.

Winter Wheat

Aphids

Cereal aphids are the most important pests of winter wheat in Oklahoma (Figure 1). The most common include the greenbug, the bird cherry-oat aphid, and the Russian wheat aphid. Published research has provided mixed results with regard to the effects of conservation tillage. Oklahoma research has shown that the presence of crop residue inhibits greenbug infestations. Research in the northern Great Plains showed that bird cherry-oat aphids survived better in spring wheat grown under no-till. At best, we can say conservation tillage either has little effect or that aphid numbers will be less abundant in fields grown under conservation tillage. Fortunately, control recommendations for aphids in winter wheat are based upon the number of aphids present at any given time. Scouting procedures are not altered because of the tillage system. An area of research that needs attention is the effect of crop residue on some important natural enemies of cereal aphids, including the lady beetle complex and the parasitic wasp, *Lysiphlebus testaceipes*.

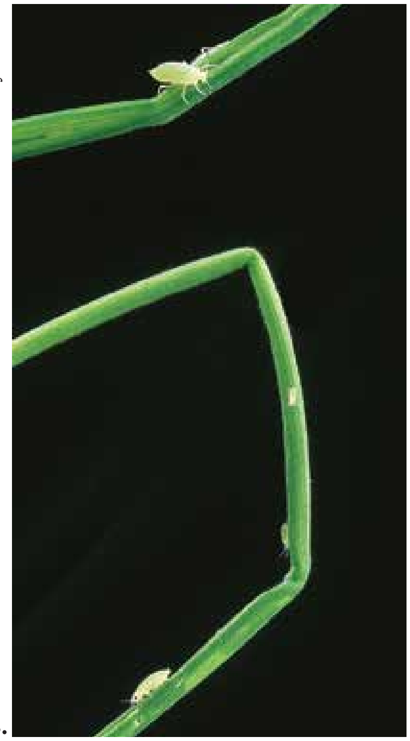

Photo courtesy USDA.

Figure 1. Aphids.

Armyworms

Several different insects are referred to as "armyworms." There are three important armyworm pests in winter wheat, including the armyworm, the fall armyworm, and the army cutworm. Each has a different biology and habits, and conservation tillage has different impacts on each of them. Little research has been published on the effects of tillage systems as it relates to infestations by armyworms in winter wheat.

The armyworm over-winters in Oklahoma and typically causes problems during the spring after wheat has jointed (Figure 2). Adult armyworm moths prefer to lay eggs in fields with dense plant populations, or in fields with lodged plants. Tillage probably does not have much effect on armyworms.

Army cutworms occur during the winter and early spring. They are a pest of winter wheat and

Figure 2. Armyworm.

Photo courtesy Tom Royer.

canola, which is being increasingly adopted as a rotational crop with winter wheat. Adult army cutworm moths prefer to lay eggs in bare fields, thus wheat grown under conservation tillage would probably be at less risk of being damaged by army cutworms.

Fall armyworms do not over-winter in Oklahoma. They typically infest wheat during the fall after it emerges. Populations die following the first killing frost in the fall. Little research-based information exists on what effects conservation tillage would have on fall armyworm infestations.

Hessian fly

The Hessian fly over-winters and over-summers in wheat stubble (Figure 3). Two major periods of egg-laying activity occur, one in the spring, and one in the fall. They seem to be stimulated by favorable temperatures and precipitation events. Hessian fly populations carry over in wheat stubble and can build from volunteer wheat. Therefore, they can be expected to be more of a problem in areas where continuous wheat is grown under conservation tillage. Since tillage can be a major factor in reducing Hessian fly, it becomes more important to utilize other management tactics to reduce the threat of Hessian fly damage. They include: use of resistant varieties, such as "Centerfield," "Duster," and "Gallagher;" destruction of volunteer wheat; and use of insecticide seed treatments. Recent research has shown that planting after the traditional "fly free planting date" is not effective in Oklahoma because we experience long stretches of warm weather in late fall and winter that allow Hessian flies to emerge long after winter wheat has emerged.

Mites

Three species of mites commonly attack winter wheat. The winter grain mite prefers cool, moist growing conditions and the brown wheat mite thrives in the hot, dry conditions seen in drought. Both mites are associated with continuous wheat cropping, and are likely to be found in conservation tillage. However, they can be controlled with insecticides regardless of the tillage system.

The wheat curl mite is a vector of wheat streak mosaic virus. They can live in other grasses, but thrive in corn and wheat. Of most concern is their potential to build in volunteer wheat in fallowed land. Since they can maintain themselves in volunteer wheat, they can be a source of virus disease in the fall. There is no effective chemical control of wheat curl mite, so they must be managed through control of volunteer wheat at least two to three weeks before the fall crop is planted.

Figure 3. Hessian Fly.

Photo courtesy Tom Royer.

Wheat Stem Maggot

Wheat stem maggot is not a serious pest of winter wheat in Oklahoma, but it does maintain populations in volunteer wheat and other grasses. It is not known how conservation tillage would affect wheat stem maggot infestations, but delayed planting is an option for decreasing infestations.

Wireworms and White Grubs

Wireworms, false wireworms, (Figure 4) and *white grubs* (Figure 5) are stand-reducing insects that are affected by tillage. Adults of these insects are attracted to fields with volunteer plants, germinated

Photo courtesy Tom Royer.

Figure 4. False Wireworm.

Photo courtesy Tom Royer.

Figure 5. White Grubs.

weeds, and crop residue to deposit their eggs. Wireworm and false wireworm damage can be minimized with the use of insecticide seed treatments, and while white grubs are not effectively controlled with insecticide seed treatments, some research suggests that a seed treatment reduces feeding damage from white grubs. It becomes imperative to control volunteer plants and weeds during the egg-laying periods to minimize damage from these pests.

Canola

Aphids

Aphids are the most important pests of canola in Oklahoma. The most common include the cabbage aphid, the turnip aphid, and the green peach aphid. There is little published research on the effects of tillage on canola aphids. Published research with other aphid/crop systems points to mixed results with regard to the effects of conservation tillage. At best, we can say conservation tillage either has little effect or that aphid numbers will be slightly less abundant in fields grown under conservation tillage. Fortunately, control recommendations for aphids in canola are based upon the number of aphids present at any given time. Scouting procedures are not altered because of the tillage system. An area of research that needs attention is the effect of crop residue on some important natural enemies of canola aphids, including the lady beetle complex and the parasitic wasp, *Diaeretiella rapae*.

Cutworms

Cutworms damage seedling plants by cutting them below their growing point, which results in stand loss. Some cutworms, such as the army cutworm and the variegated cutworm over-winter as larvae. Other cutworms, such as the black cutworm, lay eggs in early spring. Crop residue in general provides suitable habitat for survival of over-wintering cutworm larvae, but also suitable habitat for natural enemies of cutworms such as ground beetles.

Diamondback moth

Diamondback moth is a key pest of canola. There is little information on the effects of tillage on diamondback moth populations. Research in Illinois suggests that use of a cover crop followed by application of glyphosate before planting reduced infestations of diamondback moth in cabbage compared to a conventional tillage system. The effects of crop residue on natural enemies of diamondback moth need research attention.

Corn/Sorghum

Cutworm

Cutworms damage seedling plants by chewing leaves above the growing point which slows leaf expansion and/or cutting them below their growing point, which results in stand loss. Some cutworms over-winter as larvae while others such as the black cutworm, lay eggs in early spring on winter annual weeds. Conservation tillage often encourages winter annual weeds to germinate and grow until a burn-down herbicide is applied before planting. Such fields are attractive to black cutworms. Crop residue favors survival of over-wintering cutworm larvae. Generally, the risk of cutworm damage can be reduced by applying a burn-down herbicide application to a field three weeks before the field is actually planted.

Corn rootworms over-winter as eggs in soil. Most of the research on the effects of tillage on rootworm egg survival suggests that tillage, combined with cold dry winters may increase rootworm egg survival. Undisturbed soil may actually allow for increased natural enemy activity against rootworm eggs. Thus, rootworms would not likely be affected favorably or unfavorably by conservation tillage.

Corn Borers (Southwestern and European)

European and southwestern corn borers are significant pests of corn. Both insects overwinter as larvae in the corn stalk. Conservation tillage systems likely would encourage survival of southwestern corn borer larvae. Fortunately, transgenic corn varieties that control corn borers are widely available. Growers should select hybrids that aid in management of southwestern corn borers.

Other insects, such as stalk borer, stinkbug, and wireworms are more likely to be a problem in conservation tillage. All are difficult to control because they often damage plants before the producer is aware they are a problem. Stalk borers can be discouraged by controlling grassy weeds two to three weeks before planting. Wireworms are effectively controlled with one of the neonicitinoid insecticides such as imidacloprid, thiamethoxam, or clothianidin.

Cotton

In the mid-south, insect pests of cotton are favored by conservation tillage, with the exception of boll weevil, cotton fleahopper, and tarnished plant bug. In the Southwest (Texas, New Mexico, and Oklahoma), there appears to be less of a buildup of thrips, cotton aphid, bollworm, and tobacco budworm associated with conservation tillage if cotton is planted into a winter grain crop that previously has been killed with an herbicide. Recently, boll weevil has been eradicated from Oklahoma through the area-wide boll weevil eradication program. Bollworms and budworms are effectively managed with transgenic cotton varieties that contain genes which allow the plant to produce toxins that protect them from damage caused by the bollworm/budworm complex as well as other foliage-feeding caterpillars.

Cutworms

Cutworm numbers appear to increase in conservation tillage. The increased incidence of injury from cutworms is likely related to the presence of winter cover crops and the presence of weeds in conservation tillage fields. A key practice for reducing cutworm injury in conservation tillage systems is to destroy the cover crop/vegetation at least three weeks before planting.

Thrips

Thrips can utilize other host plants that might be present in the field and enable them to invade seedling cotton as it emerges. Results from research in the southwestern portion of the Cotton Belt suggest that thrips populations are no more abundant in cotton grown in conservation tillage systems compared to conventional tillage systems. However, higher thrips populations may occur in cotton if the surrounding vegetation is destroyed through an herbicide application.

Cotton Aphids

In south Texas, research shows that early season aphid numbers were higher in conservation tillage cotton compared to conventional tilled cotton, but numbers of the more damaging late-season cotton aphid infestations were lower in conservation tilled plots.

Soybean

Considerable research regarding the influence of tillage practices on soybean insects has been conducted in the north central states. Results suggest that the densities of grasshoppers, Japanese beetles, and damsel bugs (a predator) were greater in mulch–till systems. Densities of potato leafhoppers were greater in plowed fields. Densities of green cloverworms were unaffected by tillage practices. Slug problems are known to increase in conservation tillage, although the Oklahoma climate does not foster slug survival.

Another study showed that cover crops and residues dramatically affected populations of seedcorn maggots. Population densities of seedcorn maggots did not increase in no–till systems, but more seedcorn maggots were found in tillage systems that incorporated live, green cover crops into the soil compared to systems that used dead crop residue.

