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

H.A. Torbert[1], J.T. Ingram[2], J.T. Ingram Jr[2]., and R. Ingram[2]

[1]USDA-ARS National Soil Dynamics Lab, Auburn, AL 36832. USA.

[2]John Ingram & Sons Farm, 23035 U.S. Hwy 80, Opelika AL 36804. USA.

Corresponding author's e-mail: atorbert@ars.usda.gov

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 regarding tillage systems 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 in 1984 adopted a high residue conservation tillage system. Located on the Coastal Plain soils of Alabama, this farm has been successfully operating as a high residue conservation tillage system from that time to the present and has 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 perspective and observations.

KEYWORDS

Strip-tillage, residue management, cotton planter, cover crop.

INTRODUCTION

The development of herbicides in the 1960's provided the ability to produce crops without tillage to control weeds (Baeumer and Bakermans, 1970; Reeves, 1997), which in turn led to the development of cropping systems that limited tillage operations, i.e., conservation tillage systems. Conservation tillage systems have been greatly researched and have been found to provide both potential economic and environmental advantages compared to conventional tillage systems. Over the years, better herbicides and planting equipment have been developed that led to increased adoption of conservation tillage systems across the country. For example in 2002, it is estimated that approximately 70% of cotton production in Alabama will be planted with conservation tillage systems, up from 18.5 % in 1998.

Extensive research has been conducted on developing conservation tillage systems across the country. While this research has contributed to improvements in these farming systems, the wide spread adoption would not have occurred without the pioneering efforts of some individual farmers who were far sighted enough and willing to take the personal economic risk to use conservation tillage systems on a large scale 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 one of these pioneering farms. The objective of this manuscript is to describe in detail the high residue conservation tillage farming system that has evolved on the Ingram farm.

DISCUSSION

The John T. Ingram & Sons farm is located in Marvyn, AL (just south of Auburn, AL). The farm 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 family farm. Today, Tom Ingram and his two sons' farm comprises approximately 600 acres of cotton. In 1984, the Ingrams initiated a high residue conservation row tillage farming system on 100% of their farm. The conservation tillage systems used by the Ingrams 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 Ingrams plan to use this year (2002).

High Residues

Central to the Ingram's conservation tillage system has been the use of high levels of crop residues that are left on the soil surface. Research has shown the benefits of winter cover crops to provide erosion control and to provide crop

IN E. van Santen (ed.) 2002. Making Conservation Tillage Conventional: Building a Future on 25 Years of Research. Proc. of 25th Annual Southern Conservation Tillage Conference for Sustainable Agriculture. Auburn, AL 24-26 June 2002. Special Report no. 1. Alabama Agric. Expt. Stn. and Auburn University, AL 36849. USA.

rotation benefits (Reeves, 1994). Benefits such as improved soil physical condition (Folorunso *et al*., 1992; Jackson *et al*., 1993), chemical (Ebelhar *et al*., 1984; Martin and Touchton, 1983; Jackson *et al*., 1993), and biological (Curl, 1963; Barber, 1972; Ries *et al*., 1977) properties have been identified as possible rotation benefits. For example, cover crops can improve soil structure and increase soil water infiltration and storage (Folorunso *et al*., 1992; Jackson *et al*., 1993).

The Ingrams have always used a winter cover crop to provide erosion control for the winter fallow period and to produce a heavy residue for cotton production. They have tried several different plant species over the years, including both non-legume and legume plant species. The legume plant species included clover (*Trifolium incarnatum* L.) and vetch (*Vicia sativa* L.), as well as attempts to plant a winter clover crop that would naturally reseed. The non-legume species included wheat (*Triticum aestivum* L.) and oats (*Avena sativa* L.). Presently, the Ingrams are using rye (*Secale cereale* L.) as their cover crop species because they have found it to be reliable in planting while providing adequate ground cover for soil protection during the winter months (Fig. 1). Rye also exhibits good growth in early spring before killing, which provides a good heavy residue that affords good moisture conservation for the summer growing season. The cover crop is generally killed one month prior to cotton planting (Fig. 2).

