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Ground Cover Management for Conservation Tillage Burley Tobacco

Justin Lee Bryant
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Justin Lee Bryant entitled "Ground Cover Management for Conservation Tillage Burley Tobacco." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

Harry Paul Denton, Major Professor

We have read this thesis and recommend its acceptance:

Gary Bates, J. E. Morrison Jr.

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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GROUND COVER MANAGEMENT FOR CONSERVATION TILLAGE BURLEY TOBACCO

A Thesis

Presented for the

Master of Science

Degree

University of Tennessee Knoxville

Justin Lee Bryant

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ABSTRACT

There are several advantages of using conservation tillage management practices for burley tobacco production. These include reduced soil erosion, soil water conservation, and lower input costs. Inconsistent yields in past research and trials have made tobacco producers hesitant in adopting conservation tillage. This research was conducted near Springfield, Tennessee and Greeneville, Tennessee to investigate no-till and strip-till practices with different ground cover management techniques during winter and spring months in an effort to identify appropriate technologies. The first study evaluated cover management in established sod. Conventional tillage tobacco was compared to tobacco transplanted either no-till or strip-till into the following sod treatments: (a) spring killed sod, (b) fall killed sod without a winter cover crop, (c) fall killed, wheat cover, and (d) fall killed, rye cover.

The objectives of the second study were to explore the possibility of using cover crops for winter forage or straw production, harvested prior to the late-spring transplanting of the tobacco crop. In this study, conventional tillage tobacco was compared to tobacco transplanted either no-till or strip-till into the following ground cover treatments: (a) wheat cover, (b) wheat grazed, (c) rye cover, (d) rye grazed, (e) rye straw, and (f) soybean residue.

Conventional tillage produced higher tobacco yields than conservation tillage in three out of four tests. Conservation tillage yields in the sod test at Highland Rim were equal to conventional tillage. Treatments implementing strip tillage with low residue cover generally produced the highest tobacco yields of the conservation tillage

treatments. This was probably a result of higher soil temperature due to lower residue cover and the tilled strip. Soil temperatures in these treatments were comparable to conventional tillage. Soil penetration resistance was also less in strip-till (ST) than in no-till (NT), indicating a less consolidated rooting zone; this may have been another reason that ST yield was higher than NT.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Tobacco (*Nicotiana tobacum*) is an important crop to many farmers in Tennessee and other states in the United States. Conventionally grown tobacco is an intensively tilled and cultivated row crop that is very susceptible to soil erosion, which can be significantly reduced by implementing conservation tillage methods (Wood and Worsham, 1986). It has been shown in past research that using conservation tillage practices for tobacco production can be beneficial, both environmentally and economically (Shilling et al., 1986). There are many advantages of producing burley tobacco using conservation tillage practices, assuming yields are equal to conventional tillage yields. They are: elimination of seedbed preparation, conservation of soil water, reduced soil erosion, cleaner cured tobacco, more flexibility in transplanting and harvesting, and possibly lower production costs (Phillips and Zeleznik, 1989).

Conservation tillage tobacco has been studied since the 1960's. These early studies reported problems with vegetation control and fertilizer placement. Moschler et al. (1971) experimented with strip tillage, as well as no-till, in 1967 and 1968. Strip tillage refers to a modified form of conservation tillage where a strip approximately 30 cm wide is thoroughly tilled and tobacco is transplanted into this strip (Moschler et al., 1971). In 1969, their trials included an experiment comparing no-till and conventionally tilled burley tobacco. This experiment found no significant differences in yield, value per pound, or value per acre between the two tillage practices.

Cover crops play an important role in conservation tillage systems. They can be beneficially used to manage weeds (Shilling, 1996). In tobacco, they are especially important for weed suppression, due to the lack of late season, selective herbicides. Cereal cover crops, such as wheat (*Triticum aestivum*) and rye (*Secale cereale*), are often used in conservation tillage tobacco to suppress weeds by modifying the light, temperature, moisture, and the microclimate of germinating weed seed (Teasdale et al., 1991). Wheat and rye straw and stubble residues are also able to suppress weeds due to their allelopathic chemical content (Boz, 2003). To conserve soil moisture and nutrients, allow time for the residue to begin decomposition, reduce planting problems, and improve early growth of tobacco, covers should be chemically killed, "burned down", at least thirty days prior to transplanting (Pearce et al., 2002).

Small grains can provide a fall and/or spring forage source (Maloney et al., 1999). They are grown extensively in the southeastern United States for winter forage and produce a high quality forage when perennial grass species are not productive (Bruckner and Raymer, 1990). Rye, wheat, oat (*Avena sativa*), and triticale (*xTriticosecale rimpaui*) can all be used for this purpose, with wheat and rye being the preferred choice in the mid-South. In recent years, there has been a large demand for straw used as livestock bedding and in landscaping, as a ground cover. Rye straw is often used by horse owners because it provides a longer, stronger and more comfortable bedding for horses. It can also be used as mulch in fruit and vegetable crops.

Justification

With the ever present concern for soil loss and sustainable agriculture along with the increasing competitiveness in the tobacco industry due to the recent governmental buyout, the need for more sustainable practices of growing quality tobacco, while maintaining maximum yields, has never been greater. Because tobacco is a highly cultivated row crop, it is very susceptible to soil erosion. It is an established fact that soil erosion is reduced and controlled in conservation tillage systems by the use of protective soil covers.

In previous studies, tobacco grown under conservation tillage has had lower yields than in tilled systems. In some cases this has appeared to be related to the species and management of the vegetation used as a cover crop.

Cover crops are traditionally used as a winter ground cover for erosion control, and also as a weed control tool during the growing season. If cover crops could be used for dual purposes, such as winter forage or straw production, and still fulfill their primary purposes for conservation tillage, tobacco farmers may be more willing to implement strip-till and/or no-till tobacco production.

Objectives

1.) Evaluate the differences, if any, between killing sod in the fall or spring prior to tobacco transplanting.

2.) Determine if there are any benefits from establishing a cover crop in fall-killed sod.

3.) Investigate the effects of two different cover crops, wheat and rye, on strip-till and no-till tobacco.

4.) Explore the possibility of using cover crops as an alternative source of winter forage for livestock or straw production.

5.) Determine if conservation tillage, either no-till or strip-till, production practices can be implemented as an alternative to conventional tillage tobacco practices without reducing yield.

CHAPTER II: LITERATURE REVIEW

Definition and Description of Conservation Tillage

A conservation tillage system is defined as any tillage and planting system that leaves at least 30% of the soil surface covered by crop residue or cover crop mulch after planting (SSSA, 2007; Shelton and Bradley, 1987). Conservation tillage systems can include no-tillage, ridge-tillage, strip-tillage, mulch-tillage, and reduced tillage. Over 40% of the 112 million hectares of all crops in the United States are produced using a conservation tillage system (CTIC, 2004).

Phillips et al. (1980) define the no-tillage system as "one in which the crop is planted either entirely without tillage or with just sufficient tillage to allow placement and coverage of the seed with soil to allow it to germinate and emerge". In the case of no-till tobacco, there is enough tillage for the transplant to be placed firmly in the soil. Transplants are set in the soil using a modified conventional tobacco transplanter, as described by Morrison et al. (1973) and Pearce and Zeleznik (2003). In a typical no-tillage system the crop is planted into a killed grass sod or dead plant residue (Phillips et al., 1980) In this system, weeds are controlled by chemical herbicides, as opposed to cultivation in a conventional tillage system, and soil amendments are applied to the soil surface (Phillips et al., 1980). A winter cover crop can be established in the fall to control erosion and then killed prior to planting. Pearce et al. (2002) concluded that growers should kill winter cover crops at least 30 days before transplanting no-till tobacco. This will conserve soil moisture and nutrients, allow time for residue to begin to decompose, reduce planting problems, and improve early season growth of the tobacco.

Severe injury or stunting of tobacco transplants has been observed when glyphosate was used for the burn down of cover crops (Chappell and Link, 1977; Shilling et al., 1986). This may have been the result of transplanting too soon after the herbicide application. No-till can also be implemented into a perennial hay or pasture crop such as tall fescue (*Festuca arundicacea*) or orchardgrass (*Dactylis glomerata*). The perennial crop must be killed in the fall or spring prior to transplanting. Past research in no-till corn (*Zea mays*) following hay or pasture have found that the highest yields and the greatest weed control can be achieved when an herbicide treatment including glyphosate is applied in the fall prior to planting (Buhler and Mercurio, 1988; Buhler and Proost, 1990; Smith et al., 1992). Smith et al. (1992) reported that glyphosate applied in the spring can cause planting delays, soil moisture depletion, and delayed corn germination and plant growth. The killed cover crop provides a mulch that also helps with weed suppression during the growing season (Shilling et al., 1986). No-till planting into a heavy residue cover has been proven to reduce soil loss in Tennessee by 98 percent when compared to conventional tillage (Shelton and Bradley, 1987).

Strip-till is another form of conservation tillage in which a narrow strip 30 to 45 cm wide is tilled in the projected crop row (Moschler et al., 1971; Denton et al., 2001). The strip is usually tilled using an implement consisting of a coulter, a single subsoiler shank, and fluted coulters and/or a rolling basket which breaks up and smoothes the soil (Denton et al., 2001). The crop is later planted into the tilled strip and the area between the rows is left undisturbed. A conventional tobacco transplanter can be used for the strip-till system of growing tobacco. In a strip-till system, chemical pesticides and soil amendments can be either surface applied or incorporated into the tilled strip. Cover crops are used in the same manner as in no-till.

Advantages of Conservation Tillage

There are many benefits and advantages of implementing a conservation tillage cropping system into burley tobacco production. Advantages of no-till tobacco production might include reduced soil erosion from wind and water, labor and fuel savings, soil moisture conservation, and elimination of tillage for planting and weed control (Worsham, 1985; Wood and Worsham, 1986). Additional advantages of no-till tobacco production are more flexibility in transplanting, seasonal field operations and harvest times, and cleaner cured tobacco (Phillips and Zeleznik, 1989). Due to the extensive cultivation used in conventional tillage tobacco production, sloping land subject to soil erosion is generally not used for tobacco production. No-till allows these lands to be used for production (Chappell and Link, 1977).

Soil erosion is a primary concern in the southeast, the major tobacco producing region of the United States, due to the high rainfall amounts, soil types, and steep slopes that occur in this region (Healy and Sojka, 1985). Wood and Worsham (1986) reported 20 to 90 times more soil loss in conventional tobacco than in no-till tobacco. Erosion rates were reduced 70 to 95 percent, with an average reduction of 92 percent, in no-till tobacco in Tennessee (Yoder et al., 2005). As the amount of tillage decreases and the amount of residues or plant cover increases, soil erosion decreases. Both of these conditions are major characteristics in no-till agriculture, therefore reducing soil loss (Phillips et al., 1980).

Labor and fuel use can be reduced by using no-till production. Because the no-till system eliminates cultivation trips, such as plowing and disking, across the field prior to planting, the quantity of fuel used for crop production is reduced considerably. Phillips et al. (1980) reported 7 and 18 percent energy saving by using no-till production of corn and soybean (*Glycine max*), respectively, when compared to conventional tillage production. Post-transplant cultivations for weed control, as in conventional tillage tobacco, are eliminated, which results in additional fuel savings when producing tobacco using the no-till production system.

Soil water content is generally higher in no-till systems (Mygdakos et al., 2005; Diaz-Zorita et al., 2004). The killed mulch present in no-till serves as a barrier to water evaporation from the soil. Other research has shown that different tillage systems have no effect on soil water content (Erbach et al., 1992; Licht and Al-Kaisi, 2005). This could be due to different soil types or environmental conditions. Shilling et al. (1986) reported that in a year when adequate moisture is available, no-till tobacco yields will be lower than conventional yields, but under dry conditions similar yields can be achieved. This suggests that in a growing season when an adequate supply of water is present the no-till system contains too much moisture, probably because of the inability of the water to evaporate from the mulch covered soil. During a dry growing season, the killed cover crop conserves moisture in the soil while preventing the evaporation of excess moisture in a wet year.

Producers have more flexibility in transplant and harvest times when the no-till system is practiced (Phillips and Zeleznik, 1989). Because soil is not tilled, soil structure is maintained, which allows producers to be in the field under more moist conditions than if using conventional tillage. Chappell and Link (1977) reported that no-till transplanting can be done when the soil moisture is much higher than with conventional tillage. However, there are limits to this. Planting at high water content has been observed to result in sidewall compaction of the planting slot, which can constrict the growth of tobacco roots (H.P. Denton, personal communication).

Tobacco produced using no-till practices may produce a higher quality leaf due to the reduction of sand and soil on the lower leaves (Chappell and Link, 1977; Worsham, 1985; Phillips and Zeleznik, 1989). Humphries (1975) reported that in 1974 one tobacco company removed 3.9 million kg (8.6 million pounds) of sand at a cost of $9 million before the leaves could be processed (as quoted by: Wood and Worsham, 1986).

The strip-till system offers many, but not all, of the same benefits as the no-till system, and the addition of some. Strip tillage incorporates aspects of both no-tillage and conventional tillage (Hendrix et al., 2004). The inter-row area, which remains covered by a killed mulch or crop residue throughout the growing season as in no-till, offers all the benefits of a no-till system. These benefits include reduced soil loss from wind and water, conservation of soil moisture, cleaner cured tobacco leaves, and the ability to bring otherwise erodible land into production. The tilled strip offers the benefits of a conventional tillage system. Shinners et al. (1994) found that soil temperature was higher in a residue free band, as in strip till, than in soil covered with residue, as in no-till. Soil temperature is inversely related to soil water content and amount of residue cover. Therefore, in strip-till systems soil water content may be less than in no-till, but still higher than in conventional tillage. The absence of residue in the tilled strip allows solar radiation to warm the soil and increase soil moisture evaporation (Kaspar et al., 1990). The higher soil temperature will allow faster growth and development of tobacco transplants early in the growing season which has been found to be a problem with no-till tobacco (Chappell and Link, 1977). Because a smooth, tilled seedbed is prepared in strip-till, a conventional transplanter can be used without modifications.

Disadvantages of Conservation Tillage

Past research in conservation tillage tobacco has given mixed results in yields of cured tobacco leaf. Predominantly, conventional yields have been higher than those of conservation tillage (Moschler et al., 1971; Zartman et al., 1976; Chappell and Link, 1977; Shilling et al., 1986; Wood and Worsham, 1986), while others have reported conservation tillage yields equal to conventional yields (Phillips and Zeleznik, 1989). One cause of lower yields in no-till tobacco could be due to restricted root growth. Zartman et al. (1976) found that no-till tobacco roots were restricted to the transplanting trench early in the growing season, but later expanded vertically and grew equally as dense as those of conventional tillage. This could partially explain the reason no-till tobacco is usually slower growing early in the season. Thinner leaves produced by no-till tobacco also explain a reduction in yield (Moschler et al., 1971). The thinner leaves are possibly a result of the slow early season growth.

Early research indicated that vegetation control and fertilizer placement were problems with no-till tobacco. Chemical vegetation-killing management of the sod cover crop and weed suppression during the growing season were both vegetation control problems. Pre-emergence herbicides that can provide weed suppression throughout the growing season have since been labeled for use in tobacco production. Ellis et al. (1999) reported that effective weed control in no-till tobacco can be provided with the combination of a killed cover crop mulch and an effective pre-transplant herbicide combination.

While crop residues left on the soil surface are beneficial in conservation tillage systems, they can also be a hindrance. Crop residues act as an insulating layer on the soil surface, which blocks or reflects solar radiation, thus causing the soil to warm slowly due to reduced evaporation rates (Shinners et al., 1994), and may be amplified in poorly drained soils. This effect could be another reason for slow early season growth in no-till tobacco production. Worsham (1985) found that no-till yields are generally lower in high clay content soils, which are characteristically slowly drained soils.

Conservation tillage systems require more intensive or better management (Chappell and Link, 1977; Phillips et al., 1980). There are fewer alternatives and less chance to correct any errors that may occur in no-till. For example, extra disking before planting and cultivation during the growing season can be used to kill weeds that herbicides did not control in tilled systems, but not in no-till (Chappell and Link, 1977).

Cover Crops

Cover crops are a common and important component in tobacco production, especially in conservation tillage systems. A cover crop is defined as a close-growing crop that provides soil protection, seeding protection, and soil improvement between periods of normal crop production, or between trees in orchards and vines in vineyards. When plowed under and incorporated into the soil, cover crops may be referred to as green manure crops (SSSA, 2007). Benefits of cover crops include prevention of soil erosion, improvement of soil tilth, enhancement of soil structure, improvement of soil fertility, enhancement and preservation of environmental quality, and contributions to the management of weeds, insects pests, and plant pathogens (Luna, 1998). In conventional tobacco production, cover crops are planted in late summer to early fall to provide soil cover during winter months when soils are susceptible to erosion. In no-till systems, cover crops are killed with a herbicide or mowed in the spring prior to planting and left on the soil surface as a mulch (Pullaro, 2006). Common cover crops used in tobacco production are small grains, such as rye, triticale, barley, wheat, and oats, ryegrass, legumes such as hairy vetch, Austrian winter pea, and crimson clover, and mixtures of small grains and legumes (Hoyt, 2006). Wheat and rye provide the best weed suppressive activity in combination with glyphosate when compared to other small grains (Weston, 1990; Boz, 2003). Both wheat and rye are also extensively used due to their ease of establishment and cold hardiness during the winter.