Grasshoppers

Population densities of grasshoppers (Figure 6) vary widely from year to year and seem to be regulated primarily by weather, natural enemies, and diseases. Most grasshopper species over-winter as eggs buried about 2 to 3 inches in the soil. Most species deposit egg pods in the soil of uncultivated field margins, roadsides, ditch banks, fence rows, pastures, alfalfa, and clover fields in late summer and early fall. Eggs over-winter and hatch from late May through July. Grasshopper nymphs usually feed for two to three weeks near their hatching site. When their food source becomes scarce or when feeding sites are mowed or otherwise destroyed, nymphs move to nearby crops, where they feed and become adults. There is usually one generation of each grasshopper species each year. While tillage can affect grasshopper populations, such impact would have to occur over large areas to cause any significant reductions because grasshoppers are capable of migrating long distances as adults.

Photo courtesy USDA.

Figure 6. Grasshoppers.

Seedcorn Maggot

Seedcorn maggot adults (flies) emerge early in the season and seek decaying organic matter on which to lay eggs. The larvae (maggots) feed on seeds and underground portions of soybean seedlings. As stated previously, potential for seedcorn maggot injury increases if green cover crops and crop residues are incorporated into the soil or liquid or solid animal wastes are used as fertilizer.

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Chapter 11

No-till Crops

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No-till Crops

Important crops for no-till consideration include:

- Wheat
- Soybean
- Cotton
- Sorghum
- Corn
- Canola

Wheat

Wheat occupies the largest acreage of any grain crop in Oklahoma, so it is likely that any no-till production system in the state will include wheat at some time. In the presence of a crop rotation, the agronomic and managerial requirements for no-till wheat production are similar to those of a conventional till system. Without a rotation, no-till wheat production requires much more planning and management than a conventional till system.

The level of planning and management required for no-till wheat will vary by producer, region, and production objective. There are, however, some 'universal truths' regarding no-till wheat production and no-till crop production in general. Even distribution of the previous crop's residue, for example, is critical for no-till farming. Wheat farmers, especially those using custom harvesters, may not be accustomed to closely monitoring combines to ensure that straw choppers are engaged and working properly and that chaff spreaders are covering the entire header width. These farmers will quickly discover that incorrect residue management can negatively affect crops for years to come.

Photo courtesy Jeff Edwards.

Figure 1. Winter crops, such as canola, often serve as good rotational crops for wheat farmers wishing to transition to no-till.

Another management technique that will likely apply to all no-till wheat production systems is the need for starter fertilizer. Numerous experiments at OSU have revealed the benefit of in-furrow application of phosphorus fertilizers. The benefits of starter fertilizer are greatest in low pH and/or low phosphorous fertility situations. Researchers have seen advantages to starter fertilizer in dual-purpose wheat even when soil phosphorus is already at sufficiency levels. It is likely that, because of cooler soils and nutrient stratification, the benefits of starter fertilizer will be even greater in a no-till system than in conventional till wheat.

How Important is Rotation?

As stated earlier, the difficulty associated with no-till production of wheat will depend largely on whether or not crop rotation is used (Figure 1). If a crop rotation is incorporated into the production system, then no-till wheat production techniques will be very similar to those of conventional till wheat. In fact, since most Oklahoma farmers are familiar with wheat production, wheat will likely be the easiest part of the cropping system. The challenge will be in production and marketing the rotational crops incorporated into the cropping system.

In contrast to farmers using a rotation, farmers wishing to grow no-till continuous wheat will likely encounter many challenges they did not face when growing conventionally tilled continuous wheat. Paramount among these issues will likely be weed and/or disease control, but other issues such as fertility, compaction, and residue management can also create challenges. Farmers in a continuous wheat system, for example, may have paid little attention to crop rotation restrictions in the past; however, many of the most popular wheat herbicides have restrictions regarding the planting of rotational crops. Planning for crops one or two years ahead of time will likely be a new experience for most wheat farmers. With careful attention to label restrictions and good recordkeeping, wheat farmers will likely find this task easier than they first thought.

Weed Control

Most Oklahoma farmers know of someone who has tried to no-till wheat and then reverted back to conventional tillage due to poor weed control. With proper planning and management, this does not have to be the case. Perhaps one of the most important components of this planning process is to begin with clean fields. Unless a strong crop rotation program is implemented, wheat fields infested with hard-to-control weed species such as *Italian ryegrass*, feral rye, or jointed goatgrass will likely become worse in a no-till system. Broadleaf rotational crops such as winter canola offer excellent opportunities to control these grassy weeds. Rotating herbicide modes of action helps to reduce the chances of weed resistance. In a continuous wheat system grassy weeds must be addressed with an aggressive, weed-specific management plan. Much of the Italian ryegrass in Oklahoma, for example, is resistant to ALS herbicides and is most effectively controlled with a two-pass, pre-plus-post herbicide program that incorporates multiple herbicide modes of action. Feral rye and jointed goatgrass can be managed using two-gene Clearfield® wheat varieties and their associated herbicide programs. Regardless of the weed being controlled or herbicide being used, emphasis should remain on controlling weeds when they are small and ensuring that weed problems are not re-introduced or worsened through contaminated equipment or seed.

Photo courtesy Jeff Edwards.

Figure 2. Cattle traffic creates compaction regardless of the tillage system. The soil compaction from hoof traffic in the conventional till wheat field pictured will likely affect grain yield. Compaction such as this may be reduced in no-till systems over time due to greater load-bearing strength of the soil.

It is also important for new no-till farmers to realize that summer weed control is critical to moisture savings and long-term weed control. A good rule of thumb to use is to ask yourself "are there enough weeds in my field that I would normally till right now?" If the answer is yes, then you probably need to spray for weeds in a no-till wheat production system.

Disease Control

Switching to no-till will lower the incidence and severity of some diseases but increase others. There is evidence that aphids, for example, are less attracted to wheat in heavy residue and that barley yellow dwarf virus transmitted by aphids might be less severe in no-till systems. Leaf and stripe rust incidence and severity are generally not affected by tillage, but foliar diseases such as powdery mildew, tan spot, septoria leaf blotch, and stagonospora glume blotch can be worse in no-till because of increased pathogen inoculum present on wheat residue. A diversified crop rotation will reduce the amount of wheat residue present to serve as a host for these diseases. In a continuous wheat system, producers might consider a two-pass spring fungicide system to address these diseases if justified by yield potential. This typically involves one pass with a low cost fungicide just after jointing and a second pass with a full rate of fungicide after flag leaf emergence.

Using Graze-out as a Rotation

Graze-out is a management system in which cattle are allowed to graze wheat pasture well into the spring and no grain is harvested from the field.

There is some evidence that graze-out can successfully be used as a rotation in a continuous wheat production system. Under this management strategy, farmers would typically graze-out two-thirds of their acreage and harvest one-third for grain. The advantage of this system is that the intensive grazing pressure can reduce the amount of wheat residue carried over from year to year. This reduces the amount of inoculum present for disease the following year. The commonality among farmers that have made this system work seems to be they are more cattle-oriented than crop-oriented and the wheat yield potential on their farm is typically less than 30 bushels per acre.

There are also many forage-only producers who have found success with continuous no-till wheat production. In this system, the majority of wheat residue is removed during grazing. Diseases are not generally as much of a problem as in grain only or dual-purpose systems. Likewise, since the emphasis is on forage production, weed control is generally not an issue and plants normally considered to be weeds are frequently utilized as a valuable forage source. Producers using this system are often cattle-oriented and may enjoy the flexibility and simplicity that a no-till system provides.

What about Compaction?

Cattle create compaction, and dual-purpose and forage-only wheat producers are often concerned about soil compaction in a no-till system. In conventional till systems, compaction from hoof traffic is normally alleviated via tillage operations; however, this compaction is quickly reintroduced once wheat fields are stocked with cattle in the fall. As a result, conventional till and no-till fields have similar amounts of compaction by the following spring. So, the primary difference in compaction between the two systems is during planting and forage establishment in the fall. The effect of this compaction on forage production is probably minimal and should not deter someone from no-till wheat production. A properly managed no-till system might actually have less compaction in wet years due to the greater load bearing strength of the soil.

Variety and Seeding Rate

It is best to review current variety trial results and variety comparison charts (www.wheat.okstate.edu) to select a high-yielding, well-adapted wheat cultivar for your area. If incorporating a rotational crop into a no-till strategy, there probably is little difference in variety performance under no-till or conventional till management. If continuous wheat is being grown, selecting a variety with Hessian fly resistance will reduce or eliminate crop losses from this pest. If sowing early for grazing, selecting a variety with Hessian fly resistance is extremely important, as early-sown wheat is most susceptible to injury.

As long as high-quality seed is sown, seeding rates for no-till wheat production should be similar to those for conventionally tilled wheat. High-quality seed is characterized as being free from weed seed and foreign material, having good vigor, and having greater than 80 percent germination. High-quality seed is necessary to ensure adequate germination in the cool, wet conditions prevalent in no-tilled soils. This is especially true when planting after October 15.

Soybean

Soybean production in no-till cropping systems is relatively simple and gives producers flexibility. Reasons for growing no-till soybeans such as conserving soil moisture and preventing soil erosion, are similar to other crops. No-till planting soybean also provides the opportunity to double crop after wheat. Double-crop soybean production is often practiced in Oklahoma when soil moisture is available following wheat harvest. Improved planting equipment and herbicides have made double-crop, no-till soybean production easier. Planting directly into wheat stubble reduces the risk associated with double-cropping by conserving moisture and cooling soil temperatures; therefore, a double-crop soybean-wheat rotation is often an excellent way to begin practicing no-till and provides an easy transition into no-till.

Just like any no-till system, no-till soybean production should include a crop rotation. Since soybean is a legume (fixes N), it is an excellent crop to incorporate in a rotation. Planting soybeans prior to wheat, corn, or grain sorghum are all excellent choices for most parts of Oklahoma because soybean residue is easy to manage. Rotation will also help control soybean cyst nematode populations. Finally, any rotation including both broadleaf and

> *" The no-till system is ideal for double-cropping soybeans behind wheat, since time is very limited to get the soybeans planted after the wheat is harvested."*
>
> **Brent Rendel**
> **Miami, OK**

grass crops (such as soybean/wheat) is ideal because weed populations are easier to control.

Planting

One advantage soybeans have compared to other crops is the ability to plant soybeans in several different row widths. Recommended row width for no-till planting is 30 inches or narrower, and crop response to row width narrower than 30 inches is inconsistent. Yield increases for row widths narrower than 30 inches are usually associated with early/short-season varieties (MG III or early MG IV). With row width not being a reliable yield-determining factor in Oklahoma, planting width decisions are often based on producer preference.

Soybean seed should be planted at a depth of 1 to 2 inches. Depth control needs to be precise; otherwise seed is more likely to be damaged by soil-applied herbicides. Seeded populations should be approximately 110,000 seeds per acre, which should allow for a final plant population of approximately 100,000 plants per acre. Several seed metering mechanisms are available including fluted, double-run, and wobble-slot. All require repeated adjustments to obtain the correct seeding rate. Typically, drills provide less uniformity in seed spacing and seeding rates than planters, but some adjustments will cause a grain drill to be closer in performance to a unit planter. Refer to Chapter 4 No-till Equipment on page 11 for more details on planting options and adjustments.

a. Adjust the metering mechanism to drop two to three viable seeds per foot in 7.5-inch rows or four to six viable seeds per foot in 15-inch rows. Generally, less seed damage occurs with 15-inch rows due to the large flute openings. Using a wider gate opening and slower rotation of the flute will usually give better distribution of seed in the row. Always calibrate the drill on the basis of seeds per row foot. Seeds per pound can vary tremendously between varieties and even within varieties depending on growing conditions under which the seed was produced.
b. Whenever possible, avoid large seed because seed damage increases as seed size increases. Use seed having at least 2,400 seeds per pound and increase the seeding rate to compensate for the seed damaged by the metering mechanism.
c. Increase seeding rate by 10 percent for a poor seedbed.
d. Increase seeding rate by 10 percent for early maturing varieties.
e. Increase seeding rate by 10 percent when planting late or after wheat.