Fig. 1. Cover crop of rye planted into cotton stubble, with a 14-inch gap centered on cotton stalks.

Fig. 2. Cotton is planted into killed rye cover crop.

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 year's crop and cover crop. Cotton is planted on a 40 inch row spacing. In the fall after the cotton is picked, cotton stalks are chopped and left on the soil surface. A grain drill, which has been altered to allow for a 14 inch space centered on the previous year cotton stalks, is used to seed a rye cover crop (Fig. 1). The rye is left to grow during the winter months and is killed with Glyphosate[1] during the first of April (approximately 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 to a depth of approximately 16 inches, but causes almost no surface soil disturbance. Cotton is planted into the previous years cotton stalks. By planting into the same row each year, a controlled traffic system is maintained. Research has indicated that using a subsoiler along with controlled traffic can greatly reduce soil compaction that is commonly observed with strict no tillage systems (Raper *et al*., 1994). A John Deere MaxEmerge Plus VacuMeter vacuum precision planter is used for planting at a seeding rate of 1 seed per 4 inches (Fig. 3). Previously, the Ingrams used 3 seeds per hill for planting, but found that large skips could result if they had a seed emergence problem from the loss of just one hill. The planter uses row cleaners with a forward residue mover of their own design (Fig. 4). The residue mover device pushes the standing rye stalks out of the way of the planter and prevents them from becoming entangled in the row cleaner mechanism. This added feature greatly improves planter performance by preventing clogging of the moving parts of the planter. At the rear of the planter (Fig. 3), a spoked wheel row closer is used instead of a solid press wheel row closer. The Ingrams have found that solid wheel closer systems often resulted in levels of soil compression in the immediate area of the seed that obstructs plant emergence. This has not been a problem with the spooked wheel row closures, which has resulted in a more consistent level of soil compression and generates a good soil/seed contact in the sandy soils.

In recent years, the Ingrams have started to eliminate the ripping operation from their cropping system. Last year, only 50% of their farm was ripped and they do not plan to use this tillage operation for planting cotton this year (2002). They believe that improvement in soil

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

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

physical condition and increased soil organic matter with the use of cover crops has improved the soil tilth to the point that subsoil ripping may not be necessary every year. Research into soil bulk density and soil strength support this view. While bulk density has been shown to increase with strict no tillage, lower bulk densities have been reported with no tillage in cropping systems that produce greater amounts of crop residues (McFarland *et al*., 1990). In addition, soil strength measurements have been shown to be reduced when cover crops are used compared to no-till systems using the cotton residue alone (Schwab *et al*., 2002). The Ingrams expect that deep ripping may be necessary in the future due to reconsolidation in the subsoil, but plan to use a soil penitrometer to identify when reconsolidation would be root limiting.

The Ingrams have noticed that the soil temperatures are distinctively cooler in the summer with the heavy residue cover. They believe that these cooler soil temperatures help cotton production during very hot periods of the growing season due to soil moisture conservation from the cooler temperatures and reduced evaporation of soil water from the soil surface. Improved soil moisture conservation due to surface residue cover has been observed in research, due to both a reduction in cultivation and increased soil insulation with the residue (Bradford and Peterson, 2000). Also, the improved soil physical conditions and increased soil organic matter results in increased soil water storage (Reeves, 1994).

In some cases (especially in cold humid climates), yield reductions have been observed with the no-tillage system, which have been attributed to cooler soil temperatures from the residue cover reducing seed germination and slowing seedling growth (Swan *et al*., 1987; Bradford and Perterson, 2000). The Ingrams 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 for the sun to warm the soil in the immediate area of the cotton row and helps with seed germination and seedling growth during the critical early growing season (Fig. 5). This concept has been supported with research by Kasper *et al*. (1990); they reported an increase in plant performance when residue was cleared near the row. The Ingrams have not observed any problems with seed germination due to cool temperature. The Ingrams check for soil temperature before planting, but do not believe that there is a substantial difference between when they plant and their neighbors that used conventional tillage.

