DEVELOPMENT OF A MORE SUSTAINABLE

SWEETPOTATO PRODUCTION SYSTEM

IN ALABAMA

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DEVELOPMENT OF A MORE SUSTAINABLE SWEETPOTATO PRODUCTION SYSTEM IN ALABAMA

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Date of Graduation

VITA

Amanda Leigh Stone Sanders, daughter of Rocky and Angie (Blackwell) Stone, was born November 2, 1979, in Jasper, Alabama. She graduated from Curry High School in Curry in 1998. She entered Bevill State Community College in fall of 1998. In August 2000, she entered Auburn University's Department of Horticulture and graduated with a Bachelor of Science degree in Horticulture, August 2003. In August 2003, she continued in the Department of Horticulture to obtain a Master of Science degree. She married Phillip Roy Sanders, son of Roy and Phyllis (Simpson) Sanders, on August 27, 2005.

THESIS ABSTRACT

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Field experiments were conducted from 2003-2005 to evaluate the influence of grass and legume cover crops, no-tillage, and varying rates of nitrogen on commercial sweetpotato production. Cover crops used for the no-till operation were crimson clover, hairy vetch, winter rye, and winter wheat, along with a bareground treatment, which was conventionally planted. Applied nitrogen rates were 50 $kg \cdot ha^{-1}$ or 100 $kg \cdot ha^{-1}$. The experimental design was a randomized complete block design. Each experimental unit consisted of one of the four cover crops at one of the two nitrogen rates. These eight treatments were compared to two bareground treatments at one of the two nitrogen rates. Each treatment was planted with 'Beauregard' sweetpotato. Biomass samples were taken from the cover crops for biomass, carbon, and nitrogen analysis. Cone index

measurements were taken after transplanting to determine soil compaction for each treatment. Soil temperature and percent soil moisture were taken for each treatment throughout the growing season. Soil samples were taken to determine organic matter content pre and post treatment. When the sweetpotatoes were harvested, yield data was taken from each treatment.

All of the cover crops produced significant quantities of biomass compared to the bareground treatment. Hairy vetch and crimson clover produced desirable C:N ratios. Cone index measurements were reduced in 2005 compared to 2004. Rye, crimson clover, and wheat cover crops conserved soil moisture. There was an increase in organic matter from 2003 to 2005. Highest yields of sweetpotato were obtained when no-tilled into crimson clover or hairy vetch cover crops. Highest yields of sweetpotato was also obtained when either 50 $kg{\cdot}ha^{-1}$ or 100 $kg{\cdot}ha^{-1}$ of nitrogen was applied. Using crimson clover or hairy vetch cover crops with 50 $kg{\cdot}ha^{-1}$ of applied nitrogen yielded higher net returns compared to the conventional bareground method with 100 $kg{\cdot}ha^{-1}$.

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I. INTRODUCTION AND LITERATURE REVIEW

Traditionally, commercial sweetpotato (*Ipomea batatas* (L.) Lam.) growers in Alabama produce on bare ground with conventional tillage practices. A cover crop is typically not grown leaving the soil susceptible to erosion and moisture loss during winter and spring months. In a bare ground system, sweetpotato (*I. batatas*) fields are disked multiple times to prepare the seed bed and the slips are transplanted into hilled rows. In a typical bareground system, there is no natural barrier to prevent weed growth or moisture loss. Weed control and soil moisture are limiting factors in sweetpotato (*I. batatas*) production in Alabama (Kemble et al., 1996). Sweetpotatoes (*I. batatas*) have running vines that make controlling weeds with mechanical and chemical methods difficult. Cover crops, particularly in a conservation tillage system, can be used to improve weed management. Cover crops can also increase organic matter and decrease soil water evaporation and this moisture may serve as a reserve against common, summer droughts.

Conventional sweetpotato (*I. batatas*) production practices can also lead to conditions which favor high levels of soil erosion, especially on prone soils, such as sandy soils or soils with low organic matter. Soil lost from sweetpotato (*I. batatas*) production has been estimated to be up to 49 metric tons per hectare per year in places like Mississippi and Louisiana (Langdale et al., 1985). Cover crops used in either a conventional system or a no-till system would be extremely advantageous in conserving soil and reducing nutrient leaching in a sweetpotato (*I. batatas*) production system. A more sustainable production system using cover crops combined with a no-till system of planting may provide a more economical alternative both environmentally and financially to Alabama sweetpotato (*I. batatas*) growers. A no-till system combined with the use of cover crops has the potential to increase profits for growers by decreasing inputs such as, fertilizer and herbicides, fossil fuel, and man hours. Sweetpotato (*I. batatas*), being a transplanted crop and not a small seeded crop, should perform well in a no-till system (Hoyt, 1999).

Sustainable Agriculture

Over the past several decades, farmers and researchers around the world have re-discovered more ecologically-based production systems called by an array of names, such as organic, natural, low input, integrated, alternative, regenerative, holistic, biodynamic, biointensive, and biological farming systems. All of these production systems seek sustainability (Earls, 2002). These sustainable farming systems are being re-explored and refined in response to increasing costs of fossil fuel energy, devastating soil erosion, intensive use of fertilizers and pesticides, and environmental concerns in connection with water pollution as well as general operational costs (Titi, 2003). This trend has been recognized and further encouraged in Federal legislation. The 1990 Food, Agriculture, Conservation, and Trade Act (the Farm Bill) mandated that USDA support research and extension activities of sustainable agriculture (Gabriel, 1995).

The Farm Bill defines "sustainable agriculture" as an integrated system of plant and animal production practices that will over the long term satisfy human food and fiber needs; enhance environmental quality and the natural resources base upon which the agricultural economy depends; make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm operations; and enhance the quality of life for farmers and society as a whole (Gabriel, 1995). Sustainability is achieved through management strategies which help the farmers select appropriate hybrids and varieties, soil conserving cultural practices, soil fertility programs, and pest management programs. The goal of sustainable agriculture is to minimize negative impacts to the immediate and off-farm environments while providing a sustained level of production and profit (Gold, 1999).

Soil Tillage

Soil tillage is one of the oldest arts practiced by farmers for crop production (Gajri et al., 2002). Soil tillage has a long history with technologies that developed over thousands of years ago. In its simplest form, soil tillage involved early humans using their fingers or sticks to break the soil surface, later animal-drawn stone, wooden, and metallic tools were developed to provide conditions suitable for seedling germination and establishment (Gajri et al., 2002; Titi, 2003). Through implementation of various designs of cultivation equipment, the Roman plow was invented during the Roman era followed by the moldboard plow, which became available in the 1830's (Titi, 2003). The invention of the moldboard plow made tillage a standard practice in agriculture (Duley and Mathews, 1947).

Conventional tillage is a standard practice in agriculture because it buries plant materials and reduces weeds. The purpose of this practice is to establish a weed-free seedbed, and to incorporate fertilizer and other amendments into the root zone. Proper tillage will allow uniform seed placement, quick germination, and enhance early growth rate (Coolman and Hoyt, 1993). Plowing breaks insect, disease, and weed cycles during the early stages of crop growth (Sprague, 1986). Plowing inverts and mixes the soil surface, temporarily increasing the water absorbing capacity of the soil and improving aeration. The effects and benefits of conventional tillage, however, are short term.

Tillage refers to the preparation of land for planting. Traditional conventional tillage uses a moldboard plow to turn under residues and is then followed by two or more shallow tillage operations shortly before planting (Galloway et al., 1981; Titi, 2003). Conventional tillage encompasses all tillage types which leave less than 15% of crop residues on the soil surface after planting the next crop, or less than 1,100 kg/ha of small grain residue throughout a critical erosion period (Titi, 2003). In other words, fields are left fallow or with insufficient residue in the off-season subjecting land to erosion by wind and water, nutrient leaching, reduced biological diversity, loss of organic matter, and further challenges to the sustainability of farming.

Over the last two decades many farmers have reduced their pre-plant tillage operations. In doing so, farmers have saved time, labor, equipment expenses, and fuel. By reducing tillage operations farmers also hope to reduce soil compaction and soil erosion losses (Bowman et al., 2000; Galloway et al., 1981). Conventional tillage, in the long term, leads to soil compaction due to the use of heavy equipment, frequent tillage operations, and lack of organic matter. Compacted soils slow root development, hinder the uptake of nutrients, and lead to deteriorated water percolation (Bowman et al., 2000; Titi, 2003). Control of erosion, conservation of soil moisture, reduced soil compaction, and more efficient use of nonrenewable resources translate into enhanced crop performance, increased yields and lower overall cost to farmers (Titi, 2003). Conventional tillage is still used as the preferred tillage option for soils with drainage problems such as clay soils with poor structure or for predominately sandy soils (Titi, 2003).

Conservation Tillage

Unlike conventional tillage, conservation tillage places residues and fertilizers on the soil surface rather than mixing them into the plow zone (Johnson and Hoyt, 1999). Conservation tillage was introduced in the 1950's and since then has been gaining importance. Conservation tillage can be defined as any tillage sequence, the object of which is to minimize or reduce loss of soil and water; operationally, it is tillage or tillage and planting combination which leaves 30% or greater cover crop residue on the surface (Altieri, 1989). Residues left on the soil surface decompose at a slower rate than buried residue, and release nutrients for a longer time throughout the growing season (Daniel et al., 1999; Johnson and Hoyt, 1999). Some specific types of conservation tillage are no-till, ridge-till, mulch-till, and strip-till (Gold, 1999). These types of conservation tillage differ to each other mainly to the degree to which the soil is disturbed prior to planting.

