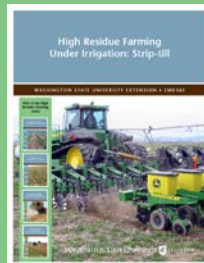
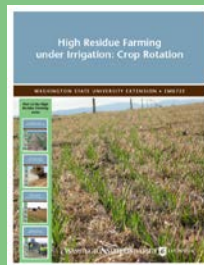
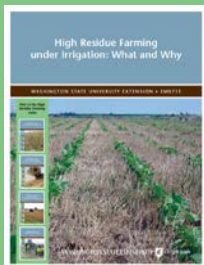


High Residue Farming under Irrigation: Residue Management Through Planting

WASHINGTON STATE UNIVERSITY EXTENSION • EM073E

Part of the High Residue Farming series



WASHINGTON STATE UNIVERSITY  EXTENSION

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High Residue Farming under Irrigation: Residue Management Through Planting

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This is the third in a series of publications on High Residue Farming under Irrigation. This publication explains how to plant crops into high residue conditions with a planter or drill. It covers residue management, planter and drill modification, and soil fertility adjustments. It starts by describing the desired conditions for the critical period from planting through seedling establishment, when high residue farming (HRF) is most different from clean-tillage farming. It then presents a range of tools that can be used to achieve these desired conditions in HRF. By being aware of the variety of tools available, you can choose the combination of tools that best matches your conditions, constraints, and goals.

For anyone wanting to implement or know more about a high residue farming system, the series includes:

EM071—High Residue Farming under Irrigation: What and Why provides an overview of high residue farming (HRF), including its benefits and challenges. It also discusses some special considerations for high residue farming in the irrigated agriculture regions of the far western United States (the “Far West”).

EM072—High Residue Farming under Irrigation: Crop Rotation covers choosing a cropping sequence, specific cover crops, and special considerations for irrigated cropping systems in the far western United States.

EM074—High Residue Farming under Irrigation: Pest Management Considerations gives an overview of the effects of adopting HRF on the management of weeds, insects, and diseases.

EM036—High Residue Farming under Irrigation: Strip-till covers the benefits, challenges, and implementation of strip-till planting. This high residue farming system combines some of the benefits of clean tillage systems with the high residue cover.

What is High Residue Farming?

High residue farming (HRF) is an umbrella term that covers cropping systems in which the volume of soil that is tilled is reduced in order to maintain residue cover of the soil. Crop residue covering the soil provides the many benefits of HRF, though the specific amount of residue will depend on the previous crop, the current crop, and soil and climate factors.

No-till, strip-till, ridge-till, and vertical tillage are all variations of HRF. Many of these terms describe the type of tillage used (for instance, strip-till) or not used (no-till) and most have other names, such as direct seeding for no-till, or zone tillage for shallow strip-till. Table 1 shows the range of tillage practices.

Because HRF is relatively new to the far western irrigated regions of the U.S., including parts of Washington, Oregon, Idaho, California, Arizona, and New Mexico

(Figure 1), there are few applicable local research results. The practices and recommendations presented here are based mostly on the research and experience from other regions. These are “best bets,” but you will have to adapt them to your specific conditions and crops, *tweaking* the system to your liking and finding *hacks* to improve performance (see below). Your commitment to innovate will be the key to maximizing the benefits of HRF while minimizing the downsides through management.

Desired Conditions for Germination and Emergence

Whether working in clean-till conditions (no surface residue) or in HRF, providing conditions that are as optimal as possible from planting through seed germination and seedling emergence is critical for establishing a good crop (Carter 1990). When yield reductions occur under HRF compared to tillage-based

Table 1. Classification of tillage systems by tillage intensity and residue coverage.

Classification	Primary Tool(s)	Tillage Intensity	Residue Coverage	
Clean-till	Moldboard plow	High, soil inversion	<30%	
Clean-till	Heavy offset disk	High	<30%	
Reduced-till	Chisel plow, disk	High	<30%	
Reduced-till, Minimum-till, Mulch-till	High residue farming (Conservation tillage)	Chisel plow	>30%	
Strip-till		Strip-till implement	Non-uniform, moderate-none, 6-12" deep	60-80%, bare soil in planted strip
Zone-till, Vertical tillage		Gang of coulters on planter, row cleaners	Non-uniform, moderate-none, 1-2" deep	60-80%, bare soil in planted strip
Direct seed, No-till*		Planter with row cleaners	None	60-80%, 0-80% in planted strip
Direct seed, No-till*		Planter without row cleaners	None	80-100%

*Direct seeding and No-till refer to the same practice.

Tweaking and Hacks – Not Just for Computer Geeks.

Both tweaking and hacks are important parts of implementing high residue farming successfully.

Tweak: Small changes to practices or machinery to tune for peak performance.

Hack: Any sort of trick, shortcut, skill, or new method to increase productivity and efficiency, in all walks of life; anything that solves an everyday problem in a clever or non-obvious way can be called a "hack." (Adapted from Wikipedia.)

systems, they are often due to differences between the systems during this phase. HRF requires increased management during this period and is generally less forgiving of mistakes. The good news is that after this period, the conditions for crop growth in a HRF system are generally superior to those in a clean tillage system.

Every crop has a unique range of preferred conditions for seed germination and seedling emergence. Yields of most crops, however, are greatest if the crop germinates and emerges uniformly and quickly. This is particularly true for corn. Uniformity of emergence is more important than speed, though both are desired. A crop that germinates and emerges uniformly will compete better with weeds while limiting competition between adjacent plants. The crop will close canopy sooner than non-uniform crop, and is easier to manage because the whole field is at the same stage at the same time. Harvest is generally easier too.

The best way to achieve uniform crop germination and emergence is to provide uniform conditions across the field at the time of planting. The first step to this is

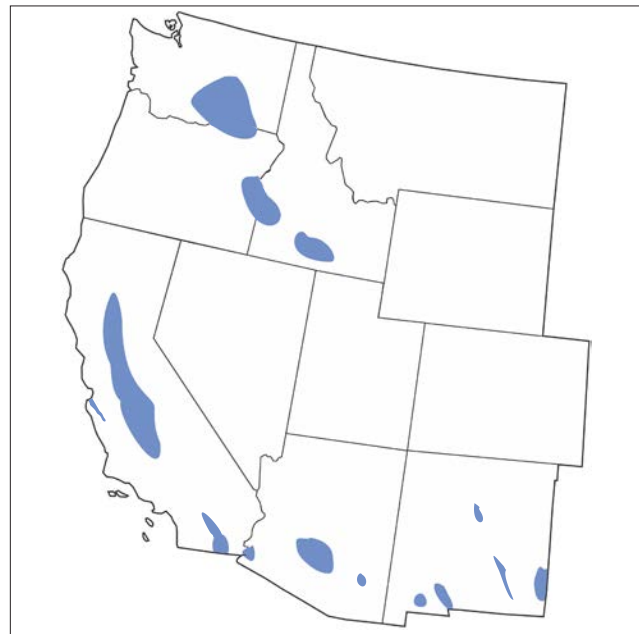


Figure 1. Irrigated vegetable-growing areas of the far western United States.

REMEMBER:

To get uniform germination and emergence, strive to provide uniform conditions across your field at planting.

achieving a uniform distribution of crop residue. This is critical because non-uniform residue distribution can cause a host of problems throughout the growing season (Smith 1986), including:

- Uneven emergence of early weeds, resulting in non-uniform soil water levels before planting;

- Decreased planter or drill performance;
- Uneven seedling emergence due to non-uniform soil temperatures, soil water levels, and nutrient availability;
- Increased disease potential and risk of insect or rodent infestation in residue piles;
- Reduced herbicide effectiveness due to non-uniform interception of herbicides; and
- Need for increased tillage to manage the residue.

The leading causes of non-uniform residue conditions are:

1. Uneven spreading of residue at harvest. Figure 2 shows wind-blown straw and chaff at harvest.
2. Ineffective attempts to fix #1. In Figure 3, one pass with a harrow has left piles of residue (indicated by arrows).
3. Attempts to do “just a little tillage.” In Figure 4, one pass of the disk necessitates more tillage to get back to more uniform conditions.
4. Small pieces of residue, unattached to the soil, can be moved by wind or water (Figure 5).



Figure 2. Wind can spread chaff and straw unevenly at harvest.



Figure 3. A single pass of the harrow only created more clumps of chaff, requiring yet more tillage to disperse residue more evenly.

5. Poor weed control before planting. Because weeds are not uniformly distributed, allowing them to grow too long creates non-uniform soil moisture and residue (from the weeds) conditions, as shown in Figure 6.



Figure 4. One pass of a disk is not enough to create uniform conditions.



Figure 5. Crop residue, unattached to the soil, is more easily moved into clumps by wind or water.



Figure 6. Poor weed control before planting allows clumps of weeds to grow, creating non-uniform field conditions.

In addition to uniform residue cover, you should aim for conditions that allow a crop to emerge as quickly as possible. Speed of germination and emergence minimizes the time when plants are most vulnerable to injury, water stress, and pests. It also allows full-season crops, like corn, to close canopy earlier, giving the crop time to attain its full yield potential.

To obtain quick germination and emergence, strive to provide near ideal conditions for the seed and seedling.