Rye is probably the most widely used cover crop in burley tobacco production due to its ability to produce an ample amount of above ground biomass (Hoyt, 2006). In past research rye has produced from 450 to 750 g/m^2 of biomass (Yenish et al., 1996; Zasada et al., 1997). Rye is also used for its weed suppression capabilities during the summer growing season (Weston, 1990; Zasada et al., 1997). Wheat is commonly used as a winter cover in tobacco production as well. When compared to rye, wheat produces similar amounts of biomass, but may take longer into the spring to do so (Hoyt, 2006).

Wheat and rye can also be grazed by livestock in late winter and early spring or harvested as straw prior to seed head maturity (Hoyt, 2006). These winter annual cereal grasses can provide a high quality forage for livestock, during a time when perennial grass pastures are not productive. The cost of producing or purchasing stored forages in the forms of hay and silage can also be reduced by grazing winter annuals. Samples and Sule (2007) describe high-quality grasses as having at least 18% crude protein (CP), less than 35% acid detergent fiber (ADF), and less than 55% neutral detergent fiber (NDF). They found levels of CP as high as 34%, ADF values as low as 17%, and NDF values as low as 28% in rye grown in Ohio. Edmisten et al. (1998) found total dry matter yields (initial growth plus all regrowth) of rye cut at the vegetative stage (four leaves unfolded) to be from 2.30 to 3.56 Mg ha^{-1} and wheat cut at the same stage to be from 2.74 to 3.57 Mg ha^{-1}. Harvesting the forages at this stage would simulate grazing by livestock. They later concluded that forages at the vegetative or boot stages would provide high quality forage for grazing, and rye would be the best choice based on yields and nutritive value (Edmisten et al., 1998). When harvested just prior to seed head maturity, in the milk stage, as in straw production, rye yielded 8.11 Mg ha^{-1} (Edmisten et al., 1998). Because rye generally breaks dormancy and begins growing earlier in the spring than wheat, it can grow into the milk stage and be harvested as straw in time to allow for preparation for no-till tobacco transplanting in late spring.

CHAPTER III: MATERIALS AND METHODS

General Description

Research was conducted in 2006 and 2007 at two locations: The University of Tennessee Highland Rim Research and Education Center (HR), in Springfield, Tennessee, and The University of Tennessee Research and Education Center at Greeneville (GR), in Greeneville, Tennessee. The HR is located in northern middle Tennessee and the GR in northeast Tennessee. Two experiments were conducted at each site during both years. The first experiment, hereafter referred to as the cover crops study, investigated the effect of cover crop species and management practices on conservation tillage burley tobacco. The second experiment, hereafter referred to as the sod study, evaluated the effects of timing of chemical burndown of an established perennial grass sod on conservation tillage burley tobacco with and without the use of cover crops. Two years of cover crop data and one year of tobacco data will be included in this thesis.

Highland Rim Soil Types

In 2006, the cover crops study was conducted on a Dickson (fine-silty, siliceous, semiactive, thermic Glossic Fragiudults) silt loam soil with inclusions of Taft (fine-silty, siliceous, semiactive, thermic Glossaquic Fragiudults) silt loam soils with 2 to 5 percent slopes. The Dickson series consists of very deep, moderately well drained soils found on nearly level to sloping uplands with slopes ranging from 0 to 12 percent. Runoff on these soils is medium to slow, and permeability above the fragipan is moderate and slow to very slow in the fragipan (USDA-NRCS, 2007). The Taft series consists of very deep, somewhat poorly drained soils found on nearly level upland flats, stream terraces, and in depressions with slopes from 0 to 2 percent. Runoff and permeability on Taft soils is slow (USDA-NRCS, 2007). In 2007, the cover crops study was largely on Dickson soils, with a small area of Hamblen (fine-loamy, siliceous, semiactive, thermic Fluvaquentic Eutrudepts) silt loam soils. Slopes ranged from 0 to 5 percent. The Hamblen series consists of very deep, moderately well drained soils on flood plains with 0 to 3 percent slopes. Runoff on these soils is slow and permeability is moderate. These soils are subject to flooding (USDA-NRCS, 2007).

The sod study in 2006 was conducted on a Dickson silt loam with a 2 to 5 percent slope. This study was also on a Dickson silt loam in 2007, but with slopes ranging from 2 to 8 percent.

Greeneville Soil Types

The cover crops study in 2006 was conducted on a combination of Nolichucky (fine-loamy, siliceous, semiactive, mesic Typic Paleudults) and Waynesboro (fine, kaolinitic, thermic Typic Paleudults) loam soils on 2 to 5 percent slopes. The Nolichucky series consists of very deep, well drained soils on high stream terraces with slopes ranging from 2 to 30 percent. Runoff on these soils is medium to rapid with moderate permeability (USDA-NRCS, 2007). The Waynesboro series consists of very deep, well drained, moderately permeable soils with 2 to 30 percent slopes. Runoff on these soils is medium and permeability is moderate (USDA-NRCS, 2007). In 2007, this study was partially on a Dunmore (fine, kaolinitic, mesic Typic Paleudults) silty clay loam on 5 to 12 percent slopes and partially on an Emory (fine-silty, siliceous, active, thermic

Fluventic Humic Dystrudepts) silt loam on 2 to 5 percent slopes. Dunmore soils are on uplands and are very deep, well drained, moderately permeable soils with slopes from 2 to 50 percent. Runoff is medium to rapid (USDA-NRCS, 2007). The Emory series is a very deep, well drained, moderately permeable soil with slopes ranging from 0 to 4 percent. This soil is usually found in narrow strips along intermittent drainageways, on toe slopes and in bottoms of upland depressions. Runoff is slow to medium (USDA-NRCS, 2007).

In 2006, the sod study was conducted on a combination of Dewey (fine, kaolinitic, thermic Typic Paleudults) silty clay loam on 5 to 12 percent slopes, Emory silt loam on 2 to 5 percent slopes, and Nolichucky loam on 2 to 5 percent slopes. The Dewey series consists of very deep, well drained, moderately permeable soils found on uplands with 2 to 40 percent slopes. Runoff on these soils is medium or rapid and permeability is moderate (USDA-NRCS, 2007). The 2007 study was largely on a Decatur (fine, kaolinitic, thermic Rhodic Paleudults) silty clay loam on 5 to 12 percent slopes, and partially on a Dewey silty clay loam on 12 to 20 percent slopes. The Decatur series consists of very deep, well drained, moderately permeable soils that are on level to strongly sloping uplands in valleys. Runoff on these soils is medium. Slopes on these soils range from 2 to 50 percent (USDA-NRCS, 2007).

Experimental Procedures – Cover Crops Study

The cover crops study was arranged in a randomized complete block design consisting of 13 treatments replicated 4 times. Treatments are

1. Wheat cover crop; no-till tobacco

2. Wheat cover crop; strip-till tobacco
3. Wheat cover; simulated grazing; no-till tobacco
4. Wheat cover; simulated grazing; strip-till tobacco
5. Rye cover crop; no-till tobacco
6. Rye cover crop; strip-till tobacco
7. Rye cover; simulated grazing; no-till tobacco
8. Rye cover; simulated grazing; strip-till tobacco
9. Rye cover; straw; no-till tobacco
10. Rye cover; straw; strip-till tobacco
11. No cover (soybean residue); no-till tobacco
12. No cover (soybean residue); strip-till tobacco
13. Conventional tillage tobacco

Plot dimensions were 4.3 m X 9.1 m, with a 9.1 m alley between replications. At GR, this study site had been in soybeans the previous year and corn the year prior to that. At HR, the study site used had been in a no-till wheat-soybean rotation for several years. In 2005, cover crops were planted on 13 October and 7 November at GR and HR, respectively. In 2006, cover crops were planted using a no-till drill 19 October and 28 November at GR and HR, respectively. At GR, 'Cardinal' and 'Verne' wheat varieties were used in 2005 and 2006, respectively. At HR, 'FFR 510' wheat was used both years. 'Winter Magic' rye was used both years at both locations. Covers were seeded at a rate of 93.2 to 132.3 kg/ha. Cover crops in the simulated grazing and straw treatments were fertilized with 50.5 kg N/ha on 14 February 2006 and 8 February 2007 at GR, and on 23

March 2006 and 23 February 2007 at HR. The simulated grazing treatments were harvested two times in the vegetative stage at both locations the first year to simulate grazing. In 2007, grazing treatments were harvested two times at HR and three times at GR. The straw treatments were harvested one time at both locations each year after head emergence. All cover crops were sprayed with glyphosate (N-(phosphonomethyl)glycine) at a rate of 2.23 kg active ingredient (a.i.)/ha on 24 April 2006 and 18 April 2006 at GR and HR, respectively. In 2007, cover crops were killed on 24 April at GR and HR. An additional application of paraquat (1,1'-dimethyl-4-4'-bipyridinium dichloride) prior to transplanting was used to kill any regrowth of the cover crops that may have occurred. Strip-till plots were prepared using a two-row KMC® (Kelley Manufacturing Company, Tifton, GA) strip-tillage implement once in late fall or winter and then 1-2 more times prior to transplanting. This implement had a single subsoiler shank, a fluted coulter on each side angled to slightly bed the soil behind the shank, and a rolling basket to firm and partially till the soil. Tilled strips were approximately 30 to 45 cm wide and 30 cm deep. Conventional plots at GR were tilled with the KMC implement to simulate chisel plowing, then a tractor mounted tiller was used to prepare the final seedbed. At HR, conventional plots were tilled primarily with a chisel plow, and then finished with a disk harrow. At GR, sulfentrazone (N-[2,4-dichloro-5-[4-(difluoromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-tria zol-1-yl]phenyl]methanesulfonamide) and clomazone (2-(2-Chlorophenyl)methyl-4, 4-dimethyl-3-isoxazolidinone) were applied at rates of 0.37 kg a.i./ha and 0.84 kg a.i./ha, respectively, prior to transplanting. There was an infestation of nutsedge (*Cyperus* spp.)

at GR and, for the sake of the experiment, 2 applications of bentazon (3-(1-methylethyl)-1*H*-2, 1,3-benzothiadiazin-4 (3*H*)-one 2,2-dioxide) were applied at a rate of 0.84 kg a.i./ha. At HR, sulfentrazone and napropamide (N,N-diethyl-2-(1-naphthalenyloxy)propanamide) were applied at rates of 0.27 kg a.i./ha and 2.23 kg a.i./ha. Fertilizer was surface applied to all plots in one broadcast application prior to transplanting. Nitrogen (N) was applied at a rate of 231 kg/ha at GR and 226 kg/ha at HR. N source was diammonium phosphate and ammonium nitrate. Phosphorous (P) and Potassium (K) were applied according to soil test at each site. Tobacco was transplanted using a modified conventional transplanter (Pearce and Zeleznik, 2003) at a row width of 1.0 m and a plant (in-row) spacing of 0.53 m. This transplanter had a single cutting coulter and a narrow fixed shank in front of the transplanter shoe. Burley tobacco variety 'TN90' was used at GR and 'KT204' at HR. Tobacco transplanting dates at GR and HR were 7 June and 9 June 2006, respectively. Standard burley production practices were used during the growing season, with the exception of cultivation for weed control. Cultivation was only conducted in conventional treatments. Tobacco was harvested on 14 September and 25 September 2006 at GR and HR, respectively. The middle two tobacco rows of each plot were used to obtain data. After curing, tobacco was stripped into four grades, by stalk position. Yield is reported as total cured leaf, with all grades combined.

Experimental Procedures – Sod Study

The sod study was arranged in a randomized complete block design consisting of 9 treatments replicated 4 times. The treatments are:

1. Spring killed sod; no-till tobacco
2. Spring killed sod; strip-till tobacco
3. Fall killed sod; no-till tobacco
4. Fall killed sod; strip-till tobacco
5. Fall killed sod, wheat cover; no-till tobacco
6. Fall killed sod, wheat cover; strip-till tobacco
7. Fall killed sod, rye cover; no-till tobacco
8. Fall killed sod, rye cover; strip-till tobacco
9. Conventional tillage tobacco

Plot dimensions were 4.3 m X 9.1 m with a 9.1 m alley between replications. At GR, an established orchardgrass sod was used and at HR, an established tall fescue sod was used. The site at GR was part of a normal tobacco rotation, and at HR the site had been in long-term pasture. Fall killed sod treatments were killed on 4 October and 8 November 2005 at GR and HR, respectively. In 2006, fall killed treatments were killed on 9 October and 28 November at GR and HR, respectively. Sod was killed with an application of glyphosate at a rate of 2.23 kg a.i./ha. Cover crops were seeded using a no-till drill on 13 October and 14 November 2005 at GR and HR, respectively. In 2006, cover crops were seeded on 19 October and 28 November at GR and HR, respectively. Cover crop planting and burndown, as well as tillage treatments were similar to procedures in the cover crops study. Sulfentrazone and clomazone were preplant applied at both locations. Rates of 0.37 kg a.i./ha and 0.27 kg a.i./ha of sulfentrazone at GR and HR, respectively, and 0.84 kg a.i./ha of clomazone at both sites, were applied. Transplanting dates were 7

June and 9 June 2006 at GR and HR, respectively. Tobacco production practices were the same for this study as the cover crops study. Tobacco was harvested on 14 September and 26 September 2006 at GR and HR, respectively. The middle two tobacco rows were used to obtain data. Once cured, tobacco was stripped into 4 grades. Yield is reported as total cured leaf.

Simulated Grazing

The grazed treatments were harvested 2 times at each location in 2006 and at HR in 2007, and 3 times at GR in 2007. At GR, grazed plots were harvested on 16 March and 11 April 2006 the first year, and 19 March, 30 March, and 23 April the second year. The criteria used to determined the timing of harvest was when one of the cover crops reached 25 cm in height. Due to timing conflicts, some simulated grazing harvests were late. At GR, plots were harvested using a push type lawn mower with a bag attached to catch the clippings. Two strips, each as wide as the mower (0.5 m), were cut and weighed. The harvested area of the sample was 9.8 m^2. Harvest dates at HR in 2006 were 23 March and 15 April. In 2007, plots were harvested on 30 March and 23 April. At HR, a self-propelled forage harvester with an onboard scale was used to harvest and weigh a sample from each plot. The machine harvested one strip (0.9 m wide) the length of the plot from each plot. Then the remaining forage was cut and removed from the plot to simulate grazing. A sub-sample was collected from each plot and taken to the lab. These samples were weighed wet, oven dried at 60ºC for 24 hours, and reweighed. Wet and dry weights were then used to calculate moisture content, which was then used to calculate total yield of dry matter forage per plot.

Straw

Rye was harvested prior to seed head maturity as straw. Plots were harvested on 18 April and 15 April 2006 at GR and HR, respectively. In 2007, plots were harvested on 23 April at both locations. At GR, straw was cut with a disc type hay mower, then a sample was collected from a 0.9 m X 9.1 m area and weighed. Straw was harvested using the forage harvester described above at HR. Sub-samples were collected from each plot, weighed, dried at 60ºC for 24 hours, and reweighed. Fresh and dry weights were used to calculate total dry matter from each plot as in the simulated grazing plots.

Residue Cover

Residue cover measurements were taken using the line transect method (Sloneker and Moldenhauer, 1977) on 13 June and 15 June 2006 at GR and HR, respectively. A tape measure was stretched diagonally for a distance of 7.62 m across each plot. One end of the tape was placed in the center of the first row of the plot, approximately 1.02 m from the end of the plot, then stretched diagonally to the center of the last row in the plot. At every 0.30 m increment along the tape an observation was made to determine if residue intersected the tape at this point. A total of 25 observations were made in each plot. The number of times residue intersected the tape measure at each observation was used to calculate the percentage of residue cover for the plot.

Soil Temperature

Soil temperature was recorded with HOBO® Pendant Temperature/Light Data Loggers (Onset Computer Corporation, Pocasset, MA), at 30 minute intervals for 35 days (14 June through 18 July 2006) during the growing season. Loggers were placed in the row equidistant between plants at a depth of 10 cm below the soil surface. Soil temperature was recorded at GR only, and only in certain treatments in each study. In the cover crops study, soil temperature was recorded in treatments 5, 6, 7, 8, and 13. In the sod study, treatments 3, 4, 7, 8, and 9 were recorded. Recordings were only taken in 3 replications in each study. A daily minimum, daily maximum, range, and average temperature was calculated for each treatment.

