INTEGRATION OF COVER CROP RESIDUES, CONSERVATION TILLAGE AND HERBICIDES FOR WEED MANAGEMENT IN CORN, COTTON, PEANUT, AND TOMATO

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INTEGRATION OF COVER CROP RESIDUES, CONSERVATION TILLAGE AND HERBICIDES FOR WEED MANAGEMENT IN CORN, COTTON, PEANUT, AND TOMATO

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VITA

Monika Saini was born in Chandigarh, India to Daulat Ram Saini and Shakuntla Devi. She received her Bachelor of Science degree from Panjab University and followed it up with a Bachelor of Education degree in 1998. She taught for a year before returning to Panjab University in 1999 and completed her Master of Science (Honors) in Botany in 2001. She then worked as a research assistant with Dr. Inderjit and taught high school science before deciding to join graduate school again. She enrolled with Department of Agronomy and Soils at Auburn University in January 2005 for her PhD degree. Monika is married to Manik and they have a wonderful daughter Siya.

DISSERTATION ABSTRACT

INTEGRATION OF COVER CROP RESIDUES, CONSERVATION TILLAGE AND HERBICIDES FOR WEED MANAGEMENT IN CORN, COTTON, PEANUT, AND TOMATO

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Reduced water and air quality coupled with declining soil productivity and increased energy costs are the greatest concerns of present day agricultural producers and environmentalists alike. This generates the need of developing new production systems to achieve the twin objectives of profitability and environmental quality. Use of conservation tillage systems and cover crops can overcome many of these concerns by reducing production costs and maintaining the soil quality. However, predictability of weed suppression provided by these systems continues to be unpredictable. In current agronomic systems, where many weeds have acquired resistance or have proliferated within continually utilized crop technology, weed suppression through conservation tillage and cover crops offer a promising solution. Therefore, the objectives of this dissertation were to (a) develop a model that recommends dates for planting and terminating cover crops for optimum growth and weed suppression in conservation-tillage cotton and corn, (b) evaluation of weed suppression provided by a high residue rye cover in strip-tilled peanut, and (c) evaluation of cover crops for weed suppression in conservation-tillage tomato. In the first study, five seeding dates and four termination dates were evaluated for cover crop biomass production and its effect on weed suppression and yield in corn and cotton rotation. Results showed biomass production by winter covers was impacted with even a week's delay in winter cover crop seeding and corresponding reduction in summer annual weed suppression. A second study was conducted at Dawson, GA and at Headland, AL. In this study strip tillage provided increased weed control in 2005 at Headland and equivalent control at all other site years. Furthermore, peanut yield was greater in three of the four site years utilizing strip tillage system indicating a yield advantage for utilizing strip vs. conventional tillage. The third study was conducted at Cullman, AL and at Tuskegee, AL. In this study we evaluated the short term effects of converting from a conventional plastic mulch system of growing tomato to three high-residue conservation tillage systems. Results of this study indicate the economic possibility of growing fresh market tomato utilizing a conservation tillage system while maintaining yields and economic returns.

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I. LITERATURE REVIEW

INTRODUCTION

Soils in the Southeastern U.S. coastal plain are mainly acidic and sandy, with a low water holding capacity and moisture content. This region faces frequent but short drought periods. The soils are also low in organic matter content and are highly weathered (Schomberg et al. 2006; Shaw et al. 2002). Use of heavy machinery in the fields and natural reconsolidation have led to the development of a compact sub-surface layer in the soil, further impacting the water and nutrient uptake by the plants. These conditions impact crop growth and yield (Radford et al. 2001), but yield increases can be obtained by reducing the soil strength (Busscher et al. 2000; Raper et al. 2000).

Inversion tillage is a typical practice to alleviate the problem of soil compaction but that practice is not without pitfalls. Tillage leads to soil erosion and increase in organic matter mineralization thus further adding to the problem of low soil organic matter (Franzluebbers et al. 1999; Schlesinger 1984). Another problem with tillage is decreased soil water infiltration leading to increased runoffs and loss of moisture.

Use of inversion tillage thus does not suffice and a complete management system is required to maintain the overall health of a cropping system. Widespread adoption of any management system in agriculture requires information about local conditions in order to optimize the benefits of that system for growers. Conservation agriculture systems have been successfully adopted to address these concerns as they offer significant agronomic, environmental and economic benefits.

Benefits of Conservation tillage Systems

A conservation tillage system as defined by USDA-NRCS is any tillage system that leaves at least 30% of the soil surface covered with residue at the time of planting the main crop. It is a system of crop production with little, if any, tillage. It increases the residue from the crop that remains in the field after harvest through planting. This results in increased natural recycling of crop residues. Currently, it is used on 38% (109 million acres) of all U.S. cropland (CTIC 2008). No-tillage is a type of conservation tillage system used where soil compaction is not present or is alleviated through use of cover crop, soil disturbance is minimized in this system. Conversely, conventional tillage leaves little or no residue on the soil surface at the time of planting crop.

The most noticeable impact of conservation tillage systems is conservation of soils prone to erosion such as the sandy loam soils of the southeastern USA. Additionally, a uniform mat of residue left on the soil surface shields the soil from the impact of raindrops by dissipating the raindrop energy. Crop residues also retard runoff from the field thereby greatly reducing the soil erosion. Other benefits of conservation tillage system include

1. **Increase soil organic matter (Rasmussen and Collins 1991; Lal 1997):** Crop residue left on the soil surface reflects light and reduces the soil temperature. Lower soil temperature reduces soil microbial activity and hence less organic matter loss by oxidation. In a study conducted on a Decatur silty loam soil in Tennessee Valley region of northern Alabama, Feng et al. (2003) reported no-till treatment increased soil organic carbon and total nitrogen contents in the surface layer by 130 and 70% respectively, compared to conventional tillage. Surface residues in conservation tillage systems prevent loss of organic matter rich top soil.

2. **Improved soil tilth**: In agricultural soils, tillage and traffic are the major factors in soil structure degradation through fragmentation and compaction process (Kay 1990). No-tillage system results in minimum disturbance of the soil resulting in improved soil aggregation and structure (Lal et al. 1994). Reduction in tillage also reduces the trips across the field thus reducing compaction of the soil and resulting in better penetration by plant roots.

3. **Enhanced water infiltration and water availability**: Improved soil macropores and root channels increase water infiltration in the soil. Surface residue also provides shading effect and reduces evaporation losses (Unger and Jones 1994).

4. **Increased soil biological activity**: Enhanced root distribution results in more activity in the rhizosphere leading to increased microbial populations under conservation tillage systems (Doran 1980). Earthworm populations also increase under conservation or no tillage management compared to the conventional tillage as reported by Edward and

Lofty (1982) in a study conducted in Great Britain. Populations of *Lumbericus terrestris* and *Allolobophora longa* were greater in direct drilled than in ploughed soil. Populations of these two deep burrowing earthworms were intermediate in chisel tilled soil.

5. **Improved water quality**: Crop residue reduces surface runoff rates from field and offsite pesticide loading into surface water bodies. Additionally, increased microbial populations can degrade the pesticides faster, hence, fewer chemicals will reach the ground water. Fawcett et al. (1994) reported all conservation tillage practices resulted in reduced pesticide runoff from the field compared to conventional tillage.

6. **Reduced labor, fuel and costs**: Conservation tillage provides economic benefits as the number of trips across the field is reduced. Frye, 1984 reported 60 to 75 % reduction in fuel use and labor by eliminating pre-plant tillage.

Crop residue left on the surface not only improves the water quality and overall soil productivity but it can also improve air quality as it reduces airborne particulates generated from wind erosion. Fossil fuel emissions from tractors are also reduced as fewer trips are made across the field and reduction in carbon sequestration into the atmospheric carbon by sequestering more carbon into the soil as organic matter.

To attain maximum benefits offered by conservation tillage systems cover crop residues must be present on the soil surface. A minority of producers in southeastern USA utilize winter cover crops. However, this region receives appreciable rainfall during these months, leaving the soils prone to erosion and nutrient losses. Use of cover crop residue has been advocated to maximize productivity of conservation systems in the southeastern USA and to overcome the above mentioned concerns (Langdale et al. 1990).

Cover Crops in Conservation Tillage Systems

Cover crops are defined as crops which are typically seeded to protect the soil from erosion and reduce nutrient leaching and water runoff (Reeves 1994). Cover crops are not harvested for immediate economic benefit. A cover crop can be grown as a living mulch or companion crop along with the main crop or can be included into the system as a rotational crop where it is usually grown in the fallow period when no main crop is being grown on the field. In the southeastern USA cover crops are usually grown during winter months. Cover crops can also be grown as a green manure or a catch crop. Based on the growth there are three types of cover crops annual, biennial, or perennials and include grasses, legumes, or other non-legume dicots. The choice of a cover crop depends on the individual needs of farmers and the costs associated with the management of a particular cover crop.

Cover crops benefit the conservation tillage systems by increasing soil organic matter content of soil, water and soil conservation and enhanced nutrient cycling (Blevins et al. 1971; Sainju and Singh 1997; Kaspar et al. 2001) thus improving the overall health and productivity of the soil. Cover crop residue left on the soil surface in conservation tillage systems helps in reducing soil erosion by reducing runoff from field as residue acts as an obstacle to the free flow of water (Naderman 1991). Cover crop residue can act as a barrier and dissipate raindrop energy and protect the top fertile soil from the dislodging effect of raindrops (Edwards and Burney 1991). Cover crop roots also improve soil porosity and increase the infiltration rate, thus reducing runoff from the field (McVay et al. 1989). Sullivan et al. (1991) reported an increase in soil moisture with increased amount of cover crop residue in a conservation tillage system compared to conventional tillage. Reduced runoff from agricultural fields can also help in reducing nutrient loss and improved water quality (Kinyangi et al. 2001). Nitrate leaching form agricultural fields is a major ground water pollutant. Cereal cover crops like cereal rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.) and oat (*Avena strigosa* Schreb.), which have rapid growth and produce large amount of biomass are very efficient in capturing additional nitrogen from the fields during winter months (Delgado 1998). The N content of a wheat cover crop increased with an increase in the amount of N fertilizer applied to the preceding crop cotton (Breitenbeck and Hutchenson 1994). Kinyangi et al. (2001) also reported reduced nitrate leaching losses with a rye cover crop.

Cover crop residues aid in increasing soil organic matter content of the soil. Cover crop residue left on the soil surface in conservation tillage systems decompose and add to the soil organic matter content (Kuo et al. 1997). Larson et al. (1978) reported that soil organic C was linearly related to the quantity of residue added to the soil. Similarly, Havlin et al. (1990) obtained increased organic C in a soil under no-tillage system that was directly related to the amount of residue left on the soil surface. A study conducted in southern Brazil on a sandy clay loam (Acrisol) concluded that cover crops increased C and N pools in both particulate and mineral-associated soil organic matter when compared with bare soil (Bayer et al. 2001). Soil organic matter plays a great role in improving soil aggregation and structure. Liua et al. (2005) concluded that cover crops increased soil organic carbon and the amount of dilute acid extractable polysaccharides in the soil, which acts as a binding agent and improve the aggregate stability of the soil. Cover crops roots also hosts mycorrhizal fungi that release glomalin into the rhizosphere; glomalin is a water insoluble protein that helps in soil aggregation (Wright and Upadhaya 1998; Wright et al. 1999).

In addition to scavenging extra nitrogen which otherwise would leach, cover crops also help in cycling nutrients such as phosphorus. Phosphorus is converted to plant usable form by cover crops like buckwheat (*Fagopyrum esculentum* Moench) and white lupin (*Lupinus albus* L.) that secrete acids into the soil thereby converting phosphorus to a soluble form. Deep rooted cover crops can also help in bringing calcium and potassium to the soil surface. Legume cover crops can fix nitrogen and thus meet some of the nitrogen requirement of the following cash crop (Decker et al. 1994).

Cover crop residue can also aid in early season weed suppression through chemical and physical inhibitory effects when winter covers are grown to maturity (Creamer et al. 1997; Teasdale and Abdul-Baki 1998; Price et al. 2006; Yenish et al. 1996). Cover crops suppress weeds either by inhibiting the growth of already established weeds through competition and smothering, or by altering the soil environment conditions necessary for weed seed germination (Creamer 1996; Teasdale 1996). Weed suppression by cover crop is better if they are managed in accordance with conservation tillage principles (Blum et al. 1997). Killed cover crops residue left on the soil surface influence factors such as soil moisture, light transmittance to the soil surface, soil temperature etc. These in turn have an effect on weed seed germination and seedling growth. The surface residue also acts as a physical barrier that inhibits the growth of weeds. Teasdale and Mohler (1993) reported that reductions in light transmission and daily soil temperature amplitude by hairy vetch (*Vicia villosa* Roth.) and rye residue reduces weed emergence but higher soil moisture during dry weather may increase weed emergence. Cover crops can also suppress weeds by changing the nutrient dynamics of the soil after the cash crop harvest. Cover crops scavenge additional nutrients such as nitrates (Ditsch et al. 1993) thus reducing the growth of weeds.

Cover crop residue may also release phytotoxins that can inhibit germination and growth of weeds. Use of allelopathic cover crop mulches for weed control has been studied extensively (Barnes and Putnam 1983; Price et al. 2006; Rice 1984). The degree of weed suppression provided by cover crops however, depends on the cover crop species and management system. Another important factor is the amount of residue produced. At equivalent amounts of residue weed suppression was similar with rye and hairy vetch cover crop residue (Teasdale and Mohler 1992).

Utilizing cover crops in crop rotations may reduce pest and/or break disease cycles. Incorporation of alfalfa into a rotation in a potato cropping system reduced the incidence of *Rhizoctonia solani* by 50% (Honeycutt et al. 1996). Cover crops have also been deployed in various cropping systems to reduce the populations of plant pathogenic nematodes. Cover crops such as cereal rye are non hosts to nematodes (Minton 1986) and incorporating them into the cropping system as a rotation crop can reduce nematode populations.

Challenges for Adoption of High Residue Cover Crops

In spite of the conservation tillage benefits, initial adoption of conservation tillage practices in the 1970s was limited due to inadequate weed control and equipment concerns. Problems resulted in yield loss due to weed competition, poor cash crop stand establishment and increases in soil strength (Raper et al. 2000; Schwab et al. 2002). Tillage is sometimes necessary to break the life cycle of soil born plant pathogens. Soil moisture depletion by cover crops is also a concern in areas of limited rainfall. However, this will be less of a concern in the southeastern United States as rainfall during the winter months is adequate. Cover crops have also been reported to increase pest problems. The conditions in the Southeast with high temperatures and humidity are conducive for growth of pathogens.

The major limiting factor in widespread adoption of conservation tillage systems in the 1970's was increased weed infestation and the corresponding increase in herbicide use. Tillage can disrupt the underground plant parts of the perennial weed species and destroy other vegetative propagules. Exclusion of tillage also results in loss of weed control that can be achieved with preplant incorporated herbicides, which are considered an important component for effective weed control in many cropping systems. Numerous studies have pointed to increased weed pressure in reduced tillage systems. Newly shed weed seed remains on the surface with reduced tillage, thus easily emerging and surviving (Barberi 2002; Cardina et al. 2002; Cardina et al. 1991). In addition, weed species composition might shift from easy to control weeds to more problematic weeds such as grasses and vegetatively-reproducing species (Young et al. 1996).

Loss in efficacy of pre emergence (PRE) herbicides has also been a major concern in high residue conservation tillage systems. Plant residue left on the soil surface can reduce the effectiveness of PRE herbicides by intercepting some of the herbicide (Banks and Robinson 1982, 1984). Lowder and Weber (1979) reported at least 30% of the atrazine applied was intercepted by residue. Banks and Robinson (1984) reported as much as 50% of the metribuzin applied was intercepted by wheat mulch when residue level exceeded 2000 kg/ha an amount easily exceeded in conservation agriculture systems today. Herbicide interception can be overcome if herbicide application is followed by a rainfall event or irrigation (Ehrback and Lovely 1975).

Allelochemicals released by cover crops which may aid in weed control can negatively affect cash crop seedlings. Bauer and Reeves (1999) showed in a greenhouse study that cotton emergence was lower when seeded into soil containing crimson clover (*Trifolium incarnatum* L.) compared to a soil that did not contain any cover crop residue. Hicks et al. (1989) reported a negative effect of wheat residue on cotton seedling growth. Reduction in stand establishment in conservation tillage systems has been reported because heavy cover crop residue interfered with seeding operations.

Persistence of residual herbicides in conservation tillage systems is another concern. The residual herbicide can severely impact stand establishment of the subsequent crop. Herbicides are often employed to terminate the cover crop. These herbicides can also negatively impact the cash crop if proper care is not taken.

Making careful management choices in accordance with soil characteristics and temperature and rainfall patterns of a particular region can increase the effectiveness of cover crops. Weed control benefits with a cover crop can be increased if the cover crop is killed and residue left on the soil surface rather than incorporating it into the soil. Incorporation of residue also disturbs the soil. Recent research has studied the benefit of mechanically rolling the cereal cover crops in addition to chemical termination (Ashford and Reeves 2003). This process leaves a uniform mat of residue on the soil surface that aids in weed suppression. Uniformly placed residue also makes the planting operations easy, the cash crop can be planted parallel to the direction of rolling thus reducing the concerns for reduced stand establishment in heavy residue.

Cover crop seeding and termination date influence many benefits associated with cover crops use in conservation tillage systems. Cover crops should be planted early enough to achieve adequate growth before winter temperatures slow down their growth. Timely planting of cover crops ensure sufficient biomass production. Cover crop termination timing is equally important as it affects biomass production, C: N ratio of the cover crops, and soil moisture. Cover crops if terminated late may increase the C: N ratio of cereal cover crops that slows their decomposition and results in immobilization of nutrients. The allelochemical effect of cover crops on cash crop seedlings is a concern if crop is planted into the fresh residue compared to when it is planted into partially decomposed residue.

Conservation Tillage Systems for Peanut

Peanut (*Arachis hypogaea* L.) production in the southeastern United States has traditionally been a tillage intensive process utilizing both primary and secondary tillage to create a residue-free seedbed. Peanut production typically utilizes pre-plant incorporated (PPI) and/or PRE herbicides in conventional tillage systems. Concerns for decreased soil and environmental quality coupled with increased management and fuel costs have led to adoption of conservation tillage systems in peanut production. The most commonly used conservation tillage system in peanut production is strip tillage, which is used to alleviate soil compaction commonly found in the southeastern US soils (Busscher and Bauer 2003; Truman et al. 2003). Benefits of strip tillage include those of both conservation tillage and conventional systems. Strip tillage utilizes coulters and rolling baskets that create a residue free smooth seedbed that offers increased seed soil contact, increased soil temperature at planting, and facilitates PRE-applied herbicide activation. Research in the southeastern United States indicated higher or equivalent yields with strip tillage compared to conventional tillage systems (Wilcut et al. 1987; Tubbs and Gallaher 2004; Johnson et al. 2001). Finally, adoption of conservation tillage systems reduces the economic inputs and brings desired cost benefits after several years of successful adoption (Bowman et al. 1998).

Another important component of strip tillage peanut production system in the southeastern United States is the use of cover crops. Cover crop residue conserves water by preventing evaporative and runoff losses, aid in soil conservation, nutrient cycling and increasing soil organic matter content (Dabney et al. 2001; Snapp et al. 2005). Presence of residue around the seedbed also reduces the chances of sandblasting. Most commonly used cover crops in peanut production are cereal grains such as rye and wheat as they are easy to establish and provide good amount of biomass (Price et al. 2007; Wright et al. 2002).

The major crop management challenge of conservation tillage systems is the loss of weed control that can be accomplished with tillage and cultivation as well as interception of PRE herbicides by cover crop residues (Banks and Robinson 1986; Isensee and Sadeghi 1994). In conservation tillage, it is common to have an increase in the seed bank present on the soil surface leading to sporadic germination of these seeds over a longer time period of time (Kells and Meggitt 1985) requiring additional herbicide inputs. Additionally, weed communities may shift from easy to control annual species to perennial perennial species with adoption of conservation tillage systems (Barberi 2002; Cardina et al. 2002). Therefore strip tillage management of peanut may require more intensive herbicide inputs compared to conventional tillage systems due mainly to reduced efficiency of PPI and PRE herbicides in these systems (Wilcut et al. 1987). Weed control is a very important factor determining profitability in peanut production; Webster (2001) reported total annual losses from weeds in Alabama and Georgia to be $11.2 and $47.5 million, respectively.

Conservation Tillage Systems for Fresh Market Tomato Production

Tomato (*Lycopersicon esculentum* L.) is the most popular fruit in the world. Nearly 1.7 million tons of fresh market field grown tomatoes were produced in USA in 2005 (U.S. Department of Agriculture [USDA] 2008). The USA produces more than 11% of the world's tomato crop; production systems typically utilize conventional tillage, a bedded plastic mulch culture, and multiple herbicide applications to control weeds. These conventional tillage systems enhance soil erosion and nutrient loss by reducing rainfall infiltration (Blough et al. 1990). Additionally, tillage increases soil aeration, which in turn increases the rate of organic matter mineralization in the surface soil, thus reducing soil organic matter content and soil cation exchange capacity (Franzluebbers et al. 1999; Mahboubi et al. 1993).

Plastic mulch can increase soil temperature which can expedite earliness (Teasdale and Abdul-Baki 1995). However, tomato growth was better only early in the season under plastic mulch compared to tomatoes grown under hairy vetch mulch systems (Abdul-Baki et al. 1996; Teasdale and Abdul-Baki 1997). The use of plastic mulch in sustainable or organic production systems is also questionable since the mulch itself is usually not biodegradable. Another issue with using plastic mulch vs. organic mulches is increased chemical runoff from the plastic mulch and offsite chemical loading. The intensive use of pesticides in vegetable production has also resulted in ecological concerns. Therefore, alternative production practices that reduce tomato production inputs while maintaining yield and quality are desirable.

One alternative for alleviating aforementioned concerns is the use of high residue cover crops combined with reduced tillage. Cover crops in conservation-tillage system are terminated during early reproductive growth by treating them with burndown herbicides followed by mechanically rolling to leave a dense mat of residue (> 4,480 kg/ha) on the soil surface into which cash crops are planted (Derpsch et al. 1991; Reeves 2003). High residue cover crops are increasingly adopted in southeastern US corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) production systems (Price et al. 2006; Reeves et al. 2005; Sainju and Singh 2001). Because the southeastern USA receives adequate rainfall during the winter months, timely planted winter cover crops can attain relatively high biomass before termination. Cover crops can enhance the overall productivity and soil quality by increasing organic matter and nitrogen content (Sainju et al. 2002), as well as aid in water conservation by increasing soil water infiltration rates (Arriaga and Balkcom 2006). Research has also focused on weed control provided by high residue cover crops in both field and vegetable crops (Teasdale and Abdul-Baki 1998; Creamer et al. 1997; Price et al. 2006).

Winter cover crop biomass can affect subsequent early season weed suppression (Saini et al. 2006; Teasdale and Mohler 2000). Weed suppression by cover crop residue is attributed to an unfavorable environment for weed germination and establishment under the residue (Teasdale 1996) and also to chemical inhibitory effects. Teasdale and Daughtry (1993) reported 52–70% reduction in weed biomass with live hairy vetch cover crop compared to a fallow treatment owing to changes in light and soil temperature regimen under the vetch canopy. Teasdale and Mohler (2000) concluded that legume mulches such as crimson clover and hairy vetch suppressed redroot pigweed (*Amaranthus retrofloxus* L.) exponentially with increasing residue biomass.

In spite of these benefits, adoption of cover crops in tomato production has been limited because (1) currently available transplanters have problems penetrating heavy residue and (2) concerns for cover crop residue intercepting delivery of soil-active herbicides. Research during the last two decades has extensively debated the advantages and disadvantages of cover crops *versus* conventional plastic mulch systems for tomato production. Better or comparable tomato yields were obtained with hairy vetch cover crop system compared to the conventional polyethylene mulch system (Abdul-Baki and Teasdale 1993; Abdul-Baki et al. 2002); Akemo et al. (2000) reported higher tomato yield with spring-sown cover crops than the conventionally cultivated check. Weed suppression with cover crops, however, varies with cover crop species, amount of residue produced, and environmental conditions. Teasdale (1996) reported that biomass levels achieved by cover crops before termination was sufficient only for early season weed suppression. Supplemental weed control measures are usually required to achieve season long weed control and to avoid yield losses (Masiunas et al. 1995; Teasdale and Abdul-Baki 1998).

Cereal rye and crimson clover are two common winter cover crops widely used in the southeastern US. Both cover crops contain allelopathic compounds and produce residues that inhibit weed growth (Price et al 2008; Barnes and Putnam 1983). Brassica cover crops such as *Raphanus sativus* L., *Brassica napus* L, *Sinapis alba* L., or *Brassica* *juncea* (L.) Czern. are relatively new in the southeastern US but are becoming increasingly popular due to their potential allelopathic effects.