Needs For Germination

The primary needs for germination are water, soil temperatures conducive for germination, and oxygen (Bowen 1966). Emerging seedlings require these factors, plus nutrients, conditions allowing unimpeded root and shoot growth, and sunlight (Figure 7).

- Water initiates germination and supports seedling growth.
- Temperature affects the rate of germination and seedling growth with each crop having an optimum range. (See Resources.)
- Oxygen is required for metabolic processes during germination and seedling growth.

- Nutrients must be present in the right amount, in the right location, at the right time, and in the right form (4R Nutrient Stewardship, see Resources, below).
- Unimpeded root growth allows the seedling to take up water and nutrients from an increasing volume of soil.
- Unimpeded shoot growth allows the seedling to emerge and begin harvesting sunlight quickly.

Let's take a more in-depth look at each of these necessary components.

Water

Water is needed for germination and seedling growth. Seeds germinate most quickly when they are in direct contact with a film of water that covers soil particles, but seeds can germinate without soil contact by absorbing water vapor (Wuest 2007). At favorable temperatures, the difference in speed of germination will generally be no more than a day in all but the driest soils.

Since the water vapor level in untilled soils is generally greater than that in tilled soils (Scotter 1976), getting good

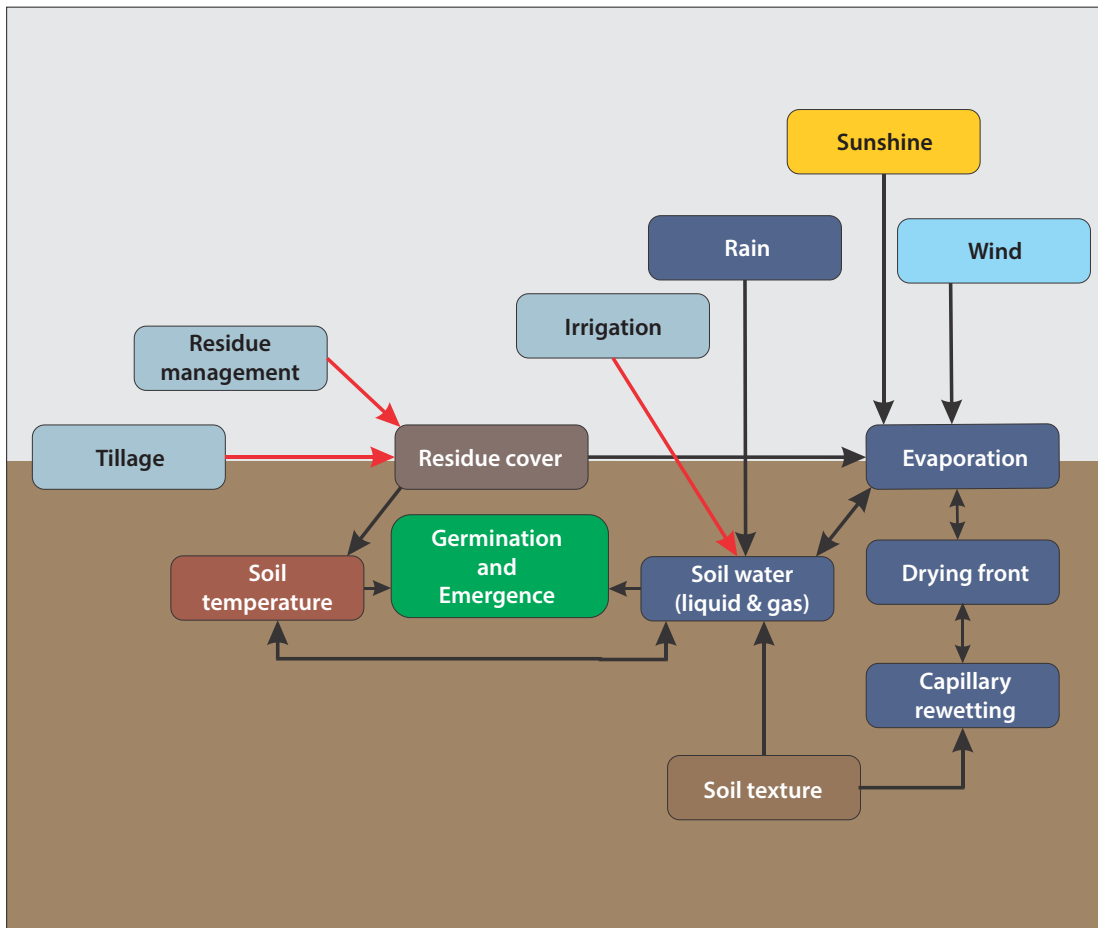


Figure 7. Interplay of factors, above ground and below, that affect germination and emergence of the crop.

seed-to-soil contact may be less important under HRF than in tilled soils. This may explain why most studies looking at the effect of tools that increase seed-to-soil contact with direct seeding have not found many benefits to stand establishment (Staggenborg et al. 2004; PAMI 2000).

A more significant danger is that soil surface evaporation, driven by sunshine and air movement, will dry the soil all the way to seed depth, delaying or preventing germination. During the day, a net water loss in the upper layers of soil can drive the “drying front” downward toward the seed. But in the evening, when evaporation diminishes, water moves up from below by capillary action to recharge the upper soil layers. As long as the seed remains below the drying front, germination is not affected.

In HRF, the residue cover reduces the water evaporation by blocking sunshine and reducing air movement. This slows the loss of water and decreases the risk of the drying front reaching seed depth. In bare, tilled soils or sandy soils and with shallowly planted seeds, there is increased danger of the drying front reaching the seed.

Once the first root emerges, this danger is usually over as the root can grow downwards faster than the drying front can (Bowen 1966), assuming the root encounters soil conditions conducive to such growth.

Temperature

Temperature affects the speed of both germination and emergence, as well as the availability of some nutrients. Under tillage, most crops are planted at dates when the soil temperatures are well within preferred ranges, so soil temperature is not a primary factor in the overall success of the crop. In HRF, however, residue cover results in reduced soil temperatures. Research has shown that these cooler soils do not reduce yields for most agronomic crops in well-drained soils with normal spring weather. The exceptions are at northern latitudes and when growing corn.

An extensive review of research results in the Corn Belt revealed that, while the overall difference between no-till and conventional corn yields was negligible, no-till corn yields in the northern U.S. (> 43° N latitude) were 5.5% lower than conventional yields on average (DeFelice et al. 2006). The likely cause for this is the delay of germination and emergence caused by cooler soil temperatures. In northern latitudes, the plant cannot make up for the germination delay and associated loss of growing season by additional growth in the later part of the season (as it can in regions further south with longer growing seasons) and so yields are reduced. This explains why research has shown the most consistent benefits from tools that lead to warmer soils in these regions (Archer and Reicosky 2009). If you farm at northern latitudes or grow corn, you will want to become familiar with the tools, discussed later in this publication, that lead to increased soil warming in HRF.

In other regions, reduced no-till corn yields have most often been associated with heavy, poorly drained soils or wet, cool spring seasons, reinforcing the conclusion that warm soils during germination and emergence are particularly important for corn.

Interaction of water and temperature

Soil temperature is related to soil water content, especially near the soil surface. Given the same weather conditions, a wet soil will warm more slowly than a dry soil. This is because incoming solar radiation goes toward evaporating the water in the soil before it starts to warm the mineral particles. Thus sandy soils, which hold less water, warm up more quickly than loam or clay soils. Similarly, well-drained soils warm up faster than poorly drained soils.

Bare and residue-covered soils will have similar temperatures until the bare soil begins to dry out. Then the bare soil will warm faster than the residue-covered soil, mainly because of the additional water remaining in the covered soil (Bristow 1988). As noted above, cooler soils can be a problem at planting time, but they are also a benefit later in the season when air temperatures are high.

Moving residue off untilled soil can allow the soil to warm more quickly. Figure 8 illustrates that most of the warming benefits come from residue removal, with only small warming benefits from tillage.

Oxygen

Oxygen enables the metabolic processes required for germination. Oxygen, as a component of air, flows through soil pores; therefore, the more pore space there is (that is, the more permeable the soil is), the better the oxygen flow, unless the pores are filled with water. A

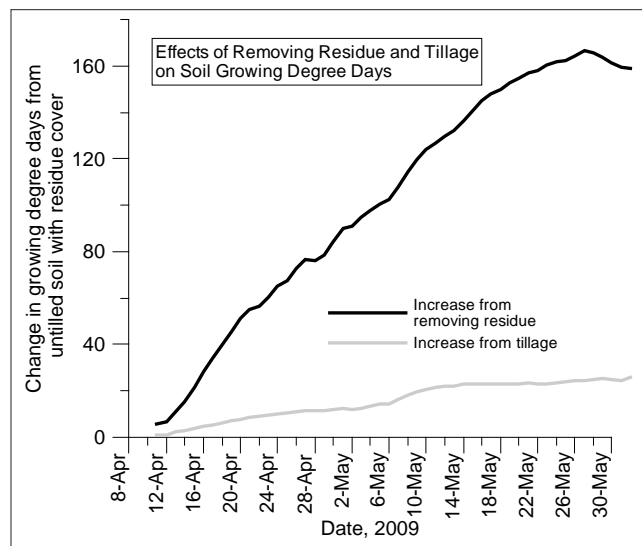


Figure 8. Comparison of effects on soil growing degree-days of removing residue with tillage.

wet or poorly drained soil will supply less oxygen than a dryer or better drained soil, given equal pore space.