No-till

No-till is the extreme form of conservation tillage where minimal soil disturbance is combined with leaving the maximum amount of cover crop residues on surface of the soil. The cover crop is mowed or rolled becoming mulch rather than disked into the ground (Altieri, 1989; Phillips and Phillips, 1984). No-till systems do not use tillage for establishing a seed bed. No-till planters are equipped with coulters that slice the soil, allowing a double-disc opener to place the seed or transplant into the soil at the proper depth (Sullivan, 2002). No-till has been practiced with agronomic and vegetable crops.

In the 1950's corn (*Zea mays* L.) was the first to be grown using no-till (Peet, 2001). No-till has become an accepted cultural practice for corn and other seeded agronomic crops such as, soybean (*Glycine max* (L.) Merr.), sorghum (*Sorghum bicolor* (L.) Moench), cotton (*Gossypium hirsutum* L.), and cereal grains (Hoyt, 1999). Acceptance can be attributed to the extensive acreage of these agronomic crops worldwide, concern for soil erosion and the environment, improved herbicide development and use, and innovative equipment modifications (Hoyt, 1999; Hoyt et al., 1994; Phillips and Phillips, 1984). Compared to field corn (*Z. mays*) and soybean (*G. max*), adoption of conservation tillage systems for vegetables is still in its infancy (Morse, 1999a).

Reluctance to adopt no-till techniques for vegetable crops before the 1990’s was due to inadequate equipment. Vegetable production using conservation tillage techniques requires seeding and transplanting equipment appropriate for planting into an undisturbed cover crop residue (no-till) or into a tilled strip in the cover crop residue (strip-tillage) (Hoyt et al., 1994). Farm equipment development such as, no-till seeders or transplanters has greatly reduced the need for conventional tillage in vegetable crops (Hoyt et al., 1994; Morse, 1999a; Rice, 1983). Today, no-till is used on 17.5% of the United States total hectares planted of agronomic and vegetable crops and is increasing in other countries as well (Titi, 2003).

Ridge-till

Ridge-till uses specialized planters and cultivators to maintain permanent or semi-permanent ridges on which crops are grown. After harvest, the crop residue is left until planting time. The planter places the seed in the top of the ridge after pushing residue out of the way and slicing off the surface of the ridge-top. Ridge-till is primarily intended for agronomic row crops (Kuepper, 2001; Sullivan, 2002).

Mulch-till

Mulch-till uses chisel plows rather than conventional moldboard plows. With a chisel plow residues are mixed in upper layers of the soil but a significant percentage of residue remains on the soil surface to reduce erosion (Kuepper, 2001).

Strip-till

Strip-till is a method in which the in-row portion of the soil surface is tilled and subsoiled, while the row middles are maintained and undisturbed. Strip-till is advantageous where soils are compacted but subject to erosion. Crops can be planted and grow well in loosened soil of the tilled strips while the untilled portions conserve water and soil and control weeds (Peet, 2001).

Advantages of Conservation Tillage

One of the most important advantages of conservation tillage compared to conventional tillage is the control of soil erosion (Hartwig, 1988). The major productivity costs to the farm associated with soil erosion come from the need to replace nutrients, and in the loss of organic matter and water holding ability. Combined these factors can account for 50-75% of productivity loss (Pimental et al., 1995). Soils erode due to the cumulative impact of falling raindrops which breaks individual soil particles from their aggregates, thus allowing runoff water to remove them (Coolman and Hoyt, 1993; Johnson and Hoyt, 1999). Unlike in a conventional system, in a conservation tillage system using cover crops the mulch cover acts as a shield against the impact of the raindrops and absorbs much of the incoming force, thus decreasing soil aggregate destruction, soil crusting and compaction, and increasing infiltration capacity, in turn, enhancing and conserving the amount of rainfall absorbed by the soil (Coolman and Hoyt, 1993; Johnson and Hoyt, 1999). Jett and Talbot (1997) found that conservation tillage combined with cover crops such as rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* L.), and wheat (*Triticum aestivum L.*) significantly reduced soil erosion in a sweetpotato (*I. batatas*) production system.

Soil water content is generally higher with conservation tillage compared to conventional tillage. With conservation tillage and associated cover crop mulch there is a decrease in water evaporation from the soil surface (Jett and Talbot, 1997; Johnson and Hoyt, 1999) and increased water infiltration (Teasdale, 1996). Accumulation of crop residue on the soil surface reduces the amount of direct solar radiation that reaches the soil surface, insulating the soil from evaporative losses. Teasdale and Mohler (1993) found that rye (*S. cereale*) residue at 4,280 kg/ha prevented soil moisture decline when compared to unmulched soils. Conservation of soil water often results in plants having a greater amount of soil water available for transpiration and has the potential to increase nutrient availability to plant's roots (Jett and Talbot, 1997; Johnson and Hoyt, 1999).

Conservation tillage can be advantageous for soils in which water limits plant growth or in situations of common summer droughts (Coolman and Hoyt, 1993). Jett and Talbot (1997) indicated a faster growth rate in sweetpotato (*I. batatas*) in a conservation tillage system relative to conventional tillage. They cited reduced soil temperatures or water stress or enhanced nutrient use efficacy as possible causes for this faster growth rate. Sullivan and others (1991) found increased soil moisture in upper soil layers during a time of reduced rainfall is related to the presence of a cover crop mulch combined with no-till for succeeding corn (*Z. mays*) crop.

However, Liebl and others, (1992) found that in a study of soybeans (*G. max*) soil water content was lowest during dry periods in June under late-killed (killed at planting) rye (*S. cereale*). This was due to water depletion caused by the growing rye (*S. cereale*). However, during wet periods, the rye treatment resulted in a wetter soil profile compared to corn (*Z. mays*) residue treatments. In addition to water conservation, soil with a crop residue helps to suppress weeds (Abdul-Baki and Teasdale, 1993; Fisk et al., 2001; Hoyt et al., 1994; Morse, 1999b; Teasdale and Mohler, 1993). In contrast, Teasdale and Mohler (1993) found that under droughty conditions, retention of soil moisture could enhance weed germination and seedling survival.

One of the most striking challenges associated with the adoption of conservation tillage for vegetable crops has been in the area of weed control (Coolman and Hoyt, 1993; Liebl et al., 1992). No-till methods have been criticized for a heavy reliance on chemical herbicides. Herbicides play a critical role in no-till, they may be used to kill cover crops prior to planting and to manage weeds before and after planting of a cash crop. Reduction in pre-plant tillage and cultivation may necessitate that herbicides be substituted for mechanical weed control. However, a recent equipment introduction, "no-till cultivator", permits cultivation in heavy residues and provides a non-chemical option to post-emergent herbicide applications (Sullivan, 2002). Dependable chemical weed control options combined with cover cropping, integrated pest management practices, plus the availability of equipment capable of planting into residues from previous crops have made the transition from conventional to conservation tillage possible for vegetable production (Galloway et al., 1981; Hoyt et al., 1994; Morse, 1999a).

Legume and grass cover crops can reduce weed competition by out-competing them for water, nutrients, and light. Cover crop mulch suppression of weeds is based on physical obstruction, chemical interactions, and micro-climate alterations (Bowman et al., 2000). Liebl and others (1992) found that in the absence of herbicides, the combination of no-till and winter rye (*S. cereale*) mulch provided weed control in soybean (*G. max*). Weed control observed in the rye (*S. cereale*) mulch may be attributable to the allelopathic effect of the rye (*S. cereale*) and the physical presence of the mulch on the soil surface. Cover crops such as, ryegrass (*L. multiflorum*), subterranean clover (*Trifolium subterraneum* L.), sorghum-sudangrass (*Sorghum bicolor* (L) Moench x *Sorghum bicolor* var. *sudanese* (Piper) A.S. Hitchc.), and buckwheat (*Fagopyrum esculentum* Moench) to name a few, produce allelopathic compounds. These allelochemicals provide natural herbicidal effects which suppress or control certain weeds (Bowman et al., 2000; Hartwig and Ammon, 2002).

Abdul-Baki and others (2001) found that a mulch mixture of winter rye (*S. cereale*) and hairy vetch (*Vicia villosa* Roth) significantly suppressed weeds in sweet corn (*Zea mays* L. var. *rugosa* L.) using no-till. Yields in the rye (*S. cereale*) and hairy vetch (*V. villosa*) mixture treatment were similar with and without residual herbicides, suggesting the effectiveness of the cover crops on weed suppression. In another study, tomatoes (*Lycopersicon esculentum* Mill.) planted into hairy vetch (*V. villosa*) and subterranean clover (*T. subterraneum*) mulches adequately suppress early season weeds in a no-till production system (Abdul-Baki and Teasdale, 1993). The vetch (*V. villosa*) and clover (*T. subterraneum*) treatments required only a postemergent application of herbicide whereas the black plastic mulch and no mulch treatments required the application of both pre and post herbicides (Abdul-Baki and Teasdale, 1993). Elimination of herbicides is not a realistic objective when using cover crops. Instead, herbicides should be considered a tool for managing cover crops and optimizing the potential for improving soils and sustaining agricultural production.