Corn and Cotton Rotation in conservation Tillage Systems

Historically, cotton production has been a tillage intensive operation in the Southeast. Many farmers have been practicing cotton monocultures. Both these practices make cotton production one of the most erosive row crop production systems in the southeastern USA. Corn is increasingly becoming an important cash crop for many growers in the Southeast, often grown as a rotation crop with cotton. Crop rotation has become an important component of the cotton production in the southeast as continuous cotton production causes many problems including increased soil borne pathogen populations. Lack of herbicide chemistry rotation also results in increased number of resistant weed species. Crop rotation can be an effective tool in reducing the buildup of problematic weeds and to keep their population under control (Reddy 2004). Using crop rotations with an effective herbicide program can help alleviate these problems. Rotations with corn are typical, due to the lower production costs, ease of production, and because corn is a non-host to many cotton pathogens. Corn can also add to the surface residue in corn-cotton rotations as cotton leaves minimal residue on the soil surface at the end of growing season. Paxton et al. (1995) reported 12% increase in cotton yield in an Arkansas study when cotton was rotated with corn. Corn is also gaining popularity as a major cash crop because of its use as a bio-fuel feedstock.

Crimson clover and hairy vetch are two common winter cover crops for corn production. ‘AU Robin’ crimson clover was specifically developed for this purpose (van Santen et al. 1992). Both of these cover crops supplement the nitrogen requirement of the corn. Their residue has low C/N ratio and their residue can decompose easily to release nitrogen into the soil. Holderbaum et al. (1990) in a Maryland study reported that corn grain and silage yields were 3.5 Mg/ha higher following crimson clover compared to following no cover crop when no additional nitrogen was applied.

Though weed control benefits associated with cover crops can be improved by increasing the amount of residue on the field, this can also result in some negative effects. High residue can interfere with cash crop establishment and also deplete the soil moisture (Teasdale 1993; Liebl et al. 1992). Dense cover crop residue can also lead to a decrease in soil temperature, which can severely impact the cash crop stand establishment and yield, though these constraints are largely dependent on local weather and soil conditions and also on the type of cover crop mulch used. Therefore having an optimum amount of residue on the soil is the key to optimizing the benefits from the cover crop system.

Experience in the Southeast has shown that cover crop planting and termination has occurred at the discretion of grower’s schedule and weather conditions. Previous research has shown that planting and termination dates influence both quality and quantity of residue production.

GENERAL OBJECTIVES

1. To compare weed control provided by high residue rye cover crop under conventional tillage and strip tillage systems and its effect on peanut yield in Alabama, and Georgia.

2. To evaluate tomato stand establishment utilizing a prototype high residue transplanter, as well as weed control and tomato performance in three different high residue conservation tillage systems utilizing the Brazilian cover crop management system. Tomato yield, quality, and net returns of conservation-transplanted tomato were compared to the plastic mulch system following three herbicide management systems.

3. To study the influence of the timing of cover crop planting and termination on winter cover crop residue production, early season weed suppression, and corn and cotton yield.

LITERATURE CITED

Abdul-Baki, A.A., and J.R. Teasdale. 1993. A no-tillage tomato production system using hairy vetch and subterranean clover mulches. HortScience. 28:106-108.

Abdul-Baki, A.A., J.R. Teasdale, R. Korcak, D.J. Chitwood, and R.N. Huettel. 1996. Fresh-market tomato production in a low-input alternative system using cover crop mulch. HortScience. 31:65-69.

Akemo, M.C., M.A. Bennett, and E.E. Regnier. 2000. Tomato growth in spring-sown cover crops. HortScience. 35:843-848.

Abdul-Baki, A.A., J.R. Teasdale, R.W. Goth, and K.G. Haynes. 2002. Marketable yields of fresh-market tomatoes grown in plastic and hairy vetch mulches. HortScience. 37:878-881.

Arriaga, F.J., and K.S. Balkcom. 2006. Benefits of conservation tillage on rainfall and water management. *In*: Hatcher, K. J., (ed.) Proceedings of the 2005 Georgia Water Resources Conference, April 25-27, 2005.

Ashford, D.L., and D.W. Reeves. 2003. Use of a mechanical roller-crimper as an alternative kill method for cover crops. Am. J. Alternative Agric. 18:37-45.

Banks, P.A., and E.L. Robinson. 1982. The influence of straw mulch on the soil reception and persistence of metribuzin. Weed Sci. 30:164-168.

Banks, P.A., and E.L. Robinson. 1984. The fate of oryzalin applied to straw-mulched and non- mulched soils. Weed Sci. 32:269-272

Banks, P.A., and E.L. Robinson. 1986. Soil reception and activity of acetachlor, alachlor, and metolachlor as affected by wheat straw and irrigation. Weed Sci. 34:607-611.

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? Weed Res. 42:177-193.

Barnes, J.P., and A.R. Putnam. 1983. Rye residues contribute weed suppression in no-tillage cropping systems. J. of Chem. Ecol. 9:1045-1057.

Bauer, P.J., and D.W. Reeves. 1999. A comparison of winter cereal species and planting dates as residue cover for cotton grown with conservation tillage. Crop Sci. 39:1824-1830.

Bayer, C., L. Martin-Neto, J. Mielniczuk, C.N. Pillon, and L. Sangoi. 2001. Changes in soil organic matter fractions under subtropical no-till systems. Soil Sci. Soc. Am. J. 65:1473-1478.

Blevins, R.L., D. Cook, S.H. Phillips, and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 63:593-596.

Blevins, R.L., G.W. Thomas, M.S. Smith, W.W. Frye, and P.L. Cornelius. 1983. Changes in soil properties after 10 years of no-tillage and conventionally tilled corn. Soil & Tillage Res. 3:135-146.

Blough, R.F., A.R. Jarrett, J.M. Hamlett, and M.D. Shaw. 1990. Runoff and erosion rate from silt, conventional, and chisel tillage under simulated rainfall. Transactions of ASAE. 33:1557-1562.

Blum, U., L.D. King, T.M. Gerig, M.E. Lehmann, and A.D. Worsham. 1997. Effects of clover and small grain cover crops and tillage techniques on seedling emergence of some dicotyledonous weed species. Am. J. of Alt. Ag. 12:146-161.

Bowman, G., C. Shirley, and C. Cramer. 1998. Managing cover crops profitably. 2nd ed. Washington, D.C.: Sustainable Ag. Network.

Breitenbeck, G.A., and R.L. Hutchinson. 1994. Influence of tillage and winter cover crops on nitrogen status of cotton. p. 50-55. *In* P.J. Bauer and W.J. Busscher (ed.) Proc. Southern Conservation Tillage Conference for Sustainable Agriculture. Columbia, SC. 7-9 June 1994. Coastal Plains Soil, Water, and Plant Research Center, Florence, SC.

Busscher, W.J., J.R. Frederick, and P.J. Bauer. 2000. Timing effects of deep tillage on penetration resistance and wheat and soybean yield. Soil Sci. Soc. Am. J. 64:999-1003.

Busscher, W.J., and P.J. Bauer. 2003. Soil strength, cotton root growth and lint yield in a southeastern USA coastal loamy sand. Soil & Tillage Res. 74:151-159.

Cardina, J., C.P. Herms, and D.J. Doohan. 2002. Crop rotation and tillage effects on weed seedbanks. Weed Sci. 50:448-460.

Cardina, J., E. Regnier, and K. Harrison. 1991. Long-term tillage effects on seedbanks in three Ohio soils. Weed Sci. 39:186-194.

Conservation Tillage Information Center. 2008. www.ctic.purdue.edu.

Creamer, N.G., M.A. Bennet, B.R. Stinner, and J. Cardina. 1996. A comparison of four processing tomato production systems differing in cover crop and chemical inputs. J. Am. Soc. HortScience. 121:559-568.

Creamer, N.G., M.A. Bennett, and B.R. Stinner. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience. 32:866-870.

Dabney, S.M., J.A. Delgado, and D.W. Reeves. 2001. Using winter cover crops to improve soil and water quality. Commun. Soil Sci. & Plant Anal. 32:1221-1250.

Decker, M., A.J. Clark, J.J. Meisinger, F.R. Mulford, and M.S. McIntosh. 1994. Legume cover crop contributions to no-tillage corn production. Agron. J. 86:126-135.

Delgado, J.A. 1998. Sequential NLEAP simulations to examine effect of early and late planted winter cover crops on nitrogen dynamics. J. Soil Water Cons. 53:241-244.

Derpsch, R., C.H. Roth, N. Sidiras, and U. Köpke. 1991. Controle da erosão no Paraná, Brazil: Sistemas de cobertura do solo, plantio directo e prepare conservacionista do solo. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, SP 245, Germany.

Ditsch, D.C., M.M. Alley, K.R. Kelley, and Y.Z. Lei. 1993. Effectiveness of winter rye for accumulating residual fertilizer N following corn. J. Soil Water Cons. 48:125-132.

Doran, J.W. 1980. Soil microbial and biochemical changes associated with reduced tillage. Soil Sci. Soc. Am. J. 44:765-771.

Edwards, L.M., and J.R. Burney. 1991. Sediment concentration of interrill runoff under varying soil, ground cover, soil compaction, and freezing regimes. J. Environ. Qual. 20:403-407.

Edwards, C.A., and J.R. Lofty. 1982. The Effect of Direct Drilling and Minimal Cultivation on Earthworm Populations. J. Appl. Ecol. 19:723-734.

Ehrbach, D.C., and W.G. Lovely. 1975. Effect of plant residue on herbicide performance in no-tillage corn. Weed Science. 23:512-515.

Fawcett, R.S., B.R. Christensen, and D.P. Tierney. 1994. The impact of conservation tillage on pesticide runoff into surface water: A review and analysis. J. Soil Water Cons. 49:126-135.

Feng, Y., A.C. Motta, D.W. Reeves, C.H. Burmester, E. van Santen, and J.A. Osborne. 2003. Soil microbial communities under conventional-till and no-till continuous cotton systems. Soil Biol. Biochem. 35:1693-1703.

Franzluebbers, A.J., G.W. Langdale, and H.H. Schomberg. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. Soil Sci. Soc. Am. J. 63:349-355.

Frye, W.W. 1984. Energy requirements in no-tillage, p. 127-151. *In* R.E. Phillips and S.H. Phillips (ed.). No-tillage agriculture: Principles and Practices, van Nostrand Reinhold, New York.

Havlin, J.L., D.E. Kissel, L.D. Maddux, M.M. Claasseen, and J.H. Long. 1990. Crop rotation and tillage effects on soil organic carbon and nitrogen. Soil Sci. Soc. Am. J. 54:448-452.

Hicks, S.K., Wendt C.W., Gannaway J.R., and Baker R.B. 1989.Allelopathic effects of wheat straw on cotton germination, emergence, and yield. Crop Sci. 29:1057-1061.

Holderbaum, J. F., A.M. Decker, J.J. Meisinger, F.R. Mulford, and L.R. Vough. 1990. Fall-seeded legume cover crops for no-tillage corn in the humid east. Agron. J. 82:117-124.

Honeycutt, C.W., W.M. Clapham, and S.S. Leach. 1996. Crop rotation and nitrogen fertilization effects on growth, yield and disease incidence in potato. Am. Potato J. 73:45-61.

Isensee, A.R., and A.M. Sadeghi. 1994. Effects of tillage and rainfall on atrazine residue levels in soil. Weed Sci. 42:462-467.

Johnson, W. Carroll III, T.B. Brenneman, S.H. Baker, A.W. Johnson, D.R. Sumner, and B.G. Mullinix, Jr. 2001. Tillage and pest management considerations in a peanut-cotton rotation in the Southeastern coastal plain. Agron. J. 93:570-576.

Kaspar, T.C., J.K. Radke, and J.M. Laflen. 2001. Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion. J. Soil Water Conserv. 56:160-164.

Kay, B.D. 1990. Rates of change of soil structure under different cropping systems. Advances in Soil Science. 12:1-52.

Kells, J.J., and W.F. Meggitt. 1985. Conservation tillage and weed control. In F.M. D'Itri (ed.) A systems approach to conservation tillage. Lewis Publishers, Inc., Chelsea, MI.

Kinyangi, J.M., A.J.M. Smucker, D.R. Mutch, and R.R. Harwood. 2001. Managing cover crops to recycle nitrogen and protect ground- water. Bull. E-2763. Michigan State Univ. Ext., East Lansing, MI.

Kuo, S., U.M. Sainju, and E.J. Jellum. 1997. Winter cover crop effects on soil organic carbon and carbohydrate. Soil Sci. Soc. Am. J. 61:145-152.

Lal, R., A.A. Mahboubi, and N.R. Fausey. 1994. Long-term tillage and rotation effects on properties of a central Ohio soil. Soil Sci. Soc. Am. J. 58:517-522.

Lal, R. 1997. Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2 enrichment. Soil & Till. Res. 43:81-107.

Langdale, G.W., R.L. Wilson, Jr., and R.R. Bruce. 1990. Cropping frequencies to sustain long-term conservation tillage systems. Soil Sci. Soc. Am. J. 54:193-198.

Larson, W.E., R.F. Holt, and C.W. Carlson. 1978. Residues for soil conservation. P. 1-15. *In* W.R. Oschwald (ed.) crop residue management systems. ASA Spec. publ. 31. ASA, CSSA, SSSA, Madison, WI.

Liebl, R., F.W. Simmons, L.M. Wax, and E.W. Stoller. 1992. Effect of rye (*Secale cereale*) mulch on weed control and soil moisture in soybean (*Glycine max*). Weed Technol. 6:838-846.

Liua, A., B.L. Mab, and A.A. Bomkec. 2005. Effects of Cover Crops on Soil Aggregate Stability, Total Organic Carbon, and Polysaccharides. Soil Sci. Soc. Am. J. 69:2041-2048.

Lowder, S.W., and J.B. Weber. 1979. Atrazine retention by crop residues in reduced-tillage systems. Proc. South. Weed Sci. Soc. 32:303-307.

Mahboubi, A.A., R. Lal, and N.R. Faussey. 1993. Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J. 57:506-512.

Masiunas, J.B., L.A. Weston, and S.C. Weller. 1995. The impact of rye cover crops on weed populations in a tomato cropping system. Weed Sci. 43:318-323.

McVay, K.A., D.E. Radcliffe, and W.L. Hargrove. 1989. Winter legume effects on soil properties and nitrogen fertilizer requirements. Soil Sci. Soc. Am. J. 53:1856-1862.

Minton, N.A. 1986. Impact of conservation tillage on nematode populations, J. Nematol. 18:135-140.

Naderman, G.C. 1991. Effects of crop residue and tillage practices on water infiltration and crop production. p. 23-24. *In* W. L. Hargrove (ed.). Cover crops for clean water. Jackson, TN. 9-11 Apr. 1991. Soil Water Conserv. Soc., Ankeny, IA.

Paxton, K.W., A. Jana, and D.J. Boquet. 1995. Economics of cotton production within alternative crop rotation systems. *In* Proc. Beltwide Cotton Conf. Memphis, TN: National Cotton Council of America. 379-381

Price, A.J., D.W. Reeves, and M.G. Patterson. 2006. Evaluation of weed control provided by three winter cereals in conservation-tillage soybean. Renewable Agric. and Food Systems. 21:159-164.

Price, A.J., D.W. Reeves, M.G. Patterson, B.E. Gmable, K.S. Balkcom, F.J. Arriaga, and C.D. Monks. 2007. Weed control in peanut grown in a high-residue conservation-tillage system. Peanut Sci. 34:59-64.

Price, A.J., M.E. Stoll, J.S. Bergtold, F.J. Arriaga, K.S. Balkcom, T.S. Kornecki, and R.L. Raper. 2008. Effect of cover crop extracts on cotton and radish radicle elongation. Comm. Biometry Crop Sci. 3:60-66.

Radford, B.J., D.F. Yule, D. McGarry, and C. Playford. 2001. Crop responses to applied soil compaction and to compaction repair treatments, Soil & Till. Res. 61:157-166.

Raper, R.L., D.W. Reeves, C.H. Burmester, and E.B. Schwab. 2000. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and energy requirements. Appl. Eng. Agric. 16:379-385.

Rasmussen, P.E. and Collins, H.P. 1991. Long-term impacts of tillage, fertilizer, and crop residue on soil organic matter in temperate semiarid regions. Adv. Agron. 45:93-134.

Reddy, K. N. 2004. Weed control and species shifts in bromoxynil and glyphosate-resistant cotton (*Gossypium hirsutum*) rotation systems. Weed Technol. 18:131-139.

Reeves, D.W. 1994. Cover crops and rotations *In* J.L.Hatfield and B.A.Stewart (ed.) Crops Residue Management. Advances in Soil Science. Lewis Publishers, BocaRaton, FL. Pp: 125-172.

Reeves, D.W. 2003. A Brazilian model for no-tillage cotton production adapted to the southeastern USA. Proc. II World Congress on Conservation Agriculture-Producing in Harmony with Nature. Iguassu Falls, Paraná, Brazil. Aug 11-15, 2003:372-374.

Reeves, D.W., A.J. Price, and M.G. Patterson. 2005. Evaluation of three winter cereals for weed control in conservation-tillage nontransgenic cotton. Weed Technol. 19: 731-736.

Rice, E. L. 1984. Allelopathy. 2nd ed. Academic Press, NY.

Saini, M., A.J. Price, and E. van Santen. 2006. Cover crop residue effects on early-season weed establishment in a conservation-tillage corn-cotton rotation. 28th Southern Conservation Tillage Conference. 28:175-178.

Sainju, U.M., and B.P. Singh. 1997. Winter cover crops for sustainable agricultural systems: Influence on soil properties, water quality, and crop yields. HortScience. 32:21-28.

Sainju, U.M., and B.P. Singh. 2001. Tillage, cover crop, and kill-planting date effects on corn yield and soil nitrogen. Agron. J. 93: 878-886.

Sainju, U.M., B.P. Singh, and W.F. Whitehead. 2002. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil & Till. Res. 63:167-179.

Schlesinger, W.H. 1984. Soil organic matter: A source of atmospheric CO_2 *In* G.M. Woodwell (ed.) The role of terrestrial vegetation in the global carbon cycle. John Wiley & Sons, New York. Pp: 111-127.

Schomberg, H.H., R.G. McDaniel, E. Mallard, D.M. Endale, D.S. Fisher, and M.L. Cabrera. 2006. Conservation tillage and cover crop influences on cotton production on a southeastern US Coastal Plain soil. Agron. J. 98:1247-1256.

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

Shaw, J.N., C.C. Truman, and D.W. Reeves. 2002. Mineralogy of eroded sediments derived from highly weathered Ultisols of central Alabama. Soil Tillage Res. 68:59-69.

Snapp, S.S., S.M. Swinton, R. Labarta, D. Mutch, J.R. Black, R. Leep, J. Nyiraneza, and K. O'Neil. 2005. Evaluating cover crops for benefits, costs and performance within cropping system niches. Agron. J. 97: 322-332.

Sullivan, P.G., D.J. Parrish, and J.M. Luna. 1991. Cover crop contributions to N supply and water conservation in corn production. Am. J. Alt. Ag. 6:106-113.

Teasdale, J. R. 1993. Reduced-herbicide weed management systems for no-tillage corn (*Zea mays*) in a hairy vetch (*Vicia villosa*) cover crop. Weed Tech. 7:879-883.

Teasdale, J.R. 1996. Contribution of cover crops to weed management in sustainable agricultural systems. J. Prod. Agric. 9:475-479.

Teasdale, J.R., and C.S.T. Daughtry. 1993. Weed suppression by live and desiccated hairy vetch (*Vicia villosa*). Weed Sci. 41:207-212

Teasdale, J.R., and C. Mohler. 1992. Weed suppression by residue from hairy vetch and rye cover crops. Proc. First Int. Weed Control Congress. 2:516-518.

Teasdale, J.R., and C.L. Mohler. 1993. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agron. J. 85:673-680.

Teasdale, J.R., and A.A. Abdul-Baki. 1995. Soil temperature and tomato growth associated with black polythene and hairy vetch mulches. J. Amer. Soc. Hort. Sci. 120:848-853.

Teasdale, J.R., and A.A. Abdul-Baki. 1997. Growth analysis of tomatoes in black plastic and hairy vetch production systems. HortScience. 32:659-663.

Teasdale, J.R., and A.A. Abdul-Baki. 1998. Comparison of mixtures vs. monocultures of cover crops for fresh-market tomato production with and without herbicide. HortScience. 33:1163-1164.

Teasdale, J.R., and C.L. Mohler. 2000. The quantitative relationship between weed emergence and the physical properties of mulches. Weed Sci. 48:385-392.

Truman, C.C., D.W. Reeves, J.N. Shaw, A.C. Motta, C.H. Burmester, R.L. Raper, and E.B. Schwab. 2003. Tillage impacts on soil property, runoff, and soil loss variations from a Rhodic Paleudult under simulated rainfall. J. Soil & Water Conserv. 58:258-267.

Tubbs, R.S., and R.N. Gallaher. 2004. Conservation tillage and herbicide management for two peanut cultivars. Agron. J. 97: 500-504.

Unger, P.W., and Jones, O.R. 1998. Long-term tillage and cropping systems affect bulk density and penetration resistance of soil cropped to dryland wheat and grain sorghum. Soil & Tillage Res. 45:39-57.

van Santen, E., J.F. Pedersen, and J.T. Touchton. 1992. Registration of 'AU Robin' crimson clover. Crop Sci. 32:1071-1072.

Webster, E.P. 2001. Economic losses due to weeds in southern states: Cotton, soybean, peanut, tobacco, and forestry. Proc. South. Weed Sci. Soc. 54:260-269.

Wilcut, J.W., G.R. Wehtje, D.L. Colvin, and M.G. Patterson. 1987. Economic assessment of herbicide systems for minimum-tillage peanut and conventional-tillage peanut. Peanut Sci. 4:83-86.

Wright, S.F., and A. Upadhyaya. 1998. A survey of soils for aggregate stability and glomalin, a glycoprotein produced by hyphae of arbuscular mycorrhizal fungi. Plant Soil. 198:97-107.

Wright, S.F., J.L. Starr, and I.C. Paltineanu. 1999. Changes in aggregate stability and concentration of glomalin during tillage management transition. Soil Sci. Soc. Am. J. 63:1825-1829.

Wright, D.L., J.J. Marois, J.R. Rich, R.K. Sprenkel, and E.B. Whitty. 2002. Conservation Tillage Peanut Production. University of Florida Institute of Food and Agricultural Sciences. SS-AGR-185.

Yenish, J.P., A.D. Worsham, and A.C. York. 1996. Cover crops for herbicide replacement in no-tillage corn (*Zea mays*). Weed Technol. 10:815-821.

Young, F.L., A.G. Ogg Jr, D.C. Thill, D.L. Young, and R.I. Papendick. 1996. Weed management for crop production in the Northwest wheat (*Triticum aestivum*) region. Weed Sci. 44:429-436.

II. HERBICIDE AND RYE COVER CROP RESIDUE INTEGRATION AFFECT WEED CONTROL AND YIELD IN CONSERVATION TILLAGE PEANUT

ABSTRACT

Acreage of reduced tillage peanut (*Arachis hypogaea* L.) production is increasing mainly due to reduced production costs and increased environmental and economic benefits compared to conventional systems. Experiments were conducted in Alabama and Georgia to evaluate strip tillage systems, utilizing high residue cereal rye cover crop for weed control and peanut yield, in comparison to conventional tillage systems. Six weed management schemes were evaluated including a pre-emergence (PRE) application of pendimethalin alone at 1.12 kg a.i. ha^{-1}or in combination with *S*-metolachlor at 1.36 kg a.i. ha^{-1}. Both PRE treatments were applied alone or in conjunction with a post emergence (POST) application consisting of a tank mixture of paraquat at 0.140 kg a.i. ha^{-1} plus bentazon at 0.56 kg a.i. ha^{-1} plus 2, 4-DB at 0.224 kg a.i. ha^{-1}. The remaining two treatments consisted of a no-herbicide control and the aforementioned POST application applied alone. In 2005 at our Alabama location, pendimethalin PRE alone provided 81%

control of yellow nutsedge and 84% control of tall morningglory in strip tillage. Pendimethalin plus metolachlor provided greater than 91% control of all weeds in strip tillage and ≥ 85% control of tall morningglory, yellow nutsedge and bermudagrass in the conventional tillage system. Greater than 97% control of all weeds was observed irrespective of tillage system in treatments containing both PRE and POST applications. In Alabama in 2007, pooled over tillage systems, pendimethalin provided 84% and 82% control of smooth pigweed and large crabgrass, but only 57% and 55% control of Florida beggarweed and sicklepod, respectively. Post-emergence application alone was inadequate in controlling these four weeds. Higher peanut yields were observed at the Georgia location compared to the Alabama location. Since weed interference was negligible at Dawson in 2005, no-herbicide plots yielded 5346 kg ha^{-1} whereas the same treatment yielded least in 2007 (2995 kg ha^{-1}). Peanut market grade was not affected by any herbicide treatments or tillage methods evaluated.

INTRODUCTION

Peanut (*Arachis hypogaea* L.) production in the southeastern United States has traditionally been a tillage intensive process utilizing both primary and secondary tillage to create residue-free raised or flat seedbeds. Peanut production typically utilizes preplant incorporated (PPI) and/or PRE herbicides in conventional tillage systems. However, increased concerns for decreased soil and environmental quality coupled with increased management and fuel costs have led to adoption of conservation tillage systems in peanut production. The most commonly used conservation tillage system in peanut production is strip tillage, which is used to alleviate soil compaction commonly found in the southeastern US soils (Busscher and Bauer 2003; Truman et al. 2003). Benefits of strip tillage include those of both conservation tillage and conventional systems. Strip tillage utilizes coulters and rolling baskets that create a residue free smooth seedbed that provides increased seed soil contact, increased soil temperature at planting and facilitates PRE herbicide activation. Previous research in the southeastern United States indicated higher or equivalent yields with strip tillage compared to conventional tillage systems (Wilcut et al. 1987; Tubbs and Gallaher 2004; Johnson et al. 2001). Finally, adoption of conservation tillage systems reduces the economic inputs and brings desired cost benefits after several years of successful adoption of conservation tillage systems (Bowman et al. 1998).

