MANAGING CROP RESIDUES

It is an accepted fact that returning crop residues to the soil environment is an agronomically sound practice. The positive effects are many and well-documented, and include:

- Providing ground cover to absorb the impact of raindrops, thus reducing soil particle detachment which in turn decreases erosion potential;
- Recycling nutrients removed by a growing crop; and
- Maintaining or increasing soil organic carbon (SOC) to provide a substrate for soil microorganisms and to increase the organic component of soil.

Residue management is a hot topic because removing aboveground biomass for energy production (as cellulosic ethanol) is receiving increased attention. In fact, it is anticipated that production of cellulosic ethanol will surge as the first high-volume refineries go into production. In 2009, the USDA-ERS published a report entitled "Ethanol and a changing agricultural landscape", which provides an analysis of the projected effects on agriculture where crop residues serve as the primary cellulosic feedstock.

Even though soybean residue is not a topic of general conversation when discussing bioenergy production from cellulose feedstocks, soybean production systems will involve residue management when corn, grain sorghum, and wheat are grown in rotation. Thus, the subject of this article will address residue management as an accompanying component of soybean production systems.

The long-term sustainability of any agronomic system is closely linked to maintaining adequate SOC, and the maintenance of SOC is linked to tillage system (Halvorson et.al., 2002). Therefore, it is critical that agricultural practices that contribute to or enhance destruction of plant residues or their removal be carefully evaluated before they are arbitrarily adopted in Midsouth crop production systems.

Management of residue from all crops is invariably linked to the amount and type of tillage that is performed following harvest of the grain portion of the above crops. Therefore, the first section of this paper presents definitions that pertain to tillage systems, and how those systems will affect residue.

Tillage in any production system is performed to prepare a seedbed, remedy compaction, incorporate fertilizers and herbicides, and control weeds. However, one of the accompanying results of tillage is the destruction of crop residues that remain after grain harvest.

The following definitions are based on the effect of a particular tillage system on residue cover.

Conventional tillage system

This system is synonymous with clean tillage. Operations involve primary tillage with moldboard plows, heavy disks, and chisel plows. These operations are followed by one or more secondary tillage operations with a tandem disk harrow and/or field cultivator and/or spring-tooth cultivator at some time before planting to smooth the soil surface.

Clean tillage leaves essentially no crop residue on the soil surface; thus, soil is exposed to maximum water runoff and heightened erosion (**Table 1**).

Reduced tillage system

This system uses tillage operations with secondary tillage implements that leave 15 to 30% of the soil covered with residue. This system can be termed a hybrid of the previously described conventional tillage system and the following conservation tillage system. It is the most flexible of the three systems in that limited tillage is used as needed to remedy an identified problem associated with continuous cropping of a site.

Using a reduced tillage system increases dependence on both pre- and post-planting chemical weed control, but does reduce erosion (**Table 1**).

Conservation tillage system

This category includes those systems commonly referred to as mulch-till, strip-till, ridge-till, and no-till. Definitions of these sometimes difficult-to-distinguish systems provide the nuances for their delineation (UWEX; USDA-ERS 2007). Fertilizer application and planting are done in narrow strips, with minimal soil disturbance outside the application and planting zone. More than 30% of the soil is covered by residue at any given time.

No-till refers to a system where tillage is essentially eliminated during both the growing season and the off-season. However, some tillage is conducted in the process of creating a seed trench or strip with a coulter or disk-opener during planting. No-till is frequently used with a narrow row spacing that precludes post-plant cultivation. This places total dependence on herbicides for both pre- and post-plant weed management.

Residue cover resulting from conservation tillage is credited as the major factor for reducing soil loss. Erosion can be reduced by as much as 50% if 30% of the soil surface (compared to bare soil) is covered with residue (MU).

It is recognized that soil erosion in excess of soil production will lead to decreased agricultural potential (Montgomery 2007). Implementation of a no-till crop production system reduces water runoff and soil erosion (Rhoton, Shipitalo, and Lindbo 2002) by leaving increased amounts of residue on the soil surface. The reduction in soil loss can be dramatic.

Deep tillage

This operation, sometimes termed "subsoiling" or "deep ripping", refers to primary tillage operations that affect soil 6 in. or deeper. These operations are used to fracture or loosen deep soil barriers, improve rainfall infiltration, and mix residue and nutrients deep into the profile. Deep tillage can be part of a conservation tillage system if it minimally disturbs the soil surface and leaves more than 30% of the soil covered by plant residue.

Table 1. Measured surface cover and soil loss for various tillage systems used for corn and soybean production in Kansas and Nebraska (Adapted from Dickey, Shelton, and Jasa, 1986)

Tillage system	Residue cover	Erosion	
	%	ton/acre	% reduction from moldboard plow
Corn residue*			
Moldboard plow, disk 2X, plant	7	7.8	--
Chisel plow, disk, plant	35	2.1	73
Disk 2X, plant	21	2.2	72
Rotary-till, plant	27	1.9	76
Till-plant	34	1.1	86
No-till, plant	39	0.7	91
Soybean residue**			
Moldboard plow, disk 2X, plant	2	14.3	--
Disk 2X, plant	5	14.3	0
Chisel plow, disk, plant	7	9.6	32
Disk, plant	9	10.6	26
Field cultivate, plant	18	7.6	46
No-till, plant	27	5.1	64

*After tillage and planting on a silt loam soil having a 10% slope, 2 in. water applied in 45 min.
**After tillage and planting on a silty clay loam soil having 5% slope, 2 in. water applied in 45 min.

General Principles for Residue Management Decisions

- Follow a crop rotation sequence that includes high-residue-producing crops such as corn and grain sorghum with low-residue-producing crops such as soybeans.
- Wait until spring for tillage operations that must be performed, especially following soybeans.
- Plant rye or wheat as a winter cover crop.
- Till shallow vs. deep because tilling deeper buries more residue.
- Use straight points and sweeps on chisel plows because twisted points bury more residue.
- Strive for even distribution of residue from a combine.
- Recognize that fragile residue from crops such as soybeans decomposes quicker than the non-fragile residue from corn, grain sorghum, and wheat.
- High grain yields result in more residue; e.g. irrigated vs. nonirrigated corn and soybeans.

- Soybean, corn, and grain sorghum produce approximately a 1:1 ratio of residue to grain. Since soybean yields about 33% as much grain as corn under similar growing conditions, it follows that soybean residue is only about 33% that of corn.

Soybean Residue Management

Soybean residue is rarely if ever removed by burning or baling. Therefore, the discussion of its residue management will deal solely with tillage.

Tillage systems used for soybeans are varied. In rotation systems involving soybean, a commonly used scheme is no-till planting. In this case, it is common for one or two disk harrowings followed by a field cultivation (shallow tillage with an implement having spring-tooth tines or sweeps) or shallow chisel plowing to be done following corn, grain sorghum, or wheat harvest preceding the soybean crop in the rotation, with no tillage following the soybean crop. These operations in combination with no-till planting will leave at least 30% residue cover following both growing seasons, and provide the most erosion control while still allowing for some tillage of the less fragile corn/grain sorghum/wheat residue.

Management of soybean residue needs special consideration for the following reasons when preparing soil for subsequent crops.

- Soybean residue degrades quickly because of its high N content.

- Residue following soybean harvest is only about 33% of the amount of residue following corn harvest.

- Erosion from areas where soybeans were grown the previous year will be significantly greater than from areas where corn was grown when the same tillage systems are used on both (**Table 1**).

- Residue levels following soybean may be sufficient to meet requirements to reduce erosion from some sites, but winter decomposition and any fall or spring tillage–even the planting operation–will easily destroy a significant amount of the residue because of its fragility (**Table 2**; UWEX). Thus, a no-till system for continuous soybean may be the only one that meets the standard of 30% surface residue cover required for a conservation tillage system (**Table 1**).

- Tillage implements such as a disk harrow and chisel plow will cover more of the flat, fragile residue from soybeans than of the sturdier, more erect residue from corn and grain sorghum.

Calculations shown in **Table 2** give examples of estimated residue losses from fall harvest to after planting of corn and soybeans when various tillage implements are used in sequence. These calculated values are less than those for using individual implements one time (**Table 3**), and leave no doubt that using multiple tillage passes with various implements drastically reduces residue cover from any crop.

Residue management in soybean production is not a hot topic. However, the management of residues from crops rotated with soybeans in the humid subtropical environment of the Midsouth should be carefully considered when options other than maintenance of soil health are available. The remainder of this article will address those topics.

Table 2. Calculations of estimated corn and soybean residue losses for indicated tillage systems (tillage operations applied in indicated equence) from fall harvest to after planting using average residue values from UWEX.

	% Residue remaining after each operation following:	
Field operation/condition	**Corn**	**Soybean**
After harvest	85	78
Fall–subsoil	x 0.80 = 68	x 0.65 = 51
Winter decomposition	x 0.88 = 60	x 0.75 = 38
Spring–disk	x 0.75 = 45	x 0.45 = 17
Spring–spring tooth cultivator	x 0.80 = 36	x 0.60 = 10
Plant double disk openers	x 0.90 = 32	x 0.80 = 8
Totals	32	8
After harvest	85	78
Fall–disk	x 0.75 = 64	x 0.45 = 35
Winter decomposition	x 0.88 = 56	x 0.75 = 25
Spring–spring tooth cultivator	x 0.80 = 45	x 0.60 = 15
Plant double disk openers	x 0.90 = 40	x 0.80 = 12
Totals	40	12
After harvest	85	78
Fall-disk	x 0.75 = 64	x 0.45 = 35
Fall–spring tooth cultivator	x 0.80 = 51	x 0.60 = 21
Winter decomposition	x 0.88 = 45	x 0.75 = 16
Plant double disk openers	x 0.90 = 40	x 0.80 = 13
Totals	40	13
After harvest	85	78
Winter decomposition	x 0.88 = 75	x 0.75 = 58
Spring–disk	x 0.75 = 56	x 0.45 = 26
Spring–spring tooth cultivator	x 0.80 = 45	x 0.60 = 16
Plant double disk openers	x 0.90 = 40	x 0.80 = 13
Totals	40	13
After harvest	85	78
Winter decomposition	x 0.88 = 75	x 0.75 = 58
Plant no-till	x 0.75 = 56	x 0.68 = 40
Totals	56	40

Table 3. Estimated range of corn, soybean, and grain sorghum residue remaining after using an individual implement following harvest of each respective crop. Values are from the linked sources shown over each table column.

	Residue (%)						
	UWEX		MU		ISU		KSU
Tillage operation/condition	**Corn**	**Soy**	**Corn**	**Soy**	**Corn**	**Soy**	**Sorghum**
After harvest	75-95	65-90	80-95	70-80	90-95	80-90	90
After winter decomposition	80-95	70-80	---	---	80-90	70-80	90
Moldboard plow	0-10	0-5	0-10	0-5	0-5	0-5	10
Subsoiler/Ripper	70-90	60-70	70-90	60-80	---	---	---
Chisel plow–straight shank	60-80	40-60	60-80	40-60	50-60	30-40	75
Tandem disk	70-80	40-50	70-80	40-50	40-70	25-35	70
Field cultivate–sweeps	70-80	60-75	80-90	65-75	80-90	55-65	90
Spring tooth cultivator	70-90	50-70	60-70	35-50	---	---	---
Bedder/hipper	---	---	15-30	5-20	---	---	---
Planter–double-disk openers	85-95	75-85	90-95	85-95	80-90	80-90	95
No-till planter–fluted coulters	65-85	55-80	65-85	55-80	---	---	---
Rotary hoe	---	---	85-90	80-90	---	---	---

Corn Residue Management–Tillage

Using any of the tillage systems shown for corn following corn in **Table 2** results in estimates of >30% residue cover after planting. Thus, the goals of conservation tillage can be achieved in a corn production system even if some tillage operations are conducted. The amount of tillage that can be performed will be limited by the amount of residue that will remain after harvest. This is especially the case in the Midsouth where the yield disparity between nonirrigated and irrigated corn is large.

Calculation (**see Table 2**) is a good way to get a rough estimate of remaining residue following tillage and relative differences resulting from using different tillage systems without making field measurements. It provides a general guide, but will not reflect the absolute conditions in any field because tractors and implements are different and perform differently, soil moisture and topography will affect residue stability, and irrigation vs. no irrigation will affect residue amounts.

A more accurate way of estimating residue cover following harvest and tillage is to take field measurements. Two selected sources give detailed measurement instructions (UWEX; ISU). These measurements can be made by a producer following any tillage operation or operations to determine their effect on the amount of plant residue remaining on the soil surface.

Two NRCS publications, Corn and soybean crop residue management guide and A guide to managing crop residues in corn and soybeans, and a Purdue University publication provide additional information about how to measure crop residues.

An NRCS publication entitled "Picture Your Residue" provides pictures and guidelines that can be helpful for visually estimating amount of crop residue.

Corn Residue Management–Removal

Various sources from the Midwestern US discuss how the removal of corn residue can be managed without jeopardizing soil properties. Research into this subject has not been conducted in the Midsouth. The findings from the Midwest indicate that Midsouth research that explores a production system that utilizes corn should include assessing the effects of stover removal on soil properties since the stover removal issue will likely be debated if cellulosic ethanol production moves into the Midsouth.

From 2001 to 2013, the Midsouthern states of Arkansas, Louisiana, and Mississippi had a significant increase in corn acreage (877,000 to 2,600,000 acres). It is likely that most of these acres are grown in rotation with another crop. However, it is also likely that Midsouth producers would grow continuous corn on some of the acreage if not for the yield drag expected from this practice.

If projected increases in demand for corn become true, continuous corn acreage–i.e., planting corn on the same field for at least 3 years–will inevitably increase. In fact, in a 2009 USDA-ERS REPORT, it is predicted that continuous corn will account for 30% of the total US corn acres by 2015, which somewhat reverses the trend of rotating corn with other crops, mainly soybeans. This figure could be even higher under the biofuel scenario of the Energy Independence and Security Act (EISA) of 2007, which has significantly increased the demand for US corn grain.

It is also predicted that a significant portion of these additional corn acres will be in no-till production.

The above two predictions raise two important points.

- The so-called "yield drag" or "yield penalty" resulting from corn following corn vs. yield of corn grown in rotation with soybeans is substantiated by results from numerous research projects.

- Continuous corn production will result in the annual, unbroken production and accumulation of corn residue in fields cropped to continuous corn.

A report in Agronomy Journal by Gentry, Ruffo, and Below at the Univ. of Illinois sheds some light on factors that control the aforementioned yield drag resulting from continuous corn production on a site. Their study was conducted from 2005-2010 on a site that had been in continuous corn or a soybean-corn rotation for the previous 2 years, with the objective of identifying the causes of the continuous corn yield drag relative to the yield of corn from a soybean-corn rotation.

Averaged across all years of their study, yield of continuous corn was about 15% below the yield of corn in the soybean-corn rotation, and this yield drag existed for the duration of the 7-year study. They concluded that the primary causes of the continuous corn yield penalty are nitrogen availability, corn residue accumulation, and weather.

Furthermore, they speculated that the primary agent of the yield penalty in the continuous corn system is accumulated corn residue, which is slow to decompose. This in turn can exert a negative effect on nutrient cycling and speed of N mineralization.

They also proffered that excellent weed control and biotech traits that impart insect resistance in corn make it unlikely that pests are a primary cause of reduced yields in continuous corn systems.

Thus, since weather cannot be controlled and the optimum N rate for continuous corn can only be determined from experience, managing corn residue has the greatest potential for reducing the yield drag associated with continuous corn production on a site.

Further analysis of the data in the above study is presented in a webinar entitled "Effects of Agricultural Intensification on Corn Yield, Root Biomass, & Nutrient Use". Dr. Gentry discusses additional findings related to corn yield, fertility, and soil organic matter following corn stover removal in traditional and high-yield environments.

The implication of accumulating corn residue as a factor in the yield drag associated with a continuous corn production system was addressed in a previously posted blog on MSSOY. The following excerpt is from that article.

According to Heggenstaller (Pioneer, 2012), "corn residues are a major factor contributing to lower yields for corn following corn compared to corn rotated with soybean, particularly in no-till management." Major points from this study are:

- With corn following corn, residue management seems to be the key to avoiding the yield-reducing effects of corn stover. This involves offsetting stover's potential for producing negative effects by reducing the interference from corn residue through removal (baling) of a portion (approximately one-half) of the stover.
- Results suggest that corn after corn with stover removal may produce yields that are similar to those from corn rotated with soybeans.
- No-till continuous corn production is amenable to stover removal due to the high amounts of residue that are produced and remain on the soil surface in the absence of tillage.
- The amount of corn residue that should remain on a site to maintain SOC level must be accounted for when considering removal of residue. Click here for an article that provides guidelines regarding the amount of corn stover that should be retained to maintain soil organic matter.

The above findings and conclusions indicate that Midsouth research that explores a production system of corn following corn vs. corn rotated with soybeans should include assessing the effects of stover removal in the continuous corn system, particularly when irrigation is used to produce high yields. If findings from this research mimic those from the above studies, then Midsouth producers can elect to grow either continuous corn or rotated corn with no concern for the yield drag associated with growing continuous corn.

An interesting addendum to the above is that cover crops can be used in a production system that includes corn to increase farm profits by allowing a greater amount of corn residue to be harvested for sale as a cellulosic ethanol feedstock. Click here for a summary of this concept and here for a Purdue University article that describes the concept in detail.

Wheat Residue Management

Doublecropping soybeans with wheat is a common production system in the Midsouth. In this system, soybeans are either planted no-till into standing wheat stubble, following tillage to incorporate the residue, or following burning or baling of the residue.

An NRCS publication has photographs and a table that can be used to estimate percent ground cover that is left on the soil surface following tillage of wheat residue. Pictures of various tillage tools that can be used to preserve ground cover are also shown.

Regardless of the method of planting soybeans, wheat should be harvested with a combine that has a straw shredder/spreader. If soybean is to be planted no-till, cut wheat at 9 to12 in. above the ground to minimize both horizontal (cut straw that interferes with planter) and vertical (shades emerging soybean seedlings) residue.

In a Nov. 2012 article in Crop Management, Dr. Kristofor Brye of the University of Arkansas reports the results from a 7-year study that was conducted to measure the effects on soil properties from burning wheat straw.

The major finding was that burning wheat residue reduced the amount of carbon recycled to the soil by an average of about 2000 lb/acre/year. Both annual aboveground residue production and wheat grain yields were unaffected by burning the residue across the years of the study. Thus, the only measurable (but very significant) negative effect from burning wheat residue in this study was the large reduction in potential SOC available for recycling to the soil. This agrees with results from tillage studies reported by Halvorson et.al., 2002.

From Dr. Brye's results, it goes without saying that the current practice of burning wheat straw in the Midsouth appears to be a non-sustainable practice for maintaining or improving soil health. Also, it can be surmised from his burning experiment that removal of wheat straw by any method and for any reason will be detrimental.

A Virginia Tech University publication provides estimates that the value of nutrients lost when wheat straw from an 80 bu/acre grain yield is baled and removed from the production site is greater than $50/acre (based on straw yield of about 2 tons/acre). This amount will vary depending on wheat yield and whether or not the stubble is cut before baling.

Grain Sorghum Residue Management

Grain sorghum is not a major crop acreage-wise in Mississippi, with only an estimated 110,000 acres harvested in 2014. However, it is recognized as being superior to corn in both drought and heat tolerance (Crop Management). Therefore, it has the potential to become a significant rotation partner with soybeans in a dryland production system in Mississippi.

Like corn, tillage following a grain sorghum crop can be performed to some degree and still leave the required 30% ground cover that is required for the conservation tillage designation (**Table 4**). Since Mississippi's grain sorghum is grown without irrigation, there will be no excess residue to deal with.

Table 4. Calculated estimate of percentage cover from and weight (lb/acre) of grain sorghum residue following indicated tillage operations applied in sequence, assuming an 80 bu/acre grain yield (Miss. average yield for 2004-2013 period = 78.6 bu/acre). Adapted from Hickman and Schoenberger.		
Operation	Residue cover	Residue weight
After harvest	90	4800
Overwinter	x 0.90 = 81	x 0.90 = 4320
Chisel plow–straight shank	x 0.75 = 61	x 0.75 = 3240
Tandem disk	x 0.70 = 42	x 0.70 = 2268
Field cultivate	x 0.80 = 34	x 0.80 = 1814
Plant	x 0.95 = 32	x 0.95 = 1724
Total	32	1724

Grain sorghum allelopathy has received considerable attention. Sorghum's allelopathic properties are more pronounced than those of most other crop plants that have been studied. Research findings support grain sorghum's allelopathic effect and the potential effect of that property in cropping systems.

Roth, Shroyer, and Paulsen reported that wheat yields following grain sorghum were reduced by 15 and 30% compared to fallow when the sorghum residue had either been tilled or left on the soil surface with no tillage, respectively. Their results suggest that tillage of the sorghum stover abated but did not completely offset the effect of the allelopathic compounds in the sorghum stover. This apparent effect of grain sorghum residue on a following crop, especially wheat, needs to be delineated in the Midsouth production environment.

Final Thoughts

A nonirrigated corn crop in Mississippi may produce 125 bu/acre of grain, or 7,000 pounds of grain and about 7,000 pounds of residue.

An irrigated corn crop in Mississippi may produce 200 bu/acre of grain, or about 11,000 pounds of grain and 11,000 to 12,000 pounds of residue.According to the data in **Table 5** below, corn crops that produce the above amounts of grain will provide sufficient (nonirrigated) and excess (irrigated) residue to provide complete ground cover.

A nonirrigated soybean crop in Mississippi may produce 35 bu/acre of grain, or about 2,000 pounds of grain and about 2,000 pounds of residue.

An irrigated soybean crop in Mississippi may produce 65 bu/acre of grain, or about 3,900 pounds of grain and about 3,900 pounds of residue.

According to the data in **Table 5** below, only the irrigated soybean crop with the above yield will provide sufficient residue to provide complete ground cover.

When establishing a production system that includes rotating a low-residue crop, e.g. soybeans, with a high-residue crop, e.g. corn, on erodible land, the high-residue crop should be grown first in the sequence (Krupinsky et. al., 2007).

Table 5. Percentage residue cover to residue weight for various crops.

	Residue weight, lb./acre	
% Cover	**Soybeans**	**Corn, sorghum**
10	150	200
20	330	600
30	530	1000
40	800	1450
50	1200	2000
60	1650	2650
70	2150	3500
80	2800	4700
90	4000	6700

From Corn and soybean crop residue management guide

Additional Resources

Crop Residue Management, NRCS 2006

Conservation Tillage and Crop Residue Management, NRCS Handbook SQ-8b

Residue Management and Cultural Practices, Iowa State Univ. PM1901a

Crop Residue Management Increases Dryland Grain Sorghum Yields in a Semiarid Region, Unger and Baumhardt, 1999

Use Crop Residues for Soil Conservation, Iowa State Univ. Extension

SUMMARY

Much of the information in this article is drawn from results of research that was conducted in the Midwestern and Great Plains areas of the US. However, it is likely that the pattern of results from Midsouth research will be similar to that from the results cited above, but the actual data points will be different because residues in Midsouth crop fields will decompose faster than those in Midwestern fields. Thus, crop residues in Midsouth fields will be less than those in Midwest fields in the spring.

Any tillage operation will decrease the amount of crop residues covering the soil. In the case of soybeans, even in a high-yield environment, any tillage will likely decrease ground cover below the amount needed to maintain a conservation tillage system.

Residue from soybeans will be less than that from corn and grain sorghum in a given production environment, and soybean residue will be quicker and easier to decompose.

Corn produced in a high-yield environment can provide residue in an amount that may be partially removed without jeopardizing the amount of residue needed to maintain soil health and a conservation tillage system.

Calculation of residue remaining at any time should be used only as a general guide. The best estimate of residue remaining on the soil surface following any operation is provided by using one of the measurement techniques described in the references above.

There is no agronomic reason to burn wheat straw. In fact, burning wheat residue reduces the amount of carbon recycled to the soil and results in loss of nutrients from the production site.

Results from limited research indicate that planting wheat following grain sorghum may be problematic because of the allelopathic effect of sorghum residue.

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