Many growers want to reduce their use of chemical inputs, therefore non-chemical methods of suppressing or killing cover crops is desirable. Mowing, rolling, roll-chopping, undercutting and partial roto-tilling are mechanical methods of managing cover crops that leave residues on the soil surface (Creamer and Dabney, 2002). Mowing and rolling during the vegetative stage have been ineffective for killing cover crops such as hairy vetch (*V. villosa*) (Teasdale and Rosecrance, 2003), winter wheat (*T. aestivum*), rye (*S. cereale*) (Wilkins and Bellinder 1996), crimson clover (*Trifolium incarnatum* L.), berseem clover (*Trifolium alexandrinum* Bory and Chaubard) and subterranean clover (*T. subterraneum*) (Dabney et al., 1991). These cover crops, however, were effectively killed during the flowering stage by either mowing or rolling.

Teasdale and Rosecrance (2003), found killing hairy vetch (*V. villosa*) at flowering by use of a flail mower, roller, or light disking provided an effective kill for hairy vetch (*V. villosa*) and left high residue levels, comparable to those achieved by the herbicide treatments. Of the three mechanical methods researched by Teasdale and Rosecrance, flail mowing left the residue shredded, resulting in faster decomposition.

The light disk treatment was less consistent while the roller offered good potential for hairy vetch management and suppressed early weed emergence in minimum-tillage corn production.

Mowing has been the most common method to mechanically kill cover crops and leave their residues as surface mulches. A flail mower is most desirable over a bush hog or rotary type mower because it leaves cover crop residues uniformly distributed on the soil surface. However, a mower may not be the best option to suppress weeds. Mowers generate small pieces of residue which decompose rapidly (Creamer and Dabney, 2002).

Mechanical rollers provide benefits when killing the cover crop as it lays the cover crop down intact, flat on the soil surface providing maximum soil coverage to prevent erosion, increase infiltration, and suppress weeds. When blades are attached to the roller to cut the cover crop into sections as it is rolled, this is referred to as roll-chopping or crimping (Creamer and Dabney, 2002). Rolling has been used effectively to kill cover crops such as black oat (*Avena strigosa* Schreb), winter rye (*S. cereale*), wheat (*T. aestivum*), foxtail millet (*Setaria italica* (L.) P. Beauv.), buckwheat (*Fagopyrum esculentum* Moench), crimson clover (*T. incarnatum*) and soybean (*G. max*) (Reeves et al., 1997; Morse 1995) with or without the use of herbicides. Research has shown that no-till transplanters function better, and cover crop persistence and weed suppression are better in rolled plots compared to mowed plots (Morse, 1995). Morse (1999b) found that transplanted broccoli (*Brassica oleracea* L. var. *italica* Plenck) can be successfully produced without herbicides in a no-till system when cover crops are effectively killed by rolling and transplants are properly established.

Creamer and others (1995) re-developed a non-chemical cover crop kill method called an undercutter. It kills the cover crop by severing the roots while flattening the intact aboveground biomass on the surface of raised beds. The design of this implement consists of one blade designed to cut a one and a half meter wide raised bed. In this study the cover crop mulch remained throughout the growing season, controlling weeds as effectively as the herbicide treatment. Unlike mowing, undercutting cover crops leaves thick, intact mulch on the soil surface and a looser soil to facilitate transplanting of vegetable crops (Creamer et al., 1995).

Disadvantages of Conservation Tillage

One potential disadvantage of conservation tillage is reduced soil temperatures in the spring. In spring, shading effects of cover crop residue prevents sunlight contacting the soil surface insulating the soil (Hoyt et al., 1994; Morse, 1999a). As a consequence, the spring temperature of soil is generally lower with conservation tillage than that of tilled soil. Lower spring temperatures delay planting dates, slow germination, reduce stand uniformity and therefore can delay maturity (Sullivan, 2002). Reduced soil temperatures may slow the growth of some warm-season vegetables such as tomato (*L. esculentum*), sweet corn (*Z. mays*), snap bean (*Phaseolus vulgaris* L.) and squash (*Cucurbita pepo* L.) planted in early spring but may not adversely affect cool-season vegetables such as Cole crops (*Brassica* spp. L.), Irish potatoes (*Solanum tuberosum* L.), and leafy greens (*Cruciferae* family) (Coolman and Hoyt, 1993; Hoyt, 1999; Peet, 2001) planted in early spring.

Hoyt (1999), however, found that Cole crops (*Brassica* spp.) grown with conservation tillage in early spring or late fall in Western North Carolina, experienced soil temperatures cool enough to delay growth compared to conventional tillage. Growth of tomatoes (*L. esculentum*) and other warm season vegetables during late spring and summer were not affected by cooler soil temperatures (Hoyt et al., 1994). Jett and Talbot, (1997) found that ryegrass (*L. multiflorum*) cover crop in the conservation tillage system reduced average soil temperatures by -13°C and was beneficial for the sweetpotato (*I. batatas*) because it provided a less stressful environment. The significance of reduced soil temperatures depends on planting date, latitude, and the crop to be grown (Johnson and Hoyt, 1999; Coolman and Hoyt, 1993).

Soil compaction is a potential problem of conservation tillage as well as conventional tillage. As a result, flooding and poor drainage can contribute to reduced yields. Unlike a strip-till system, in a no-till system a loose seedbed is not maintained which may lead to compaction impeding the root growth of some crops. Furthermore, no-till should not be practiced in poorly drained, compacted soils without first loosening a strip of in-row soil before planting (Morse, 1999b). Over time, however, root systems of cover crops act as biological plows and are highly effective in aerating and loosening compacted soils. Reluctance of farmers to accept this practice may also be a disadvantage of conservation tillage (Coolman and Hoyt, 1993).

There are other potential problems when using a conservation tillage system and cover crops which include allelopathic compounds. Allelopathic effects are most often observed when direct-seeding small seeded vegetables, such as lettuce (*Lactuca sativa* L.) or broccoli (*B. oleracea* var. *italica*) into winter rye (*S. cereale*), ryegrass (*L. multiflorum*), or subterranean clover (*T. subterraneum*) mulch (Hartwig and Ammon, 2002; Hoyt et al., 1994; Morse, 1999b; Putnam, 1986). After killing winter rye (*S.*

cereale), it is recommended to wait three to four weeks before planting small-seeded crops such as carrots (*Daucus carota* L.) and onions (*Allium cepa* L.) (Hoyt et al., 1994). Transplanted vegetables such as tomatoes (*L. esculentum*) and sweetpotatoes (*I. batatas*) and large-seeded species are less susceptible to these affects (Bowman et al., 2000; Peet, 2001).

As with conventional tillage, the potential overwintering of diseases or pests in soil or from a previous crop's residue is a consideration. Jett and Talbot (1997) found that white grub (*Phyllophaga ephilida* Say) injury on sweetpotatoes (*I. batatas*) was higher in a conservation tillage system compared to conventional tillage. No chemical treatment was applied to control the white grub (*P. ephilida*). However, the following year an insecticide was applied and white grub (*P. ephilida*) injury was reduced by 60% in the conservation tillage system. Crop rotation and destruction of previous crop debris are critical in managing insects and diseases in a conventional or conservation tillage system. Conservation tillage will not substitute for good faming practices.

<u>Crops of conservation tillage</u>

Large-seeded and transplanted vegetable crops perform well in conservation tillage systems. Large-seeded vegetable crops such as sweet corn (*Z. mays*), snap beans (*P. vulgaris* L.*)*, lima beans (*Phaseolus lunatus* L.), squash (*Cucurbita* spp.), popcorn (*Zea mays mays* L.), cucumber (*Cucumis sativus* L.), English peas (*Pisum sativum* L. ssp. *sativum*), pumpkin *(Cucurbita maxima* L.) and vegetables such as asparagus (*Asparagus officinalis* L.), beets (*Beta vulgaris* L.), dry bulb onions (*A. cepa*) and spinach (*Spinacia oleracea* L.) have been produced successfully in a conservation tillage system (Hoyt, 1999 and Peet, 2001). Direct-seeded snap peas (*Pisum sativum* L.), sweet corn (*Z. mays*), and snap beans (*P. vulgaris*) have been produced successfully using no-till (Abdul-Baki et al., 2001; Abdul-Baki and Teasdale, 1997; Grimmer and Masiunas, 2004). Small-seeded crops, such as lettuce (*Lactuca sativa* L.), carrots (*Daucas carota* L.), and broccoli (*B. oleracea* L. var. *italica* L.), do not perform well in a conservation tillage system because of a slow early growth rate, causing them to be extremely susceptible to competition by faster growing weeds and allelopathic interference.

Transplanted crops such as tomato (*L. esculentum*), cabbage (*Brassica oleracea* L. var. *capitata* L.), sweetpotato (*I. batatas*), cantaloupe (*Cucumis melo* L.), peppers (*Capsicum annuum* L.), broccoli (*B. oleracea* var. *italica*) and Irish potatoes (*Solanum tuberosum* L.) have been produced successfully using no-till (Abdul-Baki and Teasdale, 1993; Hoyt, 1999; Jett and Talbot, 1997; Morse, 1999a). Effective pre-emergence and post-emergence herbicides are registered for these crops and yields have been comparable under these conservation tillage systems than conventional systems (Hoyt et al., 1994).