Another important component of strip tillage peanut production system in the southeastern United States is the use of cover crops. The cash crop benefits from cover crop residue through increase in soil organic matter content, water and soil conservation and enhanced nutrient cycling (Blevins et al. 1971; Sainju and Singh 1997; Kaspar et al. 2001). Cover crop residue conserves water by preventing evaporative and runoff losses, aids in soil conservation by reducing wind and water erosion, enhances nutrient cycling, and increases soil organic matter content (Dabney et al. 2001; Snapp et al. 2005). The presence of residue around the seedbed also reduces the chances of sandblasting. Most commonly used cover crops in peanut production are cereal grain crops such as rye (*Secale cereale* L.) and wheat (*Triticum aestivum* L.) as they are easy to establish and provide good amount of biomass (Price et al. 2007; Wright et al. 2002). Cover crop residue can also aid in early season weed suppression through chemical and physical inhibitory effects when winter covers are grown to maturity (Creamer et al. 1997; Teasdale and Abdul-Baki 1998; Price et al. 2006; Yenish et al. 1996).

The major crop management challenge of conservation tillage systems is the loss of weed control through tillage and cultivation as well as interception of PRE herbicides by cover crop residues (Banks and Robinson 1986; Isensee and Sadeghi 1994) In conservation tillage, it is common to have an increase in the weed seed bank present on the soil surface leading to sporadic germination of these seeds over a longer time period of time (Kells and Meggitt 1985), requiring additional herbicide inputs. Additionally, with the adoption of conservation tillage systems weed communities may shift from easy to control annual species to perennial (Barberi 2002; Cardina et al. 2002). Therefore strip tillage management of peanut may require more intensive herbicide inputs compared to conventional tillage systems due mainly to reduced efficiency of PPI and PRE herbicides in these systems (Wilcutt et al. 1987). Weed control is a very important factor determining profitability in peanut production; Webster (2001) reported total annual losses from weeds in Alabama and Georgia to be \$11.2 and \$47.5 million respectively.

Because of the above mentioned concerns and adoption of conservation tillage systems utilizing high residue cover crops by growers, further research is needed to evaluate weed control and yield under different tillage systems and herbicide options. Therefore, the objectives of this study were to compare weed control provided by high residue rye cover crop under conventional tillage and strip tillage systems and its effect on peanut yield in Alabama, and Georgia.

MATERIAL AND METHODS

Field experiments were conducted at sites in Alabama and Georgia, each replicated in time for two crop years. The first site was located on a Dothan sandy loam (fine-loamy, siliceous, thermic, Plinthic Paleudults) at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center (31°24′N, 85°15′W), located near Headland, AL conducted during 2004/05 and 2006/07 crop years. The second site was located on a Red Bay loamy sand (Fine-loamy, kaolinitic, thermic Rhodic Kandiudults) at the USDA-ARS National Peanut Research Laboratory field research site near Dawson, GA, conducted during the 2004/05 and 2005/06 crop years.

At all location and years, the experiment was conducted as a randomized complete block design with four replicates. A cereal rye (cv. Elbon) cover crop was seeded (100 kg ha^{-1}) in early November every year with a no-till drill. Irrespective of tillage system, the cover crop was terminated in early May of each year approximately 2 wks prior to planting peanut (Feekes' soft dough growth stage 11.2) with an application of glyphosate at 1.12 kg a.e. ha^{-1} utilizing a compressed CO_2 backpack sprayer delivering 140 L ha^{-1} at 147 kPa. For preparation of strip tillage plots the cover crop was then rolled with a mechanical roller-crimper to flatten residue on the soil surface. Conventional tillage plots were prepared with multiple passes of a disk and a seedbed conditioner. All plots were then strip-tilled using a subsoiler equipped with coulters, rolling baskets, and drag chains to eliminate confounding deep tillage affects. An area approximately 30 cm wide strip was tilled over each row.

Peanut cultivar GA Green was planted with a four-row planter each year at both locations at a rate of 28 seed per meter of row. Cooperative Extension System recommendations were used for insect and disease control and nutrient management at each experimental site. Peanut yield was determined by machine-digging followed by harvesting the middle two rows of each 4-row plot with a plot combine.

Six herbicide weed management schemes were evaluated. The first and second included a PRE application of pendimethalin at 1.12 kg a.i. ha^{-1} either alone or in combination with *S*-metolachlor at 1.36 kg a.i. ha^{-1}. Both PRE treatments were applied alone or in conjunction with a POST application consisting of a tank mixture of paraquat at 0.140 kg a.i. ha^{-1} plus bentazon at 0.56 kg a.i. ha^{-1} plus 2, 4-DB at 0.224 kg a.e. ha^{-1}. The remaining two treatments consisted of a no-herbicide control and the aforementioned POST application applied alone (Table 2.01). These herbicide treatment schemes were applied as a factorial with the two tillage systems yielding 12 treatment combinations replicated four times. Due to lack of yellow nutsedge control late season in some treatments, imazapic (0.062 kg a.i./ha) was applied to all plots at Headland in 2007 to facilitate harvest.

The effectiveness of herbicide programs was determined by visually rating the presence of weeds relative to the weed density in the untreated control of each replication, where 0% = no control and 100% = complete control. All weed species present at the time of rating were evaluated for control as a reduction in total above ground biomass resulting from both reduced emergence and growth.

Mixed models analysis of variance procedures as implemented in SAS$^{®}$ PROC GLIMMIX were used to analyze weed control and yield data. Weed control data were analyzed separately for each environment (experiment location x year). The decision for separate analysis across locations was taken due to different weed spectrum encountered at the two locations. Herbicide treatment, tillage system and their interaction were considered fixed effects, whereas replication and their interaction with herbicide treatment and tillage system were considered random effects. Percent weed control data were subjected to the arcsine transformation to account for non-normality of residuals and heterogeneity of variances. Back-transformed means for appropriate main effects and interactions are presented with contrasts based on the transformed data. Significance of the means was tested by performing two types of comparisons. Effect of all herbicide treatments vs. no-herbicide control within each tillage system was accomplished by using Dunnett's test option in least square means statement of PROC GLIMMIX. Significance of the tillage system effect on performance of each herbicide regimen was tested using pdiff option in LSMEANS statement of PROC GLIMMIX.

RESULTS AND DISCUSSION

Weed Control

A total of twelve weed species were evaluated for weed control in this experiment but none of the species was present in all environments. This justifies the separate analysis for each environment. Since the objective of this experiment was to compare the efficacy of the chosen herbicide regimens in strip and conventional tillage systems, results for each weed species are discussed at the factorial treatment interaction level (herbicide treatment by tillage system).

Headland, AL

Interactions of tillage systems and herbicide treatments as well as their respective main effects were significant for all weed species evaluated at Headland, 2005 and 2007. Because the presence of weeds late in the season can affect yield and harvesting efficiency visual estimates for weed control of only late season estimates are reported.

Smooth pigweed. Except the pendimethalin alone application, all herbicide treatments controlled smooth pigweed (*Amaranthus hybridus* L.) effectively (Table 2.02) in both tillage systems in 2005. All herbicide treatments provided significantly higher control compared to the no-herbicide control in 2007 only under conventional tillage system. The weed control provided by pendimethalin was not significantly different from the no-herbicide control in both the tillage systems in 2005 and was significant only in conventional tillage system in 2007; it controlled smooth pigweed 13% and 78% in conventional, and 61% and 69% in the strip tillage system. Pendimethalin plus *S*-metolachlor provided 77% and 81% control under conventional tillage system and 98% and 84% in the strip tillage system. A recent study in Texas reported less than 42% control of Palmer amaranth with pendimethalin applied PPI, and 95% control with pendimethalin PPI followed by *S*-metolachlor PRE (Grichar, 2008). Treadaway-Ducar et al. (2006) reported 73% control of smooth pigweed with *S*-metolachlor alone. Wilcut et al. (1994) however, reported good control of *Amaranthus* spp. with dinitroaniline herbicides such as pendimethalin, and less consistent control with *S*-metolachlor. In our study, the tank mixture of the two herbicides applied PRE improved control in comparison to pendimethalin applied alone. These results indicate both herbicides applied as a tank mixture or sequentially can significantly improve the control of *Amaranth* spp. Addition of paraquat plus bentazon plus 2, 4-DB to either pendimethalin or pendimethalin plus *S*-metolachlor significantly improved control (≥ 98%). POST herbicide application alone was also sufficient in controlling the smooth pigweed in both tillage systems at Headland 2005. In Headland in 2007, we observed 85% smooth pigweed control under conventional tillage system and 81% under strip tillage system with this herbicide regimen.

Bermudagrass. Control of Bermudagrass [*Cynodon dactylon* (L.) Pers.] was adequate (≥ 92%) for all the herbicide by tillage combinations except the pendimethalin PRE and POST herbicides applied alone (Table 2.03). POST application alone provided only 20% control in the conventional tillage system and only 59% control in the strip tillage system.

Control was 63% with pendimethalin PRE applied alone in the conventional tillage system but provided 81% control of bermudagrass in the strip tillage system.

Large crabgrass. Without herbicides, large crabgrass [*Digitaria sanguinalis* (L.) Scop.] was controlled only 4% in conventional and 41% in the strip tillage system (Table 2.03). In the strip tillage system, treatments containing pendimethalin PRE alone or fb POST application of paraquat plus bentazon plus 2,4-DB provided only 62% and 78% control of large crabgrass. The tank mixture of pendimethalin plus *S*-metolachlor PRE applied alone provided 91% control whereas control was 95% when these herbicides were followed by the POST application. However, a POST application alone of paraquat plus bentazon plus 2, 4-DB failed to control this weed species in both tillage systems.

Yellow nutsedge. Without herbicides yellow nutsedge (*Cyperus esculentus* L.) control ranged from 0 to 18% in the conventional tillage to 28 and 51% in the strip tillage (Table 2.04). Pendimethalin alone also failed to control yellow nutsedge. Grichar et al. (1992) also reported lack of control of nutsedge with dinitroanilines. Combination of pendimethalin with *S*-metolachlor improved the control to 89% and 91% in the conventional and strip tillage respectively, at Headland 2005. However, the same treatment failed to control yellow nutsedge in both tillage systems at Headland 2007. Both of the residual treatments followed by paraquat plus bentazon plus 2,4-DB controlled yellow nutsedge ≥ 97% irrespective of the tillage system at Headland 2005. In 2007 at Headland, the only herbicide regimen which provided ≥ 90% control of yellow nutsedge was pendimethalin plus *S*-metolachlor fb paraquat plus bentazon plus 2,4-DB.

Combination of paraquat plus bentazon plus 2, 4-DB applied alone without PRE residual herbicide was inadequate in controlling yellow nutsedge. Overall, none of the herbicide treatments controlled yellow nutsedge significantly in the strip tillage system.

Tall Morningglory. Pendimethalin alone provided 65% and 84% control of tall morningglory (*Ipomoea purpurea* (L.) Roth) in conventional and strip tillage respectively, at Headland 2005 (Table 2.05). Control was 64% and 53% in conventional and strip tillage respectively, at Headland 2007. Grey and Wehtje (2005) also reported lack of tall morningglory control with pendimethalin PRE alone. Addition of *S*-metolachlor to pendimethalin (PRE 2) improved the control in 2005, but failed to control tall morningglory in 2007 in both tillage systems. Residual treatments fb paraquat plus bentazon plus 2, 4-DB provided 99% control in 2005 and ≥ 88% control in 2007 at Headland. Postemergence application of paraquat plus bentazon plus 2, 4-DB alone also provided ≥ 99% control in both conventional tillage and strip tillage. However the same treatment combination did not control tall morningglory in 2007 in either tillage system.

Florida beggarweed. Only 8% control of Florida beggarweed (*Desmodium tortuosum* (Sec) L.) was achieved without herbicide application in conventional tillage and 53% in strip tillage (Table 2.06). Application of pendimethalin alone provided only 31% control in conventional tillage, and 76% control in strip tillage. Addition of *S*-metolachlor did not improve control irrespective of tillage system. The treatment containing pendimethalin fb paraquat plus bentazon plus 2, 4-DB controlled Florida beggarweed 87% in conventional and 88% in strip tillage. Treatment containing pendimethalin plus *S*-metolachlor fb paraquat plus bentazon plus 2, 4-DB controlled Florida beggarweed 95% in conventional tillage system but 79% in strip tillage, possibly due to reduction of efficacy of these herbicide regimens in strip tillage plots due to presence of more residue. Requirement of POST herbicide application for effective control of Florida beggarweed has also been advocated by Webster and Cardina (2004) owing to the irregular germination of this weed species. Brecke and Stephenson (2006) also reported greater than 90% control of Florida beggarweed with treatments including either diclosulam or flumioxazin PRE fb either paraquat plus bentazon or paraquat plus bentazon fb 2,4 –DB. However, the POST application alone of paraquat plus bentazon plus 2,4-DB provided ≤ 31% control. Wilcut et al. (1995) have reported variable control of Florida beggarweed with bentazon plus paraquat or paraquat alone. This is likely attributed to lack of residual activity with bentazon and paraquat.

Sicklepod. Pendimethalin alone failed to control sicklepod (*Senna obtusifolia* L.) in either tillage systems (Table 2.07). Pendimethalin plus *S*-metolachlor alone provided 92% control in strip tillage but provided only 63% control in conventional tillage at Headland 2005. However the same treatment controlled sicklepod ≤ 48% at Headland 2007. Control was complete (99%) with residual herbicide treatments fb paraquat plus bentazon plus 2, 4-DB in both tillage systems at Headland 2005. The aforementioned treatments controlled sicklepod ≤ 92% at Headland in 2007. Tank mixture of paraquat plus bentazon plus 2, 4-DB also controlled sicklepod ≥ 96% in both tillage systems at Headland in 2005. This observation was similar to that of Brecke and Stephenson (2006) who reported > 90% control with paraquat and bentazon applied early postemergence fb imazapic.

Control was 80% in strip tillage system but 39% in the conventional tillage with tank mixture of paraquat plus bentazon plus 2, 4-DB at Headland 2007.

Across both tillage systems, PRE-applied herbicides performed better in strip tillage system compared to conventional tillage system at Headland 2005. Significantly higher control of all weed species was observed in no-herbicide plots under strip tillage compared to conventional tillage. Control was higher in strip tillage when PRE herbicides were applied, except yellow nutsedge, in which case pendimethalin + *S*-metolachlor efficacy was similar in both conventional and strip tillage. No statistically significant differences in the efficacy of other herbicide treatments were observed across tillage systems in all weed species at Headland 2005. The similar comparison at Headland 2007 showed no differences in the efficacy of the various herbicide regimens across tillage systems except that pendimethalin was more effective in controlling Florida beggarweed in the strip tillage system compared to conventional tillage system. Tall morningglory was also controlled better under strip tillage system without herbicides. These observations indicate synergism for weed suppression between rye residue and PRE herbicides in this study. We can further conclude that cover crop residue left on the soil surface for sustainable agricultural practices aided in weed suppression during summer.

Dawson GA, 2005 and 2006

Bermudagrass was the only weed encountered at this location in 2005 (Table 2.08). Smallflower morningglory (*Jaquemontia tamnifolia* Griseb.) (Table 2.09), large crabgrass and crow-foot grass (Table 2.10) were present in 2006 in addition to bermudagrass. Results from only the late season rating are reported. Analysis of variance showed no significant interaction or main effect of tillage system and herbicide treatments on weed control in both years.

Peanut Yield and Grade

No significant interaction of tillage system by herbicide treatment was observed for pod yield in any of the environments. In 2007, impact of herbicide treatments on peanut pod yield was significant at Headland. Tillage affected yield significantly in all the environments except Dawson in 2005. Maximum yield was observed at Dawson in 2005 (Table 11). High yield at this location corresponds to the least weed pressure encountered at this site year. Since the weed interference was negligible, no-herbicide plots yielded (5346 kg ha^{-1}) maximum. Peanut receiving only POST herbicides yielded least (4712 kg ha^{-1}) in this environment. At Dawson 2007 no-herbicide control yielded least, yield increased with additional herbicide applications; however, the difference was not statistically significant. Lower yield was observed at the Alabama location compared to the Georgia site ranging from 2555 kg ha^{-1} to 3898 kg ha^{-1} in 2005 and 2510 kg ha^{-1} to 3495 kg ha^{-1} in 2007. In general herbicide treatments did not improve the peanut yield at Headland, AL compared to the no-herbicide plots. Combined over herbicide treatments, strip tillage peanuts yielded higher than conventionally tilled peanuts in three of the four environments. Conventional tillage peanuts yielded (5179 kg ha^{-1}) significantly higher than the strip tilled (4809 kg ha^{-1}) peanuts at Dawson in 2005.

No significant interaction between years was observed for grade data; therefore, combined means over years are reported. Peanut grade was not affected by any of the herbicide treatments or tillage methods (Table 12). Percentage of TSMK (total sound mature kernels) remained unaffected by the level of the weed control inputs and increased by only one percentage point compared to the no-herbicide control in two of the five herbicide treatments.

In this study, strip tillage provided increased weed control in 2005 in Headland and equivalent control at all other site years. Our results contradict studies that show reduced weed control with decreased tillage. This may be due to relatively higher amounts of residue accumulated from the rye cover crop since the cover crop was terminated at the soft dough maturity stage. Furthermore, peanut yield was greater in 3 of 4 experiments utilizing strip tillage system indicating a yield advantages for utilizing strip vs. conventional tillage. Our results show that producers can improve weed control and equivalent grade and yield in reduced tillage systems utilizing a high residue cover crop. As interest in high-residue conservation agriculture increases due to economic advantages and agricultural policy (e.g. incentive payments), applied research evaluating these systems is helpful in understanding what cultural practices improve conservation agriculture systems.

LITERATURE CITED

Banks, P. A., and E.L. Robinson. 1986. Soil reception and activity of acetochlor, alachlor, and metolachlor as affected by wheat straw and irrigation. Weed Sci. 34:607-611.

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? Weed Res. 42:177-193.

Blevins, R.L., D. Cook, S.H. Phillips, and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 63:593-596.

Bowman, G., C. Shirley, and C. Cramer. 1998. Managing Cover Crops Profitably. 2nd ed. Washington, D.C.: Sustainable Ag. Network.

Brecke, B. J., and D.O. Stephenson IV. 2006. Weed management in single vs. twin-row peanut (*Arachis hypogaea*). Weed Technol. 20:368-376.

Busscher, W.J., and P.J. Bauer. 2003. Soil strength, cotton root growth and lint yield in a southeastern USA coastal loamy sand. Soil Tillage Res. 74:151-159.

Cardina, J., C.P. Herms, and D.J. Doohan. 2002. Crop rotation and tillage effects on weed seedbanks. Weed Sci. 50:448-460.

Creamer, N.G., M.A. Bennett, and B.R. Stinner. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience. 32:866-870.

Dabney S. M., J. A. Delgado, and D. W. Reeves. 2001. Using winter cover Crops to improve soil and water quality. Comm. Soil Sci. Plant Anal. 32:1221-1250.

Grey, T.L. and G.R. Wehtje. 2005. Residual herbicide weed control systems in peanut. Weed Technol. 19:560-567.

Grichar, W.J. 2008. Herbicide Systems for control of horse purslane (*Trianthema portulacastrum* L.), smellmelon (*Cucumis melo* L.), and Palmer Amaranth (*Amaranthus palmeri* S. Wats) in peanut. Peanut Sci. 35:38-42

Grichar, W.J., P.R. Nester, and A.E. Colburn. 1992. Nutsedge (*Cyperus* spp.) control in peanuts (*Arachis hypogaea*) with imazethapyr. Weed Technol. 6:396-400.

Isensee, A.R., and A.M. Sadeghi. 1994. Effects of tillage and rainfall on atrazine residue levels in soil. Weed Sci. 42:462-467.

Johnson, W. Carroll III, T.B. Brenneman, S. H. Baker, A. W. Johnson, D. R. Sumner, and B. G. Mullinix, Jr. 2001. Tillage and pest management considerations in a peanut-cotton rotation in the Southeastern coastal plain. Agron. J. 93: 570-576.

Kaspar, T. C., J.K. Radke, and J.M. Laflen. 2001. Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion. J. Soil Water Cons. 56:160-164.

Kells, J.J., and W.F. Meggitt. 1985. Conservation tillage and weed control. *In* F.M. D'Itri (ed.) A systems approach to conservation tillage. Lewis Publishers, Inc., Chelsea, MI.

Price, A.J., D.W. Reeves, and M.G. Patterson. 2006. Evaluation of weed control provided by three winter cereals in conservation-tillage soybean. Ren. Agric. and Food Sys. 21:159-164.

Price, A.J., D.W. Reeves, M.G. Patterson, B.E. Gamble, K.S. Balkcom, F.J. Arriaga, and C.D. Monks. 2007. Weed control in peanut grown in a high-residue conservation-tillage system. Peanut Sci. 34:59-64.

Sainju, U.M., and B.P. Singh. 1997. Winter cover crops for sustainable agricultural systems: Influence on soil properties, water quality, and crop yields. HortScience 32:21-28.

Snapp, S. S., S. M. Swinton, R. Labarta, D. Mutch, J. R. Black, R. Leep, J. Nyiraneza and K. O'Neil. 2005. Evaluating cover crops for benefits, costs and performance within cropping system niches. Agron. J. 97: 322-332.

Teasdale, J.R. and A.A. Abdul-Baki. 1998. Comparison of mixtures vs. monocultures of cover crops for fresh-market tomato production with and without herbicide. HortScience. 33: 1163-1166.

Treadaway-Ducar, J.A., J.W. Wilcut, D.L. Jordan, J. Faircloth, and C.W. Swann. 2006. Evaluation of diclosulam and *S*-metolachlor applied preplant incorporated in peanut (*Arachis hypogaea*). Peanut Sci. 33:137-141.

Truman, C.C., D.W. Reeves, J.N. Shaw, A.C. Motta, C.H. Burmester, R.L. Raper, and E.B. Schwab. 2003. Tillage impacts on soil property, runoff, and soil loss variations from a Rhodic Paleudult under simulated rainfall. J. Soil & Water Conserv. 58:258-267.

Tubbs, R. Scott, and Raymond N. Gallaher. 2004. Conservation tillage and herbicide management for two peanut cultivars. Agron. J. 97: 500-504.

Webster, E.P. 2001. Economic losses due to weeds in southern states: Cotton, soybean, peanut, tobacco, and forestry. Proc. South. Weed Sci. Soc. 54:260-269.

Webster, T.M. and J. Cardina. 2004. A review of the biology and ecology of Florida beggarweed (*Desmodium tortuosum*). Weed Sci. 52:185-200.

Wilcut, J.W., G.R. Wehtje, D.L. Colvin, and M.G. Patterson. 1987. Economic assessment of herbicide systems for minimum-tillage peanut and conventional-tillage peanut. Peanut Sci. 4:83-86.

Wilcut, J.W., A.C. York, and G.R. Wehtje. 1994. The control and interaction of weeds in peanut (*Arachis hypogaea*). Weed. Sci. 6:177-205.

Wilcut, J.W., A.C. York, W.J. Grichar, and G.R. Wehtje. 1995. The biology and management of weeds in peanut (*Arachis hypogaea*). Pages 207–244 *In* H. E. Pattee and H. T. Stalker, (ed.) Advances in Peanut Science. Stillwater, OK: American Peanut Research and Education Society.

Wright, D.L., J.J. Marois, J.R. Rich, R.K. Sprenkel, and E.B. Whitty. 2002. Conservation Tillage Peanut Production. University of Florida Institute of Food and Agricultural Sciences. SS-AGR-185.

Yenish, J.P., A.D. Worsham, and A.C. York. 1996. Cover crops for herbicide replacement in no-tillage corn (*Zea mays* L.). Weed Technol. 10:815-821.

Table 2.01: Herbicide program used in strip and conventional peanut production

Preemergence[†]		Postemergence[‡]	
Herbicides[a]	Rate	Herbicides[a]	Rate
	-------kg/ha-------		----------kg/ha--------
None	-	None	-
Pend	1.12	None	-
Pend + *S*-met	1.12 + 1.36	None	-
Pend	1.12	Pqt + Bzn + DB	0.14 + 0.56 + 0.22
Pend + *S*-met	1.12 + 1.36	Pqt + Bzn + DB	0.14 + 0.56 + 0.22
None	-	Pqt + Bzn + DB	0.14 + 0.56 + 0.22

[†] Preemergence herbicides were applied on the day of planting peanut.

[‡] Postemergence herbicides were sprayed 4 wks after planting peanut

[a] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor;
Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.02: Smooth pigweed control as influenced by herbicide treatment and tillage system: Headland, AL.