Air-filled pore space, especially in the case of macropores (>0.08 mm), can be reduced by compaction, irrigation, surface crusting, and tillage (although tillage can also improve the permeability of a compacted soil in the short term).

Sandy soils tend to have adequate pore space in both clean-tilled and HRF systems. Fine textured clays and loams are generally less permeable (have fewer, smaller, or less interconnected pore spaces) than sandy soils. Nonetheless, untilled clay and loam soils generally have sufficient stable macropores for good air permeability, except when saturated with water or compacted.

For Seedling Emergence

Water, temperature, and oxygen remain important for seedling growth and emergence, but once the first root shoot (radicle) and stem shoot (hypocotyl in broadleaved plants or coleoptile in grasses) penetrate the seed coat, additional factors become important.

For successful seedling growth and emergence, the root and stem shoots must be able to grow into the soil, either through pores of sufficient number and size or through soil whose strength is low enough to allow upward and downward growth. If there are no pores or the soil strength impedes growth, or both, then the seedling will grow laterally searching for a way down (roots) or up (stem).

Curtailed root growth may limit the water supply to the seedling and reduce seedling vigor. Blocked stem growth will delay emergence, postponing the beginning of photosynthesis and giving an advantage to soilborne pests. If soil conditions are poor enough, seedling emergence may be prevented.

The soil conditions that promote root and shoot growth also promote beneficial oxygen levels in the soil.

Soil fertility

Once roots begin to grow, they can take up water and available nutrients. Yet in HRF, cooler soils can cause short-term nutrient deficiencies, even when there are sufficient nutrient levels in soils, for one or more of the following reasons:

- For nutrients derived mainly from the decomposition of organic matter (for example, nitrogen), slower decomposition rates in cool soils can limit supply to plants.
- Other nutrients are less soluble in cool soils.
- Cool soil temperatures slow root growth, reducing the volume of soils exploited for nutrient uptake.

Nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and zinc (Zn) are all susceptible to these effects. If not managed, deficiencies of these nutrients may be severe enough to cause visible symptoms. Although these deficiencies disappear when the soil warms up, they may slow plant growth enough to affect yield, especially in corn.

Even after the soil warms, crop residue can tie up nitrogen. Under clean tillage, incorporated crop residue decomposes and releases nutrients to the soil through mineralization. In contrast, most residue in HRF stays on the soil surface where decomposition and mineralization is much slower. Although this is how soil organic matter levels increase under HRF (providing a variety of soil benefits), it means that less nitrogen is available to your crop in the short term, and you will have to apply more nitrogen to maintain yields. But the immobilized nitrogen in residue is not lost—much of it will be incorporated into your organic matter pool and then released slowly over time. After a transition period, (3–5 years in other regions) the increased levels of organic matter releasing nitrogen will balance out any immobilization and crops will not require additional N (see sidebar for details).

Building Soil Organic Matter Levels Requires Nutrients

Soil organic matter has a carbon to nitrogen ratio of about 12:1. When residue, with its lower nitrogen content (C/N ratios of 30–70:1) is incorporated into the soil, organisms involved in decomposition take up nitrogen from the soil to make up the difference. This means that nitrogen applications will probably need to be increased, at least for the first few years of HRF. On average, a 1% increase in soil organic matter will require, over time, 940 lb. of N, 400 lb. of P, and 80 lb. of S.

Another challenge is the stratification of nutrients (and sometimes pH) that can occur under long-term continuous HRF management. Tillage mixes the top 6–12 inches of soil, creating a uniform layer. Without tillage, immobile nutrients from fertilizer or soil amendments tend to accumulate at the surface. When farmers in the Midwest first started continuous no-till cropping, some thought that they would eventually have to till the soil to incorporate phosphorus and potassium. Instead, farmers found that the soil under the residue cover stays wet enough (from reduced evaporation) to allow crop roots to proliferate in the surface soil where they can take up broadcast nutrients (Newell and Wilhelm 1987). This process works best after several years of building up residue mulch and soil structure. Stratification of nutrients may still be an issue

in getting seedlings established, but is not a problem once plants are established, as long as a residue cover is maintained.

Sunlight

After the shoot emerges, it needs sunlight to begin photosynthesis. Deep residue cover can physically block sunlight from reaching small seedlings, slowing early growth, and residue that is not spread uniformly can lead to uneven seedling growth. Especially for corn, any residue left covering the row should be uniform to promote even seedling growth. Another option is to remove the residue from the crop row. More information on this is given in the Planting into Residue section, below.

The height and orientation of the residue can also affect early sunlight interception. Tall, standing residue can shade seedlings enough to reduce yield, especially with corn for which you want as much sunlight as possible.

Management Tools for Achieving Desired Conditions

Obtaining the desired conditions for uniform and quick germination and emergence, or getting as close as possible, requires that you know what tools and strategies are available, and when and how to use them to address the specific issues of HRF. They include:

1. Crop rotation
2. Residue management
3. Nutrient management
4. Planting

Crop rotation is discussed, in depth, in a separate WSU publication, EM072—*High Residue Farming under Irrigation: Crop Rotation*. The other topics are covered in the sections below.

Residue Management for Optimal Germination and Emergence

The challenge with HRF is managing the crop residue to reduce or eliminate problems, particularly at planting, while keeping the beneficial effects of residue cover intact. There are specific practices and tools for managing residue during, and after, harvest. The main goal of these tools is to spread residue uniformly, which is the key to making the HRF system work smoothly from planting through harvest.

At Harvest

Residue management starts at harvest. The first step is deciding how high you will harvest the standing crop. Cutting low will leave less standing residue, but also increases the workload of the combine and makes uniform spreading more difficult. Cutting higher will leave more standing residue that can shade out the following crop. Normally, you want to cut at a height that will not interfere with the equipment that will be planting the next crop, but that leaves as much residue upright and attached to the ground as possible (Jasa et al. 1991). This height depends on the following crop and other features of your residue management plan, but for corn, 18 inches often works, while for wheat, 12 inches is a good starting point.

Soil under the cover of residue stays wet enough (from reduced evaporation) to allow crop roots to grow right at the soil surface where they can take up broadcast nutrients.

Leaving as much residue as possible upright and attached is beneficial because planting equipment does not have to cut through standing residue. Upright residue also will not blow over the row or accumulate in piles. And, upright residue speeds soil drying and warming by allowing increased air movement at the soil surface. If it does end up on the ground, attached residue is easier to cut than loose residue.

One way to keep more residue upright is limiting traffic of harvest vehicles to certain lanes and avoiding traveling across fields when possible. This will also minimize that portion of the field at risk of compaction. When possible, avoiding harvest during high winds can also improve uniformity.

TIP:
If you cannot avoid harvesting in high winds, starting harvest on the downwind side of a field can help maintain residue uniformity.

Spreading straw and chaff

The next step is spreading the straw and chaff. For uniform distribution, the combine must be able to spread the straw and chaff across the width of the header. The wider the header, the more difficult this is. Straw spreaders on modern combines can do a good job as long as their capacity matches the header width. In contrast, chaff spreaders on modern combines often fail to spread chaff well.

If the chaff or straw is left to pile up directly behind the combine, it can prevent the planter from getting the seed to the soil (Figure 9) or stunt seedling growth



Figure 9. Thick mat of residue prevents seed from being planted in the soil.

through allelopathic effects (biochemical suppression by the plant residue). If you do not already have one, installing a high quality, after-market chaff spreader is a good investment (Figure 10).

Stripper headers

Stripper headers (Figure 11) are a specialized tool that can be used for managing the residue of small grains, peas, and dry edible beans. Instead of cutting the stems and then separating the grain, these headers strip the grain from the stem and harvest only the grain. Since the stems are not cut, only the chaff has to be spread. The resulting uniform, standing residue cover can be ideal for planting.

Combine header add-ons

If you grow corn, you might consider available header attachments that can help crimp, crush, or cut up corn stalks. Simple add-ons include more aggressive stalk rollers that crush stalks while minimizing ear toss. More complicated (and expensive) headers can chop or mow stalks. There are an increasing number of choices here, but remember the advantages of upright and attached



Figure 10. An after-market chaff spreader on a combine.

residue. Whatever is loose on the ground can move, creating non-uniform conditions. Loose residue will have to be cut or moved at planting.

Post-Harvest

The best time to manage crop residue, and the only time that chaff can be moved, is at harvest. But after harvest, heavy harrows, mowers, cover crops, residue removal, or strip-tillage can be used to address specific issues.

Heavy harrows

Heavy harrows can redistribute residue, though they will also break it up and detach much of it from the soil. Be sure this is your goal when you choose to use a harrow. Harrows are normally used with small grain stubble and work best in very dry, brittle residue.

The angle of the harrow should be set so that the harrow fills and “floats” but does not bunch up the residue. With a well-set harrow, the combination of speed and dry straw will result in good shattering and distribution of piles. If not set properly, a heavy harrow can create more problems than it solves. The harrow should not incorporate straw into the soil.

Mowing

Mowing with a rotary mower will not overcome severe distribution problems, but it can reduce the size of the straw and spread moderately sized residue piles. Mowing and harrowing can increase contact between the soil and residue. This, combined with the reduced residue size, can increase decomposition rates when moisture and temperature conditions are right.