Cover Crops

Today, cover crops have become a viable option of any cropping system that seeks to be sustainable. Cover cropping is the practice of growing pure or mixed stands of annual, perennial, or biennial herbaceous plants to cover the soil of croplands for all or part of the year when the soil might otherwise be fallow. Before commercial synthetic fertilizers were available, vegetable growers utilized cover crops to replenish soil nutrients used by cash crops, nutrients carried away in eroded soils, and those washed down into deeper soil profiles (Dabney et al., 2001; Sullivan, 2003).

Integrating cover crops into a production system may preserve or increase the productivity of the soil resource. Grass and legume cover crops can protect the soil from erosion due to wind and water by holding the soil in place. In addition, cover crops can be grown to suppress weeds, insect pests and diseases, and protect water quality by reducing losses of nutrients, pesticides, or sediment from agriculture fields. Cover crops improve the quality and health of the soil by adding biomass and increasing soil organic matter. Soil quality is one of the most important properties, which determines productivity and sustainability. Good soil quality not only produces good crop yield, but also maintains environmental quality and consequently plant, animal, and human health.

Cover crops can be a component of both conventional and conservation tillage systems by either plowing in the cover crop or leaving the residue undisturbed and seeding or transplanting into the crop residue. The choice of a cover crop or principle use depends on the crop to be grown and the cropping season (Hoyt et al., 1994). Cover crops are generally classified as “legumes” and “grasses or cereal grains” (Table 1a and Table 1b).

Advantages of Cover crops

One of the primary uses of cover crops is for the addition of organic matter. Organic matter includes substances derived from decayed leaves, roots, manure, and microorganisms. Plant materials that are succulent and rich in proteins and sugars, like annual legumes, will be decomposed quickly by soil microbes as energy sources, releasing the nutrients found in the plant material and leaving behind little organic matter. Due to rapid decomposition when using a legume cover crop, weed control may not last as long as with a grass or cereal grain (Bowman et al., 2000). Plants that are woodier or more fibrous, like grasses, will release nutrients more slowly leaving behind long term organic matter, which contributes to humus production. Adding organic matter to the soil improves soil structure, therefore improving biological, chemical, and physical properties such as organic carbon content, cation exchange capacity, aggregate stability, water infiltration, and encourages growth of beneficial soil organisms (Dabney et al., 2001; Daniel et al., 1999; Sylvia et al., 1999).

Jett and Talbot (1997) found in their study of sweetpotatoes (*I. batatas*) that cover crops significantly reduced erosion and increased the organic matter of the soil in a conservation tillage system relative to a fallow, conventional tillage system (control). From November to April, the fallow plots had a nine percent decrease in bed height compared with a one to three percent decrease for the rye (*S. cereale*) and ryegrass (*L. multiflorum*) cover crop seeded beds.

Soil temperature, soil moisture, and carbon to nitrogen (C:N) ratio influence the ability of microorganisms to break down organic matter and release plant nutrients (Sullivan, 2003). As a plant matures, fibrous (carbon) plant material increases and protein (nitrogen) decreases. Nitrogen levels in cover crops are at their peak just before flowering and lowest when setting seed (Bowman et al., 2000). The optimum C:N ratio for rapid decomposition of organic matter is between 15:1 and 25:1. Decomposition results in mineralization or ammonification of organic nitrogen to inorganic ammonium, which can be used by plants for growth (Sylvia et al., 1999). C:N ratios above 25:1 results in nitrogen being “tied up” by soil microbes during the decomposition process, thus pulling nitrogen away from crop plants (Dabney, 2001; Sullivan, 2003; Sylvia et al., 1999). This process is referred to as immobilization, consumption of ammonium by soil microbes (Sylvia et al., 1999). Thus, the lower the C:N ratio of the cover crop, the more nitrogen and other nutrients will be released into the soil for immediate crop use (Bowman et al., 2000). Legumes are generally lower in total carbon and higher in total nitrogen than grasses. Some common C:N ratios of cover crops include: hairy vetch (*V. villosa*), 10:1- 15:1; crimson clover (*T. incarnatum*), 15:1; rye (*S. cereale*) at flowering 20:1; and corn (*Z. mays*) stalks, 60:1 (Sullivan, 2003).

Combining a grass and a legume as a mixture may produce residues with some of the best characteristics of each individual cover. Mixtures of cover crop species can be planted to obtain a more desirable C:N ratio, reduce NO_3^- leaching and fix N, and increase organic matter (Rosecrance et al., 2000). Depending on the C:N ratio of the mixture, growing legumes with grasses in a mixture could be used to time the rate of nitrogen release from the cover crops. This may be advantageous in keeping excess nitrogen tied up when no crop roots are there to absorb it (Bowman et al., 2000; Creamer et al., 1997; Creamer et al., 1996a). Planting mixtures of legumes and grasses may also increase the amount of atmospheric N_2 fixed by the legume. Grasses establish effective root systems more rapidly than legumes, thus the soil N concentration will be reduced, resulting in increased legume nodulation and N_2 fixation (Giller and Cadisch, 1995).

Jett and Talbot (1998) evaluated growing legumes and grasses in a mixture for conservation-tilled sweetpotatoes (*I. batatas*). Crimson clover (*T. incarnatum*) + rye (*S. cereale*) cover crops established rapidly and produced significant quantities of residue. Conservation tillage with legume and legume/grasses had yields equal to yields of the conventional tillage treatment. Treadwell and others (2003) evaluated the effect of a mixture of hairy vetch (*V. villosa*) and 'Wrens Abruzzi' rye (*S. cereale*) cover crop on organic 'Beauregard' sweetpotato (*I. batatas*) yield. They found that yield quality of U.S. Number 1 grade sweetpotato (*I. batatas*) roots was dramatically improved in a reduced tillage organic system versus conventional, no cover crop, or cover crop incorporated prior to planting treatments.

Another important reason for planting mixtures of cover crops is to take advantage of allelopathic potential of the cover crops to suppress weeds. Creamer and others (1996b) found that four species, rye (*S. cereale*), barley (*Hordeum vulgare* L.), crimson clover (*T. incarnatum*), and hairy vetch (*V. villosa*) can be grown in a mixture and managed as a mulch for transplanted processing tomatoes (*L. esculentum*). The mix covered the soil quickly, produced large amounts of biomass, had an optimum C: N ratio, was easily killed mechanically, and suppressed weeds as well as the use of herbicides.

Grass and legume cover crops can reduce damage caused by diseases, insects and nematodes. Cover crops can provide habitats for an array of beneficial insects. Bowman and others (1998) found that sorghum-sudangrass (*S. bicolor* x *S. bicolor* var. *sudanese*) suppressed some nematode species.

The use of annual, winter annual, or perennial legumes such as red (*Trifolium pretense* L.) and white clover (*Trifolium repens* L.) provides an opportunity to reduce the use of synthetic nitrogen (Hartwig and Ammon, 2002). Cover crops can help recycle nutrients on the farm and reduce fertilizer costs (Abdul-Baki et al., 1996; Bowman et al., 2000). Besides reducing the loss of nutrients in eroded soil, cover crops contribute nitrogen to cash crops by scavenging and mining soil nutrients from deep soil layers (Sullivan, 2003). Cover crops, especially grasses and cereal grains such as winter rye (*S. cereale*), ryegrass (*L. multiflorum*), winter wheat (*T. aestivum*), barley (*H. vulgare*), oats (*Avena sativa* L.), and many others can sequester residual soil nitrate ($N0_3$-) which remained from a previous crop and make it available for the subsequent crop (Dabney et al., 2001). However, grass cover crops are high in carbon and will break down slowly making the nutrients contained in their residue less available to the next crop (Bowman et al., 2000). Over time, these residues break down and nutrients are released. Grass cover crops can also remove excess soil water in the spring, but this may be detrimental to the following cash crop if dry soil conditions exist (Teasdale and Mohler, 1993).

In general, legume cover crops do not scavenge nitrogen as well as the fibrous-rooted grasses or cereal grains. Winter annual legume cover crops such as hairy vetch (*V. villosa*), crimson clover (*T. incarnatum*), field peas (*Pisum sativum* L. ssp. *arvense*), and many others often are used to convert atmospheric nitrogen into functional nitrogenous forms (nitrogen fixation) that plants can use. The leguminous plants themselves use this nitrogen for their growth (Dabney et al., 2001). Research has shown that hairy vetch (*V. villosa*) often produces the most nitrogen (124 kg/ha) of all cover crops followed by crimson clover (*T. incarnatum*) (Sullivan, 2003; Holderbaum et al., 1990). When legume plants die, the residual nitrogen, carbon, and other elements in their tissues are recycled into the soil in forms that can be used by successive cash crop plants, possibly increasing yields. This is beneficial for warm season vegetables such as tomatoes (*L. esculentum*), sweetpotatoes (*I. batatas*), sweet corn (*Z. mays*), snap beans (*P. vulgaris*), and fall planted Cole crops (*Brassica* spp.) that are planted following a leguminous cover crop (Hoyt et al., 1994; Jett and Talbot, 1998). Small grains that require added nitrogen can also benefit (Ebelhar et al., 1984). Abdul-Baki and others (1996) found that with the use of fall planted hairy vetch (*V. villosa*), as part of the vegetable crop rotation to fix N and add organic matter to the soil, eliminates the need for polyethylene mulches and preplant herbicides, and increases yields compared to black plastic mulch for the production of fresh-market tomatoes (*L. esculentum*).