One of the main benefits to conservation tillage systems is erosion control (Reeves, 1994). The use of cover crop not only provides a cover during the winter months to protect against erosion, it also provides a large amount of residue cover for soil protection during the growing season (Fig. 5). The Ingrams have noticed that runoff water from their cotton fields is nearly clear, unlike the muddy water they observe in the conventionally tilled fields in the area. This observation is backed up in the scientific literature, with conservation tillage systems being found to be very effective in reducing erosion and limiting the amount of nutrients that leave the field in sediment (Angle *et al*., 1984; Gilley *et al*., 1987). A large part of the observed effect is increased soil water infiltration with surface residues. For example, Potter *et al*. (1995) reported

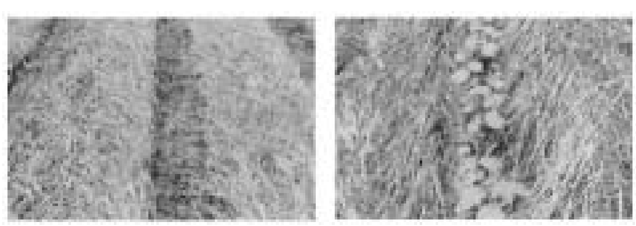

Fig. 5. Cotton is planted into a 14-inch skip in the cover crop, which improves seed germination and seedling growth.

differences in runoff volume and sediment losses between a chisel tillage system and a no tillage system, with sediment losses 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 with conventional tillage (0.67 Mg ha^{-1}), which resulted in a 12-fold increase in nutrient losses associated with sediment.

Soil Fertility

Soil fertility management on the Ingram farm follows Auburn University's soil test laboratory recommendations (Adams *et al*., 1994). Fertilizer applications of P, K, and lime are made from results of soil samples taken each year. Samples are collected from field areas representing approximately 10-15 acres each. For P and K recommendation, a blended fertilizer application is applied in the spring just before planting. For example, this year an application of 250 lbs $acre^{-1}$ of 14-4-14 blended fertilizer was used. Fertilizer N is applied at a rate of approximately 90 lb/acre (recommended rate for cotton). After application of the blended fertilizer, ammonium nitrate (approximately 200 lbs $acre^{-1}$) is used to supply the remaining N fertilizer needs.

The use of conservation tillage has been reported to increase short-term N immobilization due to the slower plant decomposition process caused by reduced tillage (Gilliam and Hoyt, 1987; Wood and Edwards, 1992). Often, it is recommended that fertilizer N applications be increased by as much as 25% when using conservation tillage systems (Randall and Bandel, 1991) due to the increased biomass limiting soil N availability to the growing crop. However, the Ingrams have been successful with a 90 lb/acre rate that is the same as that recommended for conventionally tilled cotton. While the increased biomass inputs may cause short term N immobilization, they will also (due to reduced microbial decomposition from not plowing) result in increased soil organic matter. Soil organic matter will greatly improve soil fertility by increasing not only plant available N, P, and K but other micronutrients. It has been reported that winter cover crops can capture and utilize fertilizer that is left over from the previous crop production and reduce nutrient losses through leaching in the winter months (Reeves, 1994). These captured nutrients will become available to the subsequent crops as the plant material decomposes and forms soil organic matter.

It is believed that the length of time that N immobilization would significantly reduce N availability to the point of reducing plant growth is reduced in a well established conservation tillage system. This is due to the improved soil nutrient availability with increased soil organic matter levels with conservation tillage systems. While the influx of new residue would reduce available N, the increased level of total N in the soil makes the cycling time when N is at a limiting level shorter. In addition, since the cover crop is killed one month before planting, there is time for the short term N immobilization to be substantially reduced before cotton plants reach a growth stage where N availability would be a limiting factor for cotton growth. This has been affirmed 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 that study, there was no advantage for corn (*Zea mays* L.) production for increased N fertilizer application compared to the conventional tillage system.