> *"I have had some success in planting dryland cotton following harvested wheat. It has reduced, and in most cases, eliminated wind damage to young cotton."*
>
> **Clint Abernathy**
> **Altus, OK**

Weed Control

Failure to control weeds is often the reason producers have a negative experience with no-till soybean production. As with any cropping system, early-season weed interference is the most damaging. Burndown herbicides, such as glyphosate or paraquat, should be used to ensure that fields are weed free prior to soybean emergence. This might be difficult in harvested small grain stubble, as harvesting removes much of the foliage from weeds thereby reducing the amount of available surface area for herbicide contact. This potentially reduces herbicide efficacy. Pre-emerge herbicides are effective at reducing early-season weed competition and provide a 'buffer' for post-emergence herbicide applications that are sometimes delayed due to weather or wet soil conditions. While Roundup® Ready programs are still very effective on some weed species, glyphosate resistant weeds have made them less effective as an easy, one-stop weed control program. Most weeds can still be managed with a well thought-out herbicide program. It is important to rotate herbicide modes of action to ensure that resistance is kept to a minimum.

Cotton

Evolution of Reduced Tillage and No-Till Cotton

Cotton is an excellent fit in no-till or reduced tillage systems because of its early-season sensitivity to environmental damage typically caused by high winds and blowing soil (Figure 3). Modern conservation tillage systems have evolved due to a convergence of important factors. Developments in transgenic varieties, boll weevil eradication, equipment, and other management practices have facilitated the adoption of no-till production techniques.

Photo courtesy Randy Boman.

Figure 3. No-till cotton in Tillman County, 2013.

The synergism of these factors has resulted in record yields and quality in Oklahoma. This simultaneously allows producers to efficiently manage more acres in less time than ever before.

Reduced tillage systems in cotton were developed in the mid-1960s in Washita County, but due to difficulty in terminating the wheat or rye cover crops and weed control, they were not adopted by many producers. When row-till equipment and spinning blade cultivators were developed in the 1980s producer adoption increased. In the 1990s a program was initiated that was referred to as the "Oklahoma Interseeded Residue Management Program." This program utilized a shielded drill to interseed wheat or rye between the cotton rows in late August or early September prior to cotton harvest. The small grains germinated, and when cotton was harvested, the cover crop was already established. In late winter or early spring, a row-till unit consisting of a ripper shank, coulters to move soil into the depression left by the ripper, and a rolling basket to firm the soil was used to till a strip of soil approximately 12 to 14 inches wide. The cover crop was allowed to continue to grow until it reached the hollow stem stage and was then terminated with glyphosate. At the hollow stem stage, the residue would remain standing and provide better protection from wind, heavy rainfall, and blowing soil. Cotton was then planted in the strips with a normal cotton planter. Weed control was accomplished by incorporating dinitroaniline herbicide in the strips, and cultivating between the rows. This cultivation operation was achieved with a spinning disk cultivator that would not be plugged by the high residue. This technique was a vast improvement over other strip-till systems, but weed control remained a season-long problem. This was primarily because soil mixing by tillage brought more seed to the soil surface and resulted in germination of additional weeds. Cultivation also resulted in root pruning of the cotton and increased mid-season stress to the plants.

In 1997, transgenic glyphosate-tolerant cotton was introduced by Monsanto and Roundup Ready® varieties became available. This first generation technology provided full vegetative, but limited reproductive tolerance to glyphosate. Higher equipment, diesel, and labor prices also discouraged tillage making no-till systems more feasible. Transgenic varieties containing Monsanto's Roundup Ready Flex® trait were later developed which allowed over-the-top applications of glyphosate throughout the growing season. Later, Liberty Link® and GlyTol® herbicide tolerance traits were introduced by Bayer CropScience. GlyTol® and Liberty Link® technologies both allow essentially full-season over-the-top application windows of glyphosate and glufosinate, respectively. Varieties with GlyTol® plus Liberty Link® ("stacked" herbicide tolerance) technologies were recently released. Additional transgenic herbicide tolerance traits in cotton are expected in the near future. When properly managed, these technologies have resulted in weed control improvements and have likely contributed to yield increases.

Improvements in insect pest management have also contributed to higher productivity. The advent and success of boll weevil eradication reduced cotton production costs and subsequently increased yields. Transgenic traits based on *Bacillus thuringiensis* (Bt) technology decrease or eliminate yield losses due to many species of caterpillar pests, thus resulting in yield gains. Bt traits have essentially eliminated insecticide use for these pests in Oklahoma cotton. With the omission of in-season insecticide applications targeting caterpillar pests, disruption of beneficial arthropod populations is also prevented. The initial single-gene Bt technology, Bollgard®, was introduced in cotton in 1996 and followed a few years later by dual or "stacked" Bt genes (Bollgard II® from Monsanto and Widestrike® from Dow AgroSciences). Bayer CropScience also recently released TwinLink® varieties with their proprietary dual-Bt traits. In order to significantly reduce the likelihood of resistance in caterpillar pests, various triple-gene Bt products from the above companies are expected in the near future.

Highly efficient auto-steer tractors and large sprayers with guidance systems have enhanced management of various farming operations. Improved planters have also been developed, which allow highly accurate seed placement and facilitate seeding into high residue conditions.

No-till has quickly become the preferred technique of many Oklahoma cotton producers in dryland, and in center pivot and subsurface drip irrigated systems. Producers planning to initiate no-till production systems should develop a strategy that is specific for their individual areas and equipment inventories. Crop rotation programs, soil texture, and rainfall patterns should all contribute to the decision making process. Most equipment that producers currently own can be modified for no-till production by adding attachments to facilitate planting into residue. Immediate input cost savings result from less equipment wear and less time spent per acre producing the crop. Soil benefits accumulate over a multi-year period, and increased organic matter and improved crop rooting potential are definite long-term benefits of no-till production.

Residues

One of the keys to successful no-till cotton production is having sufficient residue available during the early part of the season to protect young cotton plants from high wind and thunderstorm events. Many cover crops have been evaluated, but wheat or rye is generally the small grains species of choice with center pivot or subsurface drip irrigation. The cover crop should be planted as soon as possible following harvest and should be terminated with glyphosate immediately following jointing to eliminate water use. If the crop is terminated prior to jointing, it will not remain standing, nor provide as much protection to the cotton seedlings. Under marginal irrigation conditions, it is important to have the cover crop fully terminated prior to planting. With lack of rainfall, high temperatures and wind, cotton establishment can be difficult with low irrigation capacity. It is recommended to not allow a cover crop to compete for moisture during cotton stand establishment. When considering small grains cover cropping under non-irrigated conditions, producers need to be fully aware of any crop insurance challenges that might arise. It is important to discuss these issues with your crop insurance agent to determine the latest regulations that might impact compliance.

Planting

Planters should be equipped with coulters, residue managers, or disks to move surface residue from the row. If the small grains crop is harvested for grain, the combine should have a good straw chopper and spreader to evenly disperse crop residues. Cotton can be planted into a considerable amount of residue if the planter is properly equipped. Residue is always more easily handled when left standing and planter attachments should be able to "cut and roll." Environmental conditions such as high humidity or dew may affect the ability of the planter to traverse the residue properly, so residue should be dry during planting operations. Disks on the planter which are normally used for clean till can be used if the residue is left standing and the soil is mellow. Heavy duty down pressure springs should be available for use on the planter under hard soil conditions. Good seed to soil contact is important, and a seed press wheel attachment immediately following the openers should be considered. Closing attachments are also very important and several types are available. "Baking" or crust formation in the row after planting is a challenge that can affect the typically weak cotton seedling. This generally occurs when high temperatures and winds are encountered immediately after planting. Managing the correct amount of dry soil at seed trench closure is important.

Cotton seed with transgenic trait technology is an expensive input cost. Seeding rate will vary if the field is dryland or irrigated. Generally a range of 30,000 to 40,000 seeds per acre is a good target for dryland fields, whereas a 40,000 to 55,000 seeds per acre goal is normally adequate for irrigated production. When planting low seeding rates, producers must have faith in their seed quality, planter, its adjustment, soil moisture and environmental conditions.

Weed Control

It is critical to "start clean and stay clean" when producing no-till cotton. When adopting no-till practices, herbicides are used as a replacement for tillage. Due to weed resistance to glyphosate and other herbicides – especially by Palmer amaranth, it is now required to mix herbicide modes of action during the growing season. The days of sole reliance on glyphosate for weed control in glyphosate-tolerant cotton are over due to these weed resistance issues. This situation is rapidly changing, so to obtain the latest information, contact extension personnel. Many cotton herbicides have soil residual activity. It is imperative to read the herbicide label and identify any potential issues with a future rotational crop. It should be noted that ideally, producers should have spraying equipment dedicated solely to use in cotton if possible. Phenoxy (2,4-D) and other herbicide contamination in tanks and hoses can be very damaging to cotton.

For no-till fields preplant burndown prior to planting is required. Horseweed is a major challenge in minimum tillage cotton, and glyphosate resistant populations of this weed have been identified in some counties. Horseweed should be targeted when the plants are in the rosette stage, prior to bolting or upright growth. Tank mixes of glyphosate and 2,4-D or glyphosate and dicamba are typically used. It should be noted that 2,4-D and dicamba both have critical application rate requirements and herbicide residue dissipation timelines prior to cotton planting. If planting restrictions for 2,4-D and dicamba cannot be met, then paraquat should be considered.

Roundup Ready Flex®, GlyTol®, and Liberty Link® transgenic traits have greatly reduced weed control challenges. Varieties containing the Roundup Ready Flex® and GlyTol® traits allow glyphosate to be applied over the top at any time from emergence to shortly prior to harvest. Liberty Link® varieties can be sprayed over-the-top with glufosinate.

A pre-emergence herbicide should be considered at planting. Several are available and the rate must be matched with the soil texture in the targeted field. Herbicides containing metolachlor or acetochlor can be used to improve annual weed control over-the-top of the crop. Staple LX® herbicide is another option as an over-the-top spray for control of broadleaf weeds.

Hooded sprayers are still very useful in cotton production and to address the challenges related to weed resistance. Overlapping in-season residual herbicides is recommended, especially if Palmer amaranth and morning glory challenges exist in the field. Application methods and timeliness are critical for success. Since some herbicides can adversely affect the cotton crop if improperly applied, it is necessary that growers read and follow all herbicide labels. Additional herbicide programs for use in no-till or reduced tillage cotton are being developed. For the latest information, contact your local Extension educator.