Sweetpotatoes (*I. batatas*) are moderately heavy feeders and must be well supplied with nutrients for optimum yields (Swaider and Ware, 2002). The current fertilizer recommendation for sweetpotato (*I. batatas*) production in Alabama is 80 to 90 kilograms of nitrogen, 60 to 80 kilograms of potassium, and 150 kilograms of phosphorus per hectare (Kemble et al., 1996). Planting a legume cover crop, grass cover crop, or a mixture may decrease the need for synthetic fertilizers by recycling on farm nutrients and fixing nitrogen.

II. OBJECTIVES

The objectives of this study were to evaluate the influence of legume and grass cover crops, a no-till (NT) system of transplanting, and varying rates of nitrogen in order to develop a more sustainable sweetpotato (*Ipomea batatas* (L.) Lam.) production system.

Four cover crops - crimson clover (*Trifolium incarnatum* L.); hairy vetch (*Vicia villosa* Roth.); wheat (*Triticum aestivum* L.); and winter rye (*Secale cereale* 'Elbon' L.) were examined as potential winter cover crops preceding spring NT transplanted sweetpotatoes. Data on soil compaction, soil organic matter, soil moisture levels, soil temperatures, yields, and economics of production were collected and compared to the traditional bareground sweetpotato production system.

III. MATERIALS AND METHODS

Overview

Field experiments were conducted from 2003-2005 at the North Alabama Horticulture Research Center in Cullman, Alabama. The soil at this research station is a Hartsells fine sandy loam (fine-loamy, siliceous, thermic Typic Hapludults) (USDA series description) with less than one percent organic matter. The experimental design was a randomized complete block design (RCBD) with no rerandomization between years. Each experimental unit consisted of one of the four cover crops at one of the two nitrogen rates. These eight treatments were compared to two bareground (control) treatments at one of two nitrogen rates. There were a total of ten treatments with five replications. Cover crops were crimson clover (*Trifolium incarnatum* L.), hairy vetch (*Vicia villosa* Roth), wheat (*Triticum aestivum* L.), and winter rye (*Secale cereale* 'Elbon' L.). Applied nitrogen rates were 50 $kg \cdot ha^{-1}$ or 100 $kg \cdot ha^{-1}$.

Establishment of Cover Crops

The cover crops were planted on 15 Oct. 2003 and 13 Oct. 2004. Field preparation included one pass with a subsoiler, one pass with a chisel plow, and then the field was roto-tilled. A bedder was used to form the raised beds and the crowns of each bed were rolled flat. Next, the field was divided into 50 plots (five replications with 10 plots each), each plot measuring 9.1 m x 4.3 m. Recommended lime and fertilizer was applied prior to sowing of cover crops based on soil test results from Auburn University

Soil Testing Laboratory (Auburn, Ala.) for establishment of the cover crops. Prior to cover crops being sown, MOCAP was also applied for nematode and soil-borne insect control. The crimson clover and the hairy vetch cover crops were sown at a rate of 22 $kg{\cdot}ha^{-1}$. The winter rye and winter wheat cover crops were sown at a rate of 112 $kg{\cdot}ha^{-1}$. A plot drill was used for seeding the cover crops. Each legume cover crop was inoculated with *Rhizobia* species prior to seeding. At the same time cover crops were seeded, a bareground (control) was established.

Biomass Analysis of Cover Crops

In late Apr. 2004 and 2005, biomass samples from a 0.145 m^2 quadrat were randomly selected from within each plot at peak flowering. Cover crops were cut at the soil line then placed into labeled brown paper bags. Samples were weighed in the field to determine the fresh weight of each sample. The biomass samples were placed into a forced-air oven (60°C) for 72 hours (Auburn University Soil Testing Laboratory, Auburn, Ala.) to facilitate drying, re-weighed, and then ground fine. Dry combustion determination of total carbon and nitrogen of each sample was carried out using the Leco® CN-2000 (Leco Corporation, St Joseph, Mich.). This test was performed by the USDA-ARS National Soil Dynamics Laboratory (Auburn, Ala.). Total N and total C produced in each cover crop for each plot was determined by multiplying the percent of N and C by the dried weight of the plant sample. The numbers were adjusted to a kilogram per hectare basis. The C:N ratio for each cover crop in each year was determined by dividing the percent of C by the percent of N. Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

Tillage and Transplanting of Sweetpotatoes

In the last week of Apr. in 2004-2005, (one month prior to the anticipated transplanting date) the cover crops were rolled and then desiccated with Paraquat and Glyphosate herbicides. The roller/crimper was modified by agricultural engineer, Dr. Ted Kornecki, at the USDA-ARS, National Soils Dynamic Laboratory, to roll/crimp over raised beds used in sweetpotato production. The bareground (control) plots were tilled and re-rowed as in a conventional tillage system while the cover crop plots were left undisturbed. Uniform 'Beauregard' sweetpotato (*Ipomea batatas* (L.) Lam.) slips were mechanically transplanted on 3 June 2004 and 16 June 2005 using a modified two-row, No-till Mechanical Transplanter (Model 1000, Mechanical Transplanter Co., New Holland, Mich.). Slips were transplanted 0.3 m between plants within a row. Each 9.1 m x 4.3 m plot contained four rows. Each row was 1.1 m on centers. After transplanting, standard cultural practices, as recommended in Alabama, were performed (Kemble et al., 1996).

Soil Fertility

Prior to transplanting sweetpotato slips, all plots received 100% of recommended lime, P, and K according to soil test recommendations. When transplants were established (30 days after transplanting), either 50 or 100 $kg{\cdot}ha^{-1}$ nitrogen was applied to each plot where appropriate based on experimental design.

Evaluating Soil Compaction

To determine soil compaction five cone index measurements were taken in the middle row of each plot following transplanting in 2004 and 2005. These measurements were taken using the Rimik CP 20 Cone Penetrometer (Agridry Rinik Pty Ltd, Toowoomba, Austral.). Cone index is the force per unit base area required to push the penetrometer through a specified, small increment of soil (ASAE standards). Measurements were taken by slowly inserting the probe shaft with a cone tip (130 mm^2, 12.83 mm diameter with 9.53 mm shaft for hard soils) at a uniform speed into the soil. Cone index measurements were taken every 15 mm to a depth of 600 mm in the soil. When the maximum depth was reached the pressure readings were recorded in the data storage system of the penetrometer. Values are reported as *X* kPa at *Y* mm depth. Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

<u>Evaluating Organic Matter</u>

Before planting cover crops in fall 2003 and prior to harvest in 2005, soil samples were collected to determine organic matter content pre and post treatment. Soil samples were taken at three depths, 0-5 cm, 5-10 cm, and 10-15 cm, and analyzed individually. Determination of total carbon, by combustion, was performed by the Auburn University Soil Testing Laboratory (Auburn, Ala.). Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

<u>Monitoring Soil Moisture</u>

In 2004 and 2005, percent soil moisture was monitored in each plot at a depth of 0-15.2 cm and 15.2-30.5 cm within the middle row (of each four-row plot between plants) and between the row middles from transplanting until just prior to harvest. Measurements were taken at four- or five-day intervals from 9 June though 8 Aug. 2004 and from 27 June through 24 Aug. in 2005. Periodically intervals between measurements were longer due to weather. In 2004 the measuring instrument malfunctioned necessitating a repair. This also resulted in a longer interval between measurements from 19 June through 28 June 2004. The percentage of moisture in the soil was measured using the TRIME-FM system which is composed of the TRIME-T3 Tube Access Probe and TECANANAT tube, and the Three-Rod Probe P3 (IMKO Micromodultechnic GmbH, Ettlingen, Germany). The TRIME-FM generates a high frequency pulse which creates an electromagnetic field around the TRIME probe. This pulse is reflected back to the source, and it is dependent on moisture content. Percent moisture of the soil is calculated by the TRIME-FM device. The TRIME Tube Access Probe was used to measure the percent soil moisture at the deeper soil depth. The access tubes (for measuring at a depth of 15.2-30.5 cm) were put in place using a hand auger. A plastic collar was mounted around these tubes to prevent water from running down along the tube wall, and a plastic cap was installed to protect the tube from filling with rain. The Three-Rod Probe P3 was used for measuring at the shallower soil depth. Using a rubber mallet, a small rod and guide pattern (included with the TRIME-FM), small holes were made so that the Three-Rod Probe could be pushed into the ground to the appropriate depth. These measurements were taken to determine to what extent the cover crops were affecting soil moisture. Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

Monitoring Soil Temperature

In 2004 and 2005 from transplanting until harvest, soil temperatures were measured in each plot at the depth of storage root formation (15 cm depth within the row of developing sweetpotatoes). Soil temperature was measured using the HOBO® Water