Pest Control

Because soil tillage is removed as a means of weed control in conservation tillage systems, weed control is a very important aspect of the crop management. The Ingrams 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 (Caporol) application 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 and a high residue conservation tillage system. For example, by having a winter cover crop, weeds that become established and contribute to the seed bank during winter and early spring have trouble competing with the rye. In addition, any winter weeds that do establish themselves in the field are killed with the rye before cotton planting and become part of the surface residue. While it is estimated that there is sufficient weed seed stock in cultivated soil to maintaining damaging weed levels for many years, numerous weed seeds depend on tillage to develop conditions favorable for germination. The elimination of plowing greatly reduced the ability of the seeds to reach the soil surface and provide satisfactory conditions where they can germinate (Wiese, 1985).

The Ingrams use Aldicarb at planting (3 lbs $acre^{-1}$ 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 rarely reach economic thresholds. The boll weevil eradication program that was established in Central Alabama in the late 1980's has greatly changed insect dynamics in that part of the state. At the present time, boll weevils have been eradicated in the area and this has eliminated the need to spray for boll weevil control. As a result, beneficial insects are not killed and the incidence of pests such as bollworms have been greatly reduced to the point of rarely needing insecticide control.

In addition to the boll weevil eradication, the Ingrams believe that their high residue conservation tillage system has greatly improved the population of beneficial insects and resulted in a great reduction in the need for insecticide applications. The cooler soil temperatures that is afforded by the residue in the inter rows results in a greatly improved environment for beneficial insect survival during the growing season. Fire ants, which have been shown to be a vigilant predator to 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 greatly reducing the fire ant bed disturbance.

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

In addition to pest control, plant growth regulators are used as needed. The Ingram 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.

CONCLUSION

Cotton yields in the Alabama Coastal Plain varied greatly from year to year in response to weather conditions (especially rainfall during the growing season). In 2001 (a favorable year for rainfall), the Ingram farm produced approximately 2 bales of lint cotton per acre on most of their farm (lower yields were observed in fields with substantial wildlife damage). While lower yields have been realized in years with less favorable weather conditions, over the years the Ingrams believe that their yield levels have become more consistent with the high residue conservation tillage system, especially compared to their conventional tillage neighbors. In addition to stable yield levels, the Ingrams believe that they are improving the overall soil condition on their farm. They have observed much improved soil tilth conditions and a tremendous reduction in erosion losses, which was continuously degrading their farmland before instigating the conservation tillage system. The Ingrams are very satisfied with the high residue conservation tillage systems that they are using on their farm and believe that it is economically sustainable for cotton production in the region (Fig. 6). Research would indicate that this system is also environmentally sustainable compared to conventional farming techniques.

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

LITERATURE CITED

Adams, J.F., C.C. Mitchell, and H.H. Bryant. 1994. Soil testing fertilizer recommendations for Alabama crops. Ala. Agric. Exp. Stn. Circ. 178. Auburn, AL, Auburn University. 68p.

Angle, J.S., G. McClung, M.S. McIntosh, P.M. Thomas, and D.C. Wolf. 1984. Nutrient losses in runoff from conventional and no-till watersheds. J. Environ. Qual. 13:431-435.

Baeumer, K., and W.A. Bakermans. 1970. Zero tillage. Adv. Agron. 25:77-123.

Barber, S.A. 1972. Relation of weather to the influence of hay crops on subsequent corn yields on a Chalmers silt loam. Agron. J. 64:8-10.

Bradford, J.M., and G.A. Peterson. 2000. Conservation tillage.pp. 247-270. *IN* M.E. Sumner (ed.) Handbook of Soil Science. CRC Press. Boca Raton FL.

Curl, E.A. 1963. Control of plant diseases by plant rotation. Bot. Rev. 29:413-479.

Ebelhar, S.A., W.W. Frye, and R.L. Blevins. 1984. Nitrogen from legume cover crops for no-till corn. Agron. J. 76:51-55.

Folorunso, O.A., D.E. Rolston, T. Prichard, and D.T. Louie. 1992. Soil surface strength and infiltration rate as affected by winter cover crops. Soil Technology 5:189-197.