Cover crops

Although not their primary purpose, cover crops can contribute to residue management. After early-harvested crops like wheat, a cover crop that establishes a canopy over the residue can increase decomposition rates



Figure 11. Stripper header for residue management.

(by increasing humidity levels), thereby reducing the amount of residue that you have to deal with in the spring. To do this, you must establish the cover crop as early as possible and manage it to close canopy as soon as possible. This may require fertilization and irrigation—activities that may also increase decomposition rates. Overwintering cover crops do this best and can usually outcompete weeds, but they also require careful management in the spring (SARE Outreach 2007).

Residue removal

In situations with high amounts of residue, cutting and baling part of the residue is one approach that can make direct seeding easier. Depending on the markets for crop residues, this strategy may be more economical than burying the residue with tillage.

To maintain soil health and control erosion, remove only as much residue as needed to facilitate planting of the next crop, and remember to spread the remaining residue uniformly. Also, recognize that the nutrients removed with the residue will need to be replaced.

Strip-tillage

Strip-tillage (Figure 12) creates both clean-till conditions and high residue conditions, in alternating strips, taking advantage of both systems while minimizing drawbacks. Strip-till equipment tills the soil under a 6- to 12-inch-wide band where the crop will be planted. The residue is either removed from this band or buried in it. A residue-covered area between the strips is left undisturbed.

When considering strip-tillage or other tillage options, take into account the effects of tillage on your soil. Tillage will destroy the network of macropores that form after several years of no-till. It can also reduce soil organic matter levels and the associated benefits. See WSU Extension publication EM036—*High Residue Farming under Irrigation: Strip-till* for more information on strip-tillage.



Figure 12. One-pass strip-tillage operation.

At Planting

You can do some residue management at planting, but because it is one of the many tasks your planter equipment will have to carry out, it will be covered in the planting section.

Planting into Residue (Direct Seeding, No-Till Planting)

You have done your job. Your crop sequence has given you the amount and type of residue cover you want. You have spread the crop residue uniformly, covering the soil but not too deep. Much of the residue is upright, but short enough not to interfere with the planter. Much of it remains attached to the soil so it did not move with wind or water. Now it is time to plant.

We have discussed the conditions needed for rapid and uniform germination and emergence. To achieve these conditions, the planter or drill must carry out four tasks (adapted from Murray et al. 2006):

1. Cut or move the residue, or both
2. Penetrate the soil to the proper seeding depth
3. Place the seed
4. Cover the seed

You can use either a planter or a drill to carry out these steps. The process is described in detail below for a planter followed by the needed modifications of this process for direct seeding with a drill.

Step One: Cut/Move the Residue

There are three choices for handling residue at planting:

1. Cut it.
2. Cut and then move it.
3. Move it.

Deciding which option is most appropriate depends on your residue conditions and the crop you are planting.

Cutting residue

Consider just cutting the residue when planting wheat, peas, dry beans and other crops that are not highly temperature sensitive or that are planted when soil temperatures are conducive to their growth. For crops like grain corn or sweet corn, which are temperature sensitive at the time they are normally planted, either of the last two options can work.

The ease of cutting varies greatly with the condition of the residue. In the fall, after wheat harvest, residue may be fresh and tough to cut. In contrast, residues that have decomposed over the winter are usually easy to cut. Residue may be dry or wet. It may be upright or lying down, attached to roots in the soil, or loose.

Depending on conditions, you can use disk coulters or openers to cut the residue at planting.

Disk openers. The advantages of using opening disks (Figure 13) to cut residue instead of coulters include:

- They are generally sharper, reducing “hairpinning” of residue (see description of this problem below);
- They do not require extra down pressure, assuming you have sufficient down pressure for planting;
- They do not require any modifications on most planters.

The angle of the disc opener blade against the residue affects its cutting ability. The best cutting angle is



Figure 13. Top view, looking down on a single disk opener.

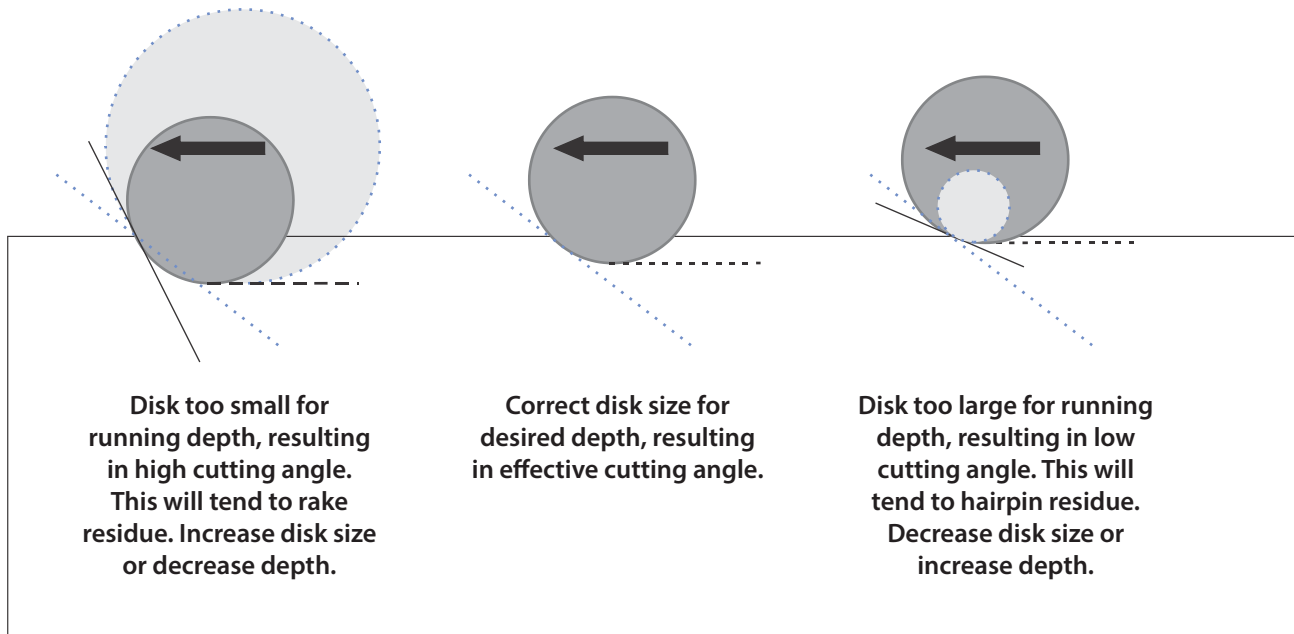


Figure 14. Disk size in relation to planting depth to attain best cutting angle (indicated by blue dotted line).

TIP:

Residue that is wet from rain or early morning dew can be difficult to cut. If possible, wait until residue dries before planting.

30–45°. Too shallow an angle will hairpin residue (see below), too deep will drag it.

The cutting angle of the disk (this also applies to coulters) is determined by the size of the disk and its running depth (Figure 14). Shallow depths require smaller disks and deeper depths require larger disks. As indicated in Table 2, 15- to 18-inch disks cut well for corn planting depths.

Single disk openers are the best at cutting residue. Among double disks, offset opening disks—where there is one leading disk—tend to cut residue better than double disks that are even. Some farmers, by using one worn disk with one new disk, have accomplished this on planters that originally used two even disks.

Coulters. There are several reasons to avoid using coulters if possible:

- Coulters are not as sharp as disk openers, so can cause more hairpinning of residue (see below).
- Coulters can kick up clods or disturb the soil in front of the opening disks, or both.
- Coulters are an additional tool being pushed into the soil, so extra weight is required to keep them in the ground.

Table 2. Cutting Angle of Opening Disks and Coulters at Various Depths

Disk or Coulters Depth (in.)	Diameter of Opening Disk (in.)								
	12	14	15	16	18	20	22	24	
0.25	16.6	15.4	14.8	14.4	13.5	12.8	12.2	11.7	
0.50	23.6	21.8	21.0	20.4	19.2	18.2	17.3	16.6	
0.75	29.0	26.8	25.8	25.0	23.6	22.3	21.3	20.4	
1.00	33.6	31.0	29.9	29.0	27.3	25.8	24.6	23.6	
1.50	41.4	38.2	36.9	35.7	33.6	31.8	30.3	29.0	
2.00	48.2	44.4	42.8	41.4	38.9	36.9	35.1	33.6	
2.50	54.3	50.0	48.2	46.6	43.8	41.4	39.4	37.7	
3.00	60.0	55.2	53.1	51.3	48.2	45.6	43.3	41.4	
4.00	70.5	64.6	62.2	60.0	56.3	53.1	50.5	48.2	

Note: Green shading indicates best cutting angle for each combination.

While it is usually best to avoid coulters (many Midwest no-till farmers have removed them from their planters), they can be useful in some situations. In abrasive sandy soils, coulters can break up the soil and reduce the wear on disk openers. Coulters can also be useful in fields that have long stalks or straw on the ground and are being planted to a crop where the residue needs to be moved (for example, with corn). In this case, the coulters can cut the long residue before the row cleaners move it off the row.

If coulters are used, set them at seeding depth and not below, and use as narrow a coulters blade as possible to minimize soil disturbance. As with a disk opener, the cutting angle is determined by the size of the coulters and its running depth. Shallow depths require smaller coulters and deeper depths require larger coulters. If the coulters is needed only to cut residue, it can be located well off to the side of the planting row.