Temp Pro (Onset Computer Corporation, Bourne, Mass.). These probes recorded temperature measurements from 8 June through 7 Sept. 2004, and from 16 June through 7 Sept. 2005 every 30 minutes throughout the day. The temperature probes were inserted by hand into the center of one of the middle rows of each four-row plot. Temperature measurements were taken in three of the five replications (replications one, three and five). These measurements were taken to test the effects of the cover crop residue on soil temperature. Initiation and bulking of sweetpotatoes can be hindered by high soil temperatures (Kim, 1961). Therefore soil temperatures only during root initiation (14 to 35 days after transplanting) and only during root bulking (53 to 70 days after transplanting) were examined. Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

Harvesting

Sweetpotato vines were cut before harvest using a flail mower. Each plot of sweetpotatoes was harvested by mid-Sept. in 2004 and 2005, cured at 29.4°C for six to eight days, and then separated into individual grade classes and weighed, according to USDA standards (2005a). Sweetpotatoes were graded into Jumbos, U.S. No.1, U.S. No.2, and culls. Sweetpotatoes were size separated according to length and diameter: Jumbos (>22.86 cm long, >8.89 cm diameter), U.S. No.1 (>7.62 cm and not more than 22.86 cm long, <8.89 cm in diameter), and U.S. No.2 (<3.81 cm in diameter). Sweetpotatoes that displayed symptoms of disease, decay, insect or rat damage, or were too small or misshapen were considered culls. Yield data included the weight of Jumbos, U.S. No.1, U.S. No.2, and culls. Total yield was the sum of each grade class including culls, and total marketable yield was the sum of Jumbos, U.S. No.1, and U.S. No.2

grades. Data were subjected to appropriate analysis of variance procedure (ANOVA) for a RCBD using SAS (SAS Institute, Inc., Cary, N.C.).

Economic Analysis

The Alabama Enterprise Budget for commercial sweetpotato production (Appendix 1) was revised (Appendix 2-10) to determine differences in net returns above expenses among all treatments (Fields, III. et al., 2005). Variable costs such as insecticides, fungicides, and fertilizer were amended to include the chemicals and rates used over the two years of this study. The additional seed costs for the cover crops were also added. Fixed costs such as tractor and machinery use were updated to include the cost of the cover crops, roller, and no-tillage. An average wholesale value of $15.00 per 18.1 kg box of U.S. No.1's, $5.00 per cwt. of U.S. No.2's, and $5.00 per cwt. of Jumbos was used which represented the average wholesale price for 2004 and 2005.

IV. RESULTS AND DISCUSSION

Sweetpotato Yield

In the preliminary statistical analysis of the yield data, both years were combined (Table 2). This analysis determined if there were differences in yield among the treatments between the two years based on cover crop, applied nitrogen rate, or from interactions between these factors. There was a significant interaction between cover crop and year for U.S. No. 1 grade sweetpotatoes per hectare (No. 1's), total yield per hectare (TY), and total marketable yield per hectare (TMY) ($p \leq 0.0301$, $p \leq 0.0288$, and $p \leq 0.0281$, respectively) (Table 2). The amount of culls per hectare in each treatment differed by year ($p \leq 0.0001$) but no other factor (Table 3). There were no differences among treatments for culls. In 2005, there were more culls produced than in 2004 (1,974 $kg \cdot ha^{-1}$ vs. 1,026 $kg \cdot ha^{-1}$; $p \leq 0.05$). U.S. No. 2's and Jumbos per hectare were not influenced by any factor. U.S. No. 2's averaged 4,929 $kg \cdot ha^{-1}$ for all treatments. Jumbos averaged 3,122 $kg \cdot ha^{-1}$ for all treatments (Table 4). Nitrogen rate did not significantly affect any component of yield.

U.S. No. 1

Since the influence of cover crop on average No.1's was dependent on year, the statistical analysis was performed by year (cover crop x year interaction). Nitrogen rate did not significantly affect U.S. No. 1 grade sweetpotatoes. Pairwise tests ($p \leq 0.05$) were performed to determine differences in average No.1's between the cover crops (Table 4).

In 2004 average No.1's of all cover crop treatments were similar. Average No.1's from the bareground treatment was lowest (23,126 $kg \cdot ha^{-1}$), but was not significantly different from the rye or wheat treatment (28,360 $kg \cdot ha^{-1}$ and 26,028 $kg \cdot ha^{-1}$, respectively). The crimson clover and hairy vetch treatments (33,277 $kg \cdot ha^{-1}$ and 32,405 $kg \cdot ha^{-1}$, respectively) produced significantly higher yields of No.1's than the bareground treatment (Table 4). In 2005 average No.1's did not differ between the cover crops or the bareground treatments averaging 16,463 $kg \cdot ha^{-1}$ across all of the treatments (Table 4).

Total Yield

Since the influence of cover crop on average TY was dependent on year, the statistical analysis was performed by year (cover crop x year interaction). Nitrogen rate did not affect total yield. Pairwise tests ($p \leq 0.05$) were performed to determine differences in average TY between the cover crops (Table 4).

In 2004 average TY from the bareground treatment was lowest (31,365 $kg \cdot ha^{-1}$), but was not significantly different from the rye or wheat treatment (38,402 $kg \cdot ha^{-1}$ and 34,834 $kg \cdot ha^{-1}$, respectively). Average TY produced from the crimson clover and hairy vetch treatments were the highest (41,794 $kg \cdot ha^{-1}$ and 41,074 $kg \cdot ha^{-1}$, respectively). The crimson clover and hairy vetch treatments produced significantly higher yields than the bareground treatment (Table 4). In 2005 average TY did not differ between the cover crops or the bareground treatments averaging 26,710 $kg \cdot ha^{-1}$ across all of the treatments (Table 4).

Total Marketable Yield

Since the influence of cover crop on average TMY was dependent on year, the statistical analysis was performed by year (cover crop x year interaction). Nitrogen rate did not affect TMY. Pairwise tests ($p \leq 0.05$) were performed to determine differences in average TMY between the cover crops (Table 4).

In 2004 average TMY from the bareground treatment was lowest (30,731 $kg \cdot ha^{1}$), but was not significantly different from the rye or wheat treatment (36,801 $kg \cdot ha^{-1}$ and 33,585 $kg \cdot ha^{-1}$, respectively). Average TMY produced from the crimson clover and hairy vetch treatments were the highest (41,057 $kg \cdot ha^{-1}$ and 40,160 $kg \cdot ha^{-1}$, respectively). The crimson clover and hairy vetch treatments produced significantly higher yields than the bareground treatment (Table 4). In 2005 average TMY did not differ between the cover crop or the bareground treatments averaging 24,736 $kg \cdot ha^{-1}$ across all of the treatments (Table 4).

Cover Crop Biomass Analysis

Table 5 shows the average biomass yields, nitrogen, carbon, and C:N ratios for fall planted cover crops in 2004 and 2005. Analysis of data showed significant differences among cover crops in 2004 and 2005 ($p \leq 0.0001$ and $p \leq 0.0001$, respectively). Pairwise tests ($p \leq 0.05$) were performed to determine differences among the cover crop treatments in 2004 and 2005 (Table 5).

In both years, the average biomass yields were significantly higher among the cover crop treatments compared to that of the bareground treatment (Table 5; $p \leq 0.05$). Winter rye, crimson clover, and wheat produced the most biomass in 2004 and were statistically similar to each other (9,453 $kg \cdot ha^{-1}$, 8,788 $kg \cdot ha^{-1}$, and 8,354 $kg \cdot ha^{-1}$, respectively). Among the cover crop species, hairy vetch produced the least amount of biomass (4,351 kg·ha^{-1}) in 2004, but it was significantly higher than the biomass produced in the bareground treatment (1,148 kg·ha^{-1}). In 2005, winter rye and crimson clover produced the most biomass (12,110 kg·ha^{-1} and 10,545 kg·ha^{-1}, respectively). Wheat and hairy vetch produced the least biomass (8,759 kg·ha^{-1} and 7,628 kg·ha^{-1}, respectively), but were significantly higher than the biomass produced in the bareground treatment (2,428 kg·ha^{-1}). The biomass produced by the wheat was statistically similar to that produced by crimson clover (Table 5; $p \leq 0.05$). In both years the winter annual weeds that colonized the bareground plots produced the poorest ground cover and decomposed earliest in the growing season (data not shown).

Cover crops improve the quality and health of the soil by adding biomass and increasing soil organic matter. One of the prime benefits of increased organic matter content is reduced soil compaction. The addition of organic matter improves the soil structure because soil microbes digest plant materials releasing sugars which act as glues in the soil to cement soil particles into clusters or aggregates. A well aggregated soil is less compacted allowing better infiltration and retention of water (Bowman et al., 2000). Planting a winter cover crop may help improve soil compaction and drainage, which is essential for growing quality sweetpotato roots.

Cover Crop Carbon and Nitrogen Content

The cover crops were analyzed for carbon and nitrogen content in 2004 and 2005. In both years, the rye cover crop produced the highest amount of carbon relative to the other cover crops ($p \leq 0.05$; Table 5). Statistically, rye, crimson clover, and wheat produced similar quantities of carbon ($p \leq 0.05$; Table 5). Hairy vetch produced the least amount of carbon both years ($p \leq 0.05$; Table 5). The carbon content of a cover crop can be an indication of the residual life of that cover crop. Cover crops high in carbon decompose more slowly leaving behind residue that acts as mulch, suppressing early season weeds, reducing soil water evaporation, and increasing infiltration rate of water.