Treatment [ab]		2005					2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast‡	Conventional Tillage		Strip Tillage		Tillage Contrast‡
Pre Emergence	Post Emergence	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value
		%		%			%		%		
		0		64		<0.001	3		52		0.113
Pend	None	13	0.275	61	0.962	<0.001	78	0.039	69	0.937	0.666
Pend + *S*-met	None	77	<0.001	98	<0.001	<0.001	81	0.027	84	0.486	0.881
Pend	Pqt + Bzn + DB	99	<0.001	99	<0.001	0.713	98	0.001	99	0.036	0.891
Pend + *S*-met	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	99	<0.001	99	0.036	1.000
None	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	85	0.015	81	0.581	0.815

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.03: Bermudagrass and large crabgrass control as influenced by herbicide treatment and tillage system: Headland, AL

Treatment[ab]		Bermudagrass, 2005					Large crabgrass, 2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]	Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%			%		%		
		0		48		<0.001	4		41		0.149
Pend	None	63	<0.001	81	<0.001	<0.001	77	0.012	62	0.797	0.438
Pend + *S*-met	None	92	<0.001	97	<0.001	0.015	61	0.081	91	0.035	0.069
Pend	Pqt + Bzn + DB	96	<0.001	98	<0.001	0.315	75	0.016	78	0.271	0.866
Pend + *S*-met	Pqt + Bzn + DB	97	<0.001	99	<0.001	0.315	93	<0.001	95	0.014	0.871
None	Pqt + Bzn + DB	20	0.009	59	0.130	<0.001	33	0.676	23	0.921	0.705

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.04: Yellow nutsedge control as influenced by herbicide treatment and tillage system: Headland, AL

Treatment [ab]		2005					2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]	Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%			%		%		
		0		51		<0.001	18		28		0.726
Pend	None	3	1.000	63	0.240	<0.001	34	0.968	25	1.000	0.746
Pend + *S*-met	None	89	<0.001	91	<0.001	0.442	54	0.549	72	0.273	0.416
Pend	Pqt + Bzn + DB	97	<0.001	97	<0.001	0.776	29	0.994	61	0.588	0.228
Pend + S-met	Pqt + Bzn + DB	99	<0.001	99	<0.001	0.730	90	0.011	62	0.546	0.123
None	Pqt + Bzn + DB	4	0.982	41	0.374	<0.001	13	1.000	46	0.948	0.241

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.05: Tall Morningglory control as influenced by herbicide treatment and tillage system: Headland, AL

Treatment ^{ab}		2005					2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast‡	Conventional Tillage		Strip Tillage		Tillage Contrast‡
Pre Emergence	Post Emergence	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value
		%		%			%		%		
		0		49		<0.001	5		69		0.050
Pend	None	65	<0.001	84	<0.001	0.002	64	0.254	53	0.962	0.689
Pend + *S*-met	None	83	<0.001	94	<0.001	0.012	56	0.402	67	1.000	0.694
Pend	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	98	0.004	99	0.240	0.835
Pend + *S*-met	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	96	0.006	88	0.858	0.518
None	Pqt + Bzn + DB	96	<0.001	99	<0.001	0.155	63	0.279	76	0.999	0.602

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.06: Florida beggarweed control as influenced by herbicide treatment and tillage system: Headland, AL

Treatment [ab]		2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%		
		8		53		0.140
Pend	None	31	0.916	76	0.797	0.092
Pend + *S*-met	None	45	0.633	53	1.000	0.773
Pend	Pqt + Bzn + DB	87	0.020	88	0.374	0.937
Pend + *S*-met	Pqt + Bzn + DB	95	0.004	79	0.723	0.278
None	Pqt + Bzn + DB	31	0.914	8	0.427	0.459

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.07: Sicklepod control as influenced by herbicide treatment and tillage system: Headland, AL

Treatment [ab]		2005					2007				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]	Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%			%		%		
		0		62		<0.001	13		26		0.657
Pend	None	20	0.080	55	0.776	<0.001	36	0.898	45	0.941	0.736
Pend + *S*-met	None	63	<0.001	92	<0.001	<0.001	48	0.614	31	1.000	0.532
Pend	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	76	0.079	92	0.023	0.331
Pend + *S*-met	Pqt + Bzn + DB	99	<0.001	99	<0.001	1.000	80	0.053	70	0.340	0.614
None	Pqt + Bzn + DB	96	<0.001	99	<0.001	0.068	39	0.840	80	0.130	0.089

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.08: Bermudagrass control as influenced by herbicide treatment and tillage system: Dawson, GA

Treatment[ab]		2005					2006				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]	Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%			%		%		
		47		66		0.435	88		48		0.080
Pend	None	85	0.270	60	0.999	0.214	82	0.996	73	0.780	0.648
Pend + *S*-met	None	74	0.674	52	0.965	0.348	95	0.963	74	0.740	0.186
Pend	Pqt + Bzn + DB	59	0.981	32	0.546	0.302	81	0.992	79	0.585	0.910
Pend + *S*-met	Pqt + Bzn + DB	57	0.992	74	0.996	0.463	61	0.550	68	0.902	0.771
None	Pqt + Bzn + DB	38	0.997	57	0.993	0.461	72	0.856	51	1.000	0.421

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.09: Smallflower Morningglory control as influenced by herbicide treatment and tillage system: Dawson, GA

Treatment [ab]		2006				
		Conventional Tillage		Strip Tillage		Tillage Contrast[‡]
Pre Emergence	Post Emergence	Mean	Dunnett's P[†]	Mean	Dunnett's P[†]	P Value
		%		%		
		79		70		0.657
Pend	None	98	0.366	89	0.701	0.347
Pend + *S*-met	None	94	0.647	92	0.523	0.790
Pend	Pqt + Bzn + DB	80	1.000	74	1.000	0.721
Pend + *S*-met	Pqt + Bzn + DB	82	1.000	86	0.827	0.799
None	Pqt + Bzn + DB	81	1.000	95	0.325	0.278

[a] For herbicide rate and application timing information refer to Table 2.01

[†] P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

[‡] P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.10: Large crabgrass and Crowfoot grass control as influenced by herbicide treatment and tillage system: Dawson, GA

Treatment [ab]		Large crabgrass, 2006					Crowfoot grass, 2006				
		Conventional Tillage		Strip Tillage		Tillage Contrast‡	Conventional Tillage		Strip Tillage		Tillage Contrast‡
Pre Emergence	Post Emergence	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value	Mean	Dunnett's P†	Mean	Dunnett's P†	P Value
		%		%			%		%		
		99		94		0.408	96		91		0.347
Pend	None	96	0.976	92	0.999	0.586	99	0.918	97	0.659	0.610
Pend + *S*-met	None	93	0.796	95	1.000	0.846	99	0.918	98	0.481	0.799
Pend	Pqt + Bzn + DB	99	1.000	71	0.237	0.010	93	0.965	99	0.328	0.196
Pend + *S*-met	Pqt + Bzn + DB	89	0.502	99	0.870	0.172	96	1.000	99	0.328	0.469
None	Pqt + Bzn + DB	94	0.855	96	0.998	0.743	89	0.644	96	0.804	0.242

[a] For herbicide rate and application timing information refer to Table 2.01

† P - values from Dunnett test conducted to compare means of herbicide treatments with the non treated control

‡ P-values form contrast performed to compare efficacy of herbicide regimens across tillage systems

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.11: Effect of herbicide treatments and tillage system on peanut yield

Treatment[ab]		Dawson GA		Headland AL	
Preemergence	Postemergence	2005	2006	2005	2007
		------------------ kg/ha ------------------			
None	None	5346	2925	3239	2539
Pend	None	4891	3161	2555	2596
Pend + *S*-met	None	4968	3849	3312	3495
Pend	Pqt + Bzn + DB	4878	3236	3336	2791
Pend + *S*-met	Pqt + Bzn + DB	5171	3560	2816	2510
None	Pqt + Bzn + DB	4712	3149	3898	2388
P Values from Dunnett's test vs. untreated control					
Pend	None	0.577	0.980	0.529	1.000
Pend + *S*-met	None	0.729	0.217	1.000	0.015
Pend	Pqt + Bzn + DB	0.553	0.949	1.000	0.873
Pend + *S*-met	Pqt + Bzn + DB	0.983	0.512	0.868	1.000
None	Pqt + Bzn + DB	0.275	0.984	0.562	0.983
Conventional Tillage(CT)		5179	3193	2699	2433
Strip Tillage(ST)		4809	3435	3686	3007
Contrast P-values					
CT *vs* ST		0.079	0.381	0.002	0.002

[a] For herbicide rate and application timing information refer to Table 2.01

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB

Table 2.12: Effect of herbicide treatments and tillage system on peanut market grade

Treatment[ab]		Grade[b]		
Preemergence	Postemergence	SMK	SS	TSMK
		----------------%--------------		
		61	10	71
None	None	59	12	71
Pend	None	59	12	72
Pend + *S*-met	None	58	13	71
Pend	Pqt + Bzn + DB	59	12	71
Pend + *S*-met	Pqt + Bzn + DB	60	12	72
None	Pqt + Bzn + DB			
P Values from Dunnett's test vs. untreated control				
Pend	None	0.862	0.421	1.000
Pend + *S*-met	None	0.936	0.416	0.997
Pend	Pqt + Bzn + DB	0.770	0.230	1.000
Pend + *S*-met	Pqt + Bzn + DB	0.862	0.453	1.000
None	Pqt + Bzn + DB	0.999	0.645	0.949
Conventional Tillage(CT)		59	12	71
Strip Tillage(ST)		60	12	71
Contrast P-values				
CT *vs* ST		0.693	0.594	0.942

[a] For herbicide rate and application timing information refer to Table 2.01

[b] Abbreviations: Pend, Pendimethalin; *S*-met, *S*-metolachlor; Pqt, paraquat; Bzn, Bentazon; DB, 2, 4-DB
SMK, Sound mature kernels; SS, Sound split; TSMK, Total sound mature kernels

III. HERBICIDE AND COVER CROP RESIDUE INTEGRATION AFFECTS ON WEED CONTROL, QUALITY AND YIELD IN CONSERVATION TILLAGE TOMATOES

ABSTRACT

The increased adoption of conservation tillage in vegetable production requires more information on the role of cover crops in weed control, tomato quality and yield. Three conservation-tillage systems utilizing crimson clover, turnip or cereal rye as winter cover crops were compared to a conventional black polythene mulch system, with or without herbicide, for weed control and tomato yield. Herbicide treatments included a preemergence (PRE) application of *S*-metolachlor (1.87 kg a.i. /ha) either alone or followed by an early postemergence (POST) metribuzin (0.56 kg a.i. /ha), application followed by a late POST application of clethodim (0.28 kg a.i. /ha). All cover crops were flattened with a mechanical roller/crimper prior to chemical desiccation. Rye produced 9363 kg/ha of dry matter at Cullman and 6404 kg/ha at Tuskegee. Pooled over ground cover treatments weed control ranged from 6 to 30%, 4 WAT at Cullman 2005 without herbicides. Yellow nutsedge was controlled 84% at Tuskegee and 80% at Cullman 2006 without herbicides. Turnip and crimson clover residue failed to control most of the weeds at Cullman 2005 and Tuskegee. For a majority of weed species evaluated, no significant differences in weed control were observed under rye residue and plastic mulch treatments. Plastic mulch failed to control smallflower morningglory and Virginia buttonweed and large crabgrass was controlled only 33% under rye residue at Tuskegee. Tomato yield was least in no herbicide treatments and was maximized with inclusion of the POST application. Pooled over herbicide treatments yield was less following either crimson clover or turnip cover crops compared to rye or the polythene mulch system. Averaged across cover crops, both herbicide programs resulted in better yields compared to the no-herbicide treatments. Economic analysis indicated that there was no significant difference between using a rye cover crop or plastic under any of the alternative herbicide treatment regimes in year 2005.

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) is the most popular fruit in the world. Nearly 1.7 million tons of fresh market field grown tomatoes were produced in USA in 2005 (U.S. Department of Agriculture [USDA] 2008). The USA produces more than 11% of the world’s tomato crop. USA tomato production systems typically utilize conventional tillage, a bedded plastic mulch culture, and multiple herbicide applications to control weeds. These conventional tillage systems enhance soil erosion and nutrient loss by reducing rainfall infiltration (Blough et al. 1990). Additionally, tillage increases aeration which increases the rate of organic matter mineralization in the surface soil, thus reducing soil organic matter content and soil cation exchange capacity (Franzluebbers et al. 1999; Mahboubi et al. 1993).

Plastic mulch can increase soil temperature which can expedite earliness (Teasdale and Abdul-Baki 1995). However, tomato growth was better only early in the season under plastic mulch compared to tomatoes grown under hairy vetch mulch systems (Abdul-Baki et al.1996; Teasdale and Abdul-Baki 1997). The use of plastic mulches in sustainable or organic production systems is also questionable since the mulch itself is non-biodegradable. Another issue with using plastic mulch vs. organic mulches is increased chemical runoff from the plastic mulch and offsite chemical loading. The intensive use of pesticides in vegetable production has also resulted in ecological concerns. Therefore, alternative production practices that reduce tomato production inputs while maintaining yields and quality are desired.

One possible alternative for alleviating aforementioned concerns is the use of high residue cover crops combined with reduced tillage. Cover crops in conservation-tillage system are terminated during early reproductive growth by treating them with burn down herbicides and can be mechanically rolled to leave a dense mat of residue (> 4,480 kg/ha) on the soil surface into which cash crops are planted (Derpsch et al. 1991; Reeves 2003). High residue cover crops are increasingly adopted in southeastern US corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.) production systems (Price et al. 2006; Reeves et al. 2005; Sainju and Singh 2001). Because the southeastern USA receives adequate rainfall in the winter months, timely planted winter cover crops can attain relatively high biomass before termination. Cover crops can enhance the overall productivity and soil quality by increasing organic matter and nitrogen content (Sainju et al. 2002), as well as aid in water conservation by increasing soil water infiltration rates (Arriaga and Balkcom 2006). Additionally, previous research has also focused on weed control provided by high residue cover crops in both field and vegetable crops (Teasdale and Abdul-Baki 1998; Creamer et al. 1997; Price et al. 2006).

Winter cover crop biomass can affect subsequent early season weed suppression (Saini et al. 2006; Teasdale and Mohler 2000). Weed suppression by cover crop residue is attributed to unfavorable environment for weed germination and establishment under the residue (Teasdale 1996) and also to chemical inhibitory effects. Teasdale and Daughtry (1993) reported a 52–70% reduction in weed biomass with live hairy vetch cover crop compared to a fallow treatment owing to changes in light and soil temperature regimen under the vetch canopy. Teasdale and Mohler (2000) concluded that legume mulches such as crimson clover and hairy vetch (*Vicia villosa* Roth) suppressed redroot pigweed (*Amaranthus retrofloxus* L.) at an exponential rate as a function of residue biomass.

In spite of these benefits adoption of cover crops in tomato production has been limited because (1) currently available transplanters have problems penetrating heavy residue and (2) concerns for cover crop residue intercepting delivery of soil-active herbicides. Research in the last two decades has extensively debated the advantages and disadvantages of cover crops vs. conventional plastic mulch systems for tomato production. Better or comparable tomato yields with hairy vetch cover crop system have been reported compared to the conventional polyethylene mulch system (Abdul-Baki and Teasdale, 1993; Abdul-Baki et al. 2002). Akemo et al. (2000) also reported higher tomato yield with spring sown cover crops than the conventionally cultivated check. Weed suppression with cover crops however varies with cover crop species, amount of residue produced, and environmental conditions. Teasdale (1996) reported that biomass levels achieved by cover crops before termination was sufficient only for early season weed suppression. Supplemental weed control measures are usually required to achieve season long weed control and to avoid yield losses (Masiunas et al. 1995; Teasdale and Abdul-Baki 1998).

Cereal rye and crimson clover are two common winter cover crops widely used in the southeastern USA. Both cover crops contain allelopathic compounds and produce residues that inhibit weed growth (Price et al. 2008; Barnes and Putnam 1983). Brassica cover crops are relatively new in the southeastern USA but are becoming increasingly popular due to their potential allelopathic effects. Therefore, the objectives of this research were to evaluate: 1) weed control and tomato performance in three different high residue conservation tillage systems utilizing the Brazilian cover crop management system and 2) tomato yield, quality, and net returns of conservation-transplanted tomatoes compared to the polythene mulch system following three different herbicide management systems.

Materials and Methods

Field Experiment. The experiment was established in the autumn of 2004 and 2005 at the North Alabama Horticulture Experiment Station, Cullman, AL and in autumn of 2005 at Tuskegee University's George Washington Carver Agriculture Experiment Station, Tuskegee, AL. The soils were a Hartsells fine sandy loam (Fine-loamy, siliceous, sub-active, thermic Typic Hapludults) at Cullman and a Marvyn fine sandy loam (Fine-loamy, kaolinitic, thermic Typic Kanhapludults) at Tuskegee. The experimental design was a randomized complete block with four replicates. Plot size at both locations was 2.5 by 6 m containing a single row of tomatoes with a 0.46 m spacing between plants.

The three winter cover crops [cereal rye cv Elbon, crimson clover cv AU Robin and turnip (*Brassica rapa* L subsp. *rapa* cv Civastro)] were compared to black polythene mulch for their weed suppressive potential and effect on yield and grade of fresh market tomatoes. Winter cover crops were planted with a no till drill each fall. Rye was seeded at a rate of 100 kg/ha, whereas clover and turnip were seeded at 28 kg/ha. Nitrogen was applied at a rate of 67 kg/ha on rye and turnip plots in early spring of each year. To determine winter cover crop biomass production, plants were clipped at ground level from one randomly selected 0.25 m^2 area per replicate immediately before termination. Plant samples were dried at 65 C for 72 hours and weighed. The winter cover crops were terminated each spring with a mechanical roller crimper prior to an application of glyphosate at 1.12 kg a.e. /ha. The rolling process produced a uniform residue cover over the plots.

All four cover systems (three winter cover crops plus plastic mulch) were evaluated with and without herbicides for weed control. Herbicide treatments included a preemergence (PRE) application of *S*-metolachlor (1.87 kg a.i./ha) either alone or followed by an early postemergence (EPOST) metribuzin (0.56 kg a.i./ha) application, followed by a late POST (LPOST) application of clethodim (0.28 kg a.i./ha). These three herbicide treatments were applied in a factorial combination with the four mulch treatments. The PRE application occurred one day before transplanting, the EPOST application was applied 14 days after transplanting, and the LPOST application was delayed until tomatoes were near mid-bloom. PRE herbicide application to plastic mulch plots was done before preparing the beds and POST applications were done over the total surface of the beds including the plant holes and any other open spaces. Tomato cv. 'Florida 47' seedlings were transplanted on 4th April 2005 and on April 9th 2006 at Cullman and April 19 th 2006 at Tuskegee.

Tomato seedlings were planted with a modified RJ No-till transplanter (RJ Equipment, Blenhiem, Ontario, Canada) (Figures 3.01 and 3.02), which had a subsoiler shank installed to penetrate the heavy residue and disrupt a naturally occurring compacted soil layer found at both experimental sites at a depth of 30-40 cm. Additionally, two driving wheels were utilized (one wheel on each side of the tomato row) instead of the original single wheel at the center of the row, to improve stability.

This modification also eliminated the driving wheel re-compaction of the soil opening created by the shank. The plastic-mulch plots were conventionally tilled utilizing a tractor mounted rototiller prior to bedding and plastic installation; tomatoes were hand transplanted in the plastic mulch each year. Water was applied to all the plots immediately after transplanting. Thereafter, plots were irrigated every other day using a surface drip tape. General production practices included staking and fertilization. Fertilizer 13-13-13 was applied prior to planting achieving 58 kg of N ha^{-1} and then 7.8 kg of calcium nitrate ha^{-1} was applied once every week with the irrigation system.

Weed control was evaluated by visual ratings (0% = no control, 100% = complete control) 28 days after treatment (DAT) of the EPOST herbicide application. All weed species present were evaluated for control (as a reduction in total above ground biomass resulting from both reduced emergence and growth). Ripe tomatoes were hand harvested from the entire plot area in weekly intervals and sorted according to size (small, medium, large, and extra large categories).

Statistical Analysis. Non-normality and heterogeneous variances are usually encountered with percent control data that span a large range. Various approaches were tried to alleviate these statistical problems and the arcsine transformation was deemed the best compromise between achieving normality of residuals and among treatment homogeneity of variances. The data were subjected to analysis of variance as implemented in SAS PROC GLIMMIX. Based on the arguments presented by Piepho et al. (1998), replicate within environment was considered a fixed effect since this was not based on a randomization event. Herbicide treatments and ground cover treatments were considered fixed effects while their interaction with reps was considered random effects. If a given weed species occurred at more than a single environment, we conducted a multi-environment analysis. Because environments themselves were not replicated, tests of environment effects are questionable and thus were not conducted. Interaction effects with environments, however, can be done with confidence. Differences between treatments means were determined by single degree of freedom contrasts using the pdiff option in the LSmeans statement of PROC GLIMMIX.

Economic Analysis. Enterprise budgets were generated using Mississippi State (2005) vegetable planning budgets. These budgets, assuming a standard yield of 39,230 kg ha^{-1} (35,000 lbs ac^{-1}), are presented in Table 14. Seed and plant costs include the cost of cover crop seed (Turnip - \$146 ha^{-1}; Crimson Clover - \$58 ha^{-1}; Rye - \$49 ha^{-1}) and the cost of tomato transplants (\$838 ha^{-1}). Fertilizer costs included the cost of N application and calcium nitrate for the cash crop (\$228 ha^{-1}), as well as, the additional N applied for the rye and turnip cover crops (\$68 ha^{-1}). Herbicide costs were based on treatment applications as described above and varies with cover crop x herbicide treatment combinations. Insecticide and fungicide costs followed extension recommendations and varied by year due to different climatic conditions (i.e. insecticide and fungicide costs were \$122 ha^{-1} and \$189 ha^{-1} in 2006, respectively). Harvesting costs are based on custom rates for harvesting, packing and grading of tomatoes based on hand harvesting. Supplies costs represent purchase of stakes, string, buckets, as well as other harvesting and planting supplies. Irrigation costs are broken into the variable cost of water application (\$26 ha^{-1}) and the fixed costs of the machinery (\$1890 ha^{-1}). Irrigation costs were calculated based on the cost of surface drip tape and pumping 152 mm of water every week from surface water reservoirs located on both experiment stations.

Machinery costs are broken into variable and fixed costs. Variable machinery costs represent the cost fuel, as well as repair and maintenance costs. Fixed machinery costs represent cost of machinery purchase based on an annual payment of loan, interest, taxes and depreciation. Labor costs represent operator labor for machinery, as well as hand labor in the field. Equipment used during production included a no-till drill for sowing cover crops, a tractor mounted cover crop roller (Bingham Brothers Inc., Lubbock TX, USA), a tractor mounted rototiller, and a RJ tomato transplanter. For all the fungicide and insecticide applications a JACTO vegetable air blast sprayer (Jacto Inc., Tualatin, OR, USA) mounted on a John Deere 4030 tractor (Moline, IL, USA) was used.

The interest on operating capital represents the opportunity costs of investing monies spent on variable costs in its next best alternative. This is calculated based using an interest rate of 7 % over an investment period of six months (length of the tomato growing season). Overhead and management costs represent those costs that pertain to operation of the whole farm that are partially attributed to the vegetable production enterprise, such as the costs for property taxes and insurance. As seen in Table 14, overall costs fluctuated between \$22,131 ha^{-1} to \$22,822 ha^{-1} due to changes in herbicide treatments and cover crop regimes.

Net revenue data, representing the return over total costs, was estimated by calculating total revenues for each plot on a per hectare basis and subtracting total costs. Only data from the Cullman, AL location was utilized for this analysis. Total crop revenue ($ ha^{-1}) was calculated by multiplying the price of tomatoes ($0.63 kg^{-1}) times the plot yield (kg ha^{-1}) (USDA, 2007). Total costs were calculated using the cost budgets in Table 3.14, adjusted for year (i.e. insecticide and fungicide costs). All estimates were calculated using 2005 dollars to minimize variability due to price fluctuations, allowing comparisons over time. Net revenue data was analyzed using analysis of variance as implemented in SAS® using PROC Mixed. Difference between treatments means were determined by single degree of freedom contrasts.

RESULTS AND DISCUSSION

Cover Crop Biomass. Winter cover crop biomass estimation was done only in 2006. The quantity of cover crop biomass produced at both locations differed among cover crops, with rye producing 9363 kg/ha, and crimson clover producing 5481 kg/ha of dry matter. Turnip produced the least amount of biomass at 3860 kg/ha at Cullman. In Tuskegee dry matter production by all cover crops was less compared to Cullman. Turnip produced only 224 kg/ha of dry matter and crimson clover produced 1624 kg/ha biomass at Tuskegee. Biomass production was maximum in rye plots averaging 6404 kg/ha.

Weed Control. Twelve weed species were evaluated in this experiment. Only three weeds were present in more than one field location (Table 3.02). The major weeds in the cover crop and plastic mulch plots included yellow nutsedge (*Cyperus esculentus* L.), large crabgrass (*Digitaria sanguinalis* L.), smooth pigweed (*Amaranthus hybridus* L.), pokeweed (*Phytolaca americana* L.), ivyleaf morningglory (*Ipomoea hederacea* Jacq.), tall morningglory [*Ipomoea purpurea* (L.) Roth] and wild radish (*Raphanus raphanistrum* L.). Other weeds present included goosegrass [*Eleusine indica* (L.) Gaertn.], leafy spurge (*Euphorbia esula* L.), broadleaf signalgrass [*Urochloa platyphylla* (Munro ex C. Wright) R.D. Webster], and Virginia buttonweed (*Diodia virginiana* L.). However, they were not uniformly distributed across the test site. Since only the plastic mulch plots had raised beds weeds present in the whole plot were evaluated for control by the ground cover and herbicide treatments

Analysis of variance showed that the three way interaction (cover*herbicide treatment*environment) was not significant for any of the weed species present in multiple locations. Significant environment*herbicide treatment or environment*ground cover treatment interaction was observed for yellow nutsedge and large crabgrass. Herbicide treatment effects were significant for most weeds except ivyleaf morningglory and Virginia buttonweed. The cover* treatment interaction was significant only for tall morningglory and leafy spurge. Lack of cover by herbicide treatment interaction for most weeds indicates the absence of weed control synergism. Means for individual year, cover crop, and herbicide combinations were estimated separately if significant interactions were found. If no significant interactions were found only main effect means were estimated.