For more information on coulters, see *Best Management Practices: No-Till, Making it Work* (Lane 1997), listed under *Resources*, below.

Other tools. Farmers who have added attachments to band fertilizer at planting can use the fertilizer-opening disk to cut the residue. This is usually offset from the middle of the row.

Hairpinning. The folding and tucking of long pieces of residue into the seed furrow where they interfere with planting (Figure 15) is one of the most common problems that can occur when attempting to cut residue. Determining the cause(s) of hairpinning in your field will allow you to fix the problem; see Table 3.

Moving residue

If you are planting grain corn or sweet corn, which is temperature-sensitive at the time it is normally planted, or if you are growing in a Northern region (> 43° N), you will likely want to move the residue (or cut and



Figure 15. Hairpinning of crop residue in the seed furrow.

Table 3. Causes of hairpinning and solutions.

Cause	Solution
dull coulters or disk blades	Replace worn parts; use opening disks instead of coulters to cut residue.
incorrect cutting angle; dragging or riding over the residue without cutting	Adjust the disk depth or replace disks with larger or smaller diameter.
Too much flex in disks	Replace with 3.5 mm thick disks.
Soft soil (often sands with little structure) that gives way under residue.	Run disks or coulters deeper. Use disks with wheels on either side to pin ends of residue to the soil.
Wet residue	Plant when the residue is dry and brittle

move it). Before doing this, you will need to decide how much of the residue to move.

Moving the residue off the planting row promotes higher soil temperatures and reduces the amount of

REMEMBER:

Residue cover, not lack of tillage, causes cooler soils at planting. If the residue is moved, tillage is not required to obtain the soil temperatures needed to produce yields equal to those of tilled systems.

residue that can block seedling emergence, but there are tradeoffs to consider. Bare soil will dry out faster than residue-covered soil due to increased evaporation. Bare soil is also more prone to wind and water erosion, and to crusting.

A good strategy is to clear residue from only the width where you need to increase the soil temperature for desired emergence. Results from a 3-year experiment in Iowa show how this strategy can work (Kaspar et al. 1990).

Corn was grown in either 1) plowed soil; 2) untilled bare soil; 3) untilled soil covered with residue; or 4) rows where the residue was removed from strips of various widths centered on the seed row. The key result was that *residue removal from the seed row had greater benefits for emergence and early growth and plant growth and yield than did plowing*. This trial found that a reasonable compromise between bare soils and 100% covered soil was a 6-inch bare strip centered over the seed row. This resulted in only a 3% yield reduction and left 79% of the soil surface covered. The savings in fuel, equipment, and labor from not tilling the soil could make up economically for this small yield loss. Removing the residue from bands wider than 6 inches gave diminishing additional yield benefits.

These results apply to corn and other temperature-sensitive crops. The best compromise, however, between residue cover and crop yields must still be determined for many crops grown in the irrigated Far West, especially at northern latitudes and for early plantings.

Once you have decided how much residue to move (or cut and move), you will need to determine which equipment to use. Although tillage can be used to move crop residue, it is not necessary, and unless you have other reasons for using tillage, row cleaners are recommended. Where tillage is needed, consider a strip-till system (see Resources).

Row cleaners. Row cleaners (also called residue managers, residue movers, or trash whippers; Figure 16) can move some or all of the residue. If row cleaners are used, set them so that they do not move soil. If you want to move both soil and residue, use other tools. (See Strip-till section.)

There are numerous types of row cleaners including those with adjustable down pressure and floating row

cleaners (Figure 17) that move with the soil surface. Use finger types that allow residue to fall out while turning. Row cleaners with spiked teeth work well for wheat and bean residue but can skewer and carry corn stalks and root balls.

As mentioned before, a coulters can be used prior to a row cleaner for long residue that must be cut before being moved. There are also coulters/row cleaner combination attachments that will do this.

Step Two: Penetrate the Soil to the Proper Seeding Depth

Actual planting is done during Steps Two and Three, when the soil is opened and the seed is placed at the desired depth. Achieving a uniform planting depth consistently across the field will go a long way to obtaining a uniform stand, but some changes are needed to do this in residue-covered, firm, untilled soils.

Down pressure and planter weight

The weight of the planter and the down pressure on the row units must be adequate to penetrate the soil to the desired depth in all of a field's soil conditions. If the



Figure 16. Row cleaners move residue off the planted row.



Figure 17. Floating row cleaners preceded by a smooth coulters. These maintain their height, "floating" over uneven ground.

disk openers are also being used to cut residue, this can add to the needed down pressure.

In general, you should have down pressure springs capable of applying at least 300 lb. of down pressure per row. In dry, firm soils (not sands), you may need as much as 500 lb. per row. If you are cutting residue with unit-mounted coulters, they can require another 250 lb. each per row. Using unit-mounted fertilizer application disks requires even more down pressure. All this added down pressure must be balanced by a greater weight of the planter itself to keep the openers in the ground.

If you have too little weight, the openers will not penetrate the soil well and the seed-metering wheel may not have good soil contact. To add weight to a planter, you can use suitcase weights (Figure 18) or tanks of fertilizer or water. Folding wings on planters should be pinned, if possible, to transfer the weight to the rows.

Planting depth

While the type of opener used has little effect on the soil temperature around the seed (Tessier et al. 1991),

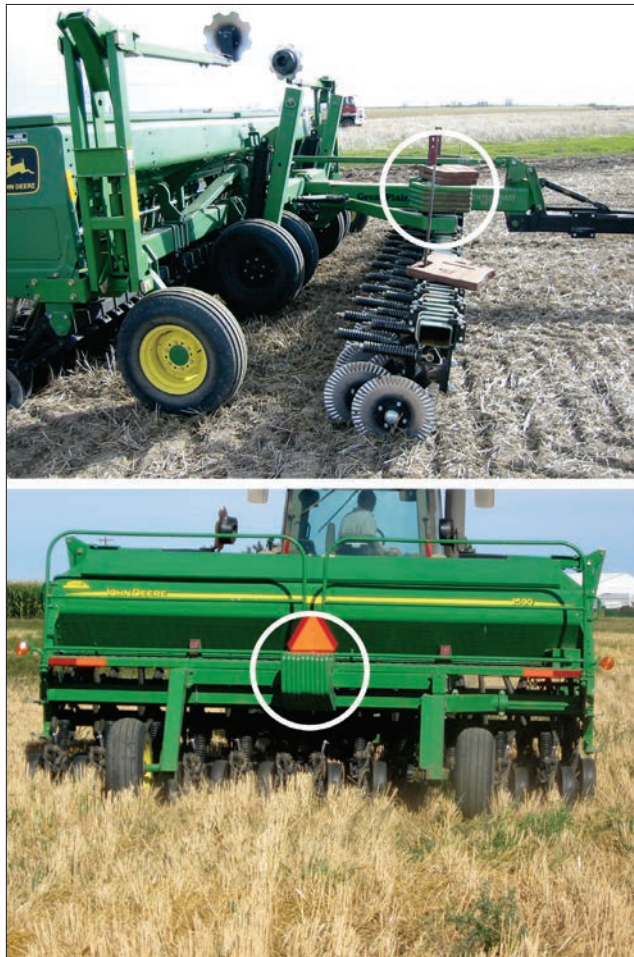


Figure 18. Weight added to a drill will allow it to plant into hard, untilled soil.

temperature does vary with planting depth. Yet reducing planting depth to take advantage of the warmer soil temperatures is not always a good idea. The soil at shallow depths can be warmer, but it can also get colder at night, especially when the soil is bare. Planting deeper can provide more uniform temperatures, leading to more uniform emergence.

Deeper planting depths also generally have decreased risk of dry soil, and more favorable crop rooting conditions. Most no-till experts recommend that corn be planted at least 1.75 in. deep and some have had good results (at lower latitudes) planting up to 3 in. deep. For corn brace roots to develop and provide stability against lodging, a planting depth of 2–2.5 in. is recommended, except in northern latitudes where soil temperatures dictate a more shallow planting. Generally, it is best to plant deeper and then try to overcome the less-than-ideal conditions through soil and fertility management and variety selection.

You will also need to make sure that your equipment can achieve your desired planting depth. This requires a bit of attention when you are moving residue, in that you will need to make sure the width of the path you are clearing with row cleaners matches the width of the depth gauge wheels. If your clear path is too narrow, the wheels will rise over residue, changing your planting depth. This can be avoided by widening the cleared path, or using narrower gauge wheels.

Opener types

In HRF, openers are the main tool used to modify seedbed conditions. In most cases, minimizing the amount of soil disturbance caused by the openers will result in better conditions than having greater disturbance. Openers are either hoe-type or disk-type (Murray et al. 2006). Both types of openers have proponents. Farmers who have invested in and learned to use hoe openers often prefer them. The same goes for those who use disk openers. Because the opener type is not easily changed, do your homework before deciding which type will work best for you, your crops, and your soils.

Hoe-type openers. These openers (Figure 19) move soil upwards and outwards while digging the seed furrow. They penetrate hard, dry soils well but cannot handle large amounts of long residue. This can be overcome by using coulters in front of the openers (but remember this adds to the weight requirement of a planter or drill) or by sizing the residue through mowing or harrowing. (See Residue Management section.)

Coulters, often on a caddy, are usually operated at or below the opener depth, which, in wet soils, can create a compacted layer. Compared to disk openers, hoe openers require less down pressure but more horsepower.