In both years, crimson clover and hairy vetch produced a significant quantity of nitrogen relative to rye and wheat ($p \leq 0.05$; Table 5). In 2004, the amount of nitrogen produced by the cover crops ranged from 77 to 250 $kg \cdot ha^{-1}$ with crimson clover and hairy vetch producing the highest amount of N (250 $kg \cdot ha^{-1}$ and 184 $kg \cdot ha^{-1}$, respectively). In 2005, the amount of nitrogen produced by the cover crops ranged from 100 to 357 $kg \cdot ha^{-1}$ with crimson clover and hairy vetch producing the highest amount of N (357 $kg \cdot ha^{-1}$ and 353 $kg \cdot ha^{-1}$, respectively). The nitrogen content of crimson clover and hairy vetch found in our study was comparable to other research findings. Past research has shown that hairy vetch and crimson clover often produces the most nitrogen of all legume cover crops (Sullivan, 2003; Holderbaum et al., 1990). In a study conducted in Louisiana, Jett and Talbot (1998) found that crimson clover and hairy vetch cover crops produced more nitrogen than any of the other cover crop species in their study (200 $kg \cdot ha^{-1}$and 284 $kg \cdot ha^{-1}$, respectively). In a study conducted in north Alabama, Carroll and others (2003) found that hairy vetch produced the most nitrogen (154 $kg \cdot ha^{-1}$) of any of the cover crops that were grown.

Efficient C:N ratios were found in the crimson clover and hairy vetch cover crops for both years (Table 5). According to Sylvia and others (1999) optimum C:N ratios for decomposition of the cover crops is less than 25:1. Ratios above 25:1, such as those reported for rye and wheat in this study, result in nitrogen being ‘tied up’ by soil microbes during the decomposition process, not contributing as much available nitrogen to the soil as cover crops with lower C:N ratios. Therefore, cover crops with C:N ratios lower than 25:1 release more nitrogen and other nutrients into the soil for immediate crop use. Hoyt (1987) estimated that 40% of plant tissue nitrogen from a cover crop being used as a no-till mulch becomes available in the first year after it is killed and that 60% becomes available if the cover crop is incorporated as a green manure.

Penetrometer Analysis

In the preliminary statistical analysis of the cone index measurements, both years were combined. This analysis determined if there were differences in cone index measurements among the treatments between the two years based on cover crop, depth, or from interactions between these factors. Cone index measurements were influenced by year ($p \leq 0.0001$) but no other factor or interaction between these factors.

Since there were no differences among any treatments pairwise tests ($p \leq 0.05$) were performed to determine differences by year for cone index. Average cone index measurements were higher in 2004 (1,726 kPa) than in 2005 (1,070 kPa) for all treatments ($p \leq 0.05$). Previous research has shown that the use of winter cover crops reduced cone index measurements, most likely due to increased soil moisture and organic matter content (Raper et al., 2000a and Raper et al., 2000b).

Soil Moisture Analysis

Shallow Depth (0-15.2 cm)

The average percent soil moisture at soil depth 0-15.2 cm within-rows was influenced by year ($p \leq 0.0001$) but no other factor (Table 6). Since there were no differences among any treatments, pairwise tests ($p \leq 0.05$) were used to determine differences by year for percent soil moisture. Percent soil moisture across all treatments averaged 20.1% in 2004 and 21.8% in 2005, respectively.

The average percent soil moisture at soil depth 0-15.2 cm between-rows was influenced by cover crop treatments ($p \leq 0.0001$) and year ($p \leq 0.0001$) with no interactions. Nitrogen rate did not significantly affect soil moisture at this depth (Table 6). Pairwise tests ($p \leq 0.05$) were performed to determine differences in soil moisture by cover crop treatments (Table 7a). The average percent soil moisture was significantly higher among the crimson clover (25.9%), winter rye (26.4%), and winter wheat (25.5%) treatments than the bareground treatment (24.3%) ($p \leq 0.05$). The percent soil moisture for the hairy vetch treatment (24.7%) was not significantly higher than that of the bareground treatment (24.3%) but similar to that of the winter wheat treatment (26.4%) ($p \leq 0.05$).

Means separation ($p \leq 0.05$) was used to determine differences by year for percent soil moisture. Percent soil moisture for all treatments averaged 24.6% in 2004 and 26.1% in 2005. These differences can be attributed to the fact that rainfall amounts were higher during the time we were monitoring soil moisture in 2005 than in 2004 (23.0 cm vs. 30.5 cm of rainfall in 2004 and 2005, respectively). Over time, the addition of organic matter can increase water infiltration, therefore increasing soil moisture content.

<u>Deep Soil Depth (15.2 cm-30.5 cm)</u>

The average percent soil moisture at soil depth 15.2-30.5 cm within-rows was influenced by cover crop ($p \leq 0.0001$) and year ($p \leq 0.0001$) but with no interactions (Table 6). Nitrogen rate did not significantly affect percent soil moisture at this soil depth (Table 6). Pairwise tests ($p \leq 0.05$) were performed to determine differences in percent soil moisture between the cover crop treatments (Table 7a). Average percent soil moisture was significantly higher among the crimson clover (28.0%), winter rye (27.8%), and winter wheat (27.0%) treatments than that of the bareground treatment (24.9%) ($p \leq 0.05$). The percent soil moisture for the hairy vetch treatment (25.7%) was similar to that of the bareground treatment (24.9%) ($p \leq 0.05$).

Means separation ($p \leq 0.05$) was used to determine differences by year for percent soil moisture. Percent soil moisture among all treatments averaged 25.5% in 2004 and 28.0% in 2005, respectively ($p \leq 0.05$).

The average percent soil moisture at soil depth 15.2-30.5 cm between-rows was influenced by cover crop ($p \leq 0.0001$) and nitrogen rate ($p \leq 0.0001$) (Table 6). There was a significant interaction between cover crop and nitrogen rate (N rate) ($p \leq 0.0028$). Since the influence of cover crop on percent soil moisture was dependent upon nitrogen rate, a pairwise test of least squares means was performed to compare the means of one factor (cover crop) within each level of the other factor (N rate) (Table 7b). Average percent soil moisture was significantly higher in the crimson clover x 50 $kg \cdot ha^{-1}$ N rate treatment (33.9%) than in the winter rye, winter wheat, or bareground x 50 $kg \cdot ha^{-1}$ N rate treatments (30.3%, 30.1%, and 29.0%, respectively) (Table 7b). Average percent soil moisture was significantly higher in the crimson clover x 100 $kg \cdot ha^{-1}$ N rate treatment than in the hairy vetch x 100 $kg \cdot ha^{-1}$ N rate treatment (31.2% vs. 28.4%, respectively) (Table 7b). All other pairwise comparisons were not significantly different (data not shown).

Conservation of water resources during the spring and summer growing months has long been the argument for the use of cover crops (Hoyt, 1999; Johnson and Hoyt, 1999; Teasdale 1996). In our study, soil moisture was significantly higher in the crimson clover, winter rye, and winter wheat cover crop treatments at the 0-15.2 cm soil depth between-rows and 15.2-30.5 cm soil depth both within-rows and between-rows compared to that of the bareground treatment (Table 7a). This conservation of soil water is important as water is a limiting factor in sweetpotato production (Kemble et al., 1996). Our research findings compare with research on conservation tillage and pumpkins in north Alabama by Carroll and others (2003). They reported that soil moisture was increased under the cover crop treatments at the 0-15.2 cm soil depth between rows and 15.2-30.5 cm soil depth between rows compared to that of the bareground treatment for strip-tilled pumpkins.

Soil Temperature Analysis

Environmental variability can affect sweetpotato growth (Ngeve and Bouwkamp, 1993). High soil temperatures (≥28.8°C) and fluctuations in soil moisture can hinder root initiation (Kim, 1961). It has been found that cover crops can lower soil temperatures, providing a less stressful environment for sweetpotato development (Jett and Talbot, 1997).

In 2004 and 2005, soil temperature was measured from 14 to 70 days after transplanting. Analysis of variance determined if there were differences in average daily temperature for the periods of root initiation (14 to 35 days after transplanting) and for root bulking (53 to 70 days after transplanting) among the treatments for the two years based on cover crop, applied nitrogen rate, or from interactions between these factors.

During root initiation the average daily temperature for both years was influenced by cover crop ($p \leq 0.0001$) but no other factor and with no interactions. In 2004 daily temperature during root initiation for the crimson clover, hairy vetch, rye, and wheat treatments averaged 26.0ºC, 25.9ºC, 25.8ºC, and 25.8ºC, respectively. The average daily temperature during root initiation from the bareground treatment was 25.8ºC. Although significant, there was a minor difference of 0.2ºC between the crimson clover treatment and bareground treatments ($p \leq 0.01$). In 2005 daily temperature during root initiation for the hairy vetch, wheat, bareground, and crimson clover treatments averaged 27.2ºC, 27.0ºC, 26.9ºC, and 26.9ºC, respectively. The average daily temperature during root initiation from the rye treatment was 26.8ºC. Although significant, there was a minor difference of 0.4ºC between the hairy vetch treatment and rye treatment ($p \leq 0.01$). It is unlikely that these minor differences would have had a significant affect on sweetpotato growth. During root bulking no differences were found among any of the treatments for the average daily temperature. During bulking, daily average temperature for all treatments in 2004 was 25.1°C and in 2005 was 25.8°C ($p \leq 0.01$).