Soil Water Content

Soil water content measurements were taken using the gravimetric method at both GR and HR. Samples were taken in treatments 5, 6, 7, 8, 11, 12, and 13 in the cover study, and 3, 4, 7, 8, and 9 in the sod study. All replications were sampled. Measurements were taken three times in each study at both locations. At HR, sampling dates for both studies were 15 June, 21 June, and 6 July 2006. At GR, dates were 13 June, 27 June, and 2 August 2006. Six soil cores were taken at a depth of 0 to 15 cm with a standard soil probe from two locations within the two middle rows of tobacco in each plot. At each location, individual cores were obtained from three row positions (in-row, between row, and between these two positions). This procedure was followed to account for soil water variability as a result of distance from plants, and the effects of strip tillage. The soil from each plot was then placed into a bucket, mixed, put into a metal can, and taken to the lab. In the lab, the soil was weighed wet in the can, dried at 105°C for 24 hours, and reweighed. The weight of the can was tared out for each sample. Soil water content, dry basis, was calculated using the equation below:

$$\% \text{ water} = ((\text{weight of wet soil} / \text{weight of dry soil}) - 1) * 100.$$

Early Season Plant Height

Plant height measurements were taken on 19 July and 21 July 2006 at GR and HR, respectively. Four plants from the middle two rows of each plot were randomly selected and measured. Leaves on the upper part of the stalk were extended upwards and the height of the upper most tip was measured.

Penetrometer

Penetrometer readings were taken in both studies, in the same treatments as soil water content, at both locations to determine soil penetration resistance. At GR, measurements were taken on 27 September 2006. At HR, they were taken on 21 June and 6 July 2006 in the sod and cover crops test, respectively. Six readings were taken using a hand held cone-type penetrometer at a depth of 15 cm at two randomly selected plot locations within the middle two rows of each plot. Readings are the maximum resistance encountered. At each plot location readings were taken at 3 positions (in row, between row, and between these spots). Measurements were recorded in the field and then converted to kilograms (kg) of force using the following equation:

$$X \text{ (kg)} = 0.146730302 * Y \text{ (indicator gauge reading)} + 0.9881864888$$

In some plots, readings of over 177.06 kg were taken. Readings this high are out of the calibration range of the instrument, therefore were inaccurate measurements. All measurements above 177.06 kg were recorded as 177.06 kg.

Bulk Density

Bulk density samples were taken on 27 September and 12 October 2006 at GR and HR, respectively. The core method was used to obtain bulk density measurements

(Blake and Hartge, 1986). Bulk density was measured only in those treatments sampled for soil water content and penetration resistance. One cylindrical core sample measuring 7.62 cm in diameter and 7.62 cm in height was taken from each plot. Sampling locations within each plot were randomly selected. The sample was obtained by using a sliding hammer device which drove the empty core into the soil to a depth of 7.62 cm. The soil surface was smoothed prior to sampling by removal of a few mm of surface soil. The core was then dug out of the ground with a shovel and the ends trimmed flush so there was no soil outside the core. The soil was then removed from the cylinder, placed in a bag, and dried at 105°C for 24 hours and then weighed. Bulk density was then calculated using the following equation:

$$Db = \text{Mass of dried soil (g)} / \text{volume of sample (cc)}.$$

Statistical Analysis

Data collected from both studies were analyzed using standard analysis of variance procedures with NCSS (2004) software package. Linear comparisons were made between treatments and groups of treatments at a probability level of 0.10. All comparisons were pre-determined based on particular questions of interest.

Comparisons for the cover crops study were: (1) conventional tillage versus NT and ST, (2) conventional tillage versus NT, (3) conventional tillage versus ST, (4) NT versus ST, (5) cover unharvested (wheat and rye) versus cover harvested (simulated grazing and straw), (6) cover unharvested versus soybean crop residue, (7) cover harvested versus soybean crop residue, (8) wheat cover crop (unharvested and simulated grazing) versus rye cover crop (unharvested and simulated grazing), (9) the interaction between comparisons 4 and 5, (10) the interaction between comparisons 4 and 6, (11) the interaction between comparisons 4 and 7, and (12) the interaction between comparisons 4 and 8. These comparisons were made for yield, early season plant height, and residue cover. For soil water content, bulk density, and penetrometer readings, only comparisons 1-6 were made. Comparisons 1, 3, 4, and 5 were made for soil temperature readings. Comparisons for the sod study were: (1) conventional tillage versus NT and ST, (2) conventional tillage versus NT, (3) conventional tillage versus ST, (4) NT versus ST, (5) fall killed sod versus spring killed sod, (6) fall killed sod versus fall killed sod with a cover crop (wheat and rye), (7) wheat cover crop versus rye cover crop, and (8) the interaction between comparisons 4 and 5. These comparisons were made for yield, early season plant height, and residue cover. For soil water content, bulk density, and penetrometer readings, only comparisons 1-4 were made. Comparisons 1, 3, 4, and 6 were made for soil temperature readings. In addition to the comparisons already mentioned for penetrometer readings in both studies, two comparisons for row position ((1) in row position versus other two row positions and (2) row middle versus intermediate position) and eight comparsisons for the interactions between these two row position comparisons and the previously mentioned treatment comparisons were made.

CHAPTER IV: RESULTS AND DISCUSSION

Simulated Grazing

GR – 2006

Simulated grazing treatments were harvested on 16 March and 11 April 2006 (Table 4.1 and Figure 4-1). Wheat yielded 1250 kg/ha and rye 1575 kg/ha on the first harvest date. On the second harvest date, wheat yielded 951 kg/ha and rye 797 kg/ha. Yields were significantly different on the first date but not on the second date. Total yield of wheat was 2201 kg/ha and total yield of rye was 2372 kg/ha, which is not significantly different. The lower yield of rye the second harvest can probably be attributed to the height at which it was cut the first harvest, which was 44 cm compared to a height of only 24 cm for the wheat.

HR – 2006

Simulated grazing treatments were harvested on 23 March and 15 April 2006 (Table 4.1 and Figure 4-1). Wheat yielded 636 kg/ha and rye 814 kg/ha on the first harvest date. On the second harvest date, wheat yielded 1121 kg/ha and rye 1563 kg/ha. Yields were not significantly different on the first date but were on the second date. Total yields were 1757 kg/ha for wheat and 2377 kg/ha for rye, which is significantly different.

GR -2007

Simulated grazing treatments were harvested on 19 and 30 March and 23 April 2007 (Table 4.2 and Figure 4-2). Wheat yielded 797 kg/ha and rye 1068 kg/ha on the first harvest date. On the second harvest date, wheat yielded 1175 kg/ha and rye 1118 kg/ha.

Table 4. 1. 2006 Grazing Yields

	GR		HR	
Treatments	16-Mar-06	11-Apr-06	23-Mar-06	15-Apr-06
	--------------------	(kg/ha)	--------------------	
wheat	1250	951	636	1121
rye	1575	797	814	1563
sig. diff.	*	NS	NS	*

* = sig. diff. at 0.10 prob., NS = not significant

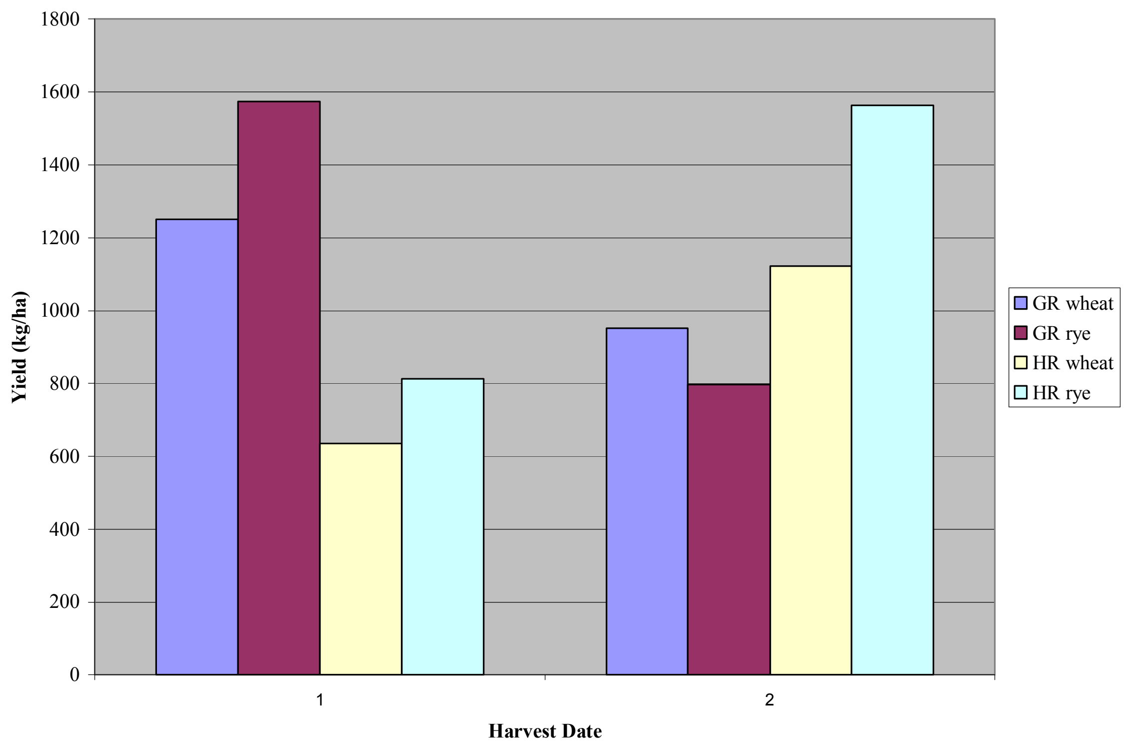

Figure 4- 1. 2006 Grazing Yields

The third cutting yielded 445 kg/ha of wheat and 749 kg/ha of rye. Yields were not significantly different on the second date, but were on the first and third dates. Total yield of wheat was 2417 kg/ha and total yield of rye was 2935 kg/ha, which was significantly different.

HR – 2007

Simulated grazing treatments were harvested on 30 March and 23 April 2007 (Table 4.2 and Figure 4-2). On the first harvest date, wheat yielded 366 kg/ha and 1168 kg/ha on the second harvest date. Rye yielded 1011 kg/ha on the first harvest date and 1387 on the second. Yields were significantly different on the first date, but not on the second date. The total yields were 1534 kg/ha for wheat and 2398 kg/ha for rye, which was significantly different.

Straw

GR and HR – 2006

Straw treatments were harvested on 18 April and 15 April 2006 at GR and HR, respectively. Straw yields were 10102 kg/ha at GR and 4939 kg/ha at HR. When dry matter yields of rye managed for straw and rye and wheat for grazing were compared, rye straw yields were four fold at GR and over two fold at HR (Table 4.3 and Figure 4-3).

Table 4. 2. 2007 Grazing Yields

	GR			HR	
Treatments	19-Mar-07	30-Mar-07	23-Apr-07	30-Mar-07	23-Apr-07
	------------------------- (kg/ha) --------------------------				
wheat	797	1175	445	366	1168
Rye	1068	1118	749	1011	1387
sig. diff.	*	NS	*	*	NS

* = sig. diff. at 0.10 prob., NS = not significant

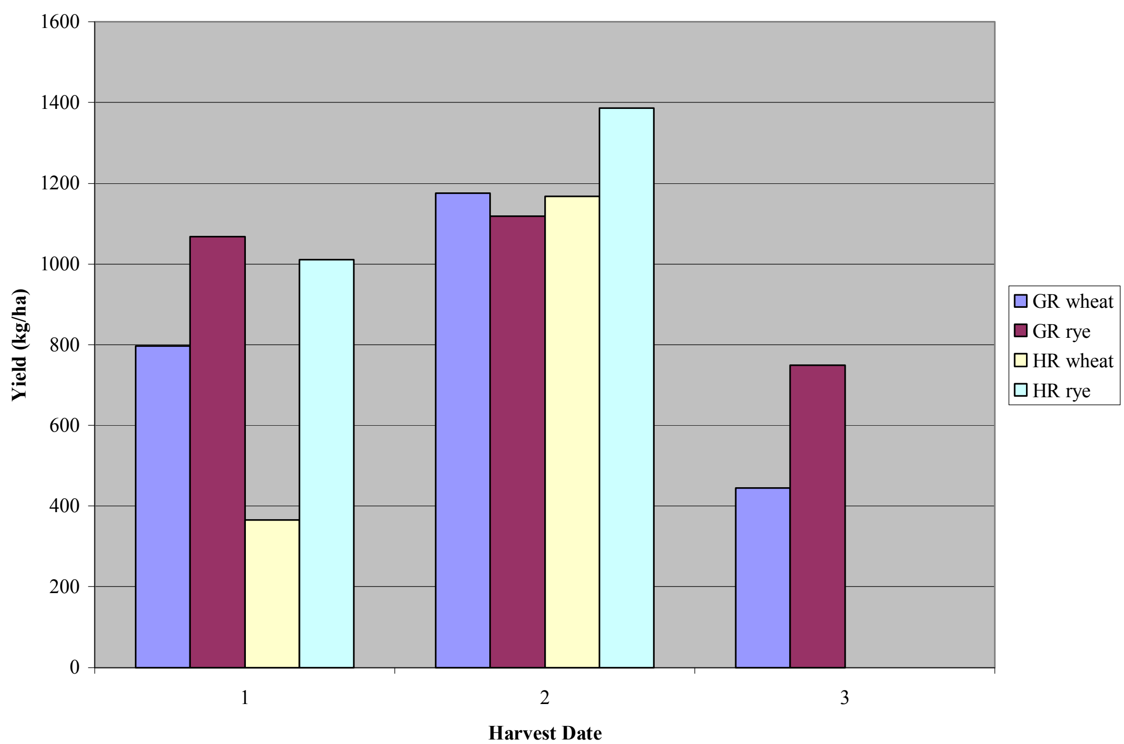

Figure 4- 2. 2007 Grazing Yields

Table 4. 3. 2006 Grazing and Straw Yield Totals

Treatments	GR 2006	HR 2006
	-------- (kg/ha) --------	
wheat	2201	1757
rye	2372	2377
rye straw	10102	4939
Comparison		
wheat vs. rye	NS	S

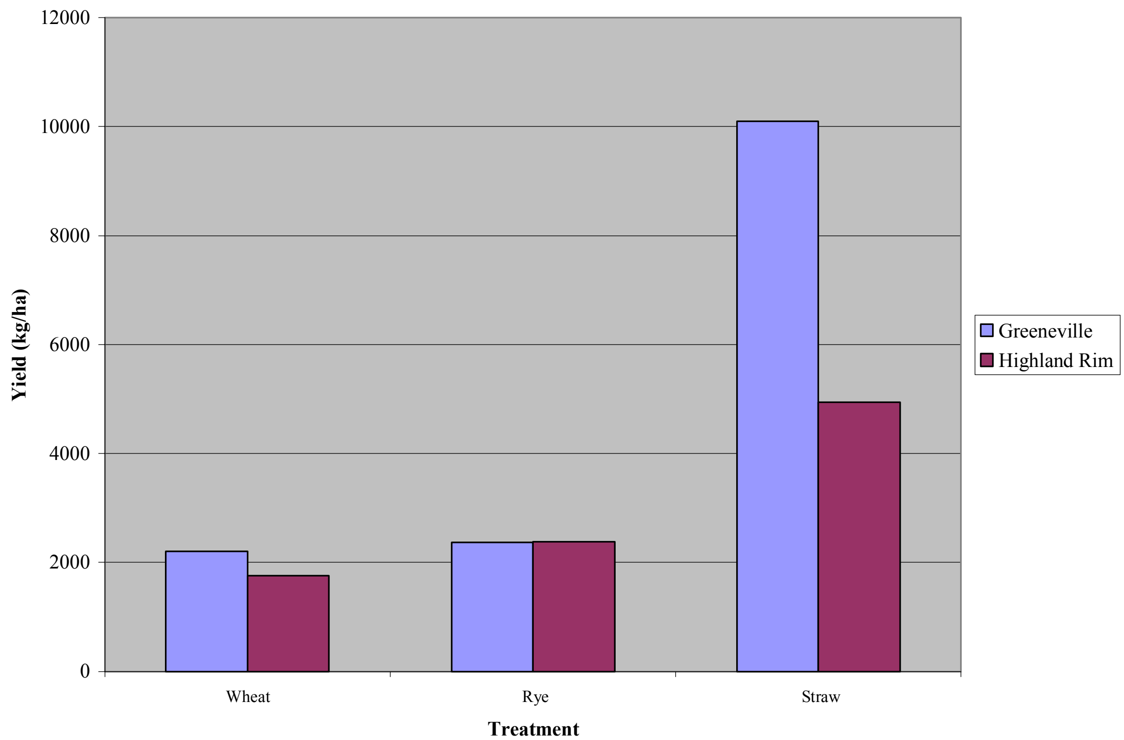

Figure 4- 3. 2006 Grazing and Straw Yield Totals

GR and HR – 2007

Straw treatments were harvested on 23 April 2007 at GR and HR. Straw yields were 7570 kg/ha at GR and 4287 kg/ha at HR. When compared with the combined yields from both harvest dates of the grazing treatments, rye straw yields were two fold at GR and almost two fold at HR (Table 4.4 and Figure 4-4).

