# High Residue Conservation Tillage System for Cotton Production: A Farmer's Perspective

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**Abstract**

High residue conservation tillage systems for cotton (*Gossypium hirsutum* L.) production have been proposed as having the potential to be both economically and environmentally sustainable, and research has indicated that several advantages may exist for conservation tillage systems compared to conventional tillage systems. However, adoption of new farming systems on a regional scale is difficult unless an individual farmer is willing to take the personal risk and demonstrate the sustainability of the new system on a farm. The John T. Ingram and Sons Farm is an example that adopted a high residue conservation tillage system. Located on the Coastal Plains of Alabama, this farm has successfully operated as a high residue conservation tillage system since 1984 and served as an example for other farmers in the region. The following describes the system presently used on the John T. Ingram and Sons Farm and presents their perspectives and observations.

**Keywords**: Strip-tillage, residue management, cotton planter, cover crop

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**1. Introduction**

The development of herbicides in the 1960's provided the ability to produce crops without tillage to control weeds (Baeumer & Bakermans, 1970; Reeves, 1997), which in turn led to the development of cropping systems to limit tillage operations (i.e., conservation tillage systems). Conservation tillage systems have been greatly researched and were found to provide potential economic and environmental advantages compared to conventional tillage systems. Over the years, more effective herbicides and planting equipment led to increased adoption of conservation practices across the country. For example in 2002, approximately 70% of cotton production in Alabama was under conservation tillage.

Extensive research has been conducted on developing conservation tillage systems across the country. While this research contributed to improvements in these farming systems, wide spread adoption relied on the pioneering efforts of individual farmers who recognized the potential and were willing to take personal economic risks to employ large-scale conservation tillage systems on their farms. In the Coastal Plain of Alabama, John T. Ingram and Sons Farm initiated a conservation tillage system in 1984 and is an example of these pioneering efforts. The objective of this manuscript is to describe in detail the high residue conservation tillage farming system that has evolved on the Ingram Farm.

**2. Discussion**

The John T. Ingram & Sons Farm is located in Marvyn, AL (south of Auburn, AL) and is operated by Tom Ingram and two of his sons (John T. Ingram Jr. and Robert Ingram). Tom Ingram returned from military service in Europe following World War II and graduated from Auburn University on the GI bill. Following graduation, he started to grow cotton on the land that his ancestor Bartholemew Ingram first cleared for farming in 1836. From the beginning, he was an innovative farmer who promoted good farming practices and communicated these to others. When they first became commercially available, Mr. Ingram was the first farmer in central Alabama to adopt herbicides for weed control and was a leading proponent of the “1988 Boll Weevil Eradication Program” for central Alabama who instituted a similar program on his land 10 years earlier. Mr. Ingram has appeared in numerous magazine and newspaper publications describing his innovative farming operations. For example, he promoted high residue conservation tillage systems in “Southeast Farm Press” and twice in the “Alabama Farmer” (1986, 1999, and 2002, respectively). Since converting his farm to conservation tillage, he has hosted numerous visitors and farm demonstrations and has willingly participated in meetings promoting conservation tillage. His innovative approach to conservation farming practices were featured at the 2002 Southern Conservation Tillage Conference.

Mr. Ingram has tirelessly promoted conservation tillage practices and worked to benefit cotton farmers by serving on state, regional, and national cotton organizations as a member of the Alabama Farmers Cotton Commission, Southern Cotton Growers, and the National Cotton Council. He was also president of the Lee County Alabama Farmers Federation, District VII Director of the Alabama

Farmers Federation and received the 1989 Lee County Extension Volunteer Award, and the 2000 Southeast Cotton Farmer of the Year Award. Mr. Ingram was inducted into the Alabama Agricultural Hall of Honor in 2003.

Today, Tom Ingram and his two sons farm approximately 600 acres of cotton. In 1984, the Ingram's initiated a high residue conservation row tillage farming system on 100% of their farm. The conservation tillage systems used by the Ingram's has changed over the years as they have developed better farming techniques and adapted to changing technology. The following is a description of the farming system the Ingram's currently utilize.