Volunteer cotton has become a legitimate challenge for producers adopting no-till production practices. Volunteer plants that are not located in the row cannot be harvested with the crop, and essentially should be considered "weeds" since they compete with the actual planted crop for sunlight, nutrients and water. Volunteer cotton often germinates at the same time the crop emerges leaving producers with very few options. The lack of height differential between the crop and the volunteer can make it difficult to safely and effectively control the volunteer with hooded or shielded applications. For this reason it is required that producers make every attempt to control any volunteer present prior to planting. There is a relatively small window of opportunity to effectively control volunteer cotton. This window is often overlooked. With good growing conditions seedling cotton can add an additional leaf every three days. One-leaf volunteer plants can turn into 4-leaf plants in a very short period of time (about 10 to 14 days). Once the volunteer exceeds the 4-leaf stage, effective chemical control is nearly impossible. Therefore, when relying on chemical control it is recommended to spray volunteers prior to the 4-leaf stage. Circumstances often require growers to control large volunteer cotton with some form of tillage. If volunteers pass the "easy to control" stage (one to four leaves), then shallow cultivation should be considered.

Harvest

Cotton harvest in no-till conditions should not be different from conventionally tilled fields. In most years, the wheat or rye cover crop is almost completely degraded and will not be gathered by the stripper harvester row units. In strip-till systems, no wheat or rye remains in the row and therefore cannot be picked up by the harvester.

In summary, conservation tillage management practices will substantially reduce environmental injury to the developing cotton. It is well documented that the first 30 to 40 days in the production season set the potential for maximum yield. When soil is not tilled, more water will infiltrate the field, soil erosion is greatly decreased, and organic matter is increased. The system might require more herbicide applications the first few years, but control costs will likely decrease if weeds are managed in an effective and timely manner. With recent advances in transgenic technology and modern equipment, adoption of a no-till cotton system is more easily accomplished than in the past.

Sorghum

There are two important things to consider before switching to no-till grain sorghum. They are the history of herbicide and if a compacted layer (hardpan) is present. Herbicide carryover in a wheat only system can have rotation restrictions for grain sorghum up to two years from application. Therefore planning is crucial before trying sorghum in a rotation. For producers switching to no-till, taking care of a compacted layer should be the first step. The compacted layer will inhibit root growth and reduce yields in any production system. Shattering of the compacted layer by deep tillage or strip-till should be done before adopting no-till. Utilizing strip-till to break the compacted layer will also allow producers to apply fertilizer and prepare a seedbed similar to conventional tillage. Research at Kansas State University has shown a 3 F to 4 F increase in soil temperature for strip-till when compared to no-till. This increase in soil temperature may be important when planting sorghum during the last two weeks of April. Although with row cleaners on today's no-till planters, this soil temperature difference will be minimal in a week to ten days.

Grain sorghum production utilizing no-till does not require drastic changes when compared to conventional till. The goal in both production practices is to obtain proper seed spacing and good seed-to-soil contact. For any successful production practice, getting proper seed-to-soil contact is the first step. This allows the seed to germinate and grow without undue stress. The same planter can be utilized in both no-till and conventional till. The two major changes needed are row cleaners and more down pressure on the row units. The seeding rate for no-till is the same as for conventional till unless row cleaners are not used. If not using row cleaners, it is more difficult to get good seed-to-soil contact and therefore, the number of seeds germinating will be reduced. It is generally recommended to increase seeing rate by 5,000 seeds/acre when not utilizing row cleaners.

As reported in the popular press and journal articles, the benefits of no-till are not immediate. In a rotation study located at the Oklahoma Panhandle Research and Extension Center (OPREC), it was in year six before the first difference in grain sorghum yields was observed (Figure 4). One common misconception is that no-till means no yields—there was no difference in yields between no-till and conventional till the first five years of the study. Although no-till will not increase yields when no precipitation has fallen as in 2002 and 2011 when only 53 and 49 percent, respectively, of long-term mean rainfall was received. Since 2004, yields for the no-till grain sorghum have been significantly higher than for conventional till, with 2004 and 2006 yields being twice as high or more. In 2006, part of the yield difference is explained by the difference in test weights (Table 1). The difference for 2006 is explained by a short duration of drought stress observed in the conventional till grain sorghum that was not observed in the no-till. The duration of drought stress, although short and not very severe, delayed head emergence and flowering. The delay in flowering was long enough that grain fill and maturation was affected by a freeze, therefore more than 7 lb/bu difference in test weights was observed.

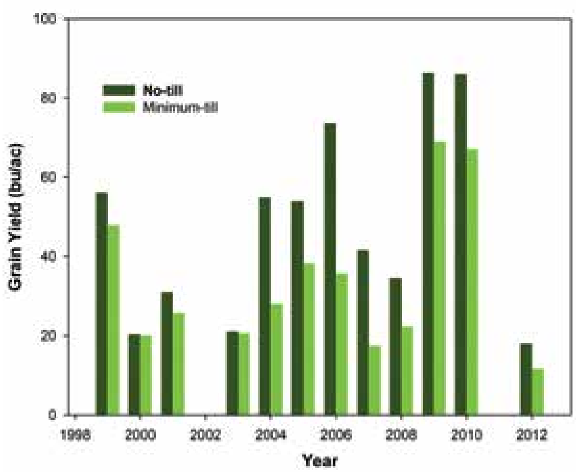

Figure 4. No-till vs. minimum-till grain sorghum yields in rainfed wheat-fallow-grain sorghum rotation at Oklahoma Panhandle Research and Extension Center, Goodwell, OK.

Photo courtesy Chad Godsey.

Figure 5. Double crop grain sorghum following canola.

Table 1. Test weight of grain sorghum (lb/bu) for dryland tillage and crop rotation study at OPREC.

Tillage	*2004*	*2005*	*2006*	*Three-year*
No-till	56.5	57.8	56.8	57.0
Strip till	56.7	57.0	52.9	55.5
Minimum till	55.8	56.9	49.6	54.1
Mean	56.3	57.2	53.1	55.6
CV %	0.8	1.6	4.2	3.7
L.S.D.	NS	NS	5.0	2.0

Corn

Given all the benefits no-till can offer, there are challenges as well. Crops grown under conservation tillage are subject to many different early season stresses that may limit the plant's ability to take up essential nutrients. Crop residue acts as an insulating layer over the soil surface, which can contribute to lower temperatures in the upper soil profile (Johnson and Lowery, 1985). Soil temperature and moisture greatly influences the mineralization cycle,

Photo courtesy Chad Godsey.

Figure 6. No-till corn – note previous years' grain sorghum and wheat residue.

which controls N release from soil organic matter (Kolberg et al., 1999). Cool wet soils slow down the mineralization process and contribute to poor early season growth due to the decreased amount of nutrients available to young plant roots. MacKay and Barber (1984) found the most profound effect of temperature on corn development was the rate of root growth. When soil temperature was increased from 64 F to 77 F, root growth increased by a factor of five. To address slow early crop growth associated with no-till soils, the use of starter fertilizer, usually containing N and P at planting, has shown to be a key management tool for corn production throughout the U.S. These factors mentioned previously make

Table 2. Effects of starter application method and composition on corn grain yield, plant population and dry whole-plant dry matter at the V-6 stage, Experiment Field, Scandia, Kansas, 2000.

	Yield bu/ac	*Population plants/ac*	*V-6 Dry Matter lb/ac*
Check 0-0-0	136	30,884	230
Method Means			
In-furrow	146	23,330	323
2x2	180	30,985	479
Dribble 2x	177	30,864	438
Row band	161	30,840	410
LSD (0.05)	11	840	32
Starter Means			
5-15-5	156	31,266	349
15-15-5	164	31,557	375
30-15-5	167	30,589	435
45-15-5	170	30,492	444
60-15-5	172	30,298	459
LSD (0.05)	10	849	33

*Source Barney Gordon Kansas State University

starter fertilizer very important for no-till corn production.

Importance of Starter Fertilizer

Several researchers have documented yield responses to starter fertilizer in no-till systems in Kansas and Missouri (Gordon et al., 1997; Gordon and Whitney, 1995; Scharf, 1999). The advantages to using higher N containing fertilizers include providing additional N supplies earlier in the growing season, reducing potential of volatilization and other N losses, flexibility in timing for future N applications, and enhanced P absorption (Lamond and Gordon, 2001). In addition, the method of applying starters has become more critical as the potential of physical incorporation of materials into the soil with tillage decreases. Deficiencies in secondary nutrients such

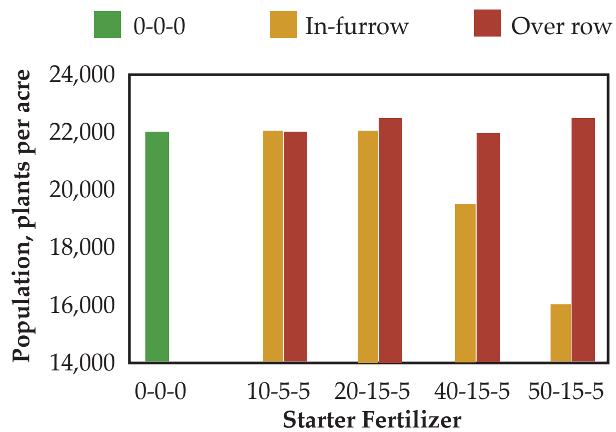

Figure 7. Modified from Niehues et al., 2004. Shows the effect of increased salt concentration from in-furrow applied fertilizer.

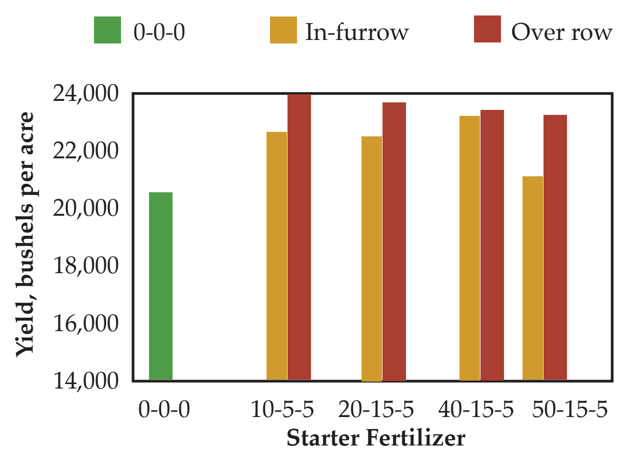

Figure 8. Modified from Niehues et al., 2004. Shows the yield response from in-furrow and over-row (dribble) starter fertilizer.

as sulfur (S) are becoming more common in no-till systems as well. As with N, S becomes available to plants mainly through soil organic matter and residue decomposition and mineralization. If this process is slowed down by cool, wet soils, the early season S needs of a developing crop could be affected.

Various placement methods have been adapted to provide options for starter fertilizer application. Some of the more common starter placements include in-furrow, banded near the seed, or dribble over the seed row. In-furrow placement of fertilizer, commonly referred to as *pop-up* fertilizer, is intended to promote more vigorous seedling growth due to a readily available supply of nutrients to young plant roots. However, placing fertilizers in the seed furrow increases the salt concentration surrounding the seed (Figures 7 and 8). Under certain circumstances this can result in delayed seedling emergence, reduced seedling germination, and reductions in crop stand (Raun et al., 1986). With an increase in salt content, the plant's capacity to absorb water is reduced until it cannot extract water even in wet soils. Another possible problem with in-furrow placement of urea-containing starters is ammonia toxicity.