Residue Cover

GR cover crops study

Residue cover measurements showed significant differences between treatments in the overall ANOVA and in linear comparisons 1-7 (Table 4.5). Measurements ranged from 0 percent cover in the conventional treatment to 85 percent in the NT, rye cover treatment. These results fall in line with what we would expect with the NT treatments having the highest percent of residue cover and the ST treatments having slightly lower cover measurements, because cover crop residues had been partially incorporated into the soil in the 30 to 45 cm tilled strips. Residue cover in the unharvested cover treatments was significantly higher than the grazed and straw treatments. Linear Comparison 7 (cover harvested vs. soybean crop residue) showed that the harvested-cover treatments had a higher percentage of residue cover than the soybean crop residue treatments. Though not statistically different, rye did provide more ground cover than wheat. All conservation tillage treatments met the standard of 30 percent residue cover. By removing cover crops, residue cover was generally reduced 15 to 20 percent. ST reduced residue cover compared to NT by 10 to 30 percent.

Table 4. 4. 2007 Grazing and Straw Yield Totals

Treatments	GR 2007	HR 2007
	-------- (kg/ha) --------	
wheat	2417	1534
rye	2935	2398
rye straw	7570	4287
Comparison		
wheat vs. rye	S	S

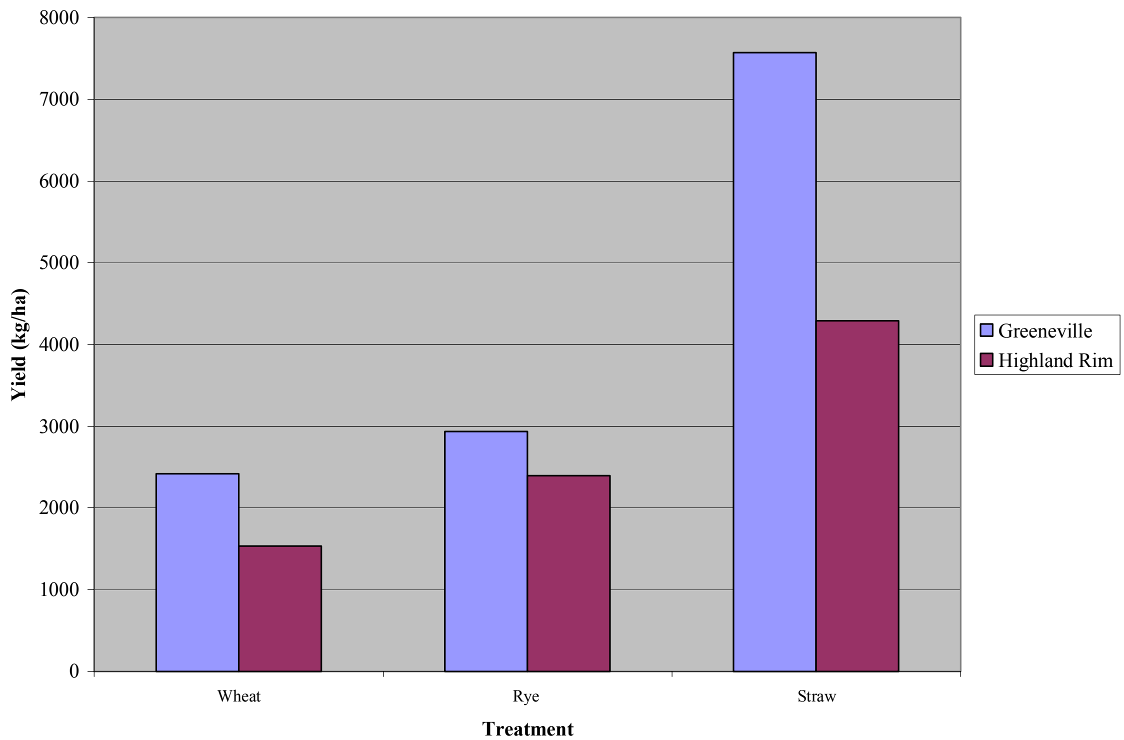

Figure 4- 4. 2007 Grazing and Straw Yield Totals

HR cover crops study

Residue cover measurements were lower at this location due to a less dense stand of cover crops. Another possible explanation for the lower residue cover measurements in the ST treatments could be dry soil conditions at the time of tillage caused the strip-till implement to till a wider strip than normal. There were significant differences between treatments and linear comparisons 1-5, 9, and 11 (Table 4.5). Measurements ranged from 0 to 71 percent in the conventional tillage treatment and the NT, rye cover treatment, respectively. The results for the NT treatments are what we would expect, but the ST treatments had less cover (due to a field procedure malfunction) than we would ideally want, which is at least 30 percent cover. ST had a much greater effect in lowering residue cover at HR than at GR. Crop residue provided as much ground cover as the cover crops at HR.

GR sod study

Significant differences were shown between treatments and linear comparisons 1-6 for residue cover measurements (Table 4.6). Measurements ranged from 74 to 1 percent residue cover in the spring killed, NT treatment and the conventional treatment, respectively. In general, residue cover levels are adequate. Residue cover in ST was reduced about 27 percent when compared to NT. When a cover crop was established in fall killed treatments, residue cover increased by 13.5 percent. These values were expected, with NT being the greatest, then ST and conventional, and both spring killed and fall killed with a cover higher than fall killed with no cover.

Table 4. 5. Cover Crops Study - Plant Height and Residue Cover

		Plant Height		Residue Cover	
Treatment		GR	HR	GR	HR
		------ (cm) ------		---- (% cover) ----	
1	wheat, NT	70.96	57.47	83	68
2	wheat, ST	82.63	70.41	67	13
3	wheat grazed, NT	69.14	61.28	63	57
4	wheat grazed, ST	76.68	66.91	54	17
5	rye, NT	73.34	57.79	85	71
6	rye, ST	74.61	73.26	73	21
7	rye grazed, NT	66.36	59.77	69	57
8	rye grazed, ST	78.66	66.99	55	16
9	rye straw, NT	67.87	60.88	73	69
10	rye straw, ST	75.41	64.93	45	20
11	soybean crop residue, NT	64.93	60.80	63	68
12	soybean crop residue, ST	70.01	71.20	44	15
13	Conventional	74.93	84.69	0	0
Linear Comparison					
1	conventional vs. NT & ST	NS	S	S	S
2	conventional vs. NT	S	S	S	S
3	conventional vs. ST	NS	S	S	S
4	NT vs. ST	S	S	S	S
5	cover unharvested vs. cover harvested	NS	NS	S	S
6	cover unharvested vs. soybean crop residue	S	NS	S	NS
7	cover harvested vs. soybean crop residue	S	NS	S	NS
8	wheat cover vs. rye cover	NS	NS	NS	NS
9	interaction between comparisons 4 & 5	NS	NS	NS	S
10	interaction between comparisons 4 & 6	NS	NS	NS	NS
11	interaction between comparisons 4 & 7	NS	NS	NS	S
12	interaction between comparisons 4 & 8	NS	NS	NS	NS

HR sod study

Residue cover measurements showed significant differences between treatments and linear comparisons 1-5 (Table 4.6). Values ranged from 83 to 0 percent cover in the spring killed, NT treatment and the conventional treatment, respectively. Residue cover in ST was reduced about 54 percent when compared to NT. Again, lower than ideal residue cover in the ST treatments are probably due to dry soil conditions at the time of tillage causing a tilled strip wider than desired. The values are similar to expected, though fall killed treatments with a cover crop were expected to be significantly higher than the fall killed treatments without a cover crop. All ST treatments were below 30 percent residue cover (due to a field procedure malfunction). Use of a cover crop made little difference at this location, and the difference between fall and spring kill was less than at GR.

Soil Temperature

GR cover crops study

Soil temperature data was obtained from 14 June to 18 July 2006 (Table 4.7 and Figure 4-5). Significant differences were shown between treatments for daily maximum, minimum, and average temperatures. For daily maximum and average temperatures, significant differences were shown for all linear comparisons made. For daily minimum temperatures, significant differences were observed for linear comparisons 1, 2, and 4. No significant differences were shown for daily range of temperatures. Temperature tended to increase as residue cover decreased among treatments, which is expected,

Table 4. 6. Sod Study - Plant Height and Residue Cover

		Plant Height		Residue Cover	
Treatment		GR	HR	GR	HR
		------ (cm) ------		---- (% cover) ----	
1	spring killed, NT	64.14	55.88	74	83
2	spring killed, ST	64.09	72.95	43	27
3	fall killed, NT	67.31	57.23	59	75
4	fall killed, ST	71.76	74.61	31	21
5	fall killed, wheat cover, NT	60.64	61.04	68	78
6	fall killed, wheat cover, ST	70.01	73.26	44	22
7	fall killed, rye cover, NT	69.45	54.69	73	75
8	fall killed, rye cover, ST	66.75	64.85	49	27
9	Conventional	62.55	73.58	1	0
Linear Comparison					
1	conventional vs. NT & ST	NS	S	S	S
2	conventional vs. NT	NS	S	S	S
3	conventional vs. ST	S	NS	S	S
4	NT vs. ST	NS	S	S	S
5	fall killed vs. spring killed	NS	NS	S	S
6	fall killed vs. fall killed with cover	NS	NS	S	NS
7	wheat cover vs. rye cover	NS	S	NS	NS
8	interaction between comparisons 4 & 5	NS	NS	NS	NS

but the effect was more pronounced for maximum than for minimum temperature. Because temperature was taken in the row, temperatures were expected to be similar, if not equal, in the ST and conventional tillage treatments, but this was not the case. This could be the result of shading of the tilled strip by the residue cover or heat transfer from the warmer, tilled strip to the cooler, residue covered, row middle.

When only the first ten days of data (14 June through 23 June 2006) were analyzed, similar results were obtained (Table 4.8), but the trends were more pronounced. However, daily range showed significant difference between treatments. Values for daily temperature range were higher in the first ten days compared to all 35 days, which indicates greater fluctuation between temperature extremes early in the season. Linear comparisons 1, 2, and 4 for range did show significant differences for the first ten days of recordings. These comparisons also indicate that as residue cover decreases, temperature range increases. However, minimum temperature was still higher in the lower residue treatments.

GR sod study

Significant differences between treatments were shown for daily minimum and average temperatures (Table 4.9 and Figure 4-6). For daily minimum temperatures, significant differences were shown for linear comparisons 1, 2, and 4, which show that conventional tillage had a higher daily minimum temperature than NT and ST combined and also ST alone. Rye cover crop treatments had lower minimum temperatures than treatments without a cover crop, which is expected. Average daily temperatures showed

Table 4. 7. GR Cover Crops Study - Soil Temperature

Treatment		Max	Min	Avg	Range
		-------------- (°C) --------------			
5	rye, NT	27.3	21.2	23.8	6.1
6	rye, ST	28.3	21.4	24.3	6.9
7	rye grazed, NT	29.5	22.2	25.4	7.3
8	rye grazed, ST	30.0	22.3	25.7	7.7
13	Conventional	30.6	22.4	26.1	8.2
Linear Comparison					
1	conventional vs. NT & ST	S	S	S	NS
2	conventional vs. ST	S	S	S	NS
3	NT vs. ST	S	NS	S	NS
4	cover unharvested vs. cover harvested	S	S	S	NS

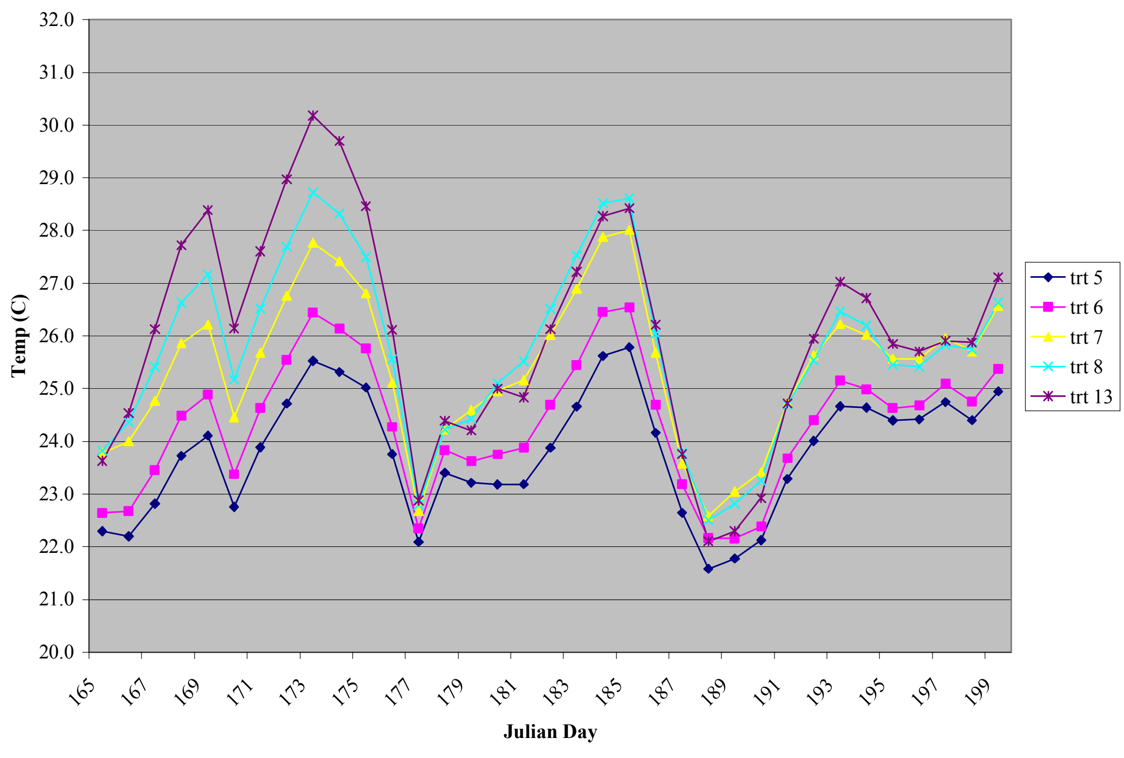

Figure 4- 5. GR Cover Crops Study - Average Daily Soil Temperature

Table 4. 8. GR Cover Crops Study - Soil Temperature (First 10 days)

Treatment		Max	Min	Avg	Range
		--------------	(°C)	--------------	
5	rye, NT	28.3	20.3	23.7	8.0
6	rye, ST	29.5	20.7	24.4	8.8
7	rye grazed, NT	30.8	21.6	25.7	9.2
8	rye grazed, ST	32.0	21.9	26.4	10.2
13	Conventional	33.7	22.2	27.3	11.5
Linear Comparison					
1	conventional vs. NT & ST	S	S	S	S
2	conventional vs. ST	S	S	S	S
3	NT vs. ST	S	NS	S	NS
4	cover unharvested vs. cover harvested	S	S	S	S

significant difference for linear comparison 4, which again shows that the more residue that is present, the lower the soil temperature will be. Linear comparison 1 for daily temperature range showed significant difference between conventional tillage and NT and ST, with conventional being the lowest. Though not statistically different, the conventional tillage temperature range is the lowest of all the treatments. Effects in this study were less than in the cover crops study, which might reflect the generally lower amount of residue cover in this test. Treatments with less than 50 to 60 percent residue cover tended to be close in temperature to conventional tillage in these studies.

When only the first ten days of data were analyzed, significant differences between treatments were seen for daily maximum, minimum, and average temperature (Table 4.10). Daily maximum temperatures for NT were significantly lower than ST. Linear comparisons 1, 2, and 4 were significantly different for daily minimum temperatures, which show that conventional is higher than NT and ST combined, and also ST alone. Minimum temperatures are also lower when a rye cover crop is present, when compared to no cover crop at all. Significant differences were shown in linear comparisons 1, 3, and 4 for average daily temperatures. Conventional tillage average soil temperature was significantly higher than NT and ST together, and ST was higher than NT. Average daily temperature was higher in treatments where there was no cover present compared to treatments where a rye cover crop was present. Linear comparison 3 for range showed that NT was significantly lower than ST, which means that temperature fluctuations in NT treatments was less extreme than in ST treatments in the early season. Compared to the cover crops study, although not statistically comparable, temperatures were generally warmer the first ten days in the sod study. Also, there is less difference between conservation tillage and conventional tillage.