Broadleaf signalgrass was present only at Cullman in 2005. Averaged over ground cover treatments (Table 3.03), broadleaf signalgrass was controlled only 11% without herbicides. Control improved significantly with herbicide application. *S*-metolachlor applied PRE controlled broadleaf signalgrass 79% control improved to 97% when *S*-metolachlor PRE was followed by EPOST application of metribuzin fb LPOST clethodim application. Averaged over herbicide treatments (Table 3.06), turnip and crimson clover residue controlled broadleaf signalgrass only 57% and 55% respectively. Control was significantly higher in rye and plastic mulch plots at 81% and 84% respectively compared to turnip and crimson clover plots.

Goosegrass was present only at Cullman 2005. Averaged over all ground cover treatments (Table 3.03), goosegrass could not be controlled (6%) without herbicides. *S*-metolachlor PRE controlled goosegrass 76%. *S*-metolachlor PRE fb metribuzin EPOST fb clethodim LPOST controlled gossegrass 96%. Averaged over herbicide treatments (Table 3.06), turnip and crimson clover residue controlled goosegrass less than 60%. Rye residue and plastic mulch provided similar (80% and 79%) and significantly higher control than turnip and crimson clover.

Pokeweed was present at Cullman 2005. Averaged over ground cover treatments (Table 3.03) pokeweed was controlled only 16% without herbicides. Control improved significantly with *S*-metolachlor PRE at 60% and *S*-metolachlor PRE fb metribuzin EPOST fb clethodim LPOST at 83%. Averaged over herbicide treatments (Table 3.06), turnip and crimson clover residue controlled pokeweed less than 40%. Rye residue controlled pokeweed only 68% whereas pokeweed control was recorded at 86% in plastic mulch plots. However, the differences were not significant (*P* = 0.324) for rye and plastic mulch plots.

Smooth pigweed was present at Cullman site during both the years. Averaged over ground cover treatments (3.03 & 3.04), similar to other aforementioned weeds smooth pigweed was controlled only 9% in 2005, and 50% in 2006 without herbicides. None of the herbicide treatments provided acceptable control of smooth pigweed (less than 70%). Averaged over herbicide treatments (Tables 3.07 & 3.08) control was in general less in 2005 compared to 2006. Turnip residue suppressed smooth pigweed 30% in 2005 and 67% in 2006. Smooth pigweed was controlled only 12% in 2005 and 52% in 2006 in crimson clover plots. Control was better in plastic mulch plots in 2005 (73%) but trend reversed in 2006, where rye plots recorded 71% and plastic mulch plots had only 57% suppression of smooth pigweed. However, differences in smooth pigweed control in rye and plastic mulch plots were not significant in either year.

Yellow nutsedge was present at all the site years in this experiment. Averaged over ground cover treatments (Tables 3.03, 3.04 & 3.05), *S*-metolachlor application was required for acceptable yellow nutsedge control (84%) at Cullman 2005. Yellow nutsedge control increased to 95% when *S*-metolachlor was fb metribuzin EPOST fb clethodim LPOST. No significant differences in yellow nutsedge control among herbicide treatments were observed at Cullman and Tuskegee 2006. Averaged over herbicide treatments (Tables 3.06, 3.07 &3.08), rye residue provided ≤ 94% control of yellow nutsedge at all site years. However no significant differences in yellow nutsedge control among rye and plastic mulch plots was observed at any site years.

Ivyleaf morningglory was present only at Cullman during 2006. Averaged over ground cover treatments (Table 3.05) ivyleaf morningglory control did not differ among herbicide treatments. Averaged over herbicide treatments (Table 3.07), turnip and rye residue provided 94% and 90% control of ivyleaf morningglory. Control was only 66% in crimson clover plots and 70% in plastic mulch plots.

Large crabgrass was present both at Cullman and Tuskegee during 2006. Averaged over ground cover treatments (Tables 3.04 & 3.05) no significant differences in large crabgrass control were observed among herbicide treatments at Cullman. However, *S*-metolachlor PRE fb metribuzin EPOST fb clethodim LPOST was required for 90% control of large crabgrass in Tuskegee. Averaged over herbicide treatments (Tables 3.07 & 3.08) large crabgrass control was 88% in both turnip and rye plots. Control was 75% in crimson clover and plastic mulch plots at Cullman. Plastic mulch was the only treatment at Tuskegee that provided 70% control of large crabgrass for all the organic mulch plots control ranged from 30-40%.

Virginia buttonweed was present only at Tuskegee test site in 2006. Averaged over ground cover treatments (Table 3.05), no significant differences in Virginia buttonweed control were observed among herbicide treatments. Unlike other weed species evaluated at this site year control of Virginia buttonweed declined with herbicide application. Averaged over herbicide treatments (Table 3.08), plastic mulch failed to suppress Virginia buttonweed growth. Rye controlled Virginia buttonweed 90%. Turnip and crimson clover provided 39% and 54% control respectively.

Smallflower morningglory [*Jacquemontia tamnifolia* (L.) Griseb.] was present at Tuskegee in 2006. Averaged over ground cover treatments (Table 3.05) smallflower morningglory was controlled 82% in no-herbicide plots and control of smallflower morningglory also decreased with herbicide treatments. Averaged over herbicide treatments (Table 3.08) plastic mulch (12%) failed to control smallflower morningglory. Maximum small flower morningglory control (96%) was observed in plots containing rye residue.

Wild radish was present only at Tuskegee in 2006. Averaged over mulch treatments (Table 3.05), wild radish could not be controlled (9%) without herbicides or with *S*-metolachlor PRE. 59% control of wild radish was recorded with treatment consisting *S*-metolachlor PRE fb metribuzin EPOST fb clethodim LPOST. Averaged over herbicide treatments (Table 3.08), none of the mulch treatments provided acceptable control of wild radish. Maximum wild radish control was 56% observed under rye residue.

Tall morningglory was present only at Cullman in 2005. Ground cover by herbicide treatment interaction was significant for tall morningglory control (Table 3.09). Ground cover treatments failed to control tall morningglory without herbicides (0-23%). Pre emergence application of *S*-metolachlor controlled tall morningglory 41% in turnip plots but did not control it in crimson clover plots. However the same treatment provided good control of tall morningglory in plastic mulch (94%) and rye residue (98%) plots. *S*-metolachlor PRE fb metribuzin EPOST fb clethodim LPOST controlled tall morningglory less than 50% in turnip and crimson clover plots but controlled tall morningglory 98% in plastic mulch plots. Tall morningglory control declined to 71% in rye residue plots when *S*-metolachlor PRE was fb metribuzin EPOST fb clethodim LPOST.

Ground cover by herbicide treatment interaction was significant for leafy spurge also. Turnip and crimson clover residue failed to control leafy spurge with or without herbicides (Table 3.09). Preemergence application of *S*-metolachlor alone controlled leafy spurge 86% in plastic mulch plots and 97% in rye residue plots. Control of leafy spurge increased in plastic mulch plots, when *S*-metolachlor PRE was fb metribuzin EPOST fb clethodim LPOST but decreased under rye residue.

This research demonstrates that high residue cover crops such as rye can provide improved weed suppression compared to black polyethylene mulch. Crimson clover and turnip residue in general were less effective in controlling summer weeds. This could partially be due to less biomass production by these cover crops and also rapid decomposition of the legume residue due to lower C: N ratio. Decomposition rate of brassicas is between grasses and legumes. Previous research has also reported improved weed control with increased mulch biomass present on the soil surface (Teasdale and Mohler 2000). Increased weed suppression has also been observed by Nagabhushna et al. (1995) with an increase in the seeding rate of rye. Another important factor which could have aided in better weed suppression by rye residue is suppression of rye with mechanical roller crimper prior to its termination with glyphosate. The rolling process leaves a uniform mat of residue on the soil surface that acts as a physical barrier for weed seedlings to emerge through, compared to only chemical termination where residue is lodged irregularly even leaving some bare soil. Despite improved weed suppression herbicides were always required to provide acceptable weed control by ground cover treatments, which is in agreement with the previous research (Teasdale and Abdul-Baki 1998). Pre emergence application alone was also not sufficient in controlling majority of weeds. Yenish et al. (1996) also reported inconsistent control with cover crop residue and concluded herbicides were always required to achieve optimum weed control in corn. They however cautioned weed control should not be the only criterion in selection of cover crops. Factors like cost and ease of establishment, impact on yield should be taken into consideration before selecting a cover crop.

Tomato Stand Establishment. Fewer tomato transplants survived at Tuskegee compared to Cullman. No significant difference in stand establishment among the plastic mulch and rye residue plots was observed when data were pooled over herbicide treatments at Cullman during both the years (Table 3.10). At Tuskegee, stand establishment was significantly higher in the rye plots compared to plastic mulch plots. Though not statistically significant, crimson clover plots had maximum stand reduction at Cullman 2005. Non-significant differences in tomato stand establishment were observed among ground cover treatments at Cullman 2006 (Table 3.11). Herbicide treatments had no significant effect on tomato stand establishment at Cullman 2005 and Tuskegee 2006

(Data pooled over ground cover treatments). Stand establishment was however reduced at Cullman in 2006 with herbicide application.

Tomato Yield. Tomatoes were harvested only at the Cullman location in 2004 and 2005. Tomato plants were lost at Tuskegee due to an irrigation system failure immediately prior to fruit maturation. There was no cover crop by herbicide interaction. Thus, the model reduces to a main effects model for cover crop and herbicide treatment effects ($P \geq 0.166$). Yield was greater in 2005 compared to 2006. Pooled over herbicide treatments (Table 3.12), tomato yield was similar following rye cover and plastic mulch systems. Both these systems yielded 50 Mg/ha and 51 Mg/ha marketable tomato respectively in 2005 and 38 Mg/ha in 2006. However the number of rotten tomato was more in plastic mulch plots than in rye plots in 2005, whereas no differences in total and marketable tomato yield were observed in these systems in 2006. Crimson clover plots yielded least in 2005. The lower yields following clover were likely due to higher weed interference in these systems. Yield was similar in turnip and crimson clover plots in 2006. Non significant differences in tomato yield among ground cover treatments were observed in 2006. Averaged across ground cover treatments (Table 3.13), both herbicide regimen resulted in better yields compared to the no herbicide plots during both the years. Higher yields were obtained with the system containing both PRE and POST herbicides. Teasdale and Abdul-Baki (1998) also concluded that marketable tomato yields were lower in cover crop treatments without herbicides than the corresponding treatments with herbicides in two of three years. No significant cover or herbicide treatment differences ($P > 0.50$) were observed for marketable classes of fruit, although there was a difference in frequency of market classes between the two years (data not shown). The number of small and medium-sized fruits was greater in 2005 than in 2006.

Our study indicates that winter cover crop residue can provide early season weed control with supplemental use of EPOST herbicides. However, total reliance on a winter cover crop for weed control was not sufficient and in all cases herbicides were required to provide season-long weed control and to maintain tomato yield. As hypothesized, it was evident that the use of winter cover crop for weed control cannot completely replace herbicides. However, by reducing the use of PRE herbicides, growers can decrease the amount of pesticide introduced into the environment. Our results further indicate that performance of a rye winter cover crop was either equal or comparable to plastic mulch in controlling weeds and maintaining tomato yields, thus reducing the need for tillage and other seedbed preparation operations. Tomato establishment was also not affected by presence of high residue at the time of transplanting, which is a valid concern in high residue conservation tillage systems. These findings can further the development of sustainable farming systems.

Economic Analysis. Economic costs of tomato production varied by treatment combination, but differences in costs due to treatment differences were relatively small overall, never larger that 3 percent of total costs (Table 3.14). Yield differences between treatments resulted in significant changes in total costs. Given that tomatoes were hand harvested, the cost of custom harvesting was the most significant cost of production (roughly 35 % of total costs). Harvesting costs are a function of tomato yield. As yield increases, harvesting costs increase as more tomatoes need to be harvested from the field. Given that tomato yield varied significantly, this affected the total costs across treatments when calculating net returns. Furthermore, yield is a significant factor in calculating total crop revenue, resulting in significant variations in total crop revenue across treatments. Thus, primary differences in net revenue were primarily due to differences in tomato yields across treatments. However, given yield impacts both costs and revenues, net returns may not move in the same direction as yield.

In 2005, for all cover crop by herbicide system interactions, rye receiving only a PRE application provided the highest returns (\$13,924 ha^{-1}) followed by rye receiving both herbicide applications (\$12,211 ha^{-1}) (Table 3.15). The lowest returns in 2005 were from clover with only a PRE application (-\$1067 ha^{-1}) followed by clover with no herbicide application (-\$765 ha^{-1}). Both treatments with the highest return were significantly different from the two treatments with the lowest returns in 2005. For all the treatment combinations in between, excluding turnips with a PRE application, treatment differences were insignificant. In addition, results in 2005 indicate that there is no significant difference between using a rye cover crop or plastic under any of the alternative herbicide treatment regimes.

In 2006, the returns in general were significantly lower compared to 2005. In addition, differences in net returns between treatment combinations were not statistically significant (Table 3.15). The highest net returns were from using turnips with only a PRE application (\$4654 ha^{-1}), followed by plastic with only a PRE application (\$4563 ha^{-1}).

Clover and rye returns were maximized when both PRE and POST herbicide application were applied. For the herbicide treatments, the highest returns were achieved with only the PRE emergence application and lowest when herbicides were excluded.

Results in this paper are short term effects of converting from a conventional plastic mulch system to three high-residue conservation tillage systems. These results indicate the economic possibility of growing fresh market tomatoes utilizing a conservation tillage system while maintaining yields and economic returns. This research also shows the feasibility of growing tomatoes in cover crop based systems without severely impacting the economic returns. However, the long term impact of these systems on yield and profitability require further investigation.

LITERATURE CITED

Abdul-Baki A.A., and J.R. Teasdale. 1993. A no-tillage tomato Production system using hairy vetch and subterranean clover mulches. HortScience. 28:106-108.

Abdul-Baki. A.A., J.R. Teasdale, R. Korcak, D.J. Chitwood, and R.N. Huettel. 1996. Fresh-market tomato production in a low-input alternative system using cover crop mulch. HortScience. 31:65-69.

Abdul-Baki, A.A., J.R. Teasdale, R.W. Goth, and K.G. Haynes. 2002. Marketable yields of fresh-market tomatoes grown in plastic and hairy vetch mulches. HortScience. 37:878-881.

Akemo, M.C., M.A. Bennett, and E.E. Regnier. 2000. Tomato growth in spring-sown cover crops. HortScience. 35:843-848.

Arriaga, F.J. and K.S. Balkcom. 2006. Benefits of conservation tillage on rainfall and water management. *In*. Hatcher, K. J., editor. Proceedings of the 2005 Georgia Water Resources Conference, April 25-27, 2005.

Barnes, J.P., and A.R. Putnam. 1983. Rye residues contribute weed suppression in no-tillage cropping systems. J. of Chem. Ecol. 9:1045-1057.

Blough, R.F., A.R. Jarrett, J.M. Hamlett, and M.D. Shaw. 1990. Runoff and erosion rater from silt, conventional, and chisel tillage under simulated rainfall. Transactions of ASAE. 33:1557-1562.

Creamer, N.G., M.A. Bennett, and B.R. Stinner. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience. 32:866-870.

Derpsch, R., C.H. Roth, N. Sidiras, and U. Köpke. 1991. Controle da erosão no Paraná, Brazil: Sistemas de cobertura do solo, plantio directo e prepare conservacionista do solo. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, SP 245, Germany.

Franzluebbers, A.J., G.W. Langdale, and H.H.Schomberg. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. Soil Sci. Soc. Am. J. 63:349-355.

Mahboubi, A.A., R. Lal, and N.R. Faussey. 1993. Twenty-eight years of tillage effects on two soils in Ohio. Soil Sci. Soc. Am. J. 57:506-512.

Masiunas, J.B., L.A. Weston, and S.C. Weller. 1995. The impact of rye cover crops on weed populations in a tomato cropping system. Weed Sci. 43:318-323.

Mississippi State Extension Service, Mississippi State University. 2005. Vegetable Planning budgets. http://msucares.com/pubs/infosheets/is1514.pdf. Accessed: July 29, 2008.

Nagabhushana, G.G., A.D. Worsham, and J.P. Yenish. 2001. Allelopathic cover crops to reduce herbicide use in sustainable agricultural systems. Allelopathy J. 8:133-146.

Piepho, H.-P., J.B. Denis, F.A. van Eeuwijk. 1998. Predicting cultivar differences using covariates. J. Agric. Biol. Env. Stat. 3:151-162.

Price, A.J., D.W. Reeves, and M.G. Patterson. 2006. Evaluation of weed control provided by three winter cereals in conservation-tillage soybean. Renewable Agric. and Food Systems. 21:159-164.

Price A.J., M.E. Stoll, J.S. Bergtold, F.J. Arriaga, K.S. Balkcom, T.S. Kornecki, and R.L.

Raper. 2008. Effect of cover crop extracts on cotton and radish radicle elongation. Comm. Biometry Crop Sci. 3:60-66.

Reeves, D.W. 2003. A Brazilian model for no-tillage cotton production adapted to the southeastern USA. Proc. II World Congress on Conservation Agriculture-Producing in Harmony with Nature. Iguassu Falls, Paraná, Brazil. Aug 11-15, 2003:372-374.

Reeves, D.W., A.J. Price, and M.G. Patterson. 2005. Evaluation of three winter cereals for weed control in conservation-tillage nontransgenic cotton. Weed Technol. 19: 731-736.

Saini, M., A.J. Price, and E. van Santen. 2006. Cover crop residue effects on early-season weed establishment in a conservation-tillage corn-cotton rotation. 28th Southern Conservation Tillage Conference. 28:175-178.

Sainju, U.M., and B.P. Singh. 2001. Tillage, cover crop, and kill-planting date effects on corn yield and soil nitrogen. Agron. J. 93: 878–886

Sainju, U.M., B.P. Singh, and W.F. Whitehead. 2002. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil & Tillage Res. 63:167-179.

Teasdale, J. R. 1996. Contribution of cover crops to weed management in sustainable agriculture systems. J. Prod. Agric. 9:575-479.

Teasdale, J.R. and C.S.T. Daughtry. 1993. Weed suppression by live and desiccated hairy vetch (*Vicia villosa*). Weed Sci. 41:207-212

Teasdale, J.R., and A.A. Abdul-Baki. 1995. Soil temperature and tomato growth associated with black polythene and hairy vetch mulches. J. Amer. Soc. Hort. Sci. 120:848-853.

Teasdale, J.R., and A. A. Abdul-Baki. 1997. Growth analysis of tomatoes in black plastic and hairy vetch production systems. HortScience. 32:659-663.

Teasdale, J.R., and A.A. Abdul-Baki. 1998. Comparison of mixtures vs. monocultures of cover crops for fresh-market tomato production with and without herbicide. HortScience. 33:1163-1166.

Teasdale, J.R., and C.L. Mohler. 2000. The quantitative relationship between weed emergence and the physical properties of mulches. Weed Sci. 48:385-392.

[USDA] United States Department of Agriculture. 2008. Background Statistics: Fresh-market Tomatoes. http://www.ers.usda.gov/News/tomatocoverage.htm. Accessed: June 26, 2008.

Yenish, J.P., A.D. Worsham, and A.C. York. 1996. Cover crops for herbicide replacement in no-tillage corn (*Zea mays*). Weed Technol. 10:815-821.

Table 3.01: Details of herbicide treatment rates and application timings

Preemergence[†]		Postemergence[‡]	
Herbicides	Rate (kg/ha)	Herbicides	Rate (kg/ha)
None	-	None	-
S-metolachlor	1.87	None	-
S-metolachlor	1.87	Metribuzin fb Clethodim	0.56 + 0.28

[†] All preemergence herbicides were applied on the day of transplanting tomato.

[‡] Postemergence application of metribuzin was accomplished 4 weeks after transplanting tomato followed by clethodim application at bloom initiation.

Table 3.02: *P*-values from Analysis of variance for weed control[a]

Effect/Source	CYP ES	AMACH	DIGSA	BRAPP	ELEIN	PHTAM	PHBPU	EPHES	IPOHE	DIQVI	IAQTA	RAPRA
Environment (E)	0.401	0.044	<0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cover [C]	0.186	0.104	0.388	0.003	0.006	0.001	<0.001	<0.001	0.074	<0.001	<0.001	0.015
C x E	0.090	0.173	0.021	NA	NA	NA	NA	NA	NA	NA	NA	NA
Treatment (T)	0.021	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.496	0.157	0.058	<0.001
T x E	0.001	0.376	<0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA
C x T	0.268	0.981	0.143	0.307	0.254	0.762	0.009	0.004	0.968	0.788	0.891	0.763
C x T x E	0.762	0.447	0.41	NA	NA	NA	NA	NA	NA	NA	NA	NA
<u>Weeds were present in:</u>												
Year						Location						
2005	Cullman	Cullman		Cullman	Cullman	Cullman	Cullman	Cullman				
2006	Cullman	Cullman	Cullman						Cullman			
2006	Tuskegee	Tuskegee	Tuskegee							Tuskegee	Tuskegee	Tuskegee

[a] Abbreviations: CYPES, Yellow nutsedge, AMAPA, Palmer amaranth, DIGSA, Large crabgrass, BRAPP, Broadleaf signalgrass ELEIN, Goosegrass, PHTAM, Pokeweed, PHBPU, Tall morningglory, EPHES, Leafy spurge, IPOHE, Ivyleaf morningglory DIQVI, Virginia buttonweed, IAQTA, Smallflower morningglory, RAPRA Wild radish

Table 3.03: Effect of herbicide treatments on broadleaf signalgrass (BRAPP), goosegrass (EELEIN), pokeweed (PHTAM), smooth pigweed (AMACH) and yellow nutsedge control at Cullman, AL in 2005. Herbicide rate and application timing can be found in Table 3.01

Herbicide Treatments[†]		Weed Control				
Preemergence	Postemergence	BRAPP	ELEIN	PHTAM	AMACH	CYPES
		------------	------------	%	------------	------------
None	None	11	6	16	9	30
S-metolachlor	None	79	76	60	43	84
S-metolachlor	metribuzin fb clethodim	97	96	83	69	95
P-values from contrasts:						
PRE+POST *vs*.PRE alone		0.002	0.002	0.110	0.141	0.183
PRE+POST *vs*. Non Treated		<0.001	<0.001	<0.001	<0.001	<0.001
PRE alone *vs*. Non Treated		<0.001	<0.001	0.013	0.098	<0.001

Table 3.04: Effect of herbicide treatments on ivyleaf morningglory (IPOHE), large crabgrass (DIGSA), smooth pigweed (AMACH), and yellow nutsedge control at Cullman, AL in 2006. Herbicide rate and application timing can be found in Table 3.01

Herbicide Treatments		Weed Control			
Preemergence	Postemergence	IPOHE	DIGSA	AMACH	CYPES
		-------------------------%----------------------			
None	None	76	73	50	80
S-metolachlor	None	88	90	65	89
S-metolachlor	metribuzin fb clethodim	81	81	70	83
<u>P-values from contrasts:</u>					
PRE+POST *vs*.PRE alone		0.781	0.624	0.958	0.800
PRE+POST *vs*. Non Treated		0.907	0.793	0.546	0.973
PRE alone *vs*. Non Treated		0.539	0.284	0.717	0.682

Table 3.05: Effect of herbicide treatments on yellow nutsedge (CYPES), large crabgrass (DIGSA), Virginia buttonweed (DIQVI), smallflower morningglory (JAQTA), and wild radish control at Tuskegee, AL in 2006. Herbicide rate and application timing can be found in Table 3.01

Herbicide Treatments		Weed Control				
Preemergence	Postemergence	CYPES	DIGSA	DIQVI	JAQTA	RAPRA
		--------------------------------		%		-----------------------------
None	None	84	6	64	82	13
S-metolachlor	None	68	28	48	51	9
S-metolachlor	metribuzin fb clethodim	77	90	36	56	59
<u>P-values from contrasts:</u>						
PRE+POST *vs*.PRE alone		0.837	<0.001	0.761	0.949	0.003
PRE+POST *vs*. Non Treated		0.856	<0.001	0.214	0.184	0.006
PRE alone *vs*. Non Treated		0.510	0.133	0.587	0.103	0.965

Table 3.06: Effect of ground cover treatments on broadleaf signalgrass (BRAPP), goosegrass (EELEIN), pokeweed (PHTAM), smooth pigweed (AMACH) and yellow nutsedge control at Cullman, AL in 2005.