Gilley, J.E., S.C. Finker, and G.E. Varvel. 1987. Slope length and surface residue influences on runoff and erosion. Trans. ASAE 39:148-152.

Kasper, T.C., D.C. Erbach, and R.M. Cruse. 1990. Corn response to seed-row residue removal. Soil Sci. Soc. Am. J. 54:1112-1117.

Potter, K.N., H.A. Torbert, and J.E. Morrison, Jr. 1995. Tillage and residue effects on infiltration and sediment losses on Vertisols. Trans. ASAE 38:1413-1419.

Gilliam, J.W., and G.D. Hoyt. 1987. Effect of conservation tillage on fate and transport of nitrogen.pp. 217-240.*IN* T.J. Logan, J.M. Davidson, J.L. Baker, and M.R. Overcash (eds.) Effects of conservation tillage on groundwater quality, nitrogen and pesticides. Lewis Publ. Inc., Chelsea, MI.

Jackson, L.E., L.J. Wyland, and L.J. Stivers. 1993. Winter cover crops to minimize nitrate losses in intensive lettuce production. J. Agric. Sci. 121:55-62.

Martin, G.W., and J.T. Touchton. 1983. Legumes as a cover crop and source of nitrogen. J. Soil Water Conserv. 38:214-216.

McFarland, M.L., F.M. Hons, and R.G. Lemon. 1990. Effects of tillage and cropping sequence on soil physical properties. Soil Tillage Res. 17:77-86.

Randall, G.W., and V.A. Bandel. 1991. Nitrogen management for conservation tillage systems: an overview. pp. *39-63* *IN* T.J. Logan, J.M. Davidson, J.L. Baker, and M.R. Overcash (eds.) Effects of conservation tillage on groundwater quality, nitrogen and pesticides. Lewis Publ. Inc., Chelsea, MI.

Raper, R.L., D.W. Reeves, E.C. Burt, and H.A. Torbert. 1994. Conservation tillage and traffic effects on soil condition. Trans. ASAE 37:763-768.

Reeves, D. W. 1994. Cover crops and rotations. *IN* J. L. Hatfield and B. A. Stewart (eds.) Advances in Soil Science: Crops Residue Management. pp. 125-172. Lewis Publishers, CRC Press Inc., Boca Raton, FL.

Reeves, D. W. 1997. The role of soil organic matter in maintaining soil quality in continuous cropping systems. Soil Tillage Res. 43:131-167.

Ries, S.K., V. Wert, C.C. Sweeley, and R.A. Leavitt. 1977. Triacontanol: A new naturally occurring plant growth regulator. Science 195:1339-1341.

Schwab, E.B., D.W. Reeves, C.H. Burmester, and R.L. Rapper. 2002. Conservation tillage systems for cotton in the Tennessee Valley. Soil Sci. Soc. Am. J. 66:569-577.

Swan, J.B., E.C. Schneider, J.F. Moncrief, W.H. Paulson, and A.E. Peterson. 1987. Estimating corn growth, yield, and grain moisture from air growing degrees days and residue cover. Agron. J. 79:53-60.

Torbert, H.A., K.N. Potter, D.W. Hoffman, T.J. Gerik, and C.W. Richardson. 1999. Surface residue and soil moisture affect fertilizer loss in simulated runoff on a heavy clay soil. Agron. J. 91:606_612.

Torbert, H.A., K.N. Potter, and J.E. Morrison, Jr. 2001. Tillage system, fertilizer nitrogen rate and timing effect on corn yields in the Texas Blackland Prairie. Agron. J. 93:1119-1124.

Wiese, A.F. (ed.) 1985. Weed control in limited tillage systems. Weed Sci. Soc. of Amer. Monogr. 2. Weed Science Society of America, Champaign, IL.

Wood, C.W., and J.H. Edwards. 1992. Agroecosystem management effects on soil carbon and nitrogen. Agric. Ecosyst. Environ. 39:123-138.

DISCLAIMER

Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the production, the use of the name by USDA implies no approval of the product to the exclusion of others that may be suitable.