Soil Water Content

GR cover crops study

Soil water samples were collected three times during the 2006 summer (Table 4.11 and Figure 4-7). Significant differences were observed between treatments on all three sampling dates. On the first date, 13 June 2006, significant differences were shown in linear comparisons 5 and 6. Soil water content ranged from 18.13 to 20.74 percent. Rye cover treatments had higher soil water content than the rye grazed and soybean crop residue treatments, which is to be expected due to the presence of more residue cover in the rye treatments. On the second date, 27 June 2006, significant differences were

Table 4. 9. GR Sod Study - Soil Temperature

Treatment		Max	Min	Avg	Range
		-------------- (°C) --------------			
3	fall killed sod, NT tobacco	31.7	22.8	26.7	8.8
4	fall killed sod, ST tobacco	30.9	22.7	26.4	8.2
7	fall killed sod rye cover, NT tobacco	29.9	22.2	25.6	7.8
8	fall killed sod rye cover, ST tobacco	31.2	22.4	26.2	8.8
9	Conventional	30.4	23.0	26.4	7.4
Linear Comparison					
1	conventional vs. NT & ST	NS	S	NS	S
2	conventional vs. ST	NS	S	NS	NS
3	NT vs. ST	NS	NS	NS	NS
4	cover vs. no cover	NS	S	S	NS

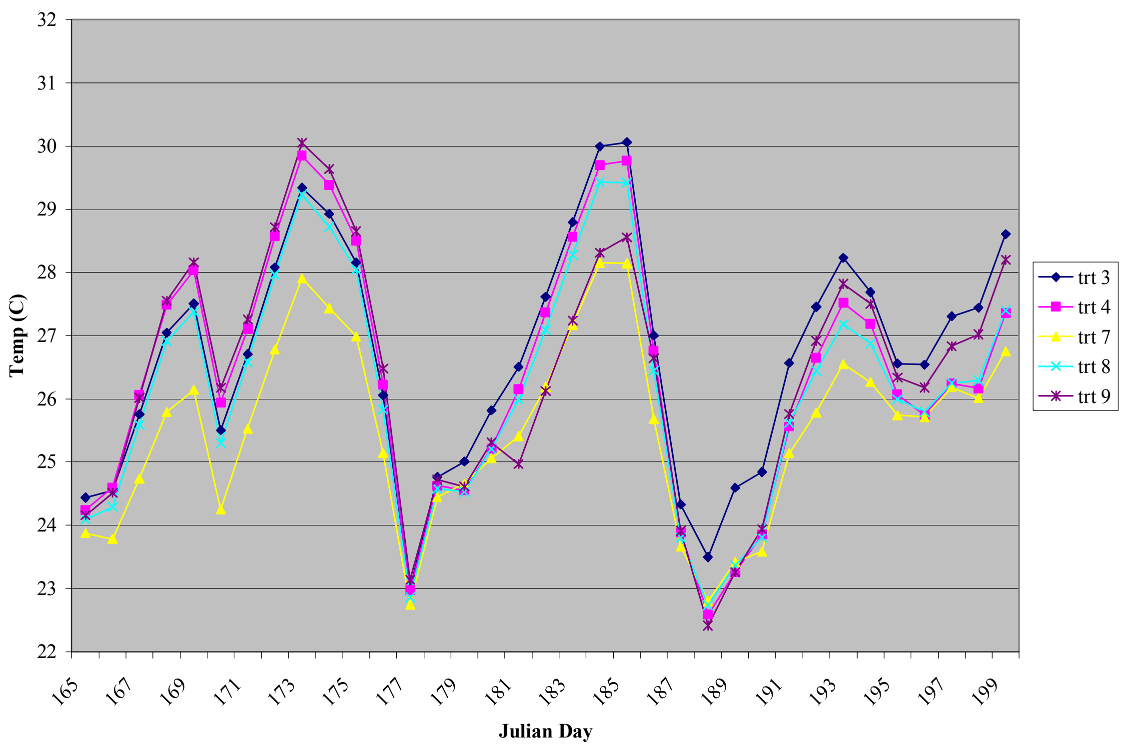

Figure 4- 6. GR Sod Study - Average Daily Soil Temperature

Table 4. 10. GR Sod Study - Soil Temperature (First 10 days)

Treatment		Max	Min	Avg	Range
		-------------- (°C) --------------			
3	fall killed sod, NT tobacco	32.4	22.4	26.8	9.9
4	fall killed sod, ST tobacco	32.8	22.6	27.1	10.2
7	fall killed sod rye cover, NT tobacco	31.0	21.6	25.6	9.4
8	fall killed sod rye cover, ST tobacco	32.9	22.0	26.6	10.8
9	Conventional	32.7	22.8	27.2	9.9
Linear Comparison					
1	conventional vs. NT & ST	NS	S	S	NS
2	conventional vs. ST	NS	S	NS	NS
3	NT vs. ST	S	NS	S	S
4	Cover vs. no cover	NS	S	S	NS

observed for linear comparisons 5 and 6. Values ranged from 15.86 to 17.14 percent. Rye grazed treatments were significantly higher than crop residue treatments. On 2 August 2006, the third and final date, soil water content values were much lower than the previous two dates. Significant differences were observed for linear comparisons 1-3 and 5. Values ranged from 9.51 to 11.37 percent. The first three comparisons showed that the conventional treatment was lower than both NT and ST, combined and individually. This shows that soil water was more conserved in the conservation tillage treatments than in the conventional treatments, allowing more water to be available to the tobacco later in the growing season.

Table 4. 11. GR Cover Crops Study - Soil Water Content

Treatment		13-Jun-06	27-Jun-06	2-Aug-06
		---------- (% water) ----------		
5	rye, NT	20.25	17.14	11.34
6	rye, ST	20.74	17.03	11.37
7	rye grazed, NT	18.36	16.11	10.87
8	rye grazed, ST	18.79	16.88	10.47
11	Crop residue, NT	18.13	15.86	11.09
12	Crop residue, ST	18.54	16.02	10.80
13	Conventional	19.55	16.69	9.51
Linear Comparison				
1	conventional vs. NT & ST	NS	NS	S
2	conventional vs. NT	NS	NS	S
3	conventional vs. ST	NS	NS	S
4	NT vs. ST	NS	NS	NS
5	cover unharvested vs. cover harvested	S	S	S
6	cover unharvested vs. crop residue	S	S	NS

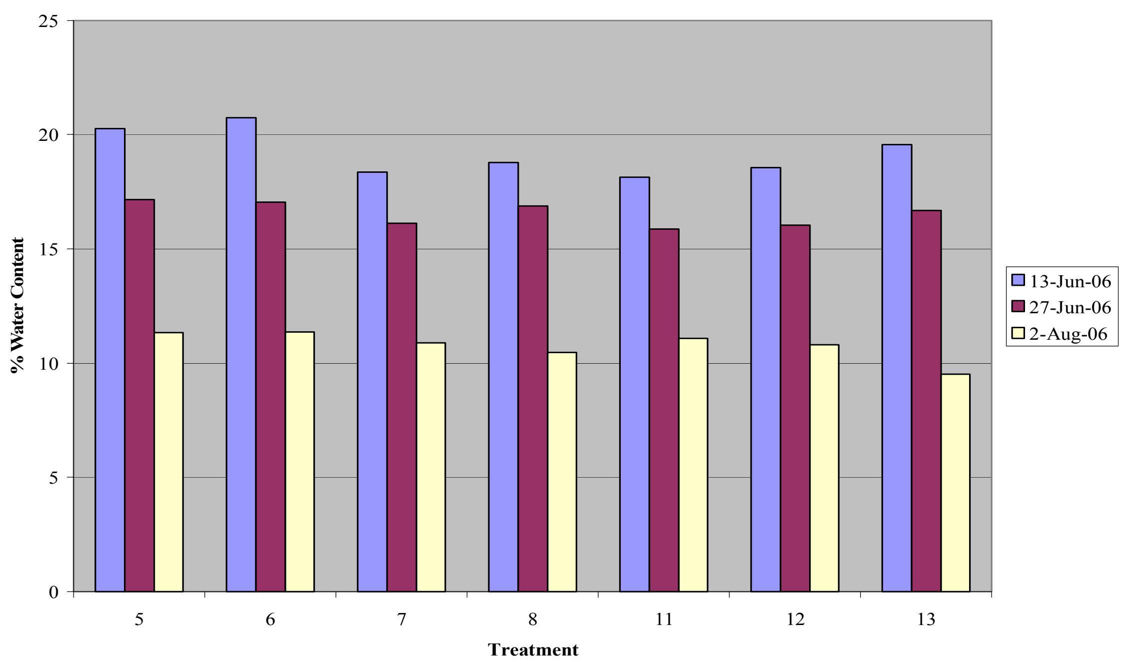

Figure 4- 7. GR Cover Crops Study - Soil Water Content

HR cover crops study

Soil water content samples were obtained three times throughout the 2006 growing season (Table 4.12 and Figure 4-8). Values for the 15 June 2006 ranged from 14.58 to 18.22 percent and showed no significant differences between treatments. On the second date, 21 June 2006, values ranged from 16.24 to 17. 43 percent and showed no significant differences between treatments in the overall ANOVA. Significant differences were observed for linear comparisons 5 and 6. Rye cover treatments had higher soil water content than the rye grazed and crop residue treatments, which is to be expected due to the presence of more residue cover in the unharvested cover crop treatments. The third date, 6 July 2006, showed significant differences between treatments, which ranged from 17.44 to 19.84 percent, and linear comparisons 1-4. These samples were collected the day after a substantial rainfall event. Comparisons show the conventional tillage treatment to be significantly higher than the NT and ST treatments, and ST to be significantly higher than NT. A possible explanation for the higher water content in the conventional tillage treatment could be due to the presence of a plow pan formed by primary tillage, which may not allow water to infiltrate past a certain depth. Another possible explanation could be that more continuous macropores in the conservation tillage treatments may have allowed more rapid downward movement of water.

GR sod study

Soil water content samples were collected three times during the 2006 summer (Table 4.13 and Figure 4-9). On the first date, 13 June 2006, there were no significant differences among treatments or linear comparisons. Soil water ranged from 18.26 to 19.60 percent in the fall killed, ST and conventional treatment, respectively. Fall killed treatments with a rye cover crop contained more soil water than the fall killed treatments without a cover crop, which is expected. Values from the second date ranged from 15.32 to 16.37 percent water in the fall killed, NT and the fall killed, rye cover, NT treatment, respectively. The third and final sampling date, 2 August 2006, showed no significant differences between treatments or linear comparisons. Soil water content ranged from 10.19 to 11.14 percent in the fall killed, ST and fall killed, rye cover, ST treatments, respectively.

HR sod study

Soil water samples were collected three times throughout the 2006 summer (Table 4.14 and Figure 4-10). On 15 June 2006 there were significant differences between treatments and linear comparisons 1, 3, and 4. NT and ST combined and ST alone were significantly higher than conventional, and ST was higher than NT. Values ranged from 16.28 percent in the conventional treatment to 19.11 percent in the fall killed, rye cover, ST treatment. The 19.11 percent soil water in the fall killed, rye cover, ST treatment might be the result of a high value in replication two of 22.76 percent. On 21 June 2006 samples showed no significant differences in treatments or linear comparisons. Soil water content ranged from 17.40 percent to 18.39 in the fall killed, NT and the fall killed, rye cover, NT treatments, respectively. The final sampling date, 6 July 2006, occurred the day after a substantial rainfall event. There were significant differences among treatments and linear comparisons 1-5. These comparisons showed conventional to be

Table 4. 12. HR Cover Crops Study - Soil Water Content

	Treatment	15-Jun-06	21-Jun-06	6-Jul-06
		----------	(% water)	----------
5	rye, NT	17.49	16.94	18.16
6	rye, ST	17.89	17.43	18.48
7	rye grazed, NT	16.28	16.50	17.44
8	rye grazed, ST	14.58	16.37	18.57
11	soybean crop residue, NT	18.22	16.83	17.81
12	soybean crop residue, ST	16.18	16.24	18.31
13	Conventional	16.92	16.68	19.84
Linear Comparison				
1	conventional vs. NT & ST	NS	NS	S
2	conventional vs. NT	NS	NS	S
3	conventional vs. ST	NS	NS	S
4	NT vs. ST	NS	NS	S
5	cover unharvested vs. cover harvested	NS	S	NS
6	cover unharvested vs. crop residue	NS	S	NS

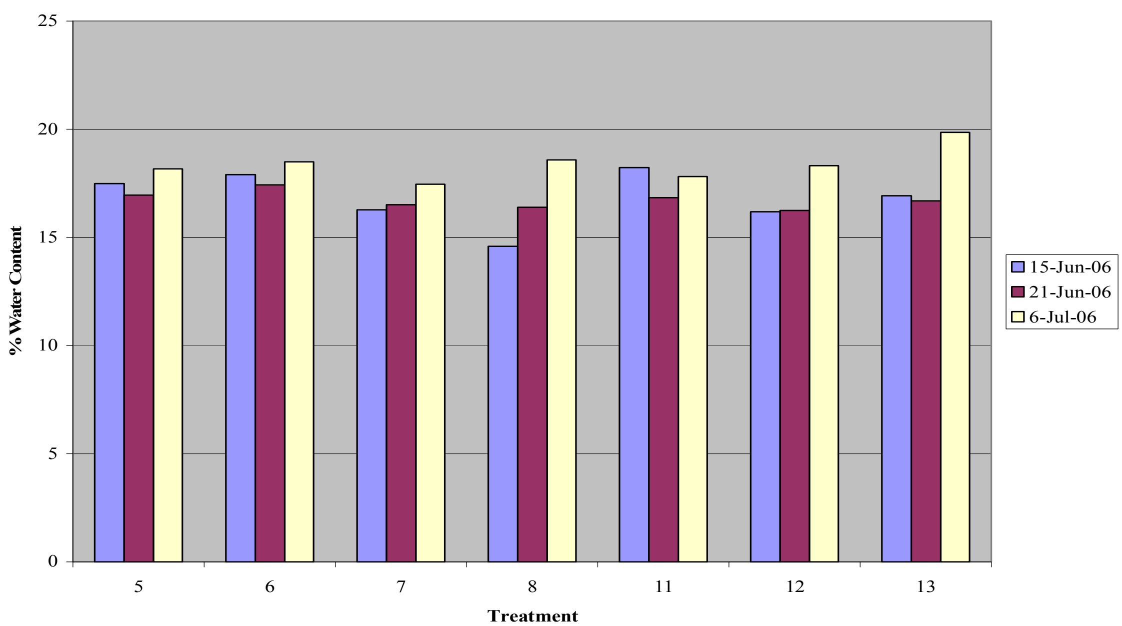

Figure 4- 8. HR Cover Crops Study - Soil Water Content

the highest in soil water content, followed by ST, and NT having the lowest soil water content. This rank is in the complete opposite order of was expected, but could possibly be explained by the same reasoning for similar results in the cover crops study.

Fall killed treatments with a cover crop were significantly higher than those without a cover crop, which is expected. Values on this date ranged from 18.79 to 20.48 percent in the fall killed, NT and conventional treatments, respectively. Overall, soil water differences were not very great.

Early Season Plant Height

GR cover crops study

Early season plant height measurements showed significant differences between treatments and linear comparisons 2, 4, 6, and 7 (Table 4.5). Both conventional tillage and ST treatments were significantly higher than NT treatments, treatments where cover crops were unharvested were significantly higher than crop residue treatments, and harvested cover crop treatments were significantly higher than crop residue treatments. Plant height measurements ranged from 64.93 to 82.63 cm. The lowest measurement was taken from the crop residue, NT treatment and the highest from the wheat cover, ST treatment. Linear regression analysis between plant height and tobacco yield at the 0.10 probability level shows a correlation between the two, with an R-squared value of 0.0581.

Table 4. 13. GR Sod Study - Soil Water Content

Treatment		13-Jun-06	27-Jun-06	2-Aug-06
		---------- (% water) ----------		
3	fall killed, NT	18.90	15.32	10.37
4	fall killed, ST	18.26	15.85	10.19
7	fall killed, rye cover, NT	18.68	16.37	10.55
8	fall killed, rye cover, ST	19.33	16.24	11.14
9	Conventional	19.60	16.13	10.56
Linear Comparison				
1	conventional vs. NT & ST	NS	NS	NS
2	conventional vs. NT	NS	NS	NS
3	conventional vs. ST	NS	NS	NS
4	NT vs. ST	NS	NS	NS

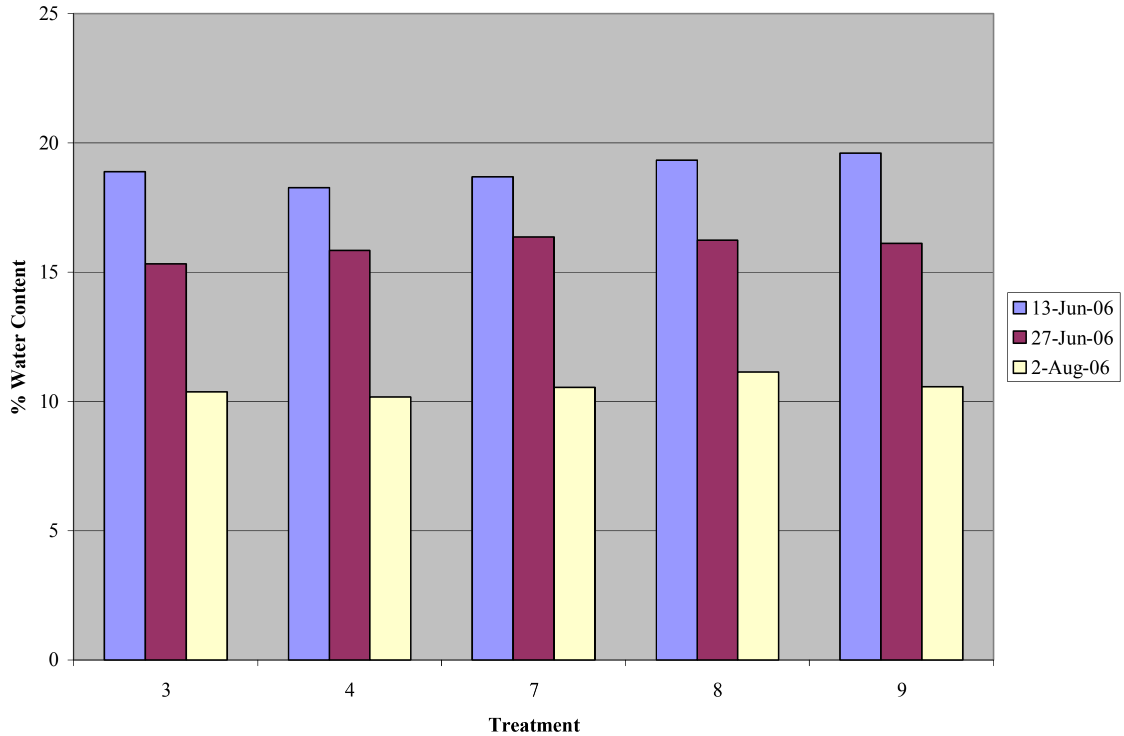

Figure 4- 9. GR Sod Study - Soil Water Content

HR cover crops study

Early season plant height measurements showed significant differences between treatments and linear comparisons 1-4 (Table 4.5). Conventional tillage was significantly higher than NT and ST treatments combined and individually, and ST was significantly higher than NT. Plant height measurements ranged from 57.47 to 84.69 cm, with the wheat cover, NT treatment being the lowest and the conventional treatment the highest. At this location, plant height was somewhat of a good indicator of tobacco yield. Linear regression analysis between plant height and tobacco yield at the 0.10 probability level shows a correlation between the two, with an R-squared value of 0.3944.