Alternative placement methods for starter fertilizer have been developed with the purpose of placing the fertilizer far enough away from the seed so germinating seeds and seedlings are not adversely affected, yet close enough to allow early uptake of essential nutrients. Many starter fertilizers are now placed in a band 2 inches below and 2 inches to the side of the seed row. This placement method is commonly referred to as *2 x 2 placement*. A band placement away from the seed allows more flexibility in the rates of fertilizer that can be safely applied, especially when higher N rates are desired. Subsurface band placements have generally been proven to be the most effective placement method for deriving the maximum benefit of the starter and greatest yield per unit of applied fertilizer in corn. A second option of a "safened" starter fertilizer application is a dribble placement (over the row). A dribble placement of starter fertilizer simply consists of dribbling fertilizer directly behind the closing wheel of the planter over the seed row on the soil surface.

Planting Considerations

In order to establish a good stand of no-till corn, close attention should be made to planting date, population, and planting depth. Planting date should be based on soil temperature. The effect of delayed planting date on grain yield can be easily observed (Figure 9). Corn will germinate at soil temperatures as low as 50 F, but germination may be delayed up to 21 days. The basic recommendation for planting is a soil temperature of 55° F at the 2" depth. Also, check the forecast to be sure that for the next three to five days the forecast is favorable. Soil temperatures can be found on the Oklahoma

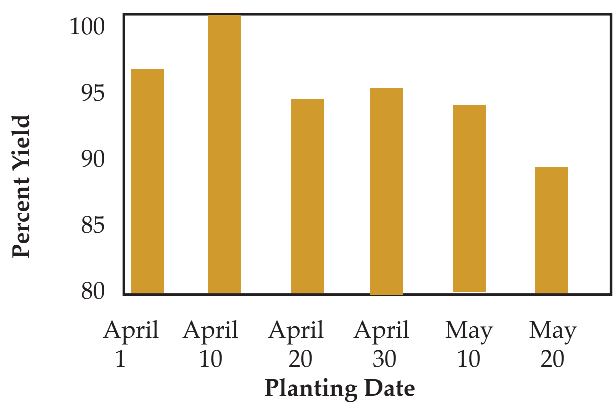

Figure 9. Four years of grain yields (114 Day Maturity) at Goodwell, Oklahoma.

Photo courtesy Chad Godsey.

Figure 10. No-till corn in Garfield County.

Mesonet (http://www.mesonet.org/index.php/agriculture/monitor). This is the recommended method for determining optimal planting date.

Dryland corn should be planted at a population from 19,000 to 25,000 seeds per acre. Corn planted in the western part of the state should be on the lower end of the range. Corn planted in the eastern half of the state should be on the upper end of the range. Keep in mind that water requirements of corn only decrease if population is less than 18,000 plants per acre. Also, hybrid selection may influence planting density, so ask seed company representatives if your selected variety performs better at a lower or higher plant population. Seed should be planted at a depth of 1.5 to 2 inches for a fine textured soil and at a depth of 2 to 2.5 inches for a coarse textured soil. Planting depth is critical for proper germination.

Canola

Winter canola was first established in Oklahoma as a weed management option when utilized in a winter wheat rotation. Since its adoption, winter canola has become a major profitable crop and has shown to work great in a one-in-three year rotation with winter wheat in no-till and reduced till systems. Rotation with a winter broadleaf crop has given producers a wider range of herbicide chemistries to control many problematic winter annual grassy weeds. This rotation has also shown to improve certain soil characteristics.

The success of direct seeding winter canola into wheat stubble has been an obstacle for some producers. These issues often are related to stand retention throughout the winter rather than initial stand establishment. The decrease in stand may be due to several factors related to crop residue management, micro-climate differences at the surface in no-till, crown height of canola plants, etc. There are some general guidelines and recommendations that can increase winter survival in a no-till system.

From research during the last several growing seasons, we have identified that stand establishment is not the problem as long as equipment is set correctly at planting. In general, the rate of emergence and total percent emergence (based on 5 lb/ac seeding rate) has been similar between no-till and traditional tillage. In some cases, we have observed a higher rate of emergence in no-till systems due to higher soil moisture content near the soil surface. Higher soil moisture is a characteristic of no-till systems. We found 40 percent to 60 percent total emergence in our studies regardless of treatment, which is common, especially with a small seeded crop such as canola. Achieving a stand in no-till is not difficult, but keeping it is more challenging. Generally, winter survival will decrease 10 percent to 20 percent in no-till fields where the stubble is retained and not removed or burned.

Seed Placement and Residue Thickness

Getting good seed to soil contact is important, especially in heavier residue. Placing the seed too shallow and not penetrating the soil surface will result in a shallow-rooted canola plant. Often the roots may not even penetrate the soil surface and simply develop underneath the residue. Achieving uniform seeding depth is more easily done when residue has been evenly distributed the width of the combine header at wheat harvest. The use of a harrow (if possible) or burning the residue are useful management options, if residue is not evenly distributed or is too thick. If burning is deemed your best option, burn just prior to seeding to help conserve soil moisture. Unfortunately, minimum disturbance grain drills can lead to more winter stand loss in heavy residue fields if soil conditions are dry and early fall freezes occur. Utilizing equipment that is more aggressive at moving residue away from the seed furrow and/or tilling a narrow strip for the seed furrow is often preferred. More aggressive seeding options include shank or hoe type openers, wavy or fluted coulters, row cleaners (more options available on planters), or strip tillage.

Crown Height

Often in heavy residue, elongation of the canola hypocotyl is observed. The hypocotyl is defined as the part of the plant that is below the cotyledons and above the seed. An elongation in the hypocotyl will increase the crown height of the plant. The crown height is important because this is directly related to winter survival. The closer the crown is to the soil surface, the better your chances for winter survival. Crown height is a plant characteristic that should be considered when choosing a variety/hybrid. Most companies have good information or ratings for crown height.

Soil Temperature

Soil temperatures in no-till fields will be lower compared to conventional till fields with no residue on the surface. Wheat residue buffers soil temperature fluctuations at the 0.5-inch to 1.5-inch depth. Lower soil temperatures in soil with residue may reduce crop growth. For this reason planting in the early part of the "planting window" would be recommended. If possible, removing just a little of the residue from the row will instantly increase soil temperature in that area. Using a more aggressive coulter or row cleaners may move enough residue to increase soil temperature in the seed zone.

Soil bulk density

Differences in yield between no-till and conventional tilled fields seem to be influenced by bulk density. Bulk density is the mass of soil divided by the total volume it occupies. A compacted soil has a very high bulk density. In a greenhouse study, to determine the effect of soil bulk density on winter canola root growth, root biomass decreased linearly with increasing bulk density for both sandy and clay soils. This means that higher bulk densities could reduce winter canola root mass, which may reduce winter survival. Canola plants rely on carbohydrates stored in the root mass to survive the winter months. This means that careful attention needs to be paid to soil physical properties in no-till fields. This especially true for young no-till fields (less than three years no-till) before seeding canola. It is common for bulk densities in young no-till fields to be 1.4 to 1.5 g/cm^3. Caution should be used when seeding into a no-till field with a high bulk density. It takes several years (more than three years) for good soil structure to develop in no-till fields.

Yield of no-till winter canola is often influenced by the factors mentioned previously. Yield can be competitive with conventional till fields once you gain experience with no-till canola production. However, the risk for stand loss and yield loss is greater in no-till fields compared with conventionally tilled fields. Producers can be successful with no-till winter canola, but careful attention must be paid at planting time.

Chapter 12

Cover Crops in No-till Systems

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Introduction

In areas of western Oklahoma (precipitation less than 35 inches per year); the use of cover crops in dryland cropping systems has generally been viewed as unacceptable due to the limited rainfall. During the last quarter of a century, crop production has switched from a relatively diversified system to a continuous winter wheat system. Wheat is often grazed, since many producers rely heavily on the production of beef as their main source of income. The current general consensus of many producers in the western part of Oklahoma is that no suitable summer crops exist for their climate and no suitable alternative exists to replace wheat forage for cattle. Consequently, they are reluctant to grow anything except winter wheat. The quality of winter wheat has continued to decline in this area due to increased weed and insect populations as a result of minimal crop rotation. No-till systems have not become popular in this region because of yield reduction and/or increased crop protection costs that can occur under no-till with continuous winter wheat. In order for Oklahoma producers to optimize their no-till cropping systems, they must be willing to rotate crops. One potential is through the use of cover crops, especially during the summer months when temperatures are high and rainfall is highly variable. Cover crops may be cheap, and if legumes are used, they may reduce nitrogen fertilizer inputs for the following crop.

> *"Cash crops grown are wheat, cotton, corn, milo, cowpeas, canola, and hay, along with cover crops…use cover crops to start a no-till rotation."*
>
> **A. Mindemann**
> **Apache, OK**

Cover crops in a No-till cropping system can:

- Provide soil cover
- Prevent soil erosion by wind and water
- Be annual, perennial, or biennial plants
- Can be grown during all or part of the year
- Fix nitrogen in the soil
- Suppress weed, insect pests, and diseases

Cover crops contribute a variety of conservation benefits. For water conservation, they offer an opportunity to utilize moisture that would otherwise be lost to evaporation during the fallow period. This is particularly true for the summer fallow period between wheat crops. In fact, on average a continuous wheat rotation in Oklahoma will lose approximately 60 percent of the water falling as precipitation to evaporation (Warren et al, 2009). A living cover crop can transfer this useless evaporation to useful transpiration to grow the cover crop. The aboveground biomass generated protects the soil surface from crusting and reduces erosion. This, along with increased porosity resulting from root growth, improves water infiltration. After termination, the residue remaining on the soil surface continues to minimize evaporation rates.

When selecting a cover crop or mix of cover crops, it is important to identify your objectives. As mentioned, cover crops can be used for production of surface residues. Additional objectives may be to break pest cycles, provide habitat for beneficial in-

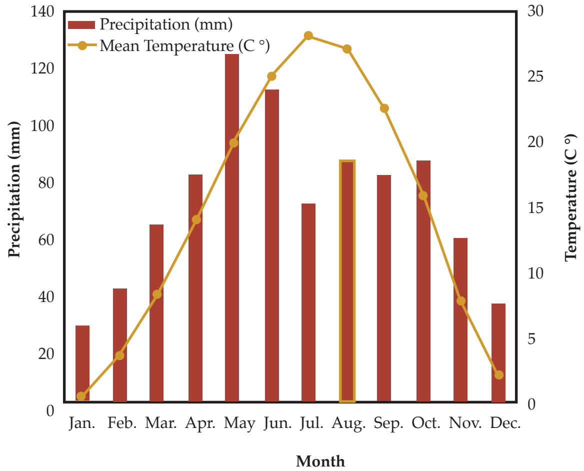

Figure 1. Average monthly precipitation and mean monthly temperature for Garfield County Oklahoma.

sects or wildlife, alleviate compaction, produce nitrogen or provide for supplemental grazing.

Cover Crops in Rotation

Cover crops can fit well into many different cropping systems during periods of the year when no cash crop is being grown. In some areas even the simplest corn/soybean rotation can accommodate a rye cover crop following corn, which will scavenge residual nitrogen and provide ground cover and forage in the fall and winter. When spring-killed as a no-till mulch, rye provides a water-conserving mulch and suppresses early-season weeds for the following soybean crop.

In Kansas, Claussen (2004) evaluated late-maturing soybeans as a cover crop. He found that they reached an average height of 24 inches, showed limited pod development, and produced 2.11 tons per acre of above-ground dry matter, with an N content of 2.11 percent, or 90 lb per acre. Sunn hemp averaged 72 inches in height and produced 3.19 tons per acre with 1.95 percent N, or 125 lb per acre. Soybean and sunn hemp suppressed volunteer wheat to some extent, but failed to give the desired level of control ahead of the wheat. Also, when averaged over N rates, soybean and sunn hemp significantly increased grain sorghum yields, by 9.7 and 13.4 bu per acre, respectively.