Figure 19. Two styles of hoe-type openers on drills.



Figure 21. Double-disk opener.

TIP:
Using disk openers in firm soils, you might see a variable furrow shape and depth due to blade flex. If you suspect this problem, try changing out 3 mm disks for heavier 3.5 mm disks.

Figure 20. Single-disk opener.

One potential drawback of hoe openers is that because they rely on a trailing press wheel for depth control, they are not as accurate as disk openers with gauge wheels. They, therefore, do not work as well for planting at shallow depths.

Disk openers. Disk openers use a cutting action to make the seed furrow, and they move or press the soil outward. There are single-disk (Figure 20) and double-disk types (Figure 21). The single disk opener is often used in high residue conditions because it has good residue cutting and soil penetration abilities, with low

soil disturbance. The double disk opener has two disks, either aligned in front or offset, with one leading disk edge. The offset configuration cuts residue and soil better than the aligned disks.

Planters and drills with disk openers generally require more down pressure but less tractor horsepower than a drill of equal-width with hoe openers. In addition, the gauge wheels of disk opener units generally offer better depth control than hoe-type systems. For better depth control on rough ground with either type of opener, look for parallel linkages.

Note, the sidewalls of the seed furrow need to remain intact until the seed is placed at the bottom. For this reason, be cautious when using “reduced inner diameter” depth wheels with disk openers. In some soil conditions, the lifting of the soil promoted by these

wheels allows a horizontal crack to form at the bottom of the seed furrow. Seeds that slip into this crack can emerge late, affecting stand uniformity. The sidewall compaction that these special depth wheels were made to prevent can be better alleviated in Step 4 (Cover the Seed) without affecting seed placement.

Step Three: Place the Seed

Now that you have a seed furrow open to the right depth, placing the seed at the bottom and keeping it there is the next task.

Your main objective is to place each seed in contact with wet, untilled soil at the bottom of the furrow. This puts the seed in close proximity to the water it needs to begin germination. Remember, the seed can germinate without seed-to-soil contact, but will do so at a somewhat slower rate. The challenge is to do this uniformly while planting 12 seeds per second in each row (driving 4 mph while planting 36,000 seeds per acre on 30-inch rows). To achieve this feat, each seed must fall to the furrow bottom on the same interval as your planter's metering system delivers it. If the seed bounces or falls on a soil clod or piece of residue that has fallen in the furrow, it can change seed spacing or depth.



Figure 22. Seed firmers.



Figure 23. Seed-firming wheel.

To minimize these problems many farmers use plastic “seed firmer” attachments (most common on planters, see Figure 22) or “seed firming” wheels (most common on drills, see Figure 23). These attachments ensure that each seed moves to the bottom of the seed furrow and once there, they press the seed into the wet, untilled soil.

Although research on seed firmer attachments has been inconsistent in showing benefits (PAMI 2000; Staggenborg et al. 2004), many farmers still use them in HRF conditions. No-till experts recommend them to help overcome non-ideal conditions such as varying soil texture.

Other changes that may be required for challenging HRF conditions include slower planting speeds and increased seeding rates. Planters should not be operated at speeds greater than the manufacturer recommends.

Should I plant between or on old rows?

The best placement of your rows in relation to the rows of the previous crop will depend on several factors including:

- The risk of soil compaction. Soil between old rows has often been driven over more than soil under the old rows and so may be more compacted. Thus, you may get soil quality benefits from always planting in the non-trafficked soil and driving on the non-planted soil.
- Your rotation. If you are following corn with corn, there is the potential to avoid some soilborne disease problems by planting off the old row (Jasa 2007). If, instead, you have a more diverse rotation, planting in the old row may allow your planted crop to take advantage of the previous crop's root channels (Rasse and Smucker 1998) with less risk of a shared soilborne disease problem.
- Your planter's ability to plant into the residue of the previous crop. For most planters, it is easy to plant on the row of the previous bean crop, but not so easy to plant on the old corn row. A compromise that many farmers make is to plant 4–6 inches to the side of the old corn rows but directly into the old rows of other crops that leave less challenging conditions.



Figure 24. Various types of spiked closing wheels.

Slower speeds generally will result in more uniform planting, with 4 miles per hour a good target for many conditions. Unless conditions are ideal, it is also recommended that you increase seeding rates by 10% over clean-till seeding rates.

Step Four: Cover the Seed

The final step is to cover the seed. This step also offers an opportunity to reduce any soil compaction that occurred during the previous steps.

Steps 3 and 4 are best kept separate. Older planters and many drills combine them by using a press wheel to both ensure seed-to-soil contact and cover the seed, but these wheels, especially in untilled soils, can compact the soil and affect emergence uniformity. Packing wheels that compact the soil over the row are also not recommended. Cast iron press wheels are often too aggressive in pressing and can cause compaction in clay soils or high moisture conditions. Angled rubber tires can work in soft soil conditions but not in firm soils.

When planting into firm, untilled soils, finger-type or spiked closing wheels (Figure 24) can do a good job of covering the seed. These types of wheels perform a bit of precision tillage by lifting the soil and breaking apart the seed furrow sidewalls (Figure 25). This covers the seed with loose, tilled soil, benefitting conditions in several ways.

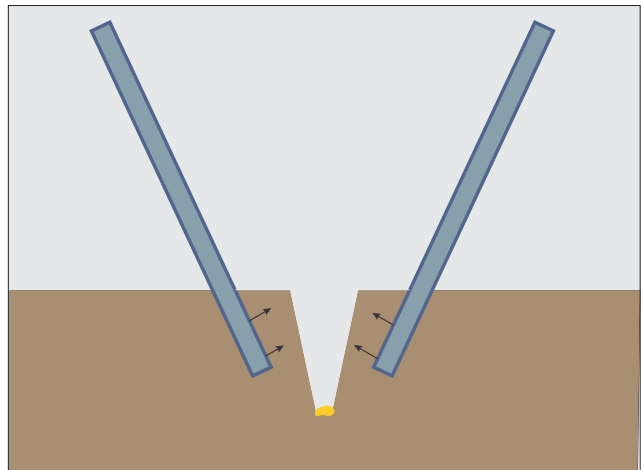


Figure 25. Using spiked closing wheels to break up sidewall compaction.

First, the tillage will dry the loosened soil but not the undisturbed soil around the seed. This dry soil will warm faster than wet soil.

Second, the tillage will disrupt the network of soil pores, reducing or eliminating the capillary action moving water to the surface in the area right around the seed. Deprived of this conduit, water can only move upward by diffusion and convection, which greatly reduces evaporation rates and loss of water from deeper soil

layers. This is similar to the surface tillage that dryland farmers use to create a “dust mulch” on the soil surface. In HRF planting, the saved water keeps the soil near and below the seed wetter longer. This benefits germination and root penetration, because as a soil dries, its resistance to root growth increases. This increase in resistance is greater in sandy soils than in clay soils (Gregory et al. 2007).

Third, covering the seed with loose, low strength soil allows the shoot to emerge quickly. This is particularly important because research indicates that seedling shoot growth is limited more by strong soils than root growth is (Whalley et al. 1999). For best results, the average clod size of the covering soil should be smaller than the buried seed to prevent the shoot from being blocked (Dürr and Aubertot 2000).

Last, the loose soil over the seed allows good oxygen supply to the seed. For all these reasons, the soil covering the seed in HRF conditions should not be firmed or compacted.

REMEMBER:

After retrofitting your planter for HRF planting, all four steps must be accomplished. Replacing your press wheels with spiked wheels will cover your seed, but will not ensure seed-to-soil contact. In this case you must also add a seed-firming device.

Nutrient Management at Planting

While the four planting steps provide the required water, oxygen, temperature, and soil conditions, you must also provide the emerging seedlings with an optimum nutrient supply.

Starter fertilizers place nutrients in an available form where the seedling roots will get them quickly, thereby minimizing or eliminating any yield-reducing nutrient deficiencies.

This is especially true for corn. Without starter fertilizer, corn grown in HRF systems can suffer from early-season phosphorus deficiency. In the Midwest Corn Belt, this often does not result in yield reductions. At northern latitudes, however, corn growth can be slowed enough by these conditions that the crop may not close canopy in time to take advantage of the longer days on either side of June 21st, the summer solstice. With full-season corn, this may reduce yields. Given the other challenges of growing corn in an HRF system, it is best not to ignore these early nutrient deficiencies.

Starter fertilizer can be applied with the seed (in a “pop-up” application) or banded away from the seed. Pop-up applications can help avoid soil-temperature-related deficiencies. Since starter fertilizers are the same as what

Adjustment of Spiked Closing Wheels

Finger-type spiked closing wheels require careful adjustment to work correctly. The following tips may help you achieve success:

- The shattering of the seed furrow side-wall by closing wheels should not affect or move the seed that has been pressed into the bottom of the seed furrow. If not adjusted correctly, closing wheels can sometimes flick seed out of the furrow. To avoid this, back off the down pressure so that the point of intersection of the closing wheel angles (about 2 inches below the bottoms of the normal rubber closing wheels) is above the seed depth.
- In fields with variable soil and moisture conditions, farmers have found that one finger-type wheel opposite one rubber wheel works the best.
- In clays and wet soils, spiked closing wheels can leave holes that can lead to drying of the seed zone. If this occurs, use a twisted drag chain to fill in the holes.
- Spiked closing wheels do not work as well in tilled soils, so may not be appropriate with strip-tillage. Here, as with clean-till systems, loose tilled soil around the seed (above and below) may need to be re-consolidated somewhat to improve water supply to the seed and reduce the risk of soil drying that results from very high air permeability.

is used in clean-till farming, they will not be covered in this publication in detail. Just be aware, when setting up equipment to apply starter fertilizers in HRF, that pop-up fertilizers are often applied through seed firmer attachments. The tanks required for the liquid fertilizer also serve as extra weight on the planter, although you may have to refill them more often if you rely on their weight for penetrating the soil.