### *2.1 High Residues*

Central to the Ingram's conservation tillage system has been the use of high levels of crop residues left on the soil surface. Research has shown that winter cover crops provide erosion control and crop rotation benefits (Torbert et al., 1996; Ducamp et al., 2012). Use of cover crops can improve soil physical (Folorunso et al., 1992; Jackson et al., 1993), chemical (Ebelhar et al., 1984; Martin & Touchton, 1983; Jackson et al., 1993), and biological (Curl, 1963; Barber, 1972; Ries et al., 1977) properties. For example, cover crops can improve soil structure and increase soil water infiltration and storage (Folorunso et al., 1992; Jackson et al., 1993).

The Ingram's have always used a winter cover crops for erosion control in the winter fallow period and to produce a heavy residue for subsequent cotton production. They have tried several different plant species over the years, including both non-legume and legume plant species. The legumes included clover (*Trifolium incarnatum* L.) and vetch (*Vicia sativa* L.). They have also experimented with winter clover crops that would naturally reseed. The non-legume species included wheat (*Triticum aestivum* L.) and oats (*Avena sativa* L.). Presently, the Ingram's use a rye (*Secale cereale* L.) cover crop because they found it to be reliable in planting while providing adequate ground cover for soil protection during the winter months (Fig. 1). Rye also exhibits excellent growth in early spring with subsequent termination one month prior to cotton planting. This yields a good heavy residue that affords moisture conservation during the summer growing season (Fig. 2).

### *2.2 Tillage System*

The cropping system used is a row-till conservation tillage system which consists of an in-row ripping operation and planting into surface residues from the previous crop and cover crop. Cotton is planted on a 40 inch row spacing. In the fall after cotton harvest, stalks are chopped and left on the soil surface. A grain drill (altered to allow for a 14 inch space centered on the previous year's cotton stalks) is used to seed the rye cover crop (Fig. 1). The rye grows during the winter months and is terminated with Glyphosate in early April (~1 month before planting). Immediately before planting, a ripping operation is performed directly into the previous year's cotton stalks (Fig. 2). The ripping operation uses a subsoil shank (depth ~16 inches) that causes little surface soil disturbance. Cotton is then planted into the previous year's cotton stalks to maintain a controlled traffic system.

Fig. 1. Rye cover crop planted into cotton stubble with a 14 inch gap centered on cotton stalks.

Fig. 2. Cotton is planted into a terminated rye cover crop.

Research has indicated that using a subsoiler along with controlled traffic can greatly reduce the soil compaction that is commonly observed in no tillage systems (Torbert & Reeves, 1994; Reiter et al., 2008). A John Deere MaxEmerge Plus VacuMeter vacuum precision planter is used for planting at a rate of 1 seed per 4 inches (Fig. 3). The planter uses row cleaners with a forward residue mover of their own design (Fig. 4; Torbert et al., 2007). The residue mover pushes standing rye stalks away from the planter which prevents stalk entanglement in the row cleaner mechanism. This added feature greatly improves planter performance by preventing clogging of the planter's moving parts. At the rear of the planter (Fig. 3), a spoked wheel row closer is used instead of a solid press wheel row closer. The Ingram's have found that solid wheels often resulted in soil compression that obstructs seedling emergence. Spoked wheel row closures result in more optimal soil compression which generates good soil/seed contact in these sandy soils.

In recent years, the Ingram's have started to eliminate the subsoiling-ripping operation from their cropping system. Subsoiling operations are generally only used on 50% of their farm each year. They believe that improvement in soil physical condition and increased soil organic matter from the use of cover crops has improved soil tilth to a point that subsoiling is no longer required each year. Research on soil bulk density and strength support this view. Although bulk density has been shown to increase in some no-till system, lower bulk densities can be found in no-till cropping systems that produce greater amounts of crop residues (McFarland et al., 1990). In addition, soil strength measurements have been shown to decrease with cover crop use compared to no-till systems that rely only on row crop residue (Schwab et al., 2002). The Ingram's expect that occasional deep ripping will be necessary due to subsoil reconsolidation; a soil penetrometer is used to identify when soil strength limits root growth due to subsoil reconsolidation.