Perhaps the greatest challenge for dryland producers in the southwestern part of the U.S. is storing and using the precipitation they receive throughout the year. Figure 1 illustrates the average monthly precipitation and mean monthly temperatures for western Oklahoma.

Production of continuous winter wheat is the common practice in the area so producers are not fully taking advantage of moisture they receive during the summer months. If we assume 40 percent water storage efficiency for a no-till system, then 5.5 inches of water is lost during a given year or >15 percent of the precipitation they receive. Summer moisture has the potential to produce cover crops and use the soil moisture that may otherwise be lost during the fallow period.

Table 1. Percent nitrogen in legume tops and roots. (McLeod, 1982)

Crop	*Tops %N*	*Roots %N*
Soybeans	93	7
Vetch	89	11
Cowpeas	84	16
Red Clover	68	32
Alfalfa	58	42

Nitrogen Contribution

One of the biggest obstacles with nitrogen contribution from cover crops is estimating or measuring the amount of nitrogen that a given cover crop will contribute to the following crops, especially in a no-till system. A review of the literature provides wide ranges of nitrogen contribution from various nitrogen fixing cover crops (McLeod, 1982; Claassen, 2004; Heer and Janke, 2004).

Nitrogen production from legumes is a key benefit of growing cover crops, especially with the recent increase in nitrogen prices. The amount of nitrogen available from legumes depends on the species of legume grown, the total biomass produced, the percentage of nitrogen in the plant tissue and the rainfall and temperatures experienced after termination of the cover crop. These factors influence

Figure 2. Cowpeas planted following wheat harvest in Major County.

Photo courtesy Chad Godsey.

the amount of N that can be released to the cash crop, and the rate at which it is mineralized to a form that can be utilized by the crop. Cultural and environmental conditions that limit legume growth, such as a delayed planting date, poor stand establishment, and drought will reduce the amount of nitrogen produced. Conditions that encourage good nitrogen production include getting a good stand, optimum soil nutrient levels, soil pH, good nodulation, and adequate soil moisture.

Generally, for legumes, each ton of biomass will contain approximately 50 pounds of N for most legume species prior to flowering and 40 pounds of N after flowering. The portion of green-manure nitrogen available to a following crop is usually about 40 to 60 percent of the total amount contained in the legume. For example, Hoyt (1987) estimated that 40 percent of plant tissue nitrogen becomes available the first year following a cover crop that is chemically killed and used as no-till mulch. Lesser amounts are available for the second or third crop following a legume, but increased yields are apparent for two to three growing seasons.

Nitrogen contributions in a no-till system will no doubt be affected by lack of tillage operations. Table 1 shows percent nitrogen in above and below-ground root mass. The most effective way to understand the amount of N supplied by a cover crop is to utilize sensor-based N recommendations combined with an N rich strip. This takes the guess work out of determining how cover crop N availability will impact your in-season N requirements. Another important thing to remember is that mineralization (release) of organic N from the cover crop takes time. Therefore you must plan on utilizing it late in the season, this being the case it is important to continue to use pre-plant or starter fertilizers to get the cash crop started and prevent early season deficiencies.

Pest Suppression

In addition to providing ground cover, and in the case of a legume, fixing nitrogen, cover crops also help suppress weeds and reduce insect pests and diseases. Weeds flourish on bare soil. Cover crops take up space and light, thereby shading the soil and reducing the opportunity for weeds to establish themselves. Providing weed suppression through the use of allelopathic cover crops and living mulches has become an important method of weed control in sustainable agriculture. Allelopathic plants are those that inhibit or slow the growth of other nearby plants by releasing natural toxins, or "allelochemicals." Cover crop plants that exhibit allelopathy include the small grains like rye and summer annual forages related to sorghum and sudangrass. The mulch that results from mowing or chemically killing allelopathic cover crops can provide significant weed control in no-till cropping systems. Claassen (2004) observed soybean and sunn hemp effectively suppressed volunteer wheat and, in the fall, reduced the density of henbit compared to areas having no cover crop.

Organic Matter and Soil Structure

A major benefit obtained from green manures is the addition of organic matter to the soil. During the breakdown of organic matter by microorganisms, compounds are formed that are resistant to decomposition, such as gums, waxes, and resins. These compounds—and the mycelia, mucous, and slime produced by the microorganisms—help bind together soil particles as granules, or aggregates. A well-aggregated soil is well aerated, and has a high water infiltration rate. An actively growing root system has significant impacts on soil structure as well. The roots can serve to prevent consolidation of the soil and create biopores as they grow. The next time you are out in the field of an actively growing crop with a soil sampling probe or a steel rod try this experiment. First, push the rod into the soil between the rows. Notice any resistance, especially at the surface. Then push the rod into the soil right next to a plant crown. You should find that it is easier to push the rod into the ground next to the plant. This is most evident when soils are somewhat dry. The affect is due to the high density of roots near the crown of the plants.

Limitations of Cover Crops

The recognized benefits of cover cropping—soil cover, improved soil structure, nitrogen from legumes—need to be evaluated in terms of cash returns to the farm as well as the long-term value of sustained soil health. For the immediate growing season, seed and establishment costs need to be weighed against reduced nitrogen fertilizer requirements and the effect on cash crop yields. Water consumption by green manure crops is a concern and is pronounced in areas with less than 30 inches of precipitation per year. Additional management is required when cover crops of any sort are added to a rotation. Utilizing cover crops requires additional time and expense when compared to having no cover crop at all. Insect communities associated with cover crops work to the farmer's advantage in some crops and create a disadvantage in others. For example, certain living mulches may enhance the biological control of insect pests but may serve as a host to non-beneficial pests. Therefore it is important to study these interactions and select cover crops that are well suited for your production goals. Because there is a multitude of cover crop species and management options it may be difficult to find research data that is specific to your system. Therefore, it is useful to experiment with cover crops, perhaps with strips of cover crops planted in an otherwise fallow field or perhaps cover crop half of each field so that you can observe the benefits of the cover crop compared to your standard practice. Detail descriptions of a variety of cover crops, their benefits and limitations can be found in the book "Managing Cover Crops profitably" which is available in hard copy or pdf at http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition

Summary

The use of leguminous cover crops has gained attention due to increased nitrogen fertilizer prices. In western Oklahoma, the lack of precipitation has precluded producers from including cover crops in their rotations. It is believed that the use of cover crops can be effective in using soil moisture that would otherwise be lost during the fallow period. Remember that inclusion of cover crops represents an additional layer of management to your cropping system. Also, some of the benefits such as improvements to the soil structure may take time to realize. Further challenges may exist when determining their impact on pest cycles. Other factors such as N production from legumes can be seen in the first year. If you are a keen observer of the affects that cover crops are having on your system, you can take advantage of those benefits that may not simply be increasing yield.

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Chapter 13

Grazing No-Till Cropland

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Grazing no-till cropland has historically gotten a negative reputation because of concerns associated with compaction. While compaction should be in the mind of anyone interested in grazing cropland, significant compaction only occurs when cropland is overgrazed. No-till cropland is no different than grass pasture in that if overgrazing occurs the damage can be dramatic and long lasting. Caution should be used when grazing no-till cropland. If managed properly, grazing can be a valuable component of a no-till system.

Soils

Soils that have only recently been converted to no-till are the most likely to be susceptible to damage from overgrazing. They are susceptible because when residues are removed through grazing, soils are prone to crusting. Young no-till soils have not yet developed stable aggregates, which reduce crusting and provide strength to counteract the downward force exerted by the grazing animal's hoof. Furthermore, the biological activity is not fully developed in a young no-till soil. As the population of burrowing insects and earthworms increases, they are better able to open the soil surface after crusting from rainfall or heavy hoof traffic. This is not to say that new no-till soils can't be grazed, it simply means that care should be taken when doing so.

Not all soils are created equal relative to their susceptibility to damage under grazing. Soil texture impacts a soil's susceptibility to compaction and crusting. Very sandy soils are difficult to compact and generally contain little or no structure; therefore, compaction and crusting will have little impact on water infiltration and root growth. At the other end of the spectrum, clay soils are generally difficult to compact. In addition, clayey soils will generally shrink and swell during wet/dry events, which will alleviate compaction if it occurs. However, if a clayey soil has low aggregate stability, root mass, and residue coverage, the cracks that form can be far apart with large blocks of soil between them. If the surfaces of these large blocks are crusted, they will be challenging to plant into. This condition should be avoided through proper residue management. Very fine sandy loams and silt loams can be compacted under a relatively wide range of moisture levels and they often don't contain enough clay to readily shrink and swell during wet/dry events. They can provide the greatest challenge when grazing. Caution should be exercised on these textures, particularly during the first years following conversion to no-till.

Residue Management

Most of the damage from grazing occurs because of too much residue removal. Although grazing "compaction" is often blamed for any difficulty in planting after grazing. The real culprit is generally the lack of residue. Removing residue through grazing allows for crusting and poor water infiltration. This results in a very dense surface soil condition that will be drier than a surface with residue coverage. This scenario is most likely to occur in a graze out system. Another concern with the graze out system is that unlike dual purpose grazing where animals are removed in late winter, they are allowed to graze through the wet spring season. Grazing during extended periods with wet soil conditions increases the potential for true compaction from grazing. However, even this compaction can be minimized by utilizing a stocking density that allows for maintenance of surface coverage. One thing to also keep in mind is that a healthy actively growing root system is effective in preventing soil compaction. Generally, to ensure a healthy root system, maintain 60 percent ground cover as green growing biomass during the grazing period. This is true for both dual purpose and graze out systems. Furthermore to prevent crusting during the fallow period it is preferred to allow regrowth after the animals are removed to regain 100 percent ground cover or utilize cover crops to regain residue.

Graze out provides an excellent opportunity to utilize cover crops. Because cattle are generally removed earlier than when grain is harvested, cover crops can be planted earlier allowing for a longer growing season. This increases potential for N fixation in legumes prior to establishing the next wheat crop. They also represent an increase in crop diversity in the no-till system, which can break pest cycles, while providing opportunity for additional on-farm forage production. Historically, grazing cover crops has been frowned upon, yet grazing provides an opportunity to generate some revenue during the fallow period. Cover crops may serve to improve your operation's resilience to summer drought by providing additional forage on your farm, which will decrease pressure on your grass pastures. However as with grazing wheat, utilizing cover crops for grazing results in tradeoffs. Specifically, grazing will remove residue. If your primary goal in planting cover crops is to regain residue, then grazing will limit the effectiveness of the cover crops.

Another important consideration is the impact of grazing cover crops on nutrient cycling. More research is needed to truly understand nutrient cycles in a grazed cover crop system. In general, grazing forages removes very little phosphorus and potassium from the soil system. There is potential for grazing to reduce the nitrogen contribution from legumes because N is lost in the form of NH_3 volatilization from urine and feces. Keep in mind that grazing is much preferred over harvesting hay, which certainly removes all nutrients in the cover crop biomass. For example, cowpea forage contains approximately 16 lbs P_2O_5/ton, 36 lbs K_2O/ton, and 50 lbs N/ton (Ayan, et al. 2012), which will be removed from the soil system if hay is harvested. Here again, your forage needs must be balanced with the cost of replacing these nutrients.