GR sod study

Plant height measurements at this location did not show any significant differences among treatments and only showed a significant difference in the linear comparison made between conventional tillage and the ST treatments where ST was higher than conventional tillage (Table 4.6). Measurements ranged from 60.64 to 71.76 cm. The lowest measurement was the fall killed, wheat cover, NT treatment and the highest was the fall killed, ST treatment. Again, at this location plant height in the early season was not a particularly good indicator of yield. Linear regression analysis between plant height and tobacco yield at the 0.10 probability level shows a correlation between the two, with an R-squared value of 0.0203.

HR sod study

Plant height measurements at HR showed significant differences between treatments and in linear comparisons 1, 2, 4, and 7 (Table 4.6). Conventional tillage was higher than NT and ST treatments combined and NT treatments alone, ST was higher than NT, and wheat cover treatments were higher than rye-cover treatments. Heights ranged from 54.69 cm in the fall killed, rye cover, NT treatment to 74.61 in the fall killed, ST treatment. Plant height measurements were indicative of yield at this location. Linear regression analysis between plant height and tobacco yield at the 0.10 probability level shows a correlation between the two, with an R-squared value of 0.1701.

Table 4. 14. HR Sod Study - Soil Water Content

Treatment		15-Jun-06	21-Jun-06	6-Jul-06
		---------- (% water) ----------		
3	fall killed, NT	16.97	17.40	18.79
4	fall killed, ST	17.77	17.88	19.06
7	fall killed, rye cover, NT	17.55	18.39	18.96
8	fall killed, rye cover, ST	19.11	17.82	19.96
9	Conventional	16.28	17.50	20.48
Linear Comparison				
1	conventional vs. NT & ST	S	NS	S
2	conventional vs. NT	NS	NS	S
3	conventional vs. ST	S	NS	S
4	NT vs. ST	S	NS	S

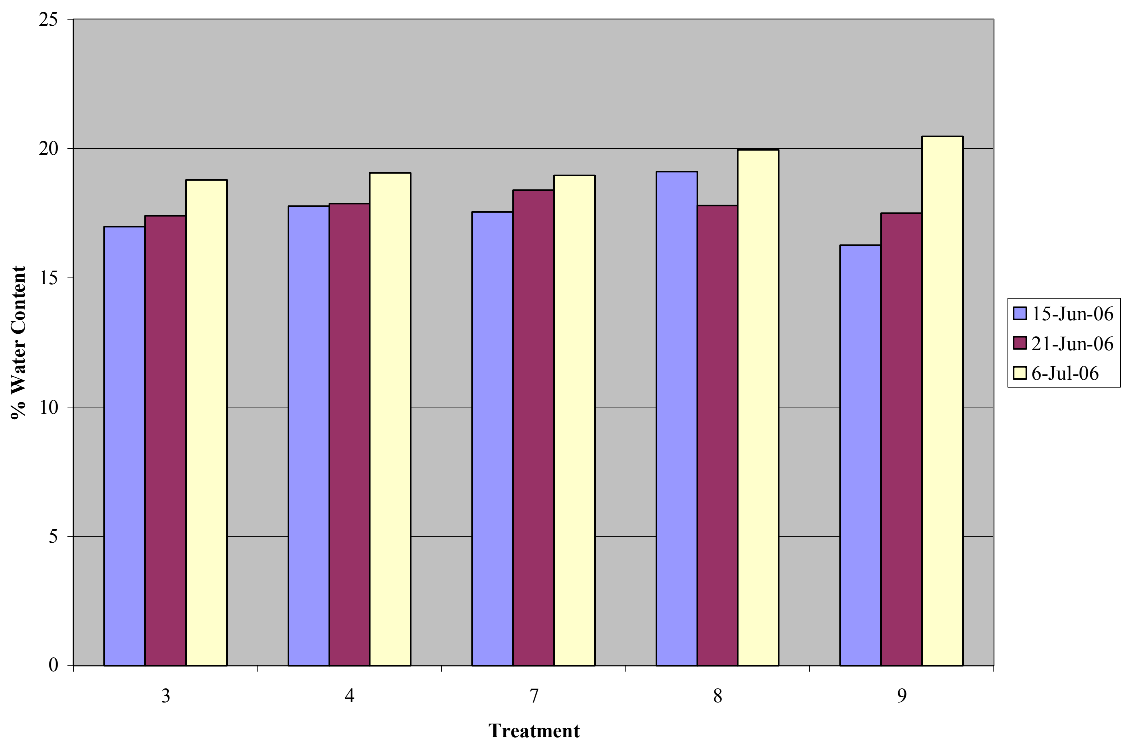

Figure 4- 10. HR Sod Study - Soil Water Content

Penetrometer

GR cover crops study

Penetrometer readings at GR were taken on 27 September 2006 (Table 4.15). Significant differences were observed between treatments and row positions. When linear comparisons were made using treatment means, significant differences were shown in comparisons 1-6. Conventional tillage was lower than NT and ST combined and individually, and ST was lower than NT. When cover crops were not removed, penetrometer readings were significantly lower than both grazed and crop residue treatments. Readings ranged from 78.96 to 124.38 kg of in the conventional tillage and crop residue, NT treatments, respectively. Linear comparisons made for row positions showed that penetration resistance increases as you move away from the row. There was not an interaction between row position and tillage; penetration resistance was less in the row and higher in the middles for all tillage practices.

HR cover crops study

Penetrometer readings were taken on 6 July 2006 in the cover crops test at HR (Table 4.15). Significant differences were shown between treatments and row positions at this location, as well as linear comparisons 1, 2, and 4. Conventional tillage was significantly lower than NT and ST combined and NT, but was statistically not different than ST. ST was lower than NT. Readings ranged from 93.26 kg in the rye grazed, ST treatment to 166.18 kg in the rye grazed, NT treatment. Linear comparisons at this location also showed greater resistance as you move away from the row. Comparisons 11,12, and 16 were also significant. Comparisons 11 and 12 tell us that penetration resistance in ST increases more than conventional and NT as you move away from the row. Comparison 16 shows us that ST has less resistance at the intermediate row position than does NT.

GR sod study

Penetrometer readings in this study showed no significant differences between treatments or linear comparisons, but did show differences between row positions (Table 4.16). Values ranged from 91.00 to 126.74 kg in the fall killed, rye cover, NT treatment and the fall killed, NT treatment, respectively. Row position comparisons show us that penetration resistance increases as you move away from the row. Again, this relationship was not different between tillage treatments.

HR sod study

Penetrometer readings in the sod study at HR were taken on 21 June 2006 (Table 4.16). Readings showed significant differences between treatments, row positions, and linear comparisons 1, 2, and 4. This indicates that conventional tillage was lower than NT and ST combined and NT, but was not different than ST. ST was significantly lower than NT. Readings ranged from 69.90 to 135.61 kg in the conventional tillage and fall killed, NT treatments, respectively. Again, row position comparisons indicate penetration resistance increases as you move away from the row. Comparisons 7-9 are also significant. They suggest that penetration resistance in ST and NT increase more than conventional as you move away from the row.

Table 4. 15. Cover Crops Study - Penetrometer

Treatment		GR			HR		
		In Row	Interm.	Betw. Row	In Row	Interm.	Betw. Row
		------------------------------- kg -------------------------------					
5	rye, NT	79.73	81.03	86.18	146.69	170.24	174.18
6	rye, ST	57.81	95.23	97.77	38.64	108.36	147.10
7	rye grazed, NT	77.62	130.83	135.49	157.86	166.86	173.82
8	rye grazed, ST	69.13	108.54	123.36	19.28	106.14	154.36
11	soybean crop residue, NT	96.22	137.87	139.04	161.18	162.46	154.26
12	soybean crop residue, ST	69.95	108.03	129.30	27.00	124.48	171.85
13	Conventional	51.65	79.36	105.86	74.48	99.65	123.97
Linear Comparison							
1	conventional vs. NT & ST		S			S	
2	conventional vs. NT		S			S	
3	conventional vs. ST		S			NS	
4	NT vs. ST		S			S	
5	unharvested vs. cover harvested		S			NS	
6	cover unharvested vs. crop residue		S			NS	
7	in row vs. other two positions		S			S	
8	middle vs. intermediate position		S			S	
9	interaction between 1 and 7		NS			NS	
10	interaction between 2 and 7		NS			NS	
11	interaction between 3 and 7		NS			S	
12	interaction between 4 and 7		NS			S	
13	interaction between 1 and 8		NS			NS	
14	interaction between 2 and 8		NS			NS	
15	interaction between 3 and 8		NS			NS	
16	interaction between 4 and 8		NS			S	

Bulk Density

GR cover crops study

Bulk density samples were collected on 27 September 2006 at GR (Table 4.17). Bulk density was not significantly different between treatments in the overall ANOVA, but was significantly different in linear comparison 2. Comparisons show that bulk density was significantly lower in conventional tillage than in NT treatments. Values ranged from 1.44 to 1.61 g/cc in the conventional tillage and rye-cover, NT treatments, respectively. The use of ST reduced bulk density in the row to levels close to those in conventional tillage. Ideal bulk density for our soils, which are loams and silty clay loams at GR and silt loams at HR, are less than 1.40 g/cc for the GR soils and less than 1.30 g/cc for the HR soils (USDA-NRCS, 2007b).

HR cover crops study

Samples were collected on 12 October 2006 at HR and were significantly different between treatments and also linear comparisons 1, 2, 4, and 5 (Table 4.17). These comparisons indicate that conventional tillage was lower than NT and ST combined and also lower than NT. ST was significantly lower than NT, and rye cover treatments were higher than rye grazed treatments. Soil bulk densities ranged from 1.34 g/cc in the rye grazed, ST and conventional treatments to 1.50 in the rye, NT and crop residue, NT treatments.

GR sod study

Soil bulk density in this study ranged from 1.53 to 1.59 g/cc and there were no significant differences among treatments or linear comparisons (Table 4.18).

Table 4. 16. Sod Study - Penetrometer

	Treatment	GR			HR		
		In Row	Interm.	Betw. Row	In Row	Interm.	Betw. Row
		------------------------------- kg -------------------------------					
3	fall killed, NT	82.13	142.64	155.46	100.45	144.80	161.57
4	fall killed, ST	55.90	91.28	152.72	36.20	84.88	146.49
7	fall killed, rye cover, NT	69.31	94.71	108.96	107.48	126.20	153.74
8	fall killed, rye cover, ST	70.21	113.44	124.90	50.55	83.42	109.88
9	Conventional	67.48	104.38	117.13	66.43	59.84	83.43
Linear Comparison							
1	conventional vs. NT & ST		NS			S	
2	conventional vs. NT		NS			S	
3	conventional vs. ST		NS			NS	
4	NT vs. ST		NS			S	
5	in row vs. other two positions		S			S	
6	middle vs. intermediate position		S			S	
7	interaction between 1 and 5		NS			S	
8	interaction between 2 and 5		NS			S	
9	interaction between 3 and 5		NS			S	
10	interaction between 4 and 5		NS			NS	
11	interaction between 1 and 6		NS			NS	
12	interaction between 2 and 6		NS			NS	
13	interaction between 3 and 6		NS			NS	
14	interaction between 4 and 6		NS			NS	

HR sod study

Bulk density was significantly different in this study among treatments and linear comparisons 2 and 4, which shows that NT is significantly higher than both conventional tillage and ST (Table 4.18). Samples ranged from 1.29 g/cc in the fall killed, rye cover, ST and conventional tillage treatments to 1.46 g/cc in the fall killed, NT and fall killed, rye cover, NT treatments. The use of ST reduced bulk density levels in the row to levels comparable to those in conventional tillage.

Tobacco Yield

GR cover crops study

Tobacco was harvested on 14 September 2006 and showed significant differences among treatments and also between linear comparisons 1, 2, 3, 5, and 6 (Table 4.19 and Figure 4-11). Yields ranged from 3162 to 3927 kg/ha for the NT wheat cover treatment and conventional tillage treatment, respectively. Conventional tillage yielded significantly higher than NT and ST treatments combined and individually, and the harvested cover (grazed and straw) and crop residue treatments both yielded significantly higher than the unharvested cover treatments.

HR cover crops study

Tobacco was harvested on 25 September 2006 and showed significant differences between treatments and linear comparisons 1-4 (Table 4.19 and Figure 4-12). Yields ranged from 2134 to 3070 kg/ha in the NT rye cover treatment and conventional tillage treatment, respectively. The relatively low yield for treatment 8 (rye grazed, ST) can be

Table 4. 17. Cover Crops Study - Bulk Density

	Treatment	GR	HR
		------ (g/cc) ------	
5	rye, NT	1.61	1.50
6	rye, ST	1.54	1.48
7	rye grazed, NT	1.55	1.48
8	rye grazed, ST	1.47	1.34
11	soybean crop residue, NT	1.53	1.50
12	soybean crop residue, ST	1.54	1.41
13	Conventional	1.44	1.34
Linear Comparison			
1	conventional vs. NT & ST	NS	S
2	conventional vs. NT	S	S
3	conventional vs. ST	NS	NS
4	NT vs. ST	NS	S
5	cover unharvested vs. cover harvested	NS	S
6	cover unharvested vs. crop residue	NS	NS

Table 4. 18. Sod Study - Bulk Density

	Treatment	GR	HR
		------ (g/cc) ------	
3	fall killed, NT	1.58	1.46
4	fall killed, ST	1.54	1.30
7	fall killed, rye cover, NT	1.59	1.46
8	fall killed, rye cover, ST	1.56	1.29
9	Conventional	1.53	1.29
Linear Comparison			
1	conventional vs. NT & ST	NS	NS
2	conventional vs. NT	NS	S
3	conventional vs. ST	NS	NS
4	NT vs. ST	NS	S

Table 4. 19 Cover Study - Tobacco Yield

		Tobacco Yield	
Treatment		GR	HR
		------ (kg/ha) ------	
1	wheat, NT	3162	2274
2	wheat, ST	3295	2591
3	wheat grazed, NT	3553	2366
4	wheat grazed, ST	3401	2533
5	rye, NT	3233	2134
6	rye, ST	3246	2445
7	rye grazed, NT	3450	2314
8	rye grazed, ST	3840	2342
9	rye straw, NT	3325	2324
10	rye straw, ST	3412	2619
11	soybean crop residue, NT	3327	2435
12	soybean crop residue, ST	3520	2594
13	Conventional	3927	3070
Linear Comparison			
1	conventional vs. NT & ST	S	S
2	conventional vs. NT	S	S
3	conventional vs. ST	S	S
4	NT vs. ST	NS	S
5	cover unharvested vs. cover harvested	S	NS
6	cover unharvested vs. soybean crop residue	S	NS
7	cover harvested vs. soybean crop residue	NS	NS
8	wheat cover vs. rye cover	NS	NS
9	interaction between comparisons 4 & 5	NS	NS
10	interaction between comparisons 4 & 6	NS	NS
11	interaction between comparisons 4 & 7	NS	NS
12	interaction between comparisons 4 & 8	NS	NS

attributed to an uncharacteristically low yield of 1556 kg/ha for this treatment in replication 3. Conventional tillage was significantly higher than NT and ST treatments combined and individually, and ST treatments were higher than NT treatments. The use of ST clearly increased yield when compared to NT, but not enough to equal conventional tillage yields. Unlike at GR, harvesting the cover did not significantly increase tobacco yield.