	Weed Control				
Cover	BRAPP	ELEIN	PHTAM	AMACH	CYPES
	--------------------------------------%----------------------------				
Brassica	57	58	25	30	53
Crimson clover	55	50	38	12	70
Plastic	84	80	86	73	85
Rye	81	79	65	46	87
P-values from contrasts:					
Brassica *vs*. Clover	0.998	0.886	0.904	0.770	0.591
Brassica *vs*. Plastic	0.023	0.107	0.002	0.050	0.043
Brassica *vs*. Rye	0.055	0.137	0.101	0.782	0.023
Clover *vs*. Plastic	0.016	0.017	0.009	0.005	0.446
Clover *vs*. Rye	0.036	0.023	0.348	0.243	0.302
Plastic vs. Rye	0.981	0.999	0.337	0.324	0.993

Table 3.07. Effect of ground cover treatments on ivyleaf morningglory (IPOHE), large crabgrass (DIGSA), smooth pigweed (AMACH), and yellow nutsedge control at Cullman, AL in 2006.

	Weed Control			
Cover	IPOHE	DIGSA	AMACH	CYPES
	----------------------------%----------------------------			
Brassica	94	88	67	95
Crimson clover	66	75	52	69
Plastic	70	75	57	71
Rye	90	88	71	94
P-values from contrasts:				
Brassica *vs*. Clover	0.139	0.726	0.916	0.219
Brassica *vs*. Plastic	0.190	0.719	0.970	0.234
Brassica *vs*. Rye	0.967	1.000	0.997	0.999
Clover *vs*. Plastic	0.995	1.000	0.997	1.000
Clover *vs*. Rye	0.277	0.735	0.817	0.263
Plastic vs. Rye	0.378	0.727	0.907	0.278

Table 3.08: Effect of ground cover treatments on yellow nutsedge (CYPES), largecrabgrass (DIGSA), Virginia buttonweed (DIQVI), smallflower morningglory (JAQTA), and wild radish control at Tuskegee, AL in 2006.

	Weed Control				
Cover	CYPES	DIGSA	DIQVI	JAQTA	RAPRA
	----------------------------%-----------------------------------				
Brassica	69	38	39	56	14
Crimson clover	80	39	54	71	9
Plastic	75	72	0	12	29
Rye	80	33	90	96	56
P-values from contrasts:					
Brassica *vs*. Clover	0.992	1.000	0.864	0.860	0.992
Brassica *vs*. Plastic	0.820	0.014	0.301	0.190	0.820
Brassica *vs*. Rye	0.069	0.970	0.014	0.035	0.069
Clover *vs*. Plastic	0.663	0.016	0.069	0.038	0.663
Clover *vs*. Rye	0.038	0.957	0.084	0.180	0.038
Plastic vs. Rye	0.366	0.005	<0.001	<0.001	0.366

Table 3.09: Effect of ground cover and herbicide treatments on tall morningglory (PHBPU) and leafy spurge (ESULA) control at Cullman, AL in 2005. Herbicide rate and application timing can be found in Table 3.01

		PHBPU				EPHES			
Herbicide Treatments		**Ground Cover Treatment**				**Ground Cover Treatment**			
Preemergence	Post emergence	Turnip	Crimson clover	Plastic	Rye	Turnip	Crimson clover	Plastic	Rye
		----------------------	----------------------	----------------------	----------------------%	----------------------	----------------------	----------------------	----------------------
None	None	0	0	23	21	0	0	35	21
S-metolachlor	None	41	0	94	99	4	0	86	97
S-metolachlor	metribuzin fb clethodim	47	21	98	71	0	43	98	71
P-values from contrasts:									
PRE+POST *vs*.PRE alone		1.000	0.999	1.000	0.470	1.000	0.793	0.939	0.592
PRE+POST *vs*. Non Treated		0.762	0.999	0.004	0.550	1.000	0.793	0.006	0.443
PRE alone *vs*. Non Treated		0.895	1.000	0.022	0.003	1.000	1.000	0.231	0.003

Table 3.10: Effect of ground cover treatments on tomato stand establishment at Cullman, AL and Tuskegee, AL.

	Cullman		Tuskegee
Cover	2005	2006	2006
	---------------No of Plants/ha------------		
Brassica	10903	10671	8274
Crimson clover	9743	10980	6495
Plastic	12140	11135	6263
Rye	11522	11599	8351
P-values from contrasts:			
Brassica *vs*. Clover	0.657	0.901	0.073
Brassica *vs*. Plastic	0.609	0.723	0.036
Brassica *vs*. Rye	0.926	0.180	1.000
Clover *vs*. Plastic	0.106	0.987	0.988
Clover *vs*. Rye	0.312	0.514	0.058
Plastic vs. Rye	0.926	0.723	0.027

Table 3.11: Effect of herbicide treatments on tomato stand establishment at Cullman, AL and Tuskegee, AL. Herbicide rate and application timing can be found in Table 3.01

		Cullamn		Tuskegee
Herbicide Treatments		2005	2006	2006
Preemergence	Postemergence	---------------No of Plants/ha-----------		
None	None	11193	10381	6901
S-metolachlor	None	11019	11599	7365
S-metolachlor	metribuzin fb clethodim	11019	11309	7771
P-values from contrasts:				
PRE+POST *vs*.PRE alone		1.000	0.730	0.789
PRE+POST *vs*. Non Treated		0.978	0.054	0.342
PRE alone *vs*. Non Treated		0.978	0.010	0.734

Table 3.12: Effect of ground cover treatments on total and marketable tomato yield at Cullman, AL.

	Tomato Yield			
	2005		2006	
Cover	Total	Marketable	Total	Marketable
	------------------------Mg/ha------------------------			
Brassica	49	42	36	29
Crimson clover	38	33	36	29
Plastic	59	50	38	31
Rye	58	51	38	31
P-values from contrasts:				
Brassica *vs*. Clover	0.323	0.375	1.000	1.000
Brassica *vs*. Plastic	0.331	0.400	0.972	0.996
Brassica *vs*. Rye	0.462	0.348	0.970	0.998
Clover *vs*. Plastic	0.007	0.013	0.975	0.995
Clover *vs*. Rye	0.014	0.010	0.973	0.997
Plastic vs. Rye	0.996	1.000	1.000	1.000

Table 3.13: Effect of herbicide treatments on total and marketable tomato yield at Cullman, AL. Herbicide rate and application timing can be found in Table 3.01

Herbicide Treatments		Tomato Yield			
		2005		2006	
Preemergence	Postemergence	Total	Marketable	Total	Marketable
		---------------------------Mg/ha----------------------------			
None	None	47	40	30	24
S-metolachlor	None	50	42	40	33
S-metolachlor	metribuzin fb clethodim	56	49	41	33
P-values from contrasts:					
PRE+POST *vs*.PRE alone		0.452	0.366	0.991	0.997
PRE+POST *vs*. Non Treated		0.227	0.145	0.107	0.161
PRE alone *vs*. Non Treated		0.890	0.856	0.135	0.139

Table 3.14: Cost Budgets (USD ha^{-1}) for Tomato Production by cover crop and herbicide treatment system at Cullman, AL, 2005[a]

Ground Cover	Turnip	Turnip	Turnip	Clover	Clover	Clover	Plastic	Plastic	Plastic	Rye	Rye	Rye
Herbicide Treatment†	None	Pre	Pre+Post	None	Pre	Pre+Post	None	Pre	Pre+Post	None	Pre	Pre+Post
Variable Costs												
Seeds/Plants	984	984	984	896	896	896	838	838	838	887	887	887
Fertilizer	295	295	295	228	228	228	228	228	228	295	295	295
Herbicides	16	68	109	16	68	109	0	68	109	16	68	109
Insecticides	182	182	182	182	182	182	182	182	182	182	182	182
Fungicides	232	232	232	232	232	232	232	232	232	232	232	232
Scouting/Soil Tests	19	19	19	19	19	19	19	19	19	19	19	19
Custom Harvest/Grade/Pack	7888	7888	7888	7888	7888	7888	7888	7888	7888	7888	7888	7888
Supplies (Stakes, Buckets etc)	6719	6719	6719	6719	6719	6719	6719	6719	6719	6719	6719	6719
Irrigation[b]	26	26	26	26	26	26	26	26	26	26	26	26
Machinery[c]	658	660	665	637	640	644	608	610	615	658	661	665
Labor[d]	559	565	575	550	555	565	1159	1164	1174	559	565	575
Interest on Operating Capital[e]	571	573	575	565	567	569	582	584	586	568	570	572
Total Variable Costs	18,150	18,211	18,268	17,958	18,019	18,076	18,480	18,558	18,615	18,050	18,111	18,168
Fixed Costs												
Machinery[c]	1085	1090	1101	1026	1032	1043	998	1003	1014	1084	1090	1101
Irrigation[b]	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890
Overhead/Management[f]	1271	1275	1279	1257	1261	1265	1294	1299	1303	1264	1268	1272
Total Fixed Costs	4245	4255	4270	4173	4183	4198	4181	4192	4207	4238	4248	4263
Total Costs	22,395	22,466	22,538	22,131	22,202	22,274	22,661	22,750	22,822	22,288	22,359	22,431

Source: Costs were based on cost estimates from Mississippi State (2005).

[a] The following assumptions were made in the estimation of the budgets: (i) plant 11960 plants ha^{-1}; (ii) fertigation was for 1 hr week^{-1}; (iii) 15.24 cm (6 in.) of water was applied during the growing season; and (iv) base yield was 39,230 kg ha^{-1} (35,000 lbs ac^{-1}). The yield assumption was needed for calculating harvesting/grading/packing costs.

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[b] Variable irrigation costs represents expenditures for application of water during the growing season. Fixed irrigation costs represent the costs of the machinery for performing irrigation.

[c] Variable machinery costs represent costs for fuel, maintenance and repair. Fixed machinery costs represent the costs of purchasing the machinery, interest and depreciation.

[d] Labor costs represent the costs of operating machinery and hand labor during the growing season.

[e] The interest on operating capital represents the opportunity cost of investing the monies spent on variable costs into vegetable production.

[f] Overhead and management fixed costs represent overall farm management costs and general expenses for the whole farm that are partially applicable to the vegetable enterprises undertaken.

† Herbicide rate and application timing can be found in Table 3.01

Table 3.15: Least square means of net returns over total costs for all the cover crop by herbicide systems at Cullman, AL. Herbicide rate and application timing can be found in Table 3.01

Treatment		Net Returns		
Grond Cover	Herbicide	2005		2006
		--------- USD ha^{-1} ---------		
Turnip	None	7838	abc	-4199
Turnip	Pre	3461	ab	4654
Turnip	Pre + Post	6176	abc[†]	390
Crimson clover	None	-765	ab	566
Crimson clover	Pre	-1067	ab	-1274
Crimson clover	Pre + Post	8288	abc	2101
Plastic	None	9487	bc	-4884
Plastic	Pre	8720	abc	4563
Plastic	Pre + Post	9918	bc	2280
Rye	None	4060	abc	-190
Rye	Pre	13,924	c	341
Rye	Pre + Post	12,311	bc	1295

[†] Single degree of freedom contrasts were conducted with SAS® PROC MIXED to examine differences between least square means at $P < 0.05$. Least square means followed by the same letter are not significantly different.

Figure 3.01: Picture of a modified RJ No-till transplanter with a subsoiler shank and two drive wheels

Figure 3.02: Picture of a modified RJ No-till transplanter operating in rolled cereal rye winter cover crop residue

IV. COVER CROP RESIDUE EFFECTS ON EARLY-SEASON WEED ESTABLISHMENT IN A CONSERVATION-TILLAGE CORN-COTTON ROTATION

ABSTRACT

Use of the winter cover crops is an integral component of the conservation systems in corn (*Zea mays* L.) and cotton (*Gossypium hirsutum* L.). Field experiments were conducted from autumn of 2003 at the Alabama Agricultural Experiment Station's E.V. Smith Research Center at Shorter, AL and Tennessee Valley Research and Extension Center at Belle Mina, AL through cash crop harvest in 2006. The experiment was also conducted at the University of Florida's West Florida Education and Research Center at Jay, FL from autumn of 2004 to cash crop harvest in 2006. The treatments were five cover crop seeding dates each autumn and four cover crop termination dates the following spring. The seeding dates were based on the 30 year average date of the first 0 C temperature at each location. The five seeding dates were: on the first average 0 C temperature date, two and four weeks prior and two and four weeks after the average 0 C date. Termination dates were four, three, two, and one week prior to the average date for the establishment of the cash crop, which is based the long-term average soil temperature.

Rotation for winter cover crops included clover (*Trifolium incarnatum* L.) preceding corn and cereal rye (*Secale cereale* L.) preceding cotton. Results showed biomass production by winter covers was impacted with even a week's delay in winter cover crop seeding and corresponding reduction in summer annual weed suppression. Different weather conditions encountered at the three locations resulted in large differences in cover crop biomass production. In general, winter cover crop biomass increased with the earlier planting and later termination and weed biomass decreased with increasing biomass. Observations indicate that high cover biomass should decrease early season weed interference and facilitate flexibility of POST application timing.

INTRODUCTION

Soils in the Southeastern USA coastal plain are mainly sandy with a low water holding capacity and moisture content. This region faces frequent but generally short drought periods. The soils are also low in organic matter content. Use of heavy machinery and natural reconsolidation in the fields has led to the development of a compact sub-surface layer in the soil, further impacting the water and nutrient uptake by the plants. These conditions impact crop growth and yield (Radford et al. 2001). However, yield increases can be obtained by reducing soil strength (Busscher et al. 2000; Raper et al. 2000).

Deep tillage is a typical practice to alleviate the problem of soil compaction but it has some negative effects as well. Tillage leads to soil erosion and increase in organic matter mineralization thus further adding to the problem of low soil organic matter

(Franzluebbers et al. 1999). Other problems with tillage include decreases in soil water infiltration leading to increased runoffs and loss of moisture. Finally, deep hard-pans may develop leading to the recommendation to confine deep tillage to a depth that just breaks the hard-pan but not deeper.

Use of inversion tillage thus does not suffice and a complete management system is required to maintain the overall health of the cropping system. Widespread adoption a management system in agriculture requires information about local conditions in order to optimize the benefits of that system for growers. Conservation crop management systems have been successfully adopted to address these concerns as they offer significant agronomic, environmental and economic benefits.

Initial adoption of conservation tillage practices in the 1970s was however limited due to environmental and economic concerns. Problems included yield loss, poor cash crop stand establishment and increases in soil strength (Brown et al. 1985; Sojka and Busscher 1989). The major limiting factor was increased weed infestation and the corresponding increase in herbicide use. Numerous studies have pointed to increased weed pressure. Newly shed weed seeds remain on the surface with reduced tillage, thus easily emerging and surviving (Barberi 2002; Cardina et al. 2002; Cardina et al. 1991). In addition, weed species composition might shift from easy to control weeds to problematic weeds such as grasses and vegetatively reproducing species (Young et al. 1996). The main problem in the 1970s was the absence of a suitable chemical weed management system.

Use of cover crop residue has been advocated to maximize productivity of conservation systems in the southeastern USA and to overcome the abovementioned concerns (Langdale et al. 1990). Benefits of cover crops include reduced soil erosion and compaction, better infiltration and moisture retention, and enhanced nutrient cycling (Blevins et al. 1971; Bradley 1995; Kaspar et al. 2001; Reeves 1997). Cover crops combined with reduced tillage results in rapid buildup of soil organic matter (Sainju et al. 2002). Cover crop research over the last two decades has also focused on weed control provided by high residue cover species (Teasdale and Abdul-Baki 1998; Creamer et al. 1997; Price et al. 2006) in agronomic and horticultural crops. One practical consequence of this research has been increased adoption of these practices in the southeastern USA, e.g., corn hectarage managed in accordance with conservation management principles increased from 50% in 1990 to more than 70% in 2004. The increase in cotton was even more dramatic, increasing from 10% in 1990 to 60% in 2004 (Fig 1).

It has been shown that cover crops in conservation tillage systems can help in achieving the dual benefits of reduced costs (Morton and Bergtold, 2006) and overall improved soil sustainability (Frye et al. 1988; Reeves 1997). Cover crops also suppress weeds either by inhibiting the growth of already established weeds through competition and smothering or by altering the soil environment conditions necessary for weed seed germination (Creamer 1996; Teasdale 1996). Cover crops influence factors such as soil moisture, light transmittance to the soil surface, soil temperature etc. These in turn affect weed seed germination and seedling growth. The surface residue also acts as a physical barrier that inhibits the growth of weeds.

Cover crop residue also releases phytotoxins that can inhibit germination and growth of weeds. Use of allelopathic cover crop mulches for weed control has been studied extensively (Barnes and Putnam 1983; Putnam and Defrank 1983, Price et al. 2006; Rice 1984). The degree of weed suppression provided by cover crops depends on the cover crop species and management system. However, the most important factor is the amount of residue produced. At equivalent amounts of residue weed suppression was similar with rye (*Secale cereale* L.) and hairy vetch cover (*Vicia villosa* Roth.) crop residue (Teasdale and Mohler 1992).

Cereal rye and soft red winter wheat (*Triticum aestivum* L.) are the two most common cereal winter cover crops in southeastern USA row crop production systems. Both have been shown to possess allelopathic activity against weeds (Akemo et al. 2000; Perez and Ormeno-Nunez 1991; Barnes and Putnam 1983). A 50% reduction in early season weed infestation has been reported compared to the fallow control by using rye along with hairy vetch (Burgos and Talbert 1996). Black oat (*Avena strigosa* Schreb.) has recently been introduced into the southeastern USA through a joint release between Auburn University and The Institute of Agronomy of Paraná, Brazil, and is currently marketed as “SoilSaver black oat” (Bauer and Reeves 1999). Crimson clover (*Trifolium incarnatum* L.), Austrian winter peas (*Pisum sativum* spp arvense (L.) Poir) and vetch (*Vicia villosa* Roth) are the main leguminous cover crops used in the southeastern USA. Allelopathic activity of these covers has been established in a greenhouse study (Price et al. 2008). Yenish et al. (1996) reported up to 95% reduction in weed biomass with rye, crimson clover and subterranean clover compared to conventionally-tilled fallow plots.

Corn (*Zea mays* L.) is increasingly becoming an important cash crop for many growers in the southeast. Corn is often grown as a rotation crop with cotton (*Gossypium hirsutum* L.) in southeastern USA. Crop rotation has become an important component of cotton production in the Southeast as continuous cotton production causes many problems including increased soil borne pathogen populations. Furthermore, the lack of herbicide chemistry rotation also results in increased number of resistant weed species. Crop rotation can be an effective tool in reducing the buildup of problematic weeds and to keep their population under control (Reddy 2004). Using crop rotations with an effective herbicide program can help alleviate these problems. Rotations with corn are typical, due to the lower production costs, ease of production, and because corn is a non-host to many cotton pathogens. In an Arkansas study, Paxton et al. (1995) reported a 12% yield increase in cotton rotated with corn. Corn is also gaining popularity as a major cash crop because of its use as a main bio-fuel feedstock.

Crimson clover and hairy vetch are the two most common winter cover crops for corn production. Both of these cover crops supplement the nitrogen requirement of the corn. Their residue has low C/N ratio and thus decomposes easily to release nitrogen into the soil. Holderbaum et al. (1990) reported in a Maryland study that corn grain yields were higher following crimson clover compared to following no cover crop.

Though weed control benefits associated with cover crops can be improved by increasing the amount of residue on the field, this can also result in some negative effects. High residue can interfere with cash crop establishment and also deplete the soil moisture

(Teasdale 1993; Liebl et al. 1992). Dense cover crop residue can also lead to a decrease in soil temperature, which can severely impact the cash crop yield, though this is largely dependent on local weather conditions and the type of mulch used. Therefore having an optimum amount of residue on the soil is the key to optimizing the benefits from the cover crop system.

Experience in the Southeast has shown that cover crop planting and termination has occurred at the discretion of growers schedule and weather conditions. Previous research has shown that planting and termination dates influence both quality and quantity of residue production. Therefore the objective of this research was to study the influence of the timing of cover crop planting and termination on winter cover crop residue production, early season weed suppression, and cash crop yield in a corn cotton rotation.

MATERIALS AND METHODS

General trial information

Field experiments were conducted at the Alabama Agricultural Experiment Station's E.V. Smith Research Center at Shorter, AL and the Tennessee Valley Research and Extension Center at Belle Mina, AL from autumn of 2003 through corn and cotton harvest in 2006. The experiment was also conducted at the University of Florida West Florida Education and Research Center at Jay, FL from autumn of 2004 to corn and cotton harvest in 2006. The soil types were Compass loamy sand (coarse-loamy, siliceous, subactive, thermic Plinthic Paleudults) at Shorter, AL, Decatur silty loam (fine, kaolinitic, thermic, Rhodic Paleudult) at Belle Mina, AL and a Dothan sandy loam (Fine-loamy, siliceous, thermic Plinthic Kandiudults) at Jay, FL. The treatments were five cover crop planting dates each autumn and four cover crop termination dates the following spring. The planting dates were based on the 30 year average date of the first 0 C freeze. The five planting dates for each location were on the first average frost day, two and four weeks prior and two and four weeks after the average freeze for a total of five planting dates (Table 4.01 & 4.02). Termination dates were four, three, two, and one week prior to the average date for the establishment of the cash crop corn and cotton, which is based the long-term average soil temperature (Table 4.01 & 4.02). Rotation for winter cover crops included crimson clover (*Trifolium incarnatum* L.) cv. AU Robin preceding corn and cereal rye (*Secale cereale* L.) cv. Elbon preceding cotton. In each crop year both the phases of rotation were present on adjacent fields.

Experiment and treatment design

The experiment design for each location was a randomized complete block design (r = 3) with a split block restriction on randomization. This design was chosen for practical reasons because it enabled us to handle seeding and termination operations for the cover crop efficiently. We assigned cover crop planting dates (PD = 5) to horizontal and termination dates (TD = 4) to vertical strips. For each location x year combination, therefore, we had three different sizes of experimental units (Steel and Torrie, 1987). The largest experimental unit (TD) equals one quarter of the block size, the second largest

(PD) equals one fifth of the block size and the smallest (PD x TD combinations) equals 1/20 of the block size (Fig. 1). This design also led to three different sources of experimental errors catering to each experimental unit. Depending on location, the smallest experimental unit (henceforth called plot) was 4m wide and 8m long with four rows of corn and cotton at a 1-m row spacing.

Cover crop management

Crimson clover (*Trifolium incarnatum* L.) cv. AU-Robin and cereal rye cv. Elbon were established with a no-till drill at a seeding rate of 28 kg ha^{-1} and 100 kg ha^{-1}, respectively, in the autumn of each year. In the spring, cover crop biomass samples were collected just before terminating the clover and rye by clipping all aboveground plant parts close to the soil surface from one randomly selected 0.25-m^2 section in each plot. Plant material was dried at 60 C for 72 h and weighed. Clover was then terminated with glyphosate at 1.12 kg ae ha^{-1} plus 2,4-D amine at 0.20 kg ai ha^{-1} utilizing a compressed CO_2 backpack sprayer delivering 140 L ha^{-1} at 147 kPa. Rye was rolled with mechanical roller crimper prior to glyphosate application as described by Ashford and Reeves, 2003 to aid in termination and the process leaves a uniform mat of residue on the soil surface.

Cash crop management

Because the central Alabama and West Florida sites had a well-developed hardpan, the experimental areas were in-row sub-soiled prior to corn planting with a narrow-shank parabolic subsoiler equipped with pneumatic tires to close the subsoil channel (KMC, Tifton GA, USA). Corn (*Zea mays L.*) hybrid cv. Dekalb 69-72RR and Cotton cultivars DP 444 BG/RR, ST 5242 BR and DP555BRR were planted at Shorter, Belle-Mina and Jay Florida, respectively. The cash crop was planted after the final termination date for winter cover crops at each location (Table 4.01) with a four-row planter equipped with row cleaners and double-disk openers (Great Plains Mfg., Inc. Salina, KS, USA).

Sampling and harvest

At the corn 8-leaf or cotton 4-leaf growth stage, all aboveground parts for all weeds were harvested from two randomly selected 0.25-m^2 sections per plot and treated in a similar manner as to cover crop samples described above. Immediately after weed sampling we applied glyphosate at 1.12 kg a.e. ha^{-1}. Plots were then kept weed-free until harvest utilizing Alabama Cooperative Extension Systems recommended herbicide applications.

Before harvest, all plants in a randomly selected 3 m-section for each of the two center rows of each plot were counted for both corn and cotton. For estimation of corn grain yield the two center rows of each plot were harvested with a plot combine, dried to constant moisture (150 g H_2O kg^{-1}) and weighed. Seed cotton yield was determined by machine harvesting the middle two rows of each plot with a spindle picker.

Statistical analysis

Data were analyzed separately for each location using generalized linear mixed models methodology as implemented in SAS® PROC GLIMMIX. Year, planting date and termination date and all their interactions were considered fixed effects. Interaction of reps with planting date and termination date were considered random effects. Interaction effects were considered to be important or at least deserving a 2nd look whenever the calculated *P*-value was less than 0.10. The arguments for this approach, based on Carmer (1976) were presented by Sulc et al. (2001, 2004). Significance of treatment differences were calculated by single degree of freedom contrasts.

RESULTS AND DISCUSSION

Crimson clover cover crop

Weather conditions encountered at the three locations resulted in large differences in biomass production. Maximum biomass production (5447 kg ha^{-1}) was observed at Shorter, AL when crimson clover was seeded four weeks prior to the average first day of a 0 C freeze and terminated one week prior to planting the corn cash crop. The least biomass production (24 kg ha^{-1}) was observed at Belle-Mina, AL when the clover was seeded at the last establishment date (4-wk post 0 C freeze) and terminated one week prior to corn planting.