References:

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Chapter 14

Personal Experiences

Interview with Robert Greenlee
Okmulgee County, Oklahoma

Robert Greenlee of Morris, Oklahoma, first tried no-till in 1980 with a Haybuster drill. The primary reason was to facilitate double-cropping soybeans after wheat, which was difficult using a moldboard plow and disc. Labor, fuel, and erosion were not an issue. Chemicals were expensive (Roundup® was $80 per gallon) and not very good. He hit some exceptionally dry years and his first experience with no-till was pretty much a failure. The only good experience was with wheat for pasture. He just about went broke and sold the drill after three years.

Greenlee tried again in 1990, and switched to a planter for double crop soybeans. At the time, he was burning wheat stubble then discing, but this lost too much moisture. The soybeans would come up then die. The herbicide options had improved (Basagran®, Blazer®, and Poast®), but he continued to cultivate. This time he mastered getting a stand and the soybeans would flourish, but he was still having weed problems. He decided, "This will work if we can control the weeds." He attended the Milan, Tennessee no-till field day in 1993 or 1994. He started out experimenting with a few acres, maybe 10 percent of the total acres, and during the next few years increased the no-tilled acres.

In 1995, Greenlee started to no-till corn on a limited scale, seven acres the first year, 30 acres the second year, and continued to increase. Robert said he received his first yield monitor in 1992 or 1993 and that opened a new world. He found that no-till was yielding a little more than conventional tillage. He was getting a three to five bushels per acre increase where he did not cultivate and quit cultivating altogether in about 1997 or 1998. In the early 1990s, it was no-till that was the trial in a field, but by the late 1990s, conventional tillage had become the trial. In 1995, he planted his first Roundup Ready® soybeans, and weeds became a nonissue. Double crop beans became more feasible.

Photo courtesy Greenlee family.

According to Greenlee, "In 2002 I pretty much committed to 100 percent no-till on every acre." His partner (Mark White) threatened to cut the tongue out of the disc. He is no-tilling soils where he was told by the neighbors it would not work and has found it has improved yields on some hard-to-manage soils. He no longer needs to rebuild terraces. He did not experience a yield reduction with no-till, but it took three to four years for a yield increase. Interestingly, Greenlee now plants wheat no-till with a conventional drill. Greenlee and White are asking themselves if they really need the coulters on the planter. Greenlee said a key is getting a good stand and that requires good seed-to-soil contact. He recommends checking the neighbors, "know what's going on with the dirt, and if it's too wet, go fishing."

Greenlee stresses the following key points for success with no-till.

1. No-till works on any soil type.
2. It takes multiple years, as many as five, to condition the ground.
3. It takes some modification of planters and keep them in good shape.
4. Must keep the fields clean.
5. Harvest residue management is important, get it spread evenly, use spreaders not choppers.
6. 'No-till' is not 'No Management.'

Interview with Jimmy Wayne Kinder
Cotton County, Oklahoma

Rotation takes on several forms for no-till producers, but for Jimmy Wayne Kinder of Cotton County, it takes on the form of graze-out wheat.

"Forage is number one, wheat (grain) is number two," Kinder says. In any given year, when wheat is around $3.00 a bushel, approximately 50 percent of his 2,000 acres is grazed-out. But if the grain price goes up, the graze-out percentage goes down.

Kinder feels his no-till wheat is able to produce more grain per acre than conventional production practices, because in wet years cattle bogging and trampling is not a significant problem on no-till. In dry years, there is little difference. He sees no difference in grain yield from his past conventional program and no-till today.

About a half mile north of his headquarters is a 25-acre field that has been in no-till production for nine years. It has been managed for wheat grain only until last year. The drought of 2005-2006 caused him to graze cattle on it. In continuous wheat production, Kinder has had some problems with grassy weeds, saying, "In no-till they haven't gotten any worse." He tries to graze-out his problem fields.

But in his other fields, he has seen a weed shift over the years in his no-till system. Purslane, thistles, and prairie cupgrass are specific weeds he notes finding.

The impact of no-till on Kinder's time came to the forefront. Farming conventionally, Kinder says, in the summer they "never had time to do anything but farm." Now he also has time for summer stockers. The conventional operation, including his father and brother's part of the operation, used to hire three to four youth during the summers and now one full-time hand is required. Kinder says that if not for the cattle, he probably would not need that hired hand. On the whole family's acreage, they used to spend as many as 10 days plowing terraces. When they farmed conventionally, they plowed and planted over terraces, but by using the no-till system, that terrace maintenance is no longer required. He also feels no-till should make the waterways last longer.

Looking around Kinders headquarters, very little equipment is seen. A few tractors, a couple of no-till drills, and a couple of sprayers is about all. He says the costliest are the drills. One of the main things that drove him to no-till was equipment. Kinder says, "tractors were worn out, equipment was worn out, and drills were worn out."

When planting, Kinder uses a fertilizer in the seed furrow that is about half urea and half 18-46-0. It comes out to be a 30-20-0 and he uses approximately 50 lbs per acre. He has been using the in-season sensor-based nitrogen management program for four years on about 50 fields. During the past five years, his operation has required very little nitrogen fertilizer.

His herbicide program centers around glyphosate, but includes 2,4-D when needed. He has noticed that in a no-till program, his weed control program works better when weeds are controlled at a young growth stage. Some of his neighbors who have tried no-till have had real difficulty with weed control because they were letting weeds get too large. Just from the cost of weed control, the dry summers are great for weed control in his no-till system.

Summers like 2006, the cost of chemical weed control was only about $5/acre due to only one or two trips being necessary. His sprayers are pulled behind pickups, each carrying 85 foot booms and can be pulled up to 15 mph in the field. The sprayers are equipped with ground-driven pumps. Putting out eight gallons of water, he uses flat-fan nozzles, even though he has tried air induction nozzles. The sprayer wheels line up with the pickup wheels and weed control is slower in those tracks. The spray rigs are equipped with GPS.

In a couple of closing thoughts, Kinder said, "I'm glad to tell you that my boys don't know how to plow," which is what most farm boys have grown up doing. He also mentioned that to do no-till, a new 'skill set' was required. Weed identification can be very important in a no-till system, and relating to conventional tillage "when plants are killed with iron, ID is not very important."

Summary of Producer Responses

Below are questions and replies from eight experienced no-till producers in Oklahoma. Some of the following you may have seen throughout the publication, but below are their full response to questions we asked. The authors encourage you to read through them and learn from their experiences and what they see as some benefits of no-till.

With your own experiences in mind…

1. What convinced you to give no-till a chance?

The lack of labor and the time savings.

Greg Leonard, Afton, OK

High fuel prices and the need for soil and water conservation. Also Roundup® resistant cotton varieties makes no-till much easier to manage.

Clint Abernathy, Altus, OK

One of the main reasons we started no-till was to lower input cost due to rising prices of fuel, fertilizer, and maintenance. As well as the opportunity to raise a crop that may increase profits for the farm and put nutrients back in the soil.

C. Trojan, Bison, OK

It was an economic driven decision. I purchased a no-till drill and rented other equipment as needed until I could build up my operation and afford necessary equipment.

A. Mindemann, Apache, OK

I went to a field tour near Tyrone in 1995. Bob Detricks had spoken to the OALP class when we were in the panhandle area a couple of months earlier and he peaked my interest. After seeing the demonstrations and going to the No-till On the Plains Conference in Salina that winter, I was sold on its benefits.

James Wuerflein, Kremlin, OK

My father began experimenting with no-till back in the 1970s and was favorably impressed with the results. Part of my experience growing up on the farm was planting no-till soybeans into wheat stubble and harvesting them in the fall. For me, no-till farming was a normal part of the farm.

Brent Rendel, Miami, OK

Started no-till with cotton production mainly because I have sandy ground and was always trying to protect small cotton from sand burn. Last couple of years has been because of labor shortage and fuel costs.

Dave Shultz, Altus, OK

The best reason to consider no-till is…less investment in machinery, labor is drastically reduced, rotating crops usually pays, and conserving moisture.

Ernest Trojan, Bison, OK

2. How long have you been using no-till? Briefly describe your no-till program.

I have been no-till planting double crop soybeans into wheat straw for 17 years. No-till wheat planting 14 years and on and off no-till corn planting for six years.

Greg Leonard, Afton, OK

Five years. Most of my no-till acres are on pivot and drip irrigation where cotton is produced. I have also had some success in planting dryland cotton following harvested wheat. It has reduced, and in most cases eliminated wind damage to young cotton.

Clint Abernathy, Altus, OK

We have had several farms in no-till for more than ten years, we continue to have fields in conventional tillage operation. The no-till operation continues to have higher yields on average. We have even split a farm in half tilling one side that had been in no-till for three years and no-tilling the other side. The side that was no-tilled raised ten to fifteen bushels an acre more than the tilled side.

C. Trojan, Bison, OK

Since the early 70s. No-till wheat (2,500 acres) double cropped into No-till soybeans (2,600 acres) every year back to wheat.

Larry Davis, Miami, OK

Eleven years. Continuous no-till rotations are used on all farmed acres. Cash crops grown are wheat, cotton, corn, milo, cowpeas, canola, and hay along with cover crops.

A. Mindemann, Apache, OK

June 1996, on my first two fields. I started slowly at first, then expanded into other fields over the next several years. I had a JD 750 15-foot drill and as I did more acres it could not keep up. My brother and I decided we needed to either go back to all tillage or sell the equipment and go all no-till. No-till was the easy choice as we could already see benefits that were occurring on the fields we had been using it on the first few years. We have been totally no-till for six or seven years. We have a JD 1890 36-foot air drill and a JD 1770 12 row 30-inch conservation planter. With less tillage we now have time to do custom planting which helps pay the bills. We hire all spraying by the COOP.

James Wuerflein, Kremlin, OK

No-till has always been a part of my farm. In the past, virtually all of my no-till was limited to double-cropping soybeans behind wheat. The no-till system is ideal for that crop since time is very limited to get the soybeans planted after the wheat is harvested. No-till provides the fastest way to get the crop in the ground and it also provides the advantage of preserving soil moisture throughout the summer. In recent years, I have begun to incorporate no-till wheat and non-double-crop, no-till soybeans into my farm.

Brent Rendel, Miami, OK

Started 35 acres of no-tilling in row crops in 1998. We went all no-till row crop in 1999. Small acreage of wheat no-till in 2004, 500 acres in 2005, and total no-till in 2006. Total no-till 3,000 acres since wheat harvest 2005. On row crop, cotton, or sorghum usually plant cover crop of wheat, usually 30 to 35 pounds per acre. I usually plant around November 1 or immediately after seeding wheat for harvest, usually burn down in March to April, depending on size of wheat, before heading. If there is good moisture, I sometimes plant into wheat stubble after harvest for double crop. I usually put liquid fertilizer down when planting row crop. Roundup® for weed control as needed. On wheat production, I usually seed around October 15 to November 15, depending on moisture and weather conditions. I only do grain production, so no grazing. Last year, I put liquid down as sowed wheat and top-dressed in February. I usually sow 80 to 90 pounds. This year, I pulled harrow after harvest to spread straw from combine. I also spray as needed, usually first spraying a quart Roundup® and 1/4 oz Cimarron®. Then it is control weeds as needed summer and winter.