GR sod study

Tobacco was harvested on 14 September 2006. Results showed significant differences between treatments and linear comparisons 1-6 (Table 4.20 and Figure 4-13). Yields ranged from 3004 to 3688 kg/ha for the spring killed NT treatment and the conventional tillage treatment, respectively. Conventional tillage was significantly higher than NT and ST combined and individually, and fall killed treatments were higher than spring killed treatments and fall killed treatments with a cover crop. Again, the use of ST increased tobacco yield, but not to the level of conventional tillage. In general, fall killed sod treatments yielded higher than spring killed treatments, even when a cover crop was established in fall killed treatments.

HR sod study

Tobacco was harvested on 26 September 2006 and showed significant differences between treatments and linear comparisons 2, 4, 5, and 6 (Table 4.20 and Figure 4-14). Yields ranged from 2878 to 3719 kg/ha for the spring killed NT treatment and the fall killed ST treatment, respectively. Both conventional tillage and ST were significantly higher than NT, and fall killed treatments were higher than spring killed treatments and

Table 4. 20 Sod Study - Tobacco Yield

Treatment		Tobaco Yield	
		GR	HR
		------ (kg/ha) ------	
1	spring killed, NT	3004	2878
2	spring killed, ST	3128	3316
3	fall killed, NT	3390	3190
4	fall killed, ST	3595	3719
5	fall killed, wheat cover, NT	3014	3127
6	fall killed, wheat cover, ST	3391	3205
7	fall killed, rye cover, NT	3025	2883
8	fall killed, rye cover, ST	3230	3387
9	Conventional	3688	3457
Linear Comparison			
1	conventional vs. NT & ST	S	NS
2	conventional vs. NT	S	S
3	conventional vs. ST	S	NS
4	NT vs. ST	S	S
5	fall killed vs. spring killed	S	S
6	fall killed vs. fall killed with cover	S	S
7	wheat cover vs. rye cover	NS	NS
8	interaction between comparisons 4 & 5	NS	NS

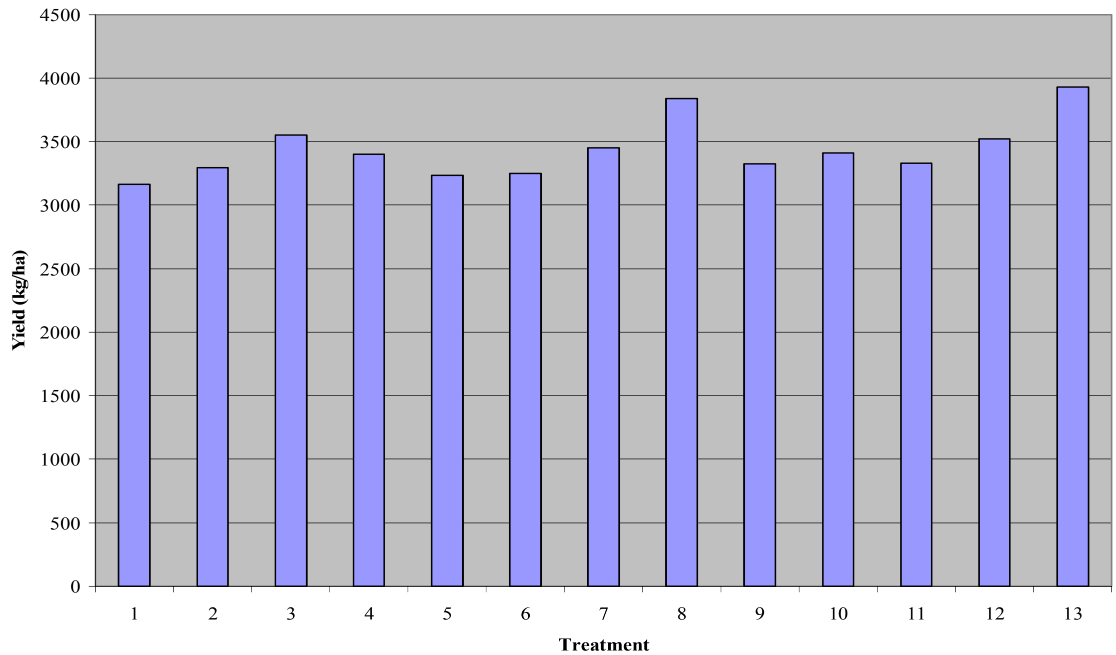

Figure 4- 11. GR Cover Crops Study - Tobacco Yield

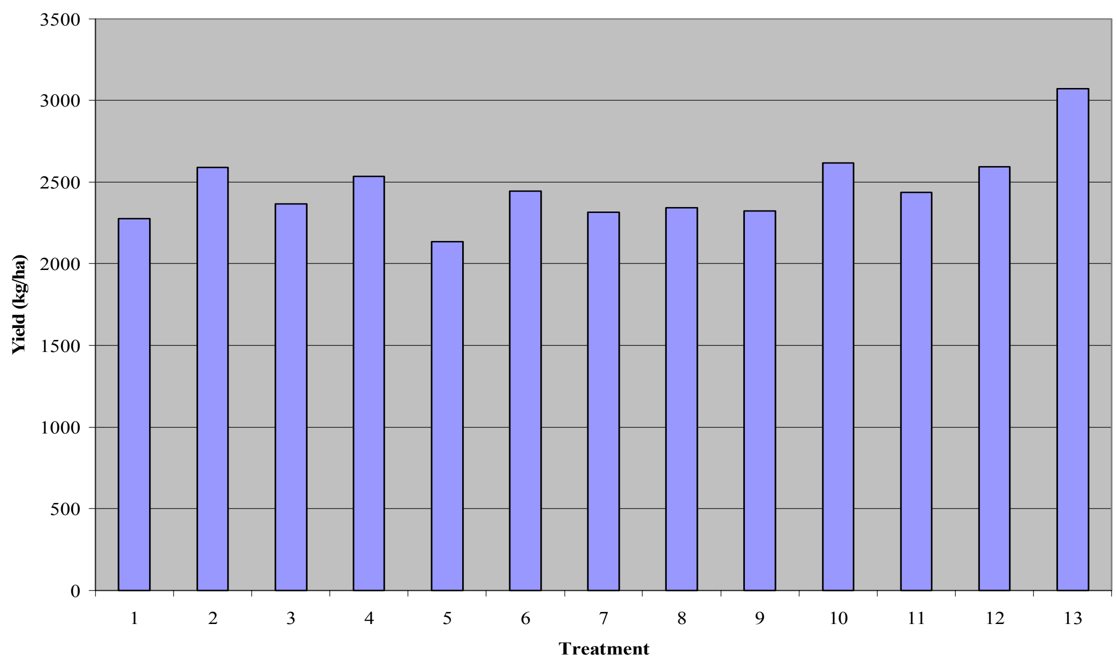

Figure 4- 12. HR Cover Crops Study - Tobacco Yield

fall killed treatments with a cover crop. Of the four studies, this was the only one in which a conservation tillage treatment (ST) equaled conventional tillage in yield.

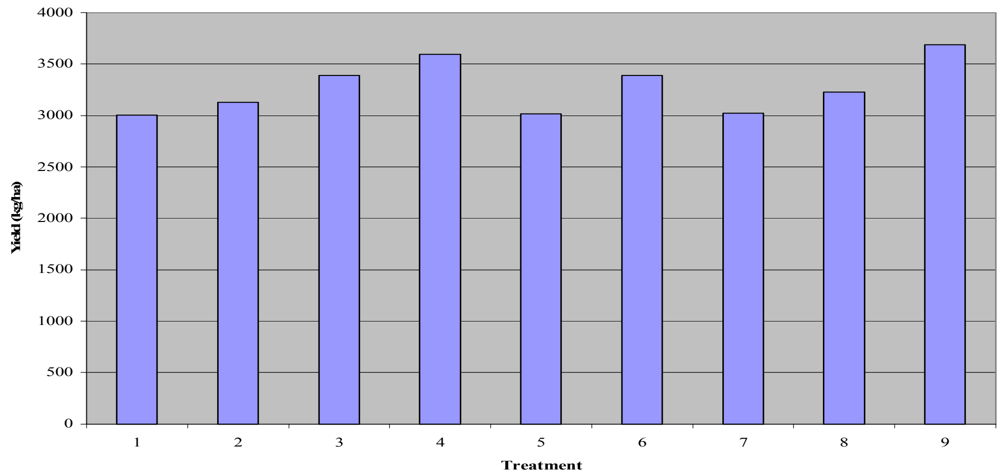

Figure 4- 13. GR Sod Study - Tobacco Yield

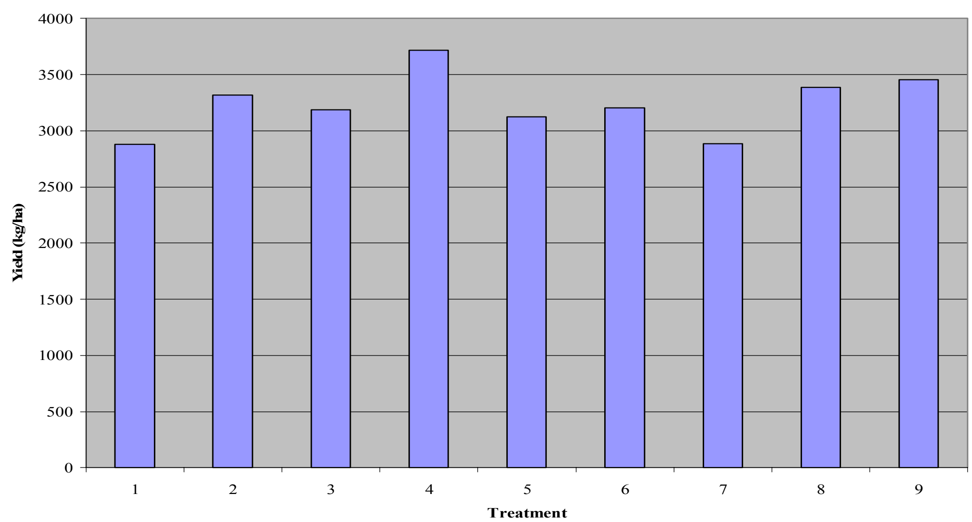

Figure 4- 14. HR Sod Study - Tobacco Yield

CHAPTER V: CONCLUSIONS

The implementation of conservation tillage production practices for burley tobacco could potentially benefit both the environment and tobacco producers. Conservation tillage tobacco production has been studied since the 1960's with mixed results. This research was conducted to evaluate the feasibility of different combinations of ground cover management and conservation tillage tobacco production practices with different degrees of soil disturbance.

In the cover crops study, the simulated grazing treatments, on average, produced approximately 2000 kg/ha of wheat and 2500 kg/ha of rye. We were only able to conduct simulated grazing harvests of these treatments in the spring due to late fall planting dates. Higher forage yields and a late fall grazing harvest could possibly be attained with an earlier planting date. This practice could provide producers with a high quality forage alternative during winter months, but could possibly cause some soil compaction problems from livestock for tobacco production. These possible soil compaction issues should be investigated in the future before this practice is adopted on a large scale.

Straw treatments yielded approximately 6700 kg/ha of straw across both locations. This practice could provide producers with an additional means of income, and still serve the purpose of a winter cover for conservation tillage tobacco production, but removal from the field reduces the amount of protective residue cover on the soil during the summer tobacco growing season. At typical farm level prices of $2.50 to $3.00 for a 20 kg bale, this would generate $850 to $1000 per hectare. Though not part of this study, cover crops could potentially be cut earlier for hay instead of straw.

In general, conventional tillage resulted in the highest tobacco yields in this research. ST yielded 10% less than conventional tillage. NT yielded 17% less than conventional and 7% less than ST. Overall, conservation tillage tobacco yields were 13% less than conventional tillage yields.

At HR, ST tobacco transplanted into a fall killed tall fescue sod out yielded the conventionally tilled tobacco by 262 kg/ha. This treatment was also comparable to the conventional tillage treatment at GR, with a difference in yield of only 93 kg/ha. At HR, ST tobacco yields were not statistically different from those of conventional tillage in the sod test. ST yielded 3407 kg/ha and conventional tillage yielded 3457 kg/ha. This was the only study where conservation tillage yields were not statistically different from the conventional tillage yield. The NT tobacco into a fall killed fescue sod was the highest yielding NT treatment at both locations. Spring killed sod treatments gave the lowest yields at both locations. While fall killed sod with cover treatments were higher than spring killed sod treatments, they were still significantly lower than fall killed sod treatments without a cover crop. These differences in yield can most likely be explained by differences in early season soil temperature and soil penetration resistance. Average daily soil temperature data shows that lower temperatures are present in treatments with a cover crop, and fall killed treatments without a cover crop are actually higher than conventional tillage treatments. A logical conclusion that low soil temperatures, which are effects of high residue cover, inhibit tobacco growth can be made here. While soil bulk densities are not at root restricting levels, according to the USDA (2007b), they do tend to be higher in conservation tillage treatments, and penetrometer readings show higher resistance in NT and ST treatments. With support from this data, perhaps we can conclude that tobacco roots are relatively less aggressive than other row crops and were restricted in conservation tillage treatments, and therefore yielded less. There was no difference in yields between wheat cover treatments and rye cover treatments.

Conventional tillage tobacco yields were significantly higher than conservation tillage yields in the cover crops study at both locations. In treatments where the cover crop was not removed, tobacco yields were the lowest. Soil temperature was also the lowest in these treatments. Highest yields for conservation tillage tobacco were attained in the crop residue treatments and the treatments in which the cover crop was harvested, either for straw or grazed. Soil temperature in rye grazed treatments was more similar to that of the conventional tillage treatment, and we can assume, since residue cover values are similar to those of rye grazed treatments, that soil temperature in crop residue and rye straw treatments are similar to rye grazed soil temperatures. In this study, soil temperature and penetrometer data support the conclusions that tobacco growth is inhibited by low soil temperatures and tobacco root growth is restricted by conservation tillage practices. In general, in row bulk densities in ST were close to those in conventional. This may partially explain the better yields in ST compared to NT. Data in this study also showed that there is no difference in tobacco yield between wheat and rye cover crops.

Another possible explanation for lower yields in the conservation tillage treatments in this study could be the timing of tobacco production practices, though we have no data to support this. Due to time and labor restraints, production practices such as topping and harvesting were done at the same time for all treatments. If all treatments could have been treated completely independent of each other, we may have gotten better or more accurate results. This could be a possible direction for future research.

At this time, with the data obtained from this research, we feel that there is certainly potential in conservation tillage tobacco, particularly with ST. It appears that the best combination of ground cover management and conservation tillage practices would be one in which the least amount of residue cover possible is present along with ST tobacco production practices. These results indicate that if cover crops are used, it would actually be to the farmers advantage to remove the cover for forage or straw, since reduced cover gave higher tobacco yield in addition to the forage value. However, there could potentially be a tradeoff here between tobacco yield, forage utilization, and soil erosion. Removal of cover combined with ST sometimes reduced surface residue cover after transplanting to levels below 30%. It is also notable that the best conservation tillage yields come from strip tillage in a fall killed, well established, sod. This is a very promising result, since rotation with perennial grass is generally thought to be the best rotation for tobacco. Many tobacco growers are beef cattle and forage producers as well, and this system would fit well in their operations. It would also allow use of sloping land for tobacco with minimal erosion, increasing the potential acreage on many farms for tobacco rotation.

It should be noted that the environment for tobacco production at both GR and HR was very good in 2006, with adequate rain throughout. This is reflected in the lack of soil water differences and the generally high yields. In this sort of year, potential water conservation advantages of more residue cover would not be observed. It could be that in a drier year the trend to higher yield with less cover might be less pronounced, or even reversed.