Banded fertilizers, which are similarly used in tilled situations, can also be helpful in HRF. The common placement is either below the seed (in strip-tillage), or in a 2x2 placement (for corn), that is, 2 inches to the side and 2 inches below the planted row. Some farmers use an over-the-row application, mainly of nitrogen, with good success.

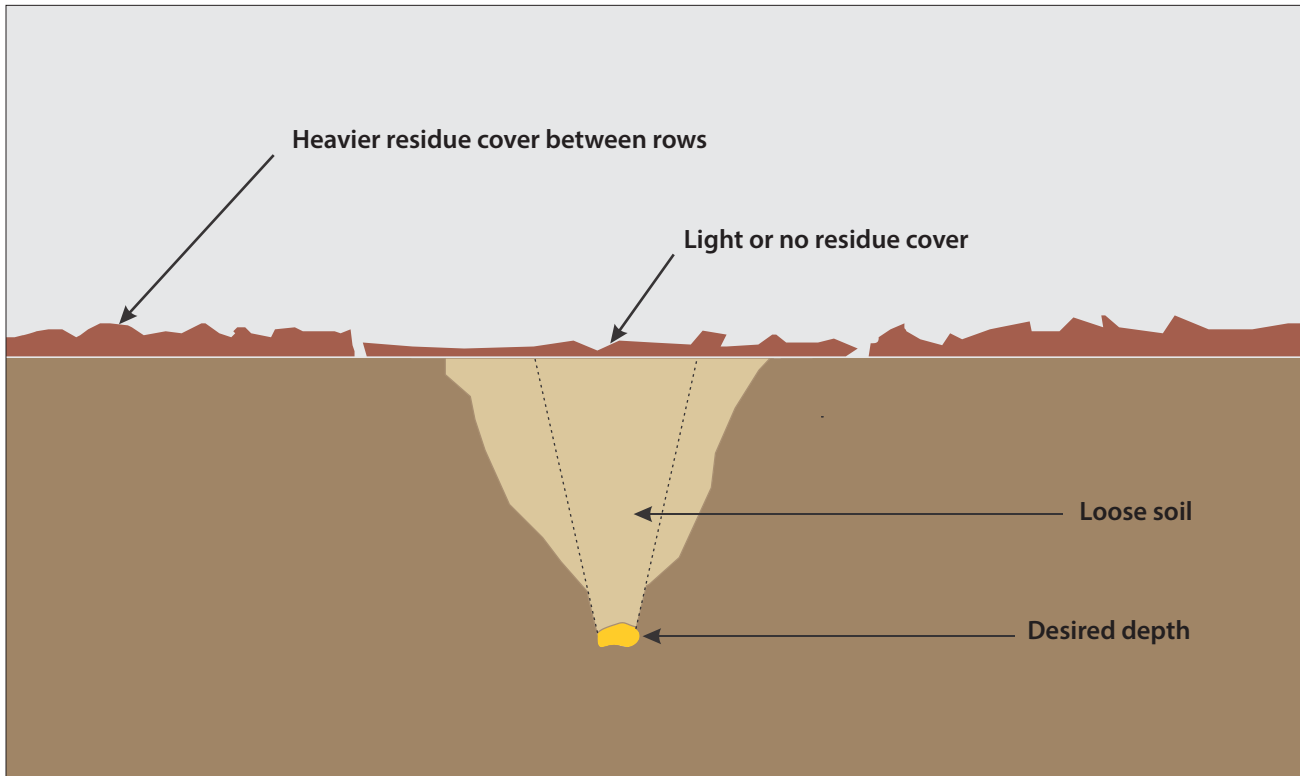


Figure 26. Ideal HRF conditions in a field after planting.

REMEMBER:

Starter fertilizers are required for producing most crops if you want HRF yields equal to those produced with tillage.

Ideal Situation after Planting

You have thought about your crop rotation, managed residue during and after harvest, successfully completed the four planting steps, and provided adequate soil fertility. The result of all your hard work is the seed in the soil. As shown in Figure 26, your optimally planted field should have the following features (Carter 1990):

- A moderate layer of residue covers the soil surface between rows. Within the planting row, the surface is lightly covered or left bare for certain temperature-sensitive crops. This residue layer will reduce evaporation, prevent erosion and crusting, and increase water infiltration.
- Above the seed is a covering of loose dry soil, promoting warming to seed depth, and good air permeability. This loose, dry soil also reduces evaporative losses from the soil at seed depth and is conducive to shoot growth. The sidewalls of the seed furrow have been shattered.



Figure 27. Seed pressed into wet, untilled soil at bottom of furrow.

- The seed lies on wet, untilled soil at the bottom of the seed furrow (Figure 27). There it can take up water from both the air and soil. It is at the proper depth and spacing, leading to uniform germination and emergence.
- Below the seed, the untilled soil provides a stable pore structure that is conducive to root growth and less prone to compaction than a tilled soil.
- The soil nutrient levels are high, especially near the seed, allowing the seedling to emerge and grow quickly.

Equipment Requirements and Modifications

Using the methods and tools discussed above, HRF planting can be as successful as any tillage system, but some equipment modification is required, both for planters and for drills. This is covered next.

Converting a Conventional Planter for Direct Seeding

You can buy a new planter or drill specifically configured for direct seeding, but, for planters, it is often much less expensive and relatively easy to retrofit the planter (Figure 28) you own. These features and attachments are needed to complete the conversion:

- Heavy duty tool bar, minimum 7"x7"
- Row cleaners, suitable for high residue conditions
- Heavy duty down-pressure springs
- Seed-firming device
- Closing wheels that shatter the seed furrow sidewalls and cover seed with loose soil
- Starter fertilizer application system



Figure 28. Planter-row-unit retrofitted for direct seeding.

Although any modern planter can be converted to direct seed, the same is not true for drills.

Direct Seeding with a Drill

Drills must carry out the same four steps as planters for successful HRF planting. Nutrient management needs at planting and the ideal seed placement also remain the same as with planters.

This section will cover the main differences between planters and drills, including the required weight to penetrate soil, residue handling, seed placement, and the durability of the components.

Drill weight. Because drills have a greater number of openers penetrating the ground per unit width than

planters do, they need to be heavier to keep them in the ground. You can add weight with iron “suitcase” weights or water/fertilizer tanks, or both. Do not count on the seed weight to keep a drill in hard ground. The down pressure needs of each row will depend on the opener used and will be similar to that described for planters.

Residue handling. Your ability to move large amounts of residue is limited by the narrower row spacing of drills. This means that row cleaners, if used, cannot be as aggressive on a drill. To help this, manufacturers have mounted adjacent openers onto separate ranks (Figure 29). Still, there is much less room on a drill for attachments like row cleaners and closing wheels.



Figure 29. Drill openers mounted on different ranks to facilitate the flow of residue between openers.

Seed placement. Instead of the paddle-type seed firmers used on planters, most drills can be equipped with seed firming wheels. Make sure they fit the width and shape of the seed furrow cross section and that they press the seed to the bottom of the furrow.

Durability of drill components. Drills not designed for direct seeding are often not heavy enough, and even if the required weight is added, the drill components may not be up to the increased wear and tear that direct seeding brings. Nevertheless, with a coulter caddy, increased weight, and good residue management, conventional drills can be used in the transition to HRF cropping as long as you are aware that they will probably wear out sooner than if used only on tilled soils.

Equipment Adjustment

“Adjustment and operation of the equipment is likely more critical than the specific equipment.” —Randal Taylor, Oklahoma State University engineer and 2010 WSU HRF workshop speaker.

The four steps above will only be successful for a properly adjusted planter or drill. The Planter/Drill

Adjustment Checklist provided in *Appendix A* (below) should help in carrying this out.

Future Planting Equipment

Having both a planter and a drill that are able to handle high residue, firm soil conditions is the ideal. This will allow you to plant all kinds of crops in many situations and take full advantage of HRF benefits, but it can be expensive. In the future, there may be single-machine options that will capture the benefits of both planters and drills. A few manufacturers are designing equipment that will be able to plant narrow rows like drills can while also being able to separate and place single seeds like a planter. Once these are proven and available, they will greatly reduce the equipment costs for farmers moving into HRF.

Additional Management Considerations

Nutrient Management

To meet the challenges of HRF, changes in nutrient management are required before, during, and after planting. Pre-plant changes are discussed below, while changes during planting are discussed in the planting section.

Before transition to HRF. Before transitioning to HRF, while full width, deep tillage is still an option, adjust soil nutrient and pH levels to tillage depth. This will make the transition to HRF easier.

Incorporate enough phosphorus (P) and potassium (K) to put your soils in the medium to high range for these nutrients. This will give your soil time to develop structure before relying solely on broadcast P and K. You should also adjust pH to the desired level using the appropriate amendments.