Dave Shultz, Altus, OK

We have been using no-till 10 years…have had success and also failures. We have success with beans for at least five years planted after wheat. One year we planted a variety of milo our seed advisor selected, which yielded one hundred bushels. We plant registered seed wheat with no additional fertilizer, which yields 60 bushels.

Ernest Trojan, Bison, OK

3. What was your greatest obstacle to overcome?

Waiting for the ground to dry out and warm up or finding the right attachment for planting corn.

Greg Leonard, Afton, OK

Difficulties are weed control and timeliness. Timeliness is for weed control, planting, and harvesting. Some of our best crops have been when we have the combine, sprayer, tractor, and drill all working in the same field at the same time. Getting the manpower to be able to do this is a challenge. Compaction and not being able to just turn cattle out on the field for grazing.

C. Trojan, Bison, OK

Fertilizing methods-especially phosphorous applications.

Clint Abernathy, Altus, OK

Stand!! Extreme heat in late June, July into wet soil causes soil to set up like concrete, breaking the neck of the soybean.

Larry Davis, Miami, OK

The "It Won't Work Here" syndrome from neighboring farmers.

A. Mindemann, Apache, OK

What would the neighbors think? Am I just too lazy to be on a tractor all summer?

James Wuerflein, Kremlin, OK

Weed control has been and remains the greatest obstacle to no-till farming. The additions of herbicide-tolerant soybeans and corn have greatly aided in dealing with undesirable vegetation in the fields, but it still presents a challenge.

Brent Rendel, Miami, OK

Probably the greatest obstacle is weed control. It is a never ending challenge with resistance, weather, etc. Also, when you have been a conventional farmer it is hard when your fields look like they are full of trash, plus the neighbors want to know if you have quit farming or what is your problem. Strange thing though, is the ones that gave me fits are now beginning to do the same thing!

Dave Shultz, Altus, OK

The greatest obstacle seems to be the drastic changes in farming methods. Weeds are the largest challenge…learning chemicals to kill weeds, yet be able to plant your next crop without affecting the next crop. A no-till conference years ago posed the question, "What is the hardest part of change to a farmer?" Between the ears!

Ernest Trojan, Bison, OK

4. What would you do differently in beginning no-till?

Make sure you either own the equipment or have access to equipment when it is needed; especially spraying is very important to do when it is needed.

C. Trojan, Bison, OK

I would not be as conservative with chemicals. I tried to stretch chemicals at first and it is easier to go ahead and use recommended rates on first spraying, then you can cut back if conditions are right. Also, you need a good sprayer and planting equipment. Getting things at the right time really seems to matter.

D. Shultz, Altus, OK

Go all in at the start. Then you cannot be tempted to get the disc out.

J. Wuerflein, Kremlin, OK

Use cover crops to start a no-till rotation.

A. Mindemann, Apache, OK

Start with the right equipment, talk to experienced no-tillers, check your planter settings constantly, adapt, adapt, adapt!!

Larry Davis, Miami, OK

I would attend more no-till meetings and visit with farmers who have been using no-till for a while.

Clint Abernathy, Altus, OK

Spend a little more money and buy a better no-till drill that had better depth control and closing system.

Greg Leonard, Afton, OK

5. What would you consider to be your greatest success with no-till?

The first year of no-till we planted soybeans right after wheat and raised a great crop, the best we have raised to date.

C. Trojan, Bison, OK

The time and moisture savings, not to mention less labor and machinery needed has allowed me to double crop many more acres with less cost and stress.

Greg Leonard, Afton, OK

Water conservation.

Clint Abernathy, Altus, OK

Double cropping has been my bread and butter. Soybeans has been my big crop.

Larry Davis, Miami, OK

Successful summer crops in an area where traditionally they do not do well with conventional tillage.

A. Mindemann, Apache, OK

Seeing the neighbors start to adopt it into their farms.

James Wuerflein, Kremlin, OK

I think double-crop, no-till CONVENTIONAL soybeans is a great challenge and I am proud to say I have been very successful doing it.

Brent Rendel, Miami, OK

I am a total dryland farmer. I have had excellent yields on cotton, sorghum, and wheat—when the weather has cooperated…hard to make crops if you have no rain!

Dave Shultz, Altus, OK

The first time we planted beans after wheat yielded 35 bushels. Heck, seems like nothing to this no-till farming…filled a semi-truck each evening starting harvest after 5:00.

Ernest Trojan, Bison, OK

6. Will you continue/increase your no-till practices?

We continue to bring some of the ideas into some of the other farms, such as some years we may spray Roundup® instead of working the field. Also, we are looking at rotating crops in our fields.

C. Trojan, Bison, OK

I will continue my total no-till operation. I have one part-time employee and myself who work the operation. All harvesting is hired. I think as time goes on no-till land will be even better. My longest no-till fields feel like I am on a sponge when spraying.

Dave Shultz, Altus, OK

No-till will definitely remain in my arsenal of farming tools. As with anything else, I am always looking for ways to improve yields and reduce input expenses. In 10 to 20 years, I may not be using no-till, but for now, no-till practices provide my greatest profit per acre in many situations.

Brent Rendel, Miami, OK

I'm 100 percent no-till and would not go back.

James Wuerflein, Kremlin, OK

Yes, I am currently looking at several new ideas for cover crops and alternative cash crops.

A. Mindemann, Apache, OK

I plan to increase my no-till acres.

Clint Abernathy, Altus, OK

Plans are to continue to no-till 100 percent of my wheat into the corn stalks and the soybeans into the wheat straw, but at this time I am looking at strip-till for the corn.

Greg Leonard, Afton, OK

7. Do you have any advice to others who might be considering no-till?

Some years there will be a crop failure, other years there will be great success. Through our history the no-till has helped increase production while saving the moisture for the dry periods.

C. Trojan, Bison, OK

With fuel and machinery costs increasing at the rates they have in the past 10 years, I can't believe that there is anyone that has not tried no-till. You must be willing to commit to no-till and buy a drill made for no-tilling. You can add attachments and make a normal planter work in normal conditions. Most of all you should plan on spending some more time with your family as you will not be out there plowing and discing all night!

Greg Leonard, Afton, OK

I think that is a good farming practice and is worth trying, but don't expect miracles.

Clint Abernathy, Altus, OK

No-till requires constant attention. You have got to be on top of everything.

Larry Davis, Miami, OK

Find someone in the area who is being successful and do not listen to those who are not.

A. Mindemann, Apache, OK

Don't worry what the neighbors say because they too will eventually see the light. (Maybe they will have to wait for the blowing dust to settle first!) Rotate crops and do not think that there is only one right rotation. Your situation may be different.

J. Wuerflein, Kremlin, OK

I like the approach my father took 30 years ago and believe it is still the best approach…start slow and be ready to learn from your mistakes. No one farm is identical to another and the approach that works best for me may not work at all for you.

Brent Rendel, Miami, OK

Make sure the year before you start the hard pan is broken. Also make sure your ground is as smooth as possible. Remember it is hard not to go get a plow when things look like a wreck and your neighbors are talking about you, but if you plow you will mess up the soil structure and earthworm activity. Just remember the neighbors will be plowing while you are enjoying your family, lake, etc.

Dave Shultz, Altus, OK

8. List three positive points to no-till.

Soil holds moisture for better crop yield, higher yields, less cost overall, less disease from crop rotation.

C. Trojan, Bison, OK

Time savings, lower fuel costs, labor savings.

Greg Leonard, Afton, OK

Soil and water conservation, less fuel used, less labor.

Clint Abernathy, Altus, OK

Less labor, time, get over the ground better.

Larry Davis, Miami, OK

Soil improvement, better infiltration rates, structure and organic matter, better long-term profitability, and most importantly passing on farm land in better shape than I received it!

A. Mindemann, Apache, OK

Water infiltration—saving more water in the soil allows you to withstand the dry spells longer than conventional ground. Less erosion—you do not worry when the wind comes up if your ground is going to blow; as more water soaks in you have less runoff erosion. More time—your workload is spread out with crop rotations, giving you time off at certain times of the year, you can use it with family or leisure activities or farm more acres.

James Wuerflein, Kremlin, OK

Conserves soil moisture, conserves fuel, and sequesters carbon dioxide.

Brent Rendel, Miami, OK

Conserves moisture, conserves fuel, less equipment, more free time.

David Shultz, Altus, OK

9. List three negative points to no-till.

Weed control, everything must be done very timely, may have some failures trying new things.

C. Trojan, Bison, OK

Must be much more attentive to details when planting. I have found that it is very difficult to make no-till work when planting corn on flat not well drained soils. More reliance on chemicals.

Greg Leonard, Afton, OK

Costly changes in equipment, weeds are becoming resistant to some herbicides, herbicide drift damage to nearby crops.

Clint Abernathy, Altus, OK

More attention, hard to get stands in adverse years, and personally, I have to plant 2,500 acres in two weeks regardless of how many rains I get.

Larry Davis, Miami, OK

Getting Dad or Grandpa to change as they typically hold the purse strings, higher level of management needed, and having to listen to your neighbors tell you "it won't work."

A. Mindemann, Apache, OK

Less runoff—if you rely on runoff to fill your ponds for livestock (or fishing) you had better pray for floods. Inexperience with new crops—it may be the first time you grow some crops but there are experienced growers out there to ask as well as Extension staff. Where do you market them? (Some elevators would rather sit empty than put anything but wheat in the bins.)

James Wuerflein, Kremlin, OK

Tougher to control weeds, requires specialized (or modified) equipment to plant, and requires more intensive management.

Brent Rendel, Miami, OK

It is hard to give up old ways, need special equipment and usually expensive if buying all new, and the chemical cost is expensive.

David Shultz, Altus, OK

10. Is there anything you would like to add concerning your no-till experiences?

It has proven to be a great choice for us and we plan on continuing the no-till and bringing more of the experiences we have had into our other operations, even changing to more no-till in the future.

C. Trojan, Bison, OK

All growers should be ready for a shift in their weed species the longer they leave a field in a no-till system, but should also observe a great increase in their soils the longer it is no-tilled.

Greg Leonard, Afton, OK

I do not no-till corn. I cannot get the needed yield to justify it. I no-till an additional 500 acres of wheat into Bermuda sod each fall. I also bale and pasture, if harvested, I burn down then use Gromoxon® in late October.

Larry Davis, Miami, OK

Learning to manage no-till well has been one of the most exciting endeavors of my life, it's allowed me to be successful in a business that did not appear to have much future when I started.

A. Mindemann, Apache, OK

Long term no-till leads to improved: soil tilth and structure, soil health, water infiltration, raising organic matter percentage, less diesel fuel use, fewer hours on the tractor; crop rotations lead to more efficient use of combine, improved root health, crops harvested/marketed at different times of the year to take advantage of favorable weather patterns.

James Wuerflein, Kremlin, OK

It is a trial and error endeavor, just when you think you have it figured out something else happens, weather, weeds, insects, etc. Once you decide to do it, stick with it, be flexible and learn all you can from different sources. No-till conferences are very good, especially in your own area.

David Shultz, Altus, OK

****Editors note:*** We wish to thank all of our contributing producers for their generous sharing of experiences and insights. It is our hope that you have benefitted from these discussions. If you have further questions or need more information, please contact your county Extension staff. They will be glad to hear from you. Good Luck!

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OKLAHOMA STATE UNIVERSITY

EXTENSION