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APPENDIX

APPENDIX I: ADDITIONAL TABLES

Table A- 1. ANOVA For All Data Sets

	Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Bulk Density							
GR – cover crops study							
	A: Trt	6	7.444286E-02	1.240714E-02	0.97	0.470810	0.422976
	B: Rep	3	2.278571E-02	7.595238E-03			
	AB	18	0.2294143	1.274524E-02			
	S	0	0				
	Total (Adjusted)	27	0.3266429				
	Total	28					
GR – sod study							
	A: Trt	4	0.01042	0.002605	0.21	0.926330	0.151156
	B: Rep	3	0.009935	3.311667E-03			
	AB	12	0.14694	0.012245			
	S	0	0				
	Total (Adjusted)	19	0.167295				
	Total	20					
HR – cover crops study							
	A: Trt	6	0.12595	2.099167E-02	3.71	0.014038*	0.936328
	B: Rep	3	4.058572E-02	1.352857E-02			
	AB	18	0.1017643	5.653571E-03			
	S	0	0				
	Total (Adjusted)	27	0.2683				
	Total	28					
HR – sod study							
	A: Trt	4	0.13827	0.0345675	2.98	0.063333*	0.757533
	B: Rep	3	0.017855	5.951667E-03			
	AB	12	0.13897	1.158083E-02			
	S	0	0				
	Total (Adjusted)	19	0.295095				
	Total	20					
Grazing – 2006							
GR – 3-16-06							
	A: Trt	1	422419.6	422419.6	4.30	0.076834*	0.588640
	B: Rep	7	880226.3	125746.6			
	AB	7	687845.4	98263.63			
	S	0	0				
	Total (Adjusted)	15	1990491				
	Total	16					
GR – 4-11-06							
	A: Trt	1	95024.93	95024.93	3.27	0.113406	0.495236
	B: Rep	7	85186.13	12169.45			
	AB	7	203297.7	29042.53			
	S	0	0				
	Total (Adjusted)	15	383508.8				
	Total	16					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
HR 3-23-06						
A: Trt	1	126649.7	126649.7	2.02	0.198179	0.360784
B: Rep	7	82903.96	11843.42			
AB	7	438791	62684.43			
S	0	0				
Total (Adjusted)	15	648344.7				
Total	16					
HR 4-15-06						
A: Trt	1	781681.4	781681.4	59.67	0.000114*	1.000000
B: Rep	7	349400.4	49914.34			
AB	7	91705.94	13100.85			
S	0	0				
Total (Adjusted)	15	1222788				
Total	16					
Grazing – 2007						
GR 3-19-07						
A: Trt	1	293577.9	293577.9	12.16	0.010175*	0.930579
B: Rep	7	79509.39	11358.48			
AB	7	169048.2	24149.75			
S	0	0				
Total (Adjusted)	15	542135.5				
Total	16					
GR 3-30-07						
A: Trt	1	364238.3	364238.3	12.16	0.010175*	0.930579
B: Rep	7	98646.28	14092.33			
AB	7	209736	29962.28			
S	0	0				
Total (Adjusted)	15	672620.6				
Total	16					
GR 4-23-07						
A: Trt	1	19552.55	19552.55	0.50	0.502881	0.168496
B: Rep	7	425568	60795.42			
AB	7	274435.7	39205.11			
S	0	0				
Total (Adjusted)	15	719556.3				
Total	16					
HR 3-30-07						
A: Trt	1	1666036	1666036	61.37	0.000104*	1.000000
B: Rep	7	129610.9	18515.85			
AB	7	190032.9	27147.56			
S	0	0				
Total (Adjusted)	15	1985680				
Total	16					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
HR 4-23-07						
A: Trt	1	191406.3	191406.3	2.49	0.158840	0.413497
B: Rep	7	992676.8	141811			
AB	7	538868.8	76981.25			
S	0	0				
Total (Adjusted)	15	1722952				
Total	16					
Grazing and Straw Totals – 2006						
GR						
A: Trt	2	3.259083E+08	1.629541E+08	109.88	0.000000*	1.000000
B: Rep	7	1.055172E+07	1507388			
AB	14	2.076294E+07	1483067			
S	0	0				
Total (Adjusted)	23	3.572229E+08				
Total	24					
HR						
A: Trt	2	4.553151E+07	2.276576E+07	39.39	0.000002*	1.000000
B: Rep	7	6124816	874973.6			
AB	14	8091279	577948.5			
S	0	0				
Total (Adjusted)	23	5.974761E+07				
Total	24					
Grazing and Straw Totals – 2007						
GR						
A: Trt	2	1.287925E+08	6.439627E+07	113.26	0.000000*	1.000000
B: Rep	7	6019251	859892.9			
AB	14	7960208	568586.3			
S	0	0				
Total (Adjusted)	23	1.42772E+08				
Total	24					
HR						
A: Trt	2	3.171309E+07	1.585655E+07	116.83	0.000000*	1.000000
B: Rep	7	2167934	309704.8			
AB	14	1900068	135719.1			
S	0	0				
Total (Adjusted)	23	3.578109E+07				
Total	24					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Penetrometer						
GR – cover crops study						
A: Trt	6	43530.29	7255.048	12.29	0.000016*	0.999998
B: Row_Pos	2	61710.29	30855.14	51.01	0.000171*	1.000000
AB	12	11344.31	945.3596	1.70	0.108750	0.849450
C: Rep	3	690.9787	230.3262	0.37	0.776768	
AC	18	10624.71	590.2618	0.94	0.533042	
BC	6	3629.542	604.9238	0.96	0.454211	
ABC	36	20052.8	557.0222	0.89	0.647066	
S	84	52671.99	627.0475			
Total (Adjusted)	167	204254.9				
Total	168					
GR – sod study						
A: Trt	4	18259.04	4564.76	1.58	0.242802	0.497136
B: Row_Pos	2	81047.84	40523.92	77.37	0.000052*	1.000000
AB	8	12299.41	1537.427	1.56	0.190246	0.690616
C: Rep	3	885.3322	295.1107	0.37	0.774339	
AC	12	34698.44	2891.537	3.63	0.000415*	
BC	6	3142.522	523.7537	0.66	0.683513	
ABC	24	23693.13	987.2139	1.24	0.246700	
S	60	47752.04	795.8674			
Total (Adjusted)	119	221777.8				
Total	120					
HR – cover crops study						
A: Trt	6	168870.9	28145.15	21.93	0.000000*	1.000000
B: Row_Pos	2	132991.7	66495.84	145.44	0.000008*	1.000000
AB	12	92265.88	7688.823	7.93	0.000001*	1.000000
C: Rep	3	6453.513	2151.171	3.72	0.014427*	
AC	18	23100.58	1283.365	2.22	0.007788*	
BC	6	2743.22	457.2033	0.79	0.579160	
ABC	36	34908.63	969.684	1.68	0.027205*	
S	84	48525.95	577.6899			
Total (Adjusted)	167	509860.3				
Total	168					
HR – sod study						
A: Trt	4	83634.56	20908.64	14.91	0.000132*	0.999974
B: Row_Pos	2	69232.2	34616.1	471.06	0.000000*	1.000000
AB	8	20767.11	2595.888	4.19	0.002954*	0.987207
C: Rep	3	3522.756	1174.252	1.81	0.154693	
AC	12	16823.76	1401.98	2.16	0.025441*	
BC	6	440.9166	73.4861	0.11	0.994519	
ABC	24	14859.13	619.1306	0.96	0.533470	
S	60	38891.52	648.192			
Total (Adjusted)	119	248172				
Total	120					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Plant Height						
GR – cover crops study						
A: Trt	12	1252.991	104.4159	3.29	0.002773*	0.991593
B: Rep	3	133.576	44.52534			
AB	36	1142.631	31.73975			
S	0	0				
Total (Adjusted)	51	2529.198				
Total	52					
GR – sod study						
A: Trt	8	427.2673	53.40841	1.50	0.209952	0.672897
B: Rep	3	255.0286	85.00954			
AB	24	855.7051	35.65438			
S	0	0				
Total (Adjusted)	35	1538.001				
Total	36					
HR – cover crops study						
A: Trt	12	2824.161	235.3467	6.19	0.000009*	0.999990
B: Rep	3	205.0147	68.33823			
AB	36	1368.495	38.01376			
S	0	0				
Total (Adjusted)	51	4397.671				
Total	52					
HR – sod study						
A: Trt	8	2247.817	280.9771	7.33	0.000065*	0.999902
B: Rep	3	739.8591	246.6197			
AB	24	920.3442	38.34768			
S	0	0				
Total (Adjusted)	35	3908.02				
Total	36					
Residue Cover						
GR – cover crops study						
A: Trt	12	23116.92	1926.41	33.55	0.000000*	1.000000
B: Rep	3	212.9231	70.97436			
AB	36	2067.077	57.4188			
S	0	0				
Total (Adjusted)	51	25396.92				
Total	52					
GR – sod study						
A: Trt	8	17403.55	2175.444	25.39	0.000000*	1.000000
B: Rep	3	912	304			
AB	24	2056	85.66666			
S	0	0				
Total (Adjusted)	35	20371.55				
Total	36					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
HR – cover crops study						
A: Trt	12	34830.77	2902.564	64.22	0.000000*	1.000000
B: Rep	3	260.9231	86.97436			
AB	36	1627.077	45.19658			
S	0	0				
Total (Adjusted)	51	36718.77				
Total	52					
HR – sod study						
A: Trt	8	32440	4055	131.43	0.000000*	1.000000
B: Rep	3	323.5555	107.8519			
AB	24	740.4445	30.85185			
S	0	0				
Total (Adjusted)	35	33504				
Total	36					
Soil temperature						
GR – cover crops study						
Max						
A: trt	4	20.95051	5.237628	9.77	0.003599*	0.993375
B: rep	2	0.8705161	0.4352581			
AB	8	4.287836	0.5359794			
S	0	0				
Total (Adjusted)	14	26.10887				
Total	15					
Min						
A: trt	4	3.64124	0.9103101	8.49	0.005602*	0.985260
B: rep	2	0.9276535	0.4638267			
AB	8	0.8579263	0.1072408			
S	0	0				
Total (Adjusted)	14	5.42682				
Total	15					
Avg						
A: trt	4	10.83244	2.70811	61.99	0.000005*	1.000000
B: rep	2	0.1595078	7.975391E-02			
AB	8	0.3494922	4.368652E-02			
S	0	0				
Total (Adjusted)	14	11.34144				
Total	15					
Range						
A: trt	4	7.40181	1.850453	1.91	0.201496	0.515905
B: rep	2	2.935604	1.467802			
AB	8	7.733475	0.9666844			
S	0	0				
Total (Adjusted)	14	18.07089				
Total	15					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
GR – sod study						
Max						
A: trt	4	4.875736	1.218934	2.11	0.170578	0.553844
B: rep	2	0.968599	0.4842995			
AB	8	4.611504	0.576438			
S	0	0				
Total (Adjusted)	14	10.45584				
Total	15					
Min						
A: trt	4	1.455931	0.3639829	8.00	0.006710*	0.980199
B: rep	2	0.2738163	0.1369082			
AB	8	0.3637999	4.547498E-02			
S	0	0				
Total (Adjusted)	14	2.093548				
Total	15					
Avg						
A: trt	4	2.026962	0.5067404	7.05	0.009807*	0.965078
B: rep	2	0.4112213	0.2056107			
AB	8	0.5748199	7.185248E-02			
S	0	0				
Total (Adjusted)	14	3.013003				
Total	15					
Range						
A: trt	4	4.640896	1.160224	1.42	0.310541	0.415165
B: rep	2	0.388822	0.194411			
AB	8	6.525905	0.8157381			
S	0	0				
Total (Adjusted)	14	11.55562				
Total	15					
Soil temperature first 10 days						
GR – cover crops study						
Max						
A: trt	4	53.1349	13.28373	14.05	0.001085*	0.999601
B: rep	2	1.646259	0.8231294			
AB	8	7.562606	0.9453257			
S	0	0				
Total (Adjusted)	14	62.34377				
Total	15					
Min						
A: trt	4	7.544255	1.886064	12.53	0.001598*	0.998893
B: rep	2	1.333167	0.6665833			
AB	8	1.204296	0.150537			
S	0	0				
Total (Adjusted)	14	10.08172				
Total	15					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Avg						
A: trt	4	24.96559	6.241396	42.00	0.000021*	1.000000
B: rep	2	0.1203155	6.015775E-02			
AB	8	1.188713	0.1485891			
S	0	0				
Total (Adjusted)	14	26.27461				
Total	15					
Range						
A: trt	4	22.11023	5.527558	4.20	0.040102*	0.831498
B: rep	2	5.611245	2.805622			
AB	8	10.52156	1.315195			
S	0	0				
Total (Adjusted)	14	38.24304				
Total	15					
GR – sod study						
Max						
A: trt	4	7.454229	1.863557	3.54	0.060588*	0.765045
B: rep	2	0.5621684	0.2810842			
AB	8	4.217144	0.5271429			
S	0	0				
Total (Adjusted)	14	12.23354				
Total	15					
Min						
A: trt	4	2.476464	0.6191159	7.04	0.009860*	0.964812
B: rep	2	0.2550247	0.1275124			
AB	8	0.70358	0.0879475			
S	0	0				
Total (Adjusted)	14	3.435068				
Total	15					
Avg						
A: trt	4	4.892996	1.223249	7.61	0.007804*	0.974974
B: rep	2	0.1103148	5.515742E-02			
AB	8	1.285143	0.1606428			
S	0	0				
Total (Adjusted)	14	6.288454				
Total	15					
Range						
A: trt	4	3.527384	0.8818461	1.78	0.226680	0.488728
B: rep	2	1.267715	0.6338573			
AB	8	3.971237	0.4964046			
S	0	0				
Total (Adjusted)	14	8.766335				
Total	15					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Soil Water						
GR 6-13-06 – cover crops study						
A: Trt	6	24.20999	4.034997	5.18	0.002980*	0.985924
B: Rep	3	2.765229	0.9217429			
AB	18	14.03047	0.7794706			
S	0	0				
Total (Adjusted)	27	41.00568				
Total	28					
GR 6-27-06 – cover crops study						
A: Trt	6	6.583686	1.097281	3.54	0.017104*	0.924898
B: Rep	3	0.6434965	0.2144988			
AB	18	5.576828	0.3098238			
S	0	0				
Total (Adjusted)	27	12.80401				
Total	28					
GR 8-2-06 – cover crops study						
A: Trt	6	9.964871	1.660812	3.14	0.027481*	0.890915
B: Rep	3	11.31403	3.771343			
AB	18	9.512671	0.5284817			
S	0	0				
Total (Adjusted)	27	30.79157				
Total	28					
GR 6-13-06 – sod study						
A: Trt	4	4.49487	1.123718	0.20	0.934709	0.147476
B: Rep	3	150.1204	50.04014			
AB	12	68.14321	5.678601			
S	0	0				
Total (Adjusted)	19	222.7585				
Total	20					
GR 6-27-06 – sod study						
A: Trt	4	2.79948	0.69987	4.65	0.016857*	0.913290
B: Rep	3	2.518095	0.839365			
AB	12	1.80468	0.15039			
S	0	0				
Total (Adjusted)	19	7.122255				
Total	20					
GR 8-2-06 – sod study						
A: Trt	4	2.06135	0.5153375	0.70	0.608011	0.276097
B: Rep	3	13.3366	4.445533			
AB	12	8.86245	0.7385375			
S	0	0				
Total (Adjusted)	19	24.2604				
Total	20					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
HR 6-15-06 – cover crops study						
A: Trt	6	36.7352	6.122533	0.69	0.657914	0.327296
B: Rep	3	44.07312	14.69104			
AB	18	158.8886	8.827145			
S	0	0				
Total (Adjusted)	27	239.6969				
Total	28					
HR 6-21-06 – cover crops study						
A: Trt	6	3.862243	0.6437072	1.67	0.186344	0.632824
B: Rep	3	3.534214	1.178071			
AB	18	6.946986	0.3859437			
S	0	0				
Total (Adjusted)	27	14.34344				
Total	28					
HR 7-6-06 – cover crops study						
A: Trt	6	13.84749	2.307914	5.01	0.003505*	0.983201
B: Rep	3	8.022871	2.67429			
AB	18	8.287429	0.4604127			
S	0	0				
Total (Adjusted)	27	30.15779				
Total	28					
HR 6-15-06 – sod study						
A: Trt	4	17.78203	4.445508	2.56	0.092562*	0.693504
B: Rep	3	3.79212	1.26404			
AB	12	20.81133	1.734277			
S	0	0				
Total (Adjusted)	19	42.38548				
Total	20					
HR 6-21-06 – sod study						
A: Trt	4	2.39935	0.5998375	1.01	0.439869	0.357621
B: Rep	3	2.3801	0.7933667			
AB	12	7.12025	0.5933542			
S	0	0				
Total (Adjusted)	19	11.8997				
Total	20					
HR 7-6-06 – sod study						
A: Trt	4	8.58733	2.146832	5.95	0.007089*	0.964129
B: Rep	3	4.847655	1.615885			
AB	12	4.33187	0.3609892			
S	0	0				
Total (Adjusted)	19	17.76686				
Total	20					

Table A-1. continued

Source Term	DF	Sum of Squares	Mean Square	F-Ratio	Prob Level	Power
Yield						
GR – cover crops study						
A: Trt	12	2494206	207850.5	3.41	0.002143*	0.993386
B: Rep	3	382478.5	127492.8			
AB	36	2196620	61017.22			
S	0	0				
Total (Adjusted)	51	5073305				
Total	52					
GR – sod study						
A: Trt	8	2108941	263617.6	3.70	0.005984*	0.974914
B: Rep	3	213497.8	71165.95			
AB	24	1707993	71166.36			
S	0	0				
Total (Adjusted)	35	4030432				
Total	36					
HR – cover crops study						
A: Trt	12	2568773	214064.4	3.08	0.004460*	0.987098
B: Rep	3	159702.5	53234.18			
AB	36	2504241	69562.23			
S	0	0				
Total (Adjusted)	51	5232716				
Total	52					
HR – sod study						
A: Trt	8	2314084	289260.5	2.18	0.066760*	0.836571
B: Rep	3	391463.4	130487.8			
AB	24	3182405	132600.2			
S	0	0				
Total (Adjusted)	35	5887952				
Total	36					

*Term significant at alpha = 0.10

VITA

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