Pre-plant soil sampling. After you transition to HRF, you must adjust your soil sampling procedure to account for the stratification of nutrients (and pH), and for the increased banding of fertilizers associated with direct seeding (discussed in the Planting section, above) and strip-till systems (if relevant). To get a realistic view of your soil nutrient status, you should increase the number of soil cores taken to monitor distribution of low and high nutrient concentrations across a field. You should also segregate the samples according to depth at which the samples were taken, to determine the extent of stratification.

Soil analysis only gives a partial view of your soil fertility. For a complete view, you should also sample plant nutrient levels every two to three years. Using both soil and plant tissue testing can give you better insight into nutrient levels, especially for those micronutrients that are difficult to measure with soil analysis (Table 4).

Table 4. Making decisions with both soil and plant nutrient information. Adapted from Walworth (2005).

Soil Nutrients	Plant Nutrients	Problem/Solution
High	High	No problems.
Low	Low	Lack of nutrients; fertilize quickly.
High	Low	Something is interfering with nutrient uptake. Look for causes.
Low	High	Current needs are met but may need future applications.

Row Orientation

Take into account the direction of your rows when planting. Particularly for corn, where you want as much sunlight as possible, orienting the rows north-south can help reduce shading of adjacent rows.

Irrigation Scheduling

The effect of HRF on irrigation scheduling is twofold. First, remember that the soil in the early season is going to remain wetter under the residue than tilled soil would. This can be an advantage in areas where dry spring seasons require pre-irrigation. Second, infiltration rates will be much higher under HRF. This means you can apply water faster without runoff. This will be an advantage when it gets hot and you need to fill the soil profile quickly.

Conclusion

Planting and establishment of your crop is just the beginning of a successful HRF system (Figure 30). While some of the other components will remain very similar to the management strategies used in clean-till systems, others will have to be modified. It is important to keep in mind the “tweaking” and “hacks” mentioned at the beginning of this publication, to successfully adapt HRF to your farm. Listed below are other publications and organizations that may be useful sources of additional information. Other farmers, Extension specialists, and personnel at the Natural Resources Conservation Service will likely also be helpful. Learn as much as you can before starting HRF. This will help you avoid repeating problems that others have already overcome.

High residue farming is relatively new in the history of agriculture. It is full of opportunities for innovation and change. Better planting and harvest equipment will make HRF an option for an increasing number of crops. Combining HRF with other new technologies perhaps holds the greatest potential. HRF with controlled traffic, along with improved varieties, cover crops, and new pest control methods are ways we will be able to continue to produce food for earth’s people and still protect the earth that allows that production.

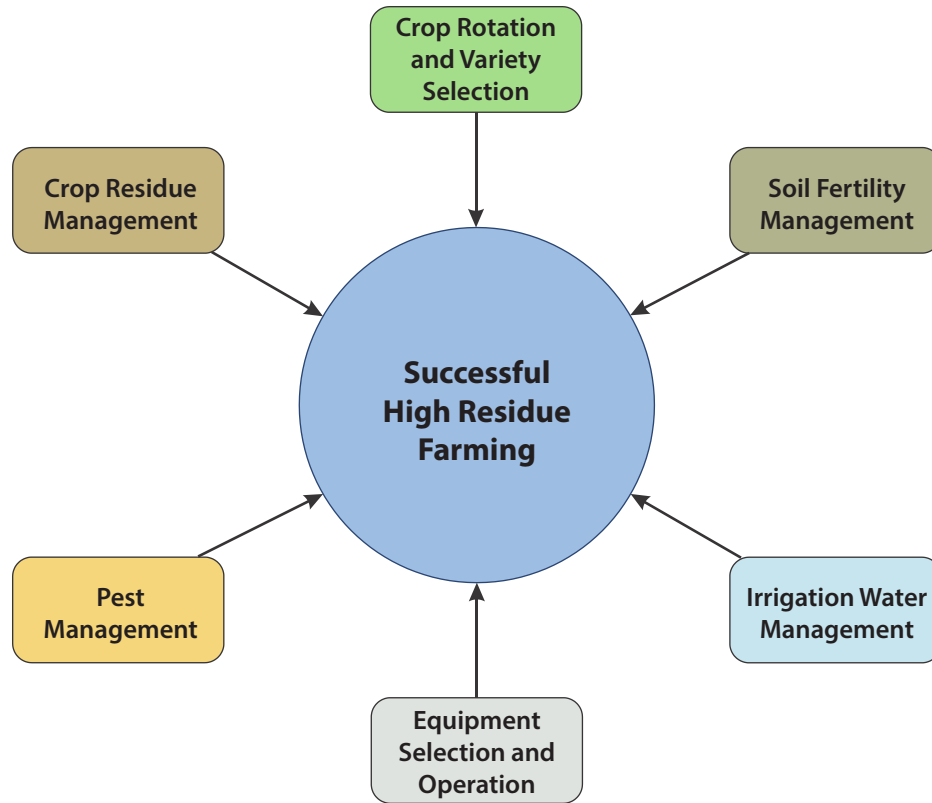


Figure 30. Components of a successful high residue farming system.

Resources

- Pacific Northwest Direct Seed Association
- Conservation Agriculture Systems Innovation
(University of California)
- WSU Center for Sustaining Agriculture and Natural
Resources (CSANR), High Residue Farming under
Irrigation
- Conservation Tillage Systems Information Resource
(WSU, OSU, UI)
- 4R Nutrient Stewardship
- Best Management Practices: No-till, Making it Work,
Agri-Food Canada (Lane 1997).
- Steps Toward a Successful Transition to No-Till,
Penn State Cooperative Extension (Duiker and
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Appendix A: Checklists

Complete this checklist in the shop, from the front of the planter/drill to back. (See your equipment manual for specific directions.)

Row units

<input type="checkbox"/> Row cleaners spin freely.	YES
<input type="checkbox"/> Coulter height 1/4" higher than opening disks. Blades sharp and diameter sufficient for cutting.	YES
<input type="checkbox"/> Disk openers are sharp and not worn below their recommended diameter.	YES
<input type="checkbox"/> Double disk openers maintain 2.5-3" of contact between disks.	YES
<input type="checkbox"/> Gauge wheels maintain light contact with opening disks.	YES
<input type="checkbox"/> Seed tubes and seed tube guards are smooth without wear that could affect seed delivery.	YES
<input type="checkbox"/> Seed firming devices are functioning and apply correct down pressure.	YES
<input type="checkbox"/> Closing wheels run parallel to the opening disks and are centered on midline of the seed furrow.	YES
<input type="checkbox"/> Row unit linkages do not rock from side to side.	YES
<input type="checkbox"/> All bearings are tight and lubricated.	YES

Other parts of the planter

<input type="checkbox"/> Chains, idlers, sprockets and clutches all move freely as designed.	YES
<input type="checkbox"/> Tires inflated to correct pressure.	YES
<input type="checkbox"/> Starter fertilizer application system functioning properly.	YES
<input type="checkbox"/> Seed metering units have been calibrated.	YES

Complete this checklist in the field. In early spring, drive the planter out into the field (not on the edge), and plant for 30' without seed, then stop and complete these checks.

<input type="checkbox"/> Toolbar is at height that allows parallel links to run parallel to the ground.	YES
<input type="checkbox"/> Planter is nearly level from front to back, set slightly tail-down.	YES
<input type="checkbox"/> Down pressure with seed bins empty is sufficient to keep gauge and drive wheels in contact with ground. You should just be able to turn the gauge wheels by hand.	YES
<input type="checkbox"/> Closing wheels do not disturb the soil at the bottom of seed furrow.	YES

Complete this checklist just before planting. Test-plant 30–40' at your planned speed (3–4 mph recommended for seed placement uniformity), with seed, then stop and complete these checks.

<input type="checkbox"/> Row cleaners do not move soil and do not turn constantly.	YES
<input type="checkbox"/> Residue is cut without hairpinning.	YES
<input type="checkbox"/> Residue has been moved, creating a bare strip of desired width.	YES
<input type="checkbox"/> Seed depth is uniform and correct—verified by digging.	YES
<input type="checkbox"/> Seed spacing is uniform and at correct distance for desired population.	YES
<input type="checkbox"/> Seed is pressed into the bottom of the seed furrow in contact with wet soil.	YES
<input type="checkbox"/> Seed furrow is completely closed with sidewalls shattered and seed covered with loose soil.	YES

Complete this checklist immediately after planting.

<input type="checkbox"/> All planter settings written down, by field.	YES
<input type="checkbox"/> Problems and solutions written down.	YES
<input type="checkbox"/> Plans for planter/planting improvements written down.	YES
<input type="checkbox"/> Planter cleaned.	YES
<input type="checkbox"/> Chains lubricated.	YES

Complete this checklist after harvest.

<input type="checkbox"/> Plant roots developed normally in all directions.	YES
<input type="checkbox"/> Depth of root penetration recorded.	YES
<input type="checkbox"/> Samples taken for nitrogen analysis (soil, corn stalk, etc.).	YES
<input type="checkbox"/> Combine settings written down.	YES
<input type="checkbox"/> Residue management results written down.	YES

Checklists adapted from NRCS No-Till Management – Planter Settings (USDA-NRCS 2004) and Planter/drill Consideration for Conservation Tillage Systems (Grisso, Hoshouser, and Pitman 2009).



Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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