The Ingram's have observed that soil temperatures are noticeably cooler in the summer from the heavy residue cover. They believe cooler soil temperatures help cotton growth during very hot periods of the growing season due to soil moisture conservation and reduced evaporation from the soil surface. Improved soil moisture conservation in systems with cover crops has been attributed to both reduced cultivation and increased soil insulation from residue (Bradford & Peterson, 2000). Also, improved soil physical properties and increased soil organic matter result in increased soil water storage (Reeves, 1994).

In some cases (especially cold humid climates), yield reductions observed in no-tillage system have been attributed to cooler soil temperatures (from residue cover) that reduce seed germination and seedling growth (Swan et al., 1987; Bradford & Peterson, 2000). The Ingram's believe that, in addition to providing a guide for controlled traffic, the 14 inch skip in the cover crop planting (centered on the cotton row) alleviates this potential problem. The skip in the residue cover allows the sun to warm the soil in the immediate area of the cotton row which helps seed germination and seedling growth during the critical establishment period (Fig. 5). This concept is supported by Kasper et al. (1990) who reported increased plant performance when residue was cleared near the row. The Ingram's have not observed problems with seed germination due to cool temperatures; they check soil temperature before planting but do not believe there is a substantial difference in planting dates between themselves and their neighbors who use conventional tillage.


Fig. 3. Cotton planter with spoked wheel row closers.

Fig. 4. Cotton planter with a forward residue mover.

Fig. 5. Cotton is planted into a 14 inch skip in the cover crop which improves seed germination and seedling growth.

One of the main benefits to conservation tillage systems is erosion control (Reeves, 1994). The use of a cover crop not only provides winter cover that protects against erosion, but also provides a large amount of residue cover for soil protection during the growing season (Fig. 5). The Ingram's have noticed that runoff water from their cotton fields is nearly clear, unlike the muddy water they observe in nearby conventional tilled fields. This observation is supported by scientific literature showing that conservation tillage systems are very effective in reducing erosion and limiting nutrients that leave the field in runoff sediment (Angle et al., 1984; Gilley et al., 1987). A large part of this is due to surface residues which enhance water infiltration. For example, Potter et al. (1995) reported differences in runoff volume and sediment losses between a chisel tillage system and a no tillage system; sediment losses were as much as 30 fold greater with chisel-till. Torbert et al. (1999) reported that total sediment lost during a simulated rainfall event was reduced in conservation tillage (0.03 Mg $ha^{-1}$) compared to conventional tillage (0.67 Mg $ha^{-1}$); nutrient losses were 12 time higher with conventional tillage.

### *2.3 Soil Fertility*

Soil fertility management on the Ingram farm follows Auburn University soil test laboratory recommendations (Adams et al., 1994). Fertilizer applications of P, K, and lime are based on results of soil samples taken each year. Samples are collected from field areas representing approximately 10-15 acres each. For P and K, a blended fertilizer is applied in the spring just before planting. For example, an application of 250 lb/acre of 14-4-14 blended fertilizer has commonly been used. Fertilizer N is applied at a rate of approximately 90 lb/acre (recommended rate for cotton). After application of the blended fertilizer, 34-0-0 fertilizer (~200 lb/acre) is used to supply the remaining required N.