The most general model for this type of study is a classification model that treats seeding and termination dates as categorical variables resulting in a 5 x 4 factorial arrangement. The three-way interaction was significant ($P = 0.051$) only for the Bella Mina location (Table 4.03). The two-way interactions termination date x year was significant for the northern and southernmost locations only ($P \leq 0.001$), whereas seeding date interacted significantly with years for all three locations ($P < 0.0001$). The seeding x termination date interaction was significant only for Belle Mina and Jay ($P < 0.026$). Main effects for seeding and termination dates were significant at all locations except for termination date at Shorter.

Crimson clover shoot dry biomass yield was significantly impacted by the delay in seeding date at all locations and years (Table 4.04). At Belle-Mina, crimson clover planted prior to the average 0 C date yielded significantly higher than the plots, which were planted after that date. This is the coldest of three locations with an average temperature of 10 C, 5.5 C and 3.8 C during November, December and January respectively. These observations indicate that it is very important to plant a legume cover crop such as crimson clover early enough to get sufficient growth before the cooler temperatures set in. Waiting too long to seed the cover crop in the northern regions of Alabama severely impacted the amount of biomass produced by crimson clover. Less than 400 kg/ha of biomass was produced when crimson clover was seeded two weeks after the average day of 0 C freeze at Belle-Mina.

At Shorter, the variability in crimson clover biomass production among the years was very pronounced; biomass production was less in 2003 compared to 2004 and 2005. Significant reduction in crimson clover biomass production was observed with an advanced seeding date only in 2004 and 2005, as indicated by contrasts. If the seeding of crimson clover was delayed by 4 weeks 3689 kg/ha and 2553 kg/ha less biomass was produced in 2004 and 2005 respectively. No significant differences in crimson clover biomass production were however observed with either early or delayed termination in 2004 and 2005 (Table 4.05). Dry biomass accumulation was maximum if crimson clover was allowed to grow until one week prior to corn planting in 2006.

At the southernmost location Jay, except the three way interaction, all other main and interaction effects were significant for crimson clover biomass production (Table 4.03). Significant differences among years were observed, biomass production was less in 2004 compared to 2005. In 2005 with every two week delay in seeding the cover crop biomass production was reduced by more than half (Table 4.04). Significantly higher biomass was accumulated when crimson clover was terminated only a week or two prior to the planting of the main crop, corn (Table 5). However, no significant differences in biomass accumulation were observed if cover crop was terminated either four or three weeks prior to planting corn.

Weed biomass in corn

The three-way interaction (Year x PD x TD) was not significant for any location. Interaction of termination date with year was significant for both Belle Mina and Shorter locations ($P \leq 0.04$). Interactions of seeding date with year as well as with termination date were not significant ($P \geq 0.11$). Years did not have a significant effect at any of the locations ($P \geq 0.12$). The effect of termination date ($P \leq 0.05$) and seeding date ($P = 0.09$) was significant at Belle Mina and Shorter only (Table 4.03).

At Belle-Mina weed biomass was only 81 kg/ha in 2003-04 growing season corresponding to crimson clover biomass of 2861 kg/ha when the cover crop was seeded four weeks prior to the average frost (Table 4.06). Weed biomass increased with delay in cover crop seeding date indicating greater amount of crimson clover residue produced on earlier seeding dates suppressed early season weed biomass production in corn. However contrasts indicate no significant reduction in weed biomass if crimson clover was planted four or two weeks prior to the average frost. In the 2004-05 growing season, weed biomass production was significantly reduced by seeding crimson clover four and two weeks prior to the average frost, the larger the biomass production the smaller was the weed biomass. No significant differences in weed biomass production were observed if crimson clover was seeded on the average day of first 0 C freeze or thereafter. In 2005-06 seeding dates had no significant effect on weed biomass production. No significant effect of delayed termination on weed biomass production was observed in 2003-04 and 2004-05 growing seasons compared to the first termination date (4 wks prior to average 0 C freeze). However in 2005-06 growing season, a significant reduction in weed biomass was observed with only a 1 wk delay in crimson clover termination. This could be attributed to the increase in crimson clover biomass production with delayed termination, which in turn resulted in early season weed suppression.

At Shorter, no significant increase or decrease in weed biomass production was observed with seeding of crimson clover earlier or later than the average frost date. However weed biomass production in general increased with delay in crimson clover seeding date, in 2003-04 and 2005-06 growing seasons weed biomass ranged from 16-28 kg/ha for the first two crimson clover seeding dates, whereas the final seeding date plots averaged nearly 109 kg/ha weed biomass during both the growing seasons. We do not have a clear explanation for higher weed biomass observed at this location for the first three seeding dates during 2004-05 growing season since the crimson clover biomass production was similar to the 2005-06 growing season. The effect of termination dates was pronounced only in 2005-06; significantly less weed biomass was produced if the termination was delayed by a even a week (Table 4.07).

At Jay, our southernmost location no definite trend in weed biomass production was observed with earlier seeding or termination of the crimson clover. This could be due to rapid decomposition of residue due to warmer temperatures at this location compared to the northern locations (Table 6 & 7).

Corn plant populations

Only the main effect of years was significant at Jay and Shorter (Table 4.03), no other effect was significant at any of the locations. Effect of years is also questionable for Jay as the estimation of plant populations was done after the crop had been severely impacted with Hurricane Dennis.

There were no significant differences in plant populations among seeding and termination date treatments at Belle-Mina and Shorter (Table 4.08 & 4.09), indicating that the presence of heavy residue in some of the plots did not impact corn seed germination and establishment. There were large differences in plant populations among the years at Jay, probably due to weather conditions. An increase in plant populations was observed with delay in termination dates at Jay, although the differences were not statistically significant from the first termination date.

Corn grain yield

Corn grain yield was not affected by crimson clover seeding and termination dates at Belle-Mina. Though no statistically significant differences were observed plots with the earliest seeding of the crimson clover yielded highest at this location. At both Shorter and Belle-Mina significant differences in corn yield were observed across the years (Table 4.10 & 4.11). Grain yield decreased with the progression of the experiment. Weather conditions were different among the years, 2004 being a normal rainfall year whereas in 2005 majority of the rainfall was received in July at Belle-Mina (6 in.) and Shorter (8.5 in.) and 2006 was a drought year at both the locations. These differences in rainfall events can explain some of the yield differences observed among years at both the locations. Corn is most sensitive to water stress during the silking or flowering and pollination stage of growth and drought stress during this period can result in poor grain development and yield losses. However, rotations with rye and cotton could also have played a role in the decreasing corn grain yield. We noticed buildup of residue at Belle

Mina (Fig. 4.02) over the soil surface as the experiment progressed, this residue could have immobilized some of the nutrients thus negatively impacting corn grain yield with time. We reached this conclusion as better yields were observed at both the locations in first year of the experiment when corn crop was preceded by crimson clover only. Residue buildup with time was also noted by Reddy et al. (2004) at this site. Halvorson et al. (2002) also found that surface crop residues increased with time under no-tillage with corn rotations due to carryovers from year to year. This study, however, was conducted in Colorado, where climatic conditions are considerably different from the subtropical climate of Tennessee Valley region of northern AL.

Reduction in corn grain yield following rye cover crop has been reported by previous research; this does not relate to our study directly but could be a valid explanation as rye was a part of the rotation and could have impacted the nutrient dynamics of the soil.

Cereal rye cover crop

When analyzed by location, the three-way interaction was not significant at Belle-Mina. Interaction of experiment years with seeding date was significant. Main effect of seeding date, termination date and year was also significant (Table 4.12). In general rye biomass production declined with every 2 wk delay in cover seeding (Table 4.13). Delaying the cereal rye planting 4 wk significantly lowered the rye biomass yield in all the years. Biomass production was in general less at this location in 2003-04 and 2004-05 growing seasons. Earlier termination of rye also significantly reduced its biomass yield. Biomass production in all the years was more if rye was terminated a week or two prior to cotton planting (Table 4.14). However, no significant differences in biomass production were observed if rye was terminated three or four weeks prior to cotton planting.

At Shorter, all interactions and main effects were significant for rye biomass production (Table 4.12). Delayed seeding of rye significantly reduced dry biomass accumulation (Table 4.13). In 2004-05 no significant differences in rye dry biomass accumulation occurred if rye was seeded on the third seeding date or later. Significant planting and termination date interaction was also observed at this location. Maximum biomass production was 8523 kg ha $^{-1}$ in year 2006 when rye planted 2 wks before the 0 C freeze and terminated one week prior to cash crop planting. Least biomass produced at Shorter was 140 kg ha $^{-1}$ when covers were planted on the last planting date and terminated on the first planting date (Data not shown).

At our southernmost location Jay all two-way interactions and main effects were significant (Table 4.12). Rye biomass production was better in year 2006 compared to year 2005. As observed at other two locations delayed seeding or earlier termination reduced dry biomass accumulation by rye (Table 4.13 & 4.14). Maximum observed rye biomass at this location was 7468 kg/ha produced when rye was planted four weeks prior to 0 C freeze and terminated two weeks before the seeding of cotton.

Weed biomass in cotton

Dry weights of weeds were more in cotton compared to corn at all site years. This is likely due to the earlier sampling time in corn when fewer summer annual weeds had emerged. The cover crop biomass observed at these locations can explain some of the results observed for weed control. The three-way interaction was not significant at any of the locations. Interaction of year with seeding and termination date was significant at all the locations except at Jay. Seeding*termination date interaction was not significant at any location (Table 4.12).

In general there was an increase in weed biomass in cotton with earlier termination and late planting of the rye cover crop. At Belle-Mina, numerically less weed dry biomass was observed corresponding to a high rye cover crop residue (Table 4.15). Weed biomass averaged only 31 kg/ha corresponding to rye biomass of 8878 kg/ha in plots seeded with rye 4 wks before 0 C freeze in 2003. No significant differences in weed biomass production were observed in 2004 among different seeding dates. In 2005, weed biomass was maximum in plots seeded with rye on the median seeding date averaging 945 kg/ha and less in the later seeded plots. This could be due to the less rye biomass (2479 kg/ha) production in these plots. No significant differences in the weed biomass production were observed among the termination dates in 2003 and 2004 (Table 4.16). In 2005 however, the plots terminated on the final termination date had the least weed biomass.

At Shorter, no significant differences in weed biomass production were observed among seeding dates in 2004 and 2005 (Table 4.15). Maximum observed weed biomass was 970 kg/ha corresponding to rye biomass of 1276 kg/ha in 2005, when rye was seeded four weeks after 0 C freeze. The effect of termination dates on weed biomass production was significant in 2003; weed biomass decreased with delay in rye cover crop termination date (Table 4.16).

At Jay, weed biomass production was less compared to other two locations. No differences in weed biomass production were observed among seeding dates at this location (Table 4.15). Delay in rye termination decreased weed biomass production. In 2004 however, plots terminated a week before cotton planting had more weed biomass than plots terminated two and three weeks prior to cotton planting (Table 4.16).

Decrease in dry weed biomass with corresponding increase in rye biomass is in accordance with the previous studies. Teasdale 1996, concluded weed biomass production is correlated with the cover crop biomass. Smeda and Weller (1996) also reported increase in residual weed suppression by no till-rye residues when the time between cover crop desiccation and crop planting was reduced, probably due to allelopathic effects.

Cotton plant populations

There was little effect of cover crop seeding and termination date treatments on the cotton stand establishment (Table 4.17 & 4.18). No significant differences in cotton populations were observed among seeding and termination dates at any of the site years, indicating presence of heavy rye residue in the early seeded or late terminated rye plots did not negatively impact cotton germination and establishment. This observation has also been supported by Reddy et al. 2004, who reported cotton seedling counts were similar in conventional tillage (no surface residue) and no-tillage systems (with rye residue on surface) in each year of the study. Stand establishment was, however, less at Jay, FL, compared to Shorter and Belle Mina but this does not appear to be related to poor soil to seed contact. In row sub-soiling was employed to break the hardpan at this location. Subsoiler was equipped with row cleaners which usually eliminate the concerns for poor soil to seed contact and reduced germination.

Seed cotton yield

There were differences in cotton yield among the years possibly due to weather conditions but cotton lint yield was not affected by rye cover crop seeding and termination dates at any site year (Table 4.19 & 4.20). Seed cotton yield averaged 3784 kg/ha in 2003, 4269kg/ha in 2004 to 2252 kg/ha in 2005 at Belle-Mina. At Shorter, maximum cotton yield was obtained in year 2004 averaging 4065 kg/ha. At Jay, yield was less in 2005 but was comparable to other two locations in 2005.

In this study, leaving cover crops alive up to 1wk before planting the cash crops corn and cotton increased cover crop biomass accumulation compared with killing 4 wks before planting. Increased cover crop biomass suppressed total weed dry biomass. These findings indicate that high residue cover crops have the potential for suppressing early season weeds in corn and cotton. If farmers are utilizing glyphosate-resistant corn-cotton rotation systems these findings hold particular importance. Weeds can be managed with a glyphosate POST-only program and reliance on preemergence herbicides can be reduced. Thus the additional costs associated with cover crop establishment can be offset by decrease in herbicide use to some extent. Because corn and cotton yields were similar between treatments we can conclude that the benefit of early season weed suppression in corn and cotton can be obtained by planting crimson clover and rye cover crops timely and terminating them a week or two prior to cash crop planting. This can result in maximum cover crop biomass production without negatively impacting the stand establishment and yield of corn and cotton crops.

LITERATURE CITED

Akemo, M.C., M.A. Bennett, and E.E. Regnier. 2000. Tomato growth in spring-sown cover crops. HortScience. 35:843-848.

Ashford, D.L. and D.W. Reeves. 2003. Use of a mechanical roller-crimper as an alternative kill method for cover crops. Am. J. Altern. Agric. 18:37-45.

Bàrberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues? Weed Res. 42:177-193.

Barnes, J.P., and A.R. Putnam. 1983. Rye residues contribute weed suppression in no-tillage cropping systems. J. Chem. Ecol. 9:1045-1057.

Bauer, P.J., and D.W. Reeves. 1999. A comparison of winter cereal species and planting dates as residue cover for cotton grown with conservation tillage. Crop Sci. 39:1824-1830.

Blevins, R.L., D. Cook, S.H. Phillips, and R.E. Phillips. 1971. Influence of no-tillage on soil moisture. Agron. J. 63:593-596.

Bradley, J.F. 1995. Success with no-till cotton. In M. R. McClelland, T. D. Valco, and R. E. Frans, eds. Conservation-Tillage Systems for Cotton. Arkansas Agricultural Experiment Station, Rep. 160:31-33.

Brown, S.M., T. Whitwell, J.T. Touchton, and C.H. Burmester. 1985. Conservation tillage system for cotton production. Soil Sci. Soc. Am. J. 49:1256-1260.

Burgos, N. R. and R. E. Talbert. 1996. Weed Control and Sweet Corn (*Zea mays* var. rugosa) Response in a No-Till System with Cover Crops. Weed Sci. 44:355-361.

Busscher, W.J., J.R. Frederick, and P.J. Bauer. 2000. Timing effects of deep tillage on penetrometer resistance and wheat and soybean yield, Soil Sci. Soc. Am. J. 64:999-1003.

Cardina, J., C.P. Herms, and D.J. Doohan. 2002. Crop rotation and tillage effects on weed seedbanks. Weed Sci. 50:448-460.

Cardina, J., E. Regnier, and K. Harrison. 1991. Long-term tillage effects on seedbanks in three Ohio soils. Weed Sci. 39:186-194.

Carmer, S.G. 1976. Optimal significance levels for application of the least significant difference in crop performance trials. Crop Sci. 16: 95-99.

Creamer, N.G. 1996. Mechanisms of weed suppression in cover crop-based production systems. HortScience. 31:410-413.

Creamer, N.G., M.A. Bennett, and B.R. Stinner. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. HortScience. 32:866-870.

CTIC. 2008. National Crop Residue Management Survey. Conservation Technology Information Center, West Lafayette, IN.

Franzluebbers, A.J., G.W. Langdale, and H.H. Schomberg. 1999. Soil carbon, nitrogen, and aggregation in response to type and frequency of tillage. Soil Sci. Soc. Am. J. 63:349-355.

Frye, W.W., B.L. Blevins, M.S. Smith, S.J. Corak, and J.J. Varco. 1988. Role of annual legume cover crops in efficient use of water and nitrogen. Pages 129–153 in W. L. Hargrove, ed. Cropping Strategies for Efficient Use of Water and Nitrogen. Madison, WI: ASA Special Publication No. 51.

Halvorson, A.D., G.A. Peterson, and C.A. Reule. 2002. Tillage system and crop rotation effects on dryland crop yields and soil carbon in the Central Great Plains. Agron. J. 94:1429-1436.

Holderbaum, J.F., A.M. Decker, J.J. Meisinger, F.R. Mulford, and L.R. Vough. 1990. Fall-seeded legume cover crops for no-tillage corn in the humid east. Agron. J. 82:117-124.

Johnson, G.A., M.S. Defelice, and Z.R. Helsel. 1993. Cover crop management and weed control in corn. Weed Technol. 7:425-430.

Kaspar, T.C., J.K. Radke, and J.M. Laflen. 2001. Small grain cover crops and wheel traffic effects on infiltration, runoff, and erosion. J. Soil Water Conserv. 56:160-164.

Langdale, G.W., R.L. Wilson, Jr., and R.R. Bruce. 1990. Cropping frequencies to sustain long-term conservation tillage systems. Soil Sci. Soc. Am. J. 54:193-198.

Liebl, R., F.W. Simmons, L.M. Wax, and E.W. Stoller. 1992. Effect of rye (*Secale cereale*) mulch on weed control and soil moisture in soybean (*Glycine max*). Weed Technol. 6:838-846.

Morton, T.A., and J.S. Bergtold. 2006. The economics of cover crop biomass for corn and cotton. In: Proceedings of the Annual Southern Conservation Tillage Systems Conference, June 26-28, 2006, Amarillo, TX.

Paxton, K.W., A. Jana, and D.J. Boquet. 1995. Economics of cotton production within alternative crop rotation systems. *In* Proc. Beltwide Cotton Conf. Memphis, TN: National Cotton Council of America. 379-381

Perez, J.F., and J. Ormeno-Nunez. 1991. Difference in hydroxamic acid content in roots and root exudates of wheat (*Triticum aestivum* L.) and rye (*Secale cereale* L.) possible role in allelopathy. Chem. Ecol 17:1037-1043.

Price A.J., M.E. Stoll, J.S. Bergtold, F.J. Arriaga, K.S. Balkcom, T.S. Kornecki, and R.L. Raper. 2008. Effect of cover crop extracts on cotton and radish radicle elongation. Comm. Biometry & Crop Sci. 3:60-66.

Price, A.J., D.W. Reeves, and M.G. Patterson. 2006. Evaluation of weed control provided by three winter cereals in conservation-tillage soybean. Renewable Agric. and Food Systems. 21:159-164.

Putnam, A.R., and J. Defrank. 1983. Use of phytotoxic plant residues for selective weed control. Crop Prot. 2:173-181.

Radford, B.J., D.F. Yule, D. McGarry, and C. Playford. 2001. Crop responses to applied soil compaction and to compaction repair treatments. Soil & Till. Res. 61:157-166.

Raper R.L., D.W. Reeves, C.H. Burmester and E.B. Schwab. 2000. Tillage depth, tillage timing, and cover crop effects on cotton yield, soil strength, and tillage energy requirements. Appl. Eng. Agric. 16:379-385.

Reddy, K. N. 2004. Weed control and species shifts in bromoxynil and glyphosate-resistant cotton (*Gossypium hirsutum*) rotation systems. Weed Technol. 18:131-139.

Reddy, K.C., E.Z. Nyakatawa, and D.W. Reeves. 2004. Tillage and poultry litter application effects on cotton growth and yield, Agron. J. 96:1641-1650.

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

Rice, E. L. 1984. Allelopathy. 2nd ed. Academic Press, NY.

Sainju, U.M., B.P. Singh, and W.F. Whitehead. 2002. Long-term effects of tillage, cover crops, and nitrogen fertilization on organic carbon and nitrogen concentrations in sandy loam soils in Georgia, USA. Soil & Till. Res. 63:167-179.

Smeda, R.J., and S.C. Weller. 1996. Use of rye cover crops for weed management in processing tomatoes. Weed Science. 44:596-602.

Sojka, R.E., and W.J. Busscher. 1989. Conservation tillage in soybean and corn in the SouthCarolina Coastal Plain. Proc. Southern Conservation Tillage Conference. Tallahassee, Florida. IFAS Spec. Bull. 89:46-48.

Steel, R.J.D. and J.H. Torrie. 1987. Principles and procedures of statistics: a biometrical approach. McGraw Hill.

Sulc, R.M., K.D. Johnson, C.C. Sheaffer, D.J. Undersande, and E. van Santen. 2004. Forage quality of potato leafhopper resistant and susceptible alfalfa cultivars. Agron. J. 96:337-343.

Sulc, R.M., E. van Santen, K.D. Johnson, C.C. Sheaffer, D.J. Undersander, L.W. Bledsoe, D.B. Hogg, and H.R. Willson. 2001. Glandular-haired cultivars reduce potato leafhopper damage in alfalfa. Agron. J. 93:1287-1296.

Teasdale, J. R. 1993. Reduced-herbicide weed management systems for no-tillage corn (*Zea mays*) in a hairy vetch (*Vicia villosa*) cover crop. Weed Tech. 7:879-883.

Teasdale, J. R. 1996. Contribution of cover crops to weed management in sustainable agriculture systems. J. Prod. Agric. 9:575-479.

Teasdale, J.R., and C. Mohler. 1992. Weed suppression by residue from hairy vetch and rye cover crops. Proc. First Int. Weed Control Congress. 2:516-518.

Teasdale, J.R., and A.A. Abdul-Baki. 1998. Comparison of mixtures vs. monocultures of cover crops for fresh-market tomato production with and without herbicide. HortScience. 33:1163-1167.

Yenish, J.P., A.D. Worsham, and A.C. York. 1996. Cover crops for herbicide replacement in no-tillage corn (*Zea mays*). Weed Technol. 10:815-821.

Young, F. L., A. G. Ogg Jr, D. C. Thill, D. L. Young and R. I. Papendick. 1996. Weed management for crop production in the Northwest wheat (*Triticum aestivum*) region. Weed Sci. 44:429-436.

Table 4.01: Crimson clover seeding and termination dates

Belle Mina, AL			Shorter, AL			Jay, FL	
2003/4	2004/5	2005/6	2003/4	2004/5	2005/6	2004/5	2005/6
Seeding dates							
25-Sep	27-Sep	25-Sep	09-Oct	08-Oct	12-Oct	29-Oct	04-Nov
09-Oct	11-Oct	11-Oct	20-Oct	21-Oct	25-Oct	10-Nov	17-Nov
22-Oct	26-Oct	24-Oct	10-Nov	10-Nov	07-Nov	29-Nov	02-Dec
04-Nov	08-Nov	07-Nov	21-Nov	03-Dec	22-Nov	13-Dec	12-Dec
18-Nov	18-Nov	18-Nov	08-Dec	16-Dec	07-Dec	20-Dec	22-Dec
Termination dates							
23-Feb	23-Feb	22-Feb	23-Feb	23-Feb	22-Feb	03-Feb	10-Feb
01-Mar	01-Mar	01-Mar	01-Mar	01-Mar	01-Mar	10-Feb	17-Feb
08-Mar	09-Mar	08-Mar	08-Mar	09-Mar	08-Mar	17-Feb	24-Feb
15-Mar	18-Mar	15-Mar	15-Mar	18-Mar	15-Mar	24-Feb	03-Mar

Table 4.02: Cereal rye seeding and termination dates

Belle Mina, AL			Shorter, AL			Jay, FL	
2003/4	2004/5	2005/6	2003/4	2004/5	2005/6	2004/5	2005/6
Seeding dates							
25-Sep	27-Sep	25-Sep	09-Oct	08-Oct	12-Oct	29-Oct	04-Nov
09-Oct	11-Oct	11-Oct	20-Oct	21-Oct	25-Oct	10-Nov	17-Nov
22-Oct	26-Oct	24-Oct	10-Nov	10-Nov	07-Nov	29-Nov	02-Dec
04-Nov	08-Nov	07-Nov	21-Nov	03-Dec	22-Nov	13-Dec	12-Dec
18-Nov	18-Nov	18-Nov	08-Dec	16-Dec	07-Dec	20-Dec	22-Dec
Termination dates							
02-Apr	04-Apr	05-Apr	23-Mar	23-Mar	22-Mar	10-Mar	16-Mar
09-Apr	11-Apr	10-Apr	31-Mar	30-Mar	29-Mar	17-Mar	24-Mar
16-Apr	18-Apr	17-Apr	07-Apr	06-Apr	04-Apr	24-Mar	31-Mar
22-Apr	28-Apr	24-Apr	13-Apr	13-Apr	12-Apr	29-Mar	07-Apr

Table 4.03: *P*-values from the analysis of variance for cover crop biomass, weed biomass, corn populations and corn grain yield.