In a sweetpotato study by Jett and Talbot (1997) they found that a conservation tillage-ryegrass cover crop treatment reduced average soil temperatures as much as -13.6°C during sweetpotato initiation relative to the conventional tillage-bareground (control) treatment. Total root set was also significantly greater with the conservation tillage-ryegrass treatment relative to the control (Jett and Talbot, 1997).

Soil Organic Matter Analysis

At planting of the cover crops in 2003, the average percent soil organic matter measured 0.55% at 0-5 cm, 0.50% at 5-10 cm, and 0.51% at 10-15 cm soil depth, respectively. In order to determine if there were any changes in soil organic matter levels over the course of this study, soil samples were collected just prior to harvest in 2005. Analysis of data from these samples showed no significant differences in soil organic matter levels between any treatments (data not shown). Despite the lack of any significant difference, there was a trend towards an increase in organic matter from 2003 to 2005 at the three soil depths sampled compared to the initial levels in 2003. Soil organic matter levels were +0.62%, +0.60%, and +0.52% higher at the 0-5 cm, 5-10 cm, and 10-15 cm soil depths, respectively. The average percent soil organic matter across all treatments in 2005 measured 1.17% at 0-5 cm, 1.10% at 5-10 cm, and 1.03% at 10-15 cm soil depth.

Growing cover crops can increase soil organic matter content. Although in our study there was a trend towards higher levels of organic matter, the increases we observed were not significant over the short time period of this study. In a similar study in sweetpotato, Jett and Talbot (1997) reported that conservation tillage combined with rye or ryegrass cover crops significantly increased soil organic matter content relative to the conventional tillage, bareground (control) treatment by as much as 0.35%.

Economic Analysis

In the United States, commercial production of sweetpotatoes is concentrated in 10 states, mostly in the southeast. According to the National Agricultural Statistics Service, USDA (2005b), Alabama is the 6th largest producer of sweetpotatoes in the United States accounting for almost 1,214 harvested hectares of vegetables in the state valued at over $12 million. North Carolina is ranked first with 18,211 harvest hectares; Louisiana, 6,475 hectares; Mississippi, 6,475 hectares; California, 4,654 hectares; and Texas 1,416 hectares (USDA-NASS, 2005). Kemble and others (1996) consider the sweetpotato one of the most economically important vegetable crops produced in Alabama.

Budgets were developed based on the Alabama Enterprise Budget for sweetpotatoes to determine potential net returns to growers using the production systems in this study (Fields III, et al., 2005). An average wholesale value of \$15.00 per 18.1 kg box of U.S. No.1's, \$5.00 per cwt. of U.S. No.2's, and \$5.00 per cwt. of Jumbos was used which represented the average wholesale price for 2004 and 2005.

Analysis of variance was used to determine if there were differences in net returns per hectare among the treatments for the two years of this study based on cover crop, applied nitrogen rate, or interactions between these factors. Nitrogen rate and cover crop influenced net returns for sweetpotato ($p \leq 0.0294$, $p \leq 0.0125$, respectively) but there were no interactions between these factors (data not shown). Pairwise tests ($p \leq 0.05$) were performed to determine differences in net returns based on applied nitrogen rate and cover crop. Across all cover crops, treatments with an applied nitrogen rate of 100 $kg \cdot ha^{-1}$ produced higher net returns (\$5,567.00 per hectare) compared to treatments with a nitrogen rate of 50 $kg \cdot ha^{-1}$ (\$4,769.80 per hectare) ($p \leq 0.05$). Within the cover crop treatments, crimson clover produced higher net returns (\$5,871.40 per hectare) compared to the wheat (\$4,748.70 per hectare) and bareground treatments (\$4,494.10 per hectare) ($p \leq 0.05$).

V. CONCLUSIONS

A winter annual cover crop combined with a no-till system of transplanting is a viable alternative to conventional tillage for producing sweetpotatoes. In 2005 we found no differences in yield between the conventional tillage, bareground treatment versus the no-till, cover crop treatments. In 2004, however, the crimson clover, no-till and hairy vetch, no-till treatments produced significantly higher yields of No. 1's, total yields, and total marketable yields compared to the conventional tillage, bareground treatment. This compares favorably with other research findings. Jett and Talbot (1997) found that conservation tillage combined with legume cover crops and legume/grass cover crop mixes had yields equal to but not greater than the conventional tillage, bareground treatment in a sweetpotato production system. In Jett and Talbot's study, the hairy vetch, conservation tillage treatment had the highest yields (though not significant) of No.1's and total marketable yield of sweetpotato.

Legume cover crops such as crimson clover and hairy vetch can contribute nitrogen to the succeeding sweetpotato crop relieving the farmer of some of the cost of buying fertilizer. According to the results of this study, the recommended nitrogen rate for sweetpotato in Alabama may be reduced from 100 $kg \cdot ha^{-1}$ to 50 $kg \cdot ha^{-1}$ when using a legume cover crop such as crimson clover or hairy vetch without a reduction in yield or an economic loss. Economically, sweetpotato production using crimson clover and hairy vetch cover crops and a reduced recommended nitrogen rate yields higher net returns

(Table 8). Although this economic profitability may not be significantly higher than that of the conventional bareground sweetpotato production system, it is still advantageous for the grower. By using a cover crop and conservation tillage, the grower can, in the long run, improve the overall health of his soil therefore increasing productivity. Our research findings compare with research on conservation tillage and pumpkins in north Alabama by Carroll and others (2003). They reported that the recommended rate of 100 $kg \cdot ha^{-1}$ of nitrogen can be lowered to 50 $kg \cdot ha^{-1}$ with no decrease in pumpkin yield for both conventional bareground production and for strip-till production using hairy vetch or yuchi arrowleaf clover (*Trifolium vesiculosus* Saki.).

Our data suggests that grass or legume cover crops can have a beneficial effect on sweetpotato development. Grass or grain cover crops such as winter rye or winter wheat can provide good erosion control and reduce nutrient leaching in the winter while the cover crop is growing. This is important because the conventional method of sweetpotato culture requires intensive soil management and results in significant soil erosion (Jett and Talbot, 1997). Cover crops can add biomass to the soil therefore increasing soil organic matter and reducing soil compaction, and over time, greatly enhancing soil tilth. Cover crop mulch reduces soil water evaporation from the soil surface and decreases rainfall runoff while enhancing infiltration. Sweetpotatoes are typically not irrigated and this could help the grower to conserve soil moisture, especially in seasons of drought. Conservation of soil moisture can improve the quality and increase the yields of sweetpotatoes (Treadwell et al., 2003). Cover crop mulch can reduce early season weeds by shading or by allelopathic effects, reducing the need for herbicide use.

According to the results of this study, we recommend that crimson clover or hairy vetch be used as the winter growing cover crop for no-tilled sweetpotatoes. Crimson clover and hairy vetch produced high yields and remained profitable compared to the conventional bareground system. The recommended nitrogen rate of 100 $kg \cdot ha^{-1}$ may be reduced to 50 $kg \cdot ha^{-1}$ for both conventional bareground production of sweetpotatoes and for no-till production using crimson clover or hairy vetch cover crops.

The benefits of legume/grass cover crop mixtures should also be examined for sweetpotato production. Combining a grass and a legume as a mixture may produce residues with some of the best characteristics of each individual cover (Rosecrance et al., 2000). It would be beneficial to track the effectiveness of several mixtures and analyze their impact on the growth and development of sweetpotato. It would be beneficial to see how sweetpotatoes respond to only the nitrogen supplied by a legume cover crop, therefore legume cover crops combined with a nitrogen rate of 0 $kg \cdot ha^{-1}$ should also be examined. It has been reported that crimson clover is susceptible to root-knot nematode (*Meloidogyne* spp. Goeldi) (Peet, 2001), so the effects of cover crops and conservation tillage on populations of pest insects, beneficial insects, and diseases should also be examined for sweetpotato. Because it takes many years to see the impact of cover crops on the soil environment, a long term study would be beneficial to better understand these effects (Johnson and Hoyt, 1999). The cover crops that were evaluated in this study may not perform the same on different soils in other parts of Alabama. Therefore, the performance of the cover crops in this study, as well as others, should be evaluated in other major sweetpotato producing areas of the state.

Table 1a. Principle Uses of Legume Cover Crops.

Use		Function	Legumes
Winter annual cover crop	Planted late summer into maturing cash crop or fall after harvest	Provide soil cover in winter to prevent erosion, legume is chosen for added benefit of nitrogen fixation	Clovers (*Trifolium* spp. L.), vetches (*Vicia* spp. L.), medics (*Medicago* spp. L.), field peas (*Pisum sativum* ssp. *arvense* (L.) Poir.)
Summer green manure crop	Occupies the land for a portion of the summer growing season	Fills a niche in crop rotations, to improve conditions of poor soils, or prepare land for perennial crop	Cowpeas (*Vigna unguiculata* (L.) Walp.), soybeans (*Glycine max* (L.) Merr.), annual sweetclover (*Melilotus officinalis* (L.) Pall.) sesbania