The use of conservation tillage has been reported to increase short-term N immobilization due to slower plant decomposition caused by reduced tillage (Gilliam & Hoyt, 1987; Torbert & Reeves, 1994; Reiter et al., 2008). In the past, it has been recommended that fertilizer N applications be increased (as much as 25%) in conservation tillage systems (Randall & Bandel, 1991) since more residue may be limiting available soil N for a growing crop. However, the Ingram's have been successful with a 90 lb/acre rate that is the same as that recommended for conventional tilled cotton. While increased residue biomass inputs may cause short term N immobilization, they will also increase soil organic matter (due to reduced microbial decomposition from not plowing). Soil organic matter will greatly improve soil fertility by increasing not only plant available N, P, and K but other micro nutrients. It has been reported that winter cover crops can capture and utilize fertilizer left over from the previous crop and reduce nutrient losses through leaching in the winter months (Torbert & Reeves, 1995). These captured nutrients will become available to the subsequent crops as the plant material decomposes and forms soil organic matter.

It is believed that a well-established conservation tillage system would decrease the time that N immobilization would significantly impact N availability to the point of reducing plant growth. This is due to improved soil nutrient availability from increased soil organic matter in conservation tillage systems. While the influx of new residue would reduce available N, the increased level of total soil N reduces the cycling time when N is a limiting factor. In addition, since the cover crop is killed one month before planting, short-term N immobilization is substantially reduced before cotton plants reach a growth stage where N availability would be a limiting growth factor. This was confirmed by research observations in a conservation tillage system study that had been established for 20 years in a heavy clay soil (Torbert et al., 2001). In this study, there was no advantage for no-till corn (*Zea mays* L.) to receive increased N fertilizer compared to the conventional tillage system.

### *2.4 Soil Condition*

The Ingram's have noticed that their soil condition has greatly improved over the years. The soil has a darker and richer color, improved soil tilth, and has more earth worms and ants compared to their neighbors who practice conventional tillage. In an attempt to measure this change, soil samples were collected from three different fields that the Ingram's managed with their high residue cropping system. Near each location, soil samples were also collected from adjacent conventionally managed fields. Approximately ten soil cores were collected from each site and composited by soil depths of 0-5, 5-10, and 10-20 cm. The soil samples were dried (55$^{o}$ C), ground to pass a 0.15 mm sieve, and analyzed for total N and C on a LECO CN 2000 (LECO Corp., Saint Joseph, MI). The results from these samples are shown in Table 1.

Soil test results indicate a remarkable change in both total C and total N in soil managed under high residue cropping compared to conventional tillage (Table 1). A stratification of organic C has often been observed in conservation tillage systems (Blevins et al., 1977; Mielke et al., 1986; Potter & Chichester, 1993); this was also the case with the samples collected from the Ingram's field. Total soil C was reduced from 12.84 g kg$^{-1}$ at the 0-5 cm depth to 6.36 g kg$^{-1}$ at the 10-20 cm depth (Table 1). Likewise, total soil N was reduced from 1.02 g kg$^{-1}$ at the 0-5 cm to 0.41 g kg$^{-1}$ at the 10-20 cm depth. This stratification was not observed between the soil depths under the conventional tillage system (Table 1). The most remarkable difference was the significant increase in both soil C and N in the conservation tillage system compared to the conventional tillage system at the 0-5 and 5-10 cm soil depths (Table 1). The high residue system resulted in a total C increase of 100% and a total N increase of 149% at the 0-5 cm depth compared to the conventional tillage system. At the 10-20 cm depth, no significant difference was observed for soil C in the conservation tillage system, but a significant difference in total N was observed even at this deeper soil depth (Table 1).

Table 1. Concentration of total N and C in soil with strip tillage and conventional tillage cropping system at the 0-5, 5-10, and 10-20 cm depths†.

| Depth | Conventional Tillage | Strip Tillage | Conventional Tillage | Strip Tillage |
|---|---|---|---|---|
| (cm) | N (g $kg^{-1}$) | N (g $kg^{-1}$) | C (g $kg^{-1}$) | C (g $kg^{-1}$) |
| 0-5 | 0.41 a | 1.02 b | 6.41 a | 12.84 b |
| 5-10 | 0.40 a | 0.63 b | 6.36 a | 8.38 b |
| 10-20 | 0.37 a | 0.41 b | 6.29 a | 6.36 a |

†Values represent means of 3 replications. Means within a row followed by the same letter do not differ significantly ($\alpha = 0.05$).