		Response variables			
Effect	DF	Clover Biomass	Weed Biomass	Corn Population	Corn Yield
Belle-Mina, AL					
PD (Seeding Date)	4	<0.0001	<0.0001	0.476	0.269
TD (Termination Date)	3	<0.0001	<0.0001	0.278	0.801
PD*TD	12	0.022	0.105	0.707	0.834
Year	2	0.596	0.674	0.242	<0.0001
Year*PD	8	<0.0001	0.834	0.436	0.084
Year*TD	6	0.001	<0.0001	0.887	0.016
Year*PD*TD	24	0.051	0.152	0.876	0.625
Shorter, AL					
PD (Seeding Date)	4	<0.0001	0.089	0.128	0.777
TD (Termination Date)	3	0.268	0.051	0.221	0.146
PD*TD	12	0.411	0.248	0.227	0.743
Year	2	0.036	0.115	0.012	<0.0001
Year*PD	8	<0.0001	0.265	0.303	0.042
Year*TD	6	0.505	0.037	0.351	<0.0001
Year*PD*TD	24	0.804	0.625	0.975	0.721
Jay, FL					
PD (Seeding Date)	4	<0.0001	0.383	0.226	0.341
TD (Termination Date)	3	0.005	0.218	0.126	0.836
PD*TD	12	0.026	0.357	0.528	0.654
Year	1	0.038	0.275	0.001	0.002
Year*PD	4	<0.0001	0.402	0.441	0.055
Year*TD	3	0.001	0.513	0.878	0.941
Year*PD*TD	12	0.186	0.249	0.958	0.805

Table 4.04: Clover biomass (kg ha^{-1}) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 weeks prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.01.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	2861	1928	1904
- 2 weeks	1435	2336	1753
Median Date	604	945	757
+ 2 weeks	304	263	381
+ 4 weeks	76	121	85
SE		172	
Dunnett's *P* vs. median seeding date			
- 4 weeks	<0.0001	<0.0001	<0.0001
- 2 weeks	<0.0001	<0.0001	<0.0001
+ 2 weeks	<0.0001	0.009	0.265
+ 4 weeks	<0.0001	0.001	0.010
		Shorter, AL	
- 4 weeks	1808	4750	4511
- 2 weeks	2135	3827	3935
Median Date	1223	1061	1958
+ 2 weeks	1321	359	805
+ 4 weeks	914	414	425
SE		332	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.462	<0.0001	<0.0001
- 2 weeks	0.117	<0.0001	<0.0001
+ 2 weeks	0.998	0.302	0.030
+ 4 weeks	0.884	0.373	0.002
		Jay, FL	
- 4 weeks	NA	601	2123
- 2 weeks	NA	468	979
Median Date	NA	230	465
+ 2 weeks	NA	103	205
+ 4 weeks	NA	90	132
SE		86	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.011	<0.0001
- 2 weeks	NA	0.164	<0.0001
+ 2 weeks	NA	0.683	0.113
+ 4 weeks	NA	0.605	0.026

Table 4.05: Clover biomass (kg ha^{-1}) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to corn planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.01.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	1637	1015	1323
- 2 week prior	1116	1364	1131
- 3 week prior	832	1119	833
- 4 week prior	639	977	617
SE		144	
Dunnett's *P* vs. First termination date			
- 1 week prior	<0.0001	0.991	<0.0001
- 2 week prior	0.022	0.059	0.007
- 3 week prior	0.550	0.729	0.431
		Shorter, AL	
- 1 week prior	1860	2348	2827
- 2 week prior	1315	2005	2385
- 3 week prior	1691	1813	2389
- 4 week prior	1054	2162	1706
SE		335	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.187	0.956	0.039
- 2 week prior	0.891	0.972	0.310
- 3 week prior	0.360	0.781	0.306
		Jay, FL	
- 1 week prior	NA	474	1144
- 2 week prior	NA	217	945
- 3 week prior	NA	201	588
- 4 week prior	NA	300	446
SE		77	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.264	<0.0001
- 2 week prior	NA	0.787	<0.0001
- 3 week prior	NA	0.687	0.426

Table 4.06: Weed dry biomass (kg ha^{-1}) in corn by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.01.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	81	27	111
- 2 weeks	103	61	119
Median Date	154	167	190
+ 2 weeks	153	159	171
+ 4 weeks	187	135	178
SE		42	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.228	0.003	0.180
- 2 weeks	0.534	0.036	0.255
+ 2 weeks	1.000	0.999	0.976
+ 4 weeks	0.842	0.852	0.996
		Shorter, AL	
- 4 weeks	26	62	16
- 2 weeks	28	120	18
Median Date	83	136	49
+ 2 weeks	75	90	100
+ 4 weeks	109	115	108
SE		27	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.329	0.134	0.768
- 2 weeks	0.358	0.978	0.798
+ 2 weeks	0.998	0.513	0.437
+ 4 weeks	0.886	0.935	0.309
		Jay, FL	
- 4 weeks	NA	26	78
- 2 weeks	NA	72	58
Median Date	NA	42	35
+ 2 weeks	NA	53	142
+ 4 weeks	NA	48	163
SE		45	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.995	0.849
- 2 weeks	NA	0.956	0.982
+ 2 weeks	NA	0.999	0.168
+ 4 weeks	NA	1.000	0.073

Table 4.07: Weed dry biomass (kg ha^{-1}) in corn by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to corn planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.01.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	132	143	73
- 2 week prior	138	47	73
- 3 week prior	142	161	159
- 4 week prior	131	89	311
SE		40	
Dunnett's *P* vs. First termination date			
- 1 week prior	1.000	0.346	<0.0001
- 2 week prior	0.996	0.540	<0.0001
- 3 week prior	0.982	0.132	<0.0001
		Shorter, AL	
- 1 week prior	40	83	38
- 2 week prior	76	116	17
- 3 week prior	68	77	31
- 4 week prior	72	142	147
SE		24	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.583	0.147	0.002
- 2 week prior	0.999	0.738	<0.0001
- 3 week prior	0.998	0.095	0.001
		Jay, FL	
- 1 week prior	NA	45	84
- 2 week prior	NA	16	101
- 3 week prior	NA	54	42
- 4 week prior	NA	77	155
SE		77	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.851	0.344
- 2 week prior	NA	0.491	0.562
- 3 week prior	NA	0.939	0.064

Table 4.08: Corn populations (No. of plants per hectare) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.01.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	21726	20909	23522
- 2 weeks	21399	19166	21072
Median Date	22597	20909	21780
+ 2 weeks	22651	20364	21562
+ 4 weeks	20854	20909	21726
SE		977	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.866	1.000	0.369
- 2 weeks	0.687	0.369	0.930
+ 2 weeks	1.000	0.971	0.999
+ 4 weeks	0.369	1.000	1.000
		Shorter, AL	
- 4 weeks	22488	24993	21834
- 2 weeks	21617	25319	21018
Median Date	23196	22433	19656
+ 2 weeks	22706	24339	21236
+ 4 weeks	24067	25319	20963
SE		922	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.923	0.080	0.168
- 2 weeks	0.430	0.039	0.561
+ 2 weeks	0.978	0.267	0.430
+ 4 weeks	0.854	0.039	0.596
		Jay, FL	
- 4 weeks	NA	15125	23172
- 2 weeks	NA	16577	24745
Median Date	NA	15125	24563
+ 2 weeks	NA	15670	26681
+ 4 weeks	NA	16880	26015
SE		945	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	1.000	0.735
- 2 weeks	NA	0.719	0.999
+ 2 weeks	NA	0.965	0.564
+ 4 weeks	NA	0.642	0.719

Table 4.09: Corn populations (No. of plants per hectare) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to corn planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.01.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	21954	20125	22433
- 2 week prior	21649	19863	21693
- 3 week prior	22346	21127	22390
- 4 week prior	21432	20691	21214
SE		837	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.879	0.852	0.361
- 2 week prior	0.989	0.658	0.903
- 3 week prior	0.588	0.924	0.390
		Shorter, AL	
- 1 week prior	22041	24176	19733
- 2 week prior	23261	22695	20604
- 3 week prior	22913	25657	21911
- 4 week prior	23043	25395	21519
SE		919	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.717	0.586	0.286
- 2 week prior	0.995	0.055	0.768
- 3 week prior	0.999	0.992	0.974
		Jay, FL	
- 1 week prior	NA	15052	23958
- 2 week prior	NA	16166	24926
- 3 week prior	NA	16262	26184
- 4 week prior	NA	16020	25071
SE		837	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.747	0.694
- 2 week prior	NA	0.997	0.997
- 3 week prior	NA	0.987	0.694

Table 4.10: Corn grain yield (kg ha^{-1}) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.01.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	10471	9262	4646
- 2 weeks	9474	8712	4686
Median Date	9963	8684	5228
+ 2 weeks	10054	8434	4607
+ 4 weeks	9344	8414	4831
SE		370	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.501	0.386	0.380
- 2 weeks	0.534	1.000	0.445
+ 2 weeks	0.998	0.919	0.324
+ 4 weeks	0.326	0.897	0.702
		Shorter, AL	
- 4 weeks	11986	7631	5703
- 2 weeks	11701	7701	5709
Median Date	12429	7333	5629
+ 2 weeks	11325	7363	5840
+ 4 weeks	11533	7864	5296
SE		379	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.592	0.847	0.999
- 2 weeks	0.175	0.731	0.999
+ 2 weeks	0.015	1.000	0.949
+ 4 weeks	0.065	0.431	0.792
		Jay, FL	
- 4 weeks	NA	5582	13520
- 2 weeks	NA	6259	14328
Median Date	NA	5236	12982
+ 2 weeks	NA	6318	12083
+ 4 weeks	NA	6432	12694
SE		945	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.972	0.878
- 2 weeks	NA	0.446	0.216
+ 2 weeks	NA	0.397	0.560
+ 4 weeks	NA	0.310	0.986

Table 4.11: Corn grain yield (kg ha^{-1}) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to corn planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.01.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	9880	8389	4946
- 2 week prior	9707	8392	5201
- 3 week prior	10117	9196	4842
- 4 week prior	9741	8827	4209
SE		425	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.988	0.745	0.370
- 2 week prior	1.000	0.748	0.155
- 3 week prior	0.818	0.827	0.491
		Shorter, AL	
- 1 week prior	10916	7579	4382
- 2 week prior	12094	7424	5949
- 3 week prior	12453	8225	6933
- 4 week prior	11717	7085	5278
SE		500	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.482	0.797	0.392
- 2 week prior	0.895	0.920	0.616
- 3 week prior	0.547	0.209	0.037
		Jay, FL	
- 1 week prior	NA	5615	12565
- 2 week prior	NA	5867	12872
- 3 week prior	NA	6225	13468
- 4 week prior	NA	6155	13581
SE		784	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.926	0.673
- 2 week prior	NA	0.987	0.853
- 3 week prior	NA	1.000	0.999

Table 4.12: *P*-values from the analysis of variance for cover crop biomass, weed biomass, cotton populations and seed cotton yield.

		Response variables			
Effect	DF	Rye Biomass	Weed Biomass	Cotton Population	Cotton Yield
Belle-Mina, AL					
PD (Seeding Date)	4	<0.0001	<0.0001	0.001	0.863
TD (Termination Date)	3	<0.0001	0.316	0.166	0.458
PD*TD	12	0.450	0.786	0.083	0.082
Year	2	0.006	0.017	0.087	0.003
Year*PD	8	0.001	0.038	<0.0001	0.088
Year*TD	6	0.601	0.020	0.091	0.048
Year*PD*TD	24	0.500	0.816	0.513	0.880
Shorter, AL					
PD (Seeding Date)	4	<0.0001	0.001	0.020	0.492
TD (Termination Date)	3	0.002	0.008	0.920	0.537
PD*TD	12	0.005	0.438	0.456	0.926
Year	2	0.006	0.011	0.000	0.001
Year*PD	8	<0.0001	0.000	0.216	0.001
Year*TD	6	<0.0001	0.000	0.052	0.357
Year*PD*TD	24	0.084	0.559	0.637	0.923
Jay, FL					
PD (Seeding Date)	4	<0.0001	0.137	0.611	0.542
TD (Termination Date)	3	0.003	<0.0001	0.321	0.540
PD*TD	12	0.012	0.923	0.579	0.874
Year	1	0.003	0.636	0.010	0.013
Year*PD	4	0.042	0.493	0.892	0.582
Year*TD	3	0.002	0.015	0.265	0.348
Year*PD*TD	12	0.170	0.859	0.863	0.519

Table 4.13: Rye biomass (kg ha^{-1}) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.02.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	8878	5062	6396
- 2 weeks	7852	5232	4078
Median Date	6584	2863	2479
+ 2 weeks	4500	2149	3085
+ 4 weeks	2649	913	2066
SE		611	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.004	0.006	<0.0001
- 2 weeks	0.200	0.003	0.070
+ 2 weeks	0.010	0.701	0.788
+ 4 weeks	<0.0001	0.018	0.933
		Shorter, AL	
- 4 weeks	5566	5331	6177
- 2 weeks	5053	4893	6269
Median Date	4344	2610	5372
+ 2 weeks	2779	518	2553
+ 4 weeks	1276	213	1370
SE		356	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.020	<0.0001	0.198
- 2 weeks	0.298	<0.0001	0.128
+ 2 weeks	0.002	<0.0001	<0.0001
+ 4 weeks	<0.0001	<0.0001	<0.0001
		Jay, FL	
- 4 weeks	NA	3605	5006
- 2 weeks	NA	2982	5341
Median Date	NA	2559	4695
+ 2 weeks	NA	1687	3349
+ 4 weeks	NA	1545	2706
SE		253	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.005	0.727
- 2 weeks	NA	0.480	0.142
+ 2 weeks	NA	0.026	<0.0001
+ 4 weeks	NA	0.007	<0.0001

Table 4.14: Rye biomass (kg ha^{-1}) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to cotton planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.02.

Cover crop termination date	Growing Season 2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	8095	4781	4725
- 2 week prior	6421	3767	3839
- 3 week prior	5460	2693	3523
- 4 week prior	4394	1734	2396
SE		552	
Dunnett's *P* vs. First termination date			
- 1 week prior	<0.0001	<0.0001	<0.0001
- 2 week prior	0.001	0.001	0.032
- 3 week prior	0.150	0.219	0.120
		Shorter, AL	
- 1 week prior	3987	2686	5435
- 2 week prior	4731	3089	4498
- 3 week prior	4659	2794	4384
- 4 week prior	1837	2282	3076
SE		338	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.637	<0.0001	0.135
- 2 week prior	0.128	0.002	0.005
- 3 week prior	0.457	0.005	0.414
		Jay, FL	
- 1 week prior	NA	2613	4840
- 2 week prior	NA	3128	5370
- 3 week prior	NA	2352	4015
- 4 week prior	NA	1809	2653
SE		295	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.135	<0.0001
- 2 week prior	NA	0.005	<0.0001
- 3 week prior	NA	0.414	0.004

Table 4.15: Weed dry biomass (kg ha^{-1}) in cotton by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.02.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	31	133	214
- 2 weeks	54	182	455
Median Date	406	275	945
+ 2 weeks	250	297	368
+ 4 weeks	345	478	664
SE		102	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.010	0.601	<0.0001
- 2 weeks	0.017	0.865	<0.0001
+ 2 weeks	0.519	0.999	<0.0001
+ 4 weeks	0.965	0.283	0.077
		Shorter, AL	
- 4 weeks	316	289	62
- 2 weeks	318	381	53
Median Date	470	440	58
+ 2 weeks	474	467	81
+ 4 weeks	970	378	88
SE		101	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.425	0.438	1.000
- 2 weeks	0.437	0.953	1.000
+ 2 weeks	1.000	0.997	0.998
+ 4 weeks	<0.0001	0.944	0.996
		Jay, FL	
- 4 weeks	NA	48	53
- 2 weeks	NA	50	48
Median Date	NA	80	88
+ 2 weeks	NA	53	85
+ 4 weeks	NA	87	65
SE		14	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.338	0.259
- 2 weeks	NA	0.390	0.160
+ 2 weeks	NA	0.495	1.000
+ 4 weeks	NA	0.993	0.626

Table 4.16: Weed dry biomass (kg ha^{-1}) in cotton by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to cotton planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.02.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	287	201	272
- 2 week prior	153	150	424
- 3 week prior	165	397	755
- 4 week prior	265	345	665
SE		116	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.998	0.678	0.035
- 2 week prior	0.815	0.456	0.288
- 3 week prior	0.858	0.975	0.890
		Shorter, AL	
- 1 week prior	104	141	17
- 2 week prior	341	389	74
- 3 week prior	532	430	64
- 4 week prior	1061	603	118
SE		24	
Dunnett's *P* vs. First termination date			
- 1 week prior	<0.0001	0.001	0.771
- 2 week prior	<0.0001	0.228	0.973
- 3 week prior	<0.0001	0.392	0.952
		Jay, FL	
- 1 week prior	NA	64	20
- 2 week prior	NA	51	51
- 3 week prior	NA	48	83
- 4 week prior	NA	91	118
SE		77	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.322	<0.0001
- 2 week prior	NA	0.070	0.001
- 3 week prior	NA	0.052	0.125

Table 4.17: Cotton populations (No of plants/ hectare) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.02.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	35447	42144	39367
- 2 weeks	44322	39204	40511
Median Date	51782	42798	39912
+ 2 weeks	51129	44976	43614
+ 4 weeks	53361	46391	43124
SE		2131	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.151	0.990	0.995
- 2 weeks	0.319	0.585	0.992
+ 2 weeks	0.990	0.784	0.572
+ 4 weeks	0.882	0.585	0.631
		Shorter, AL	
- 4 weeks	49332	51020	53415
- 2 weeks	48188	53633	51564
Median Date	51727	54995	54995
+ 2 weeks	49931	58316	53470
+ 4 weeks	49005	56138	54014
SE		1379	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.678	0.473	0.832
- 2 weeks	0.518	0.875	0.531
+ 2 weeks	0.789	0.544	0.843
+ 4 weeks	0.626	0.915	0.942
		Jay, FL	
- 4 weeks	NA	24442	36240
- 2 weeks	NA	20812	33275
Median Date	NA	22990	36603
+ 2 weeks	NA	21054	35332
+ 4 weeks	NA	20328	35514
SE		2198	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.946	1.000
- 2 weeks	NA	0.861	0.715
+ 2 weeks	NA	0.891	0.962
+ 4 weeks	NA	0.798	0.976

Table 4.18: Cotton populations (No. of plants per hectare) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to cotton planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.02.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	46174	38812	42035
- 2 week prior	47001	44693	41121
- 3 week prior	49049	44693	40337
- 4 week prior	46609	44213	41730
SE		1970	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.989	0.341	0.996
- 2 week prior	0.992	0.985	0.973
- 3 week prior	0.635	0.985	0.834
		Shorter, AL	
- 1 week prior	50617	54232	51619
- 2 week prior	47393	56367	54450
- 3 week prior	49310	54450	55321
- 4 week prior	51227	54232	52577
SE		1338	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.971	1.000	0.915
- 2 week prior	0.447	0.677	0.727
- 3 week prior	0.718	0.998	0.577
		Jay, FL	
- 1 week prior	NA	21974	33735
- 2 week prior	NA	20812	32283
- 3 week prior	NA	21877	35187
- 4 week prior	NA	23038	40366
SE		2217	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.964	0.420
- 2 week prior	NA	0.827	0.354
- 3 week prior	NA	0.955	0.512

Table 4.19: Seed cotton yield (kg ha^{-1}) by location and year as influenced by cover crop seeding date, which were based on the 30-yr average day of first frost at each location. Further seeding dates were either 2 or 4 week prior (-) or later (+) than that date. Data are averaged over termination dates. Actual seeding dates are in Table 4.02.

Cover crop seeding date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 4 weeks	3587	4261	2316
- 2 weeks	3292	4224	2274
Median Date	3645	4070	2208
+ 2 weeks	3646	4387	2177
+ 4 weeks	3699	4405	2288
SE		203	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.997	0.814	0.971
- 2 weeks	0.341	0.902	0.995
+ 2 weeks	1.000	0.435	1.000
+ 4 weeks	0.998	0.386	0.990
		Shorter, AL	
- 4 weeks	2463	3772	3399
- 2 weeks	2220	4310	3321
Median Date	2294	3943	3183
+ 2 weeks	2393	4074	3104
+ 4 weeks	2465	4233	3172
SE		166	
Dunnett's *P* vs. median seeding date			
- 4 weeks	0.550	0.536	0.332
- 2 weeks	0.955	0.031	0.710
+ 2 weeks	0.882	0.748	0.945
+ 4 weeks	0.541	0.119	1.000
		Jay, FL	
- 4 weeks	NA	1896	2868
- 2 weeks	NA	2073	2928
Median Date	NA	1980	2833
+ 2 weeks	NA	2032	2787
+ 4 weeks	NA	2266	2885
SE		174	
Dunnett's *P* vs. median seeding date			
- 4 weeks	NA	0.963	0.999
- 2 weeks	NA	0.949	0.944
+ 2 weeks	NA	0.994	0.996
+ 4 weeks	NA	0.264	0.994

Table 4.20: Seed cotton yield (kg ha^{-1}) by location and year as influenced by cover crop termination date, which were 4, 3, 2, and 1 week prior to cotton planting. Termination dates were based on 30 year average soil temperature. Data are averaged over seeding dates. Actual termination dates are in Table 4.02.

Cover crop termination date	Growing Season		
	2003-04	2004-05	2005-06
		Belle Mina, AL	
- 1 week prior	3486	4247	2375
- 2 week prior	3555	4371	2240
- 3 week prior	3480	4284	2145
- 4 week prior	3775	4177	2251
SE		159	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.029	0.864	0.548
- 2 week prior	0.126	0.202	0.999
- 3 week prior	0.025	0.654	0.665
		Shorter, AL	
- 1 week prior	2224	3803	2971
- 2 week prior	2334	4172	3214
- 3 week prior	2507	4258	3566
- 4 week prior	2404	4033	3193
SE		233	
Dunnett's *P* vs. First termination date			
- 1 week prior	0.884	0.789	0.806
- 2 week prior	0.992	0.941	1.000
- 3 week prior	0.974	0.801	0.470
		Jay, FL	
- 1 week prior	NA	1902	2898
- 2 week prior	NA	2240	2922
- 3 week prior	NA	2057	2759
- 4 week prior	NA	1998	2861
SE		172	
Dunnett's *P* vs. First termination date			
- 1 week prior	NA	0.893	0.992
- 2 week prior	NA	0.343	0.968
- 3 week prior	NA	0.971	0.874

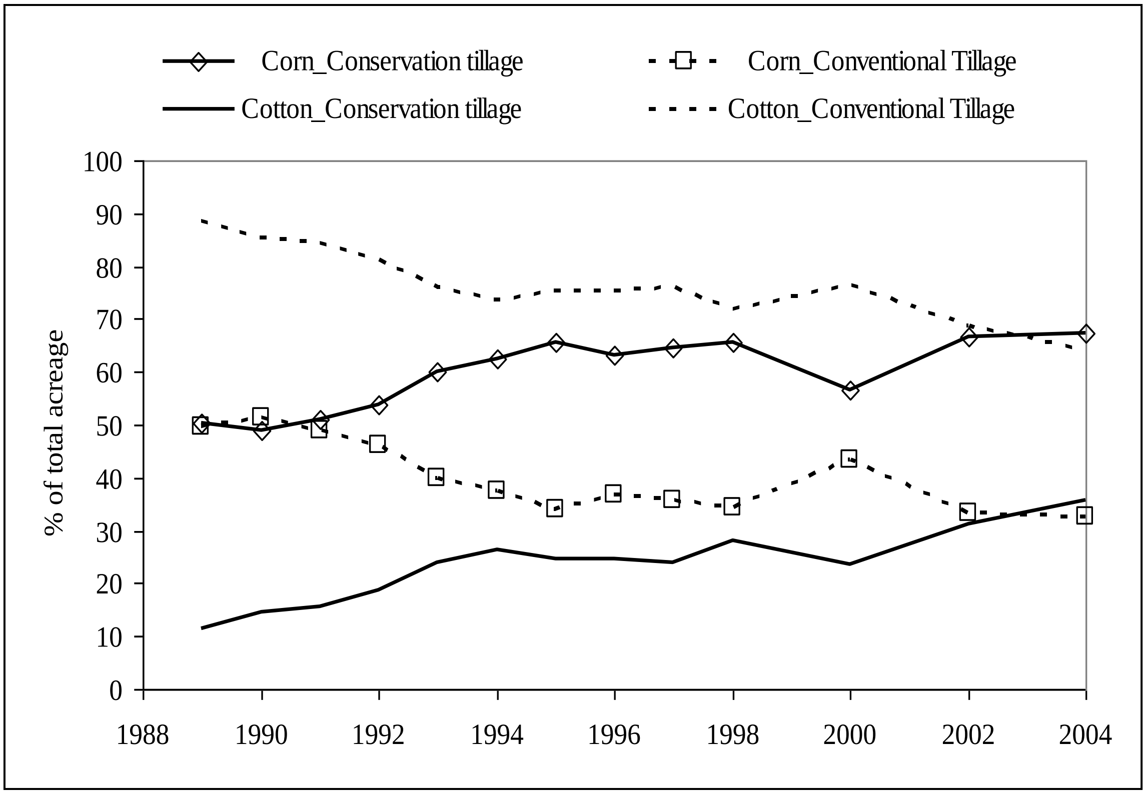

Fig. 4.01: Conservation tillage adoption for corn and cotton production in US from 1990 to 2004 (CTIC, 2008).

Fig. 4.02: Buildup of residue with time at Tennessee valley research station in Belle Mina AL