*2.5 Pest Control*

Because soil tillage is not a means of weed control in conservation tillage systems, herbicide use is a very important aspect for crop management. The Ingram's plant 'Round-up-Ready' cotton, which provides early season weed control. They spray over the top with glyphosate at the 4 leaf stage. An additional herbicide application (Caporol) is made with a shielded sprayer at the end of June to capture any late season weeds.

While cultivation is not used for weed control, some benefits are achieved from the use of cover crops in their high residue conservation tillage system. For example, by having a winter cover crop, weeds that can establish and contribute to the seed bank during winter and early spring have trouble competing with the rye. In addition, winter weeds that do establish themselves are killed with the rye before cotton planting and become part of the surface residue. While it is estimated that there is a sufficient weed seed bank in cultivated soils to maintain damaging weed levels for years, many seeds depend on tillage to develop conditions favorable for germination. The elimination of plowing greatly reduces the transport of seeds to the soil surface where conditions are favorable for weed seed germination (Wiese, 1985; Price and Norsworthy, 2013; Kelton et al., 2012).

The Ingram's use Aldicarb at planting (3 lb/acre in seed furrow) as a systemic insect control. Additional insect control is accomplished through insect monitoring and additional insecticides are sprayed as needed; however, insect problems have rarely reached economic thresholds. The boll weevil eradication program established in Central Alabama in the late 1980's greatly changed insect dynamics in the Southeastern U.S. At the present time, there is no need to spray for boll weevil control since they have been eradicated in the area. As a result, beneficial insects have proliferated and the incidence of pests such as boll worms have been greatly reduced to the point of rarely needing insecticidal control.

In addition to boll weevil eradication, the Ingram's believe that their high residue conservation tillage system has further improved beneficial insect populations on their lands which has greatly reduced insecticide applications. The cooler soil temperatures afforded by the residue in the inter rows result in a greatly improved environment for beneficial insect survival during the growing season. Fire ants, which are vigilant predators of insects harmful to cotton, are particularly favored by the conservation tillage system, not only by cooler summer temperatures, but also by the elimination of surface tillage which greatly reduces fire ant bed disturbance.

No-till has been shown to increase the incidence of plant diseases (Reeves, 1994). The Ingram's combat this potential problem by using a relatively high rate of fungicide for cotton seedling disease control. At present, they use a Ridomil PC application in the seed furrow at planting. The biggest cotton pest on the Ingram's farm is wildlife. Foraging white tail deer do considerable damage to the crop. Recently, damage to mature cotton bolls by raccoons has also become a problem. At present, no effective means of controlling wildlife damage has been developed, and the Ingram's sustain considerable crop damage, especially in areas that adjoin extensively wooded terrain.

In addition to pest control, plant growth regulators are use as needed. The Ingram's farm is not irrigated and as a result, cotton growth only occasionally becomes excessive to the point of needing a plant growth regulator. A defoliant is used to promote leaf drop before harvesting.

## 3. Conclusion

Yearly cotton yields in the U.S. Coastal Plains region vary greatly in response to weather conditions (especially rainfall during the growing season). For example in 2011 (a favorable year for rainfall), the Ingram farm produced an average of 2 bales of lint cotton/acre; some yields were lower due to wildlife damage. While lower yields have been observed due to less favorable weather, the Ingram's believe that their yearly yields have become more consistent under high residue conservation tillage compared to neighbors using conventional tillage. In addition, the Ingram's believe that improved overall soil conditions on their farm have stabilized yields. There was a 100% increase in soil C and

149% increase in soil N at the 0-5 cm depth compared to neighboring conventionally managed cropping systems. Improved soil tilth has tremendously reduced erosion losses that previously degraded their farm land before conservation tillage implementation. The Ingram's are very satisfied with their high residue conservation tillage system and believe it is economically and environmentally sustainable for cotton production compared to conventional farming techniques used in this region (Fig. 6).

Fig. 6. High residue conservation tillage affords good cotton growth and seed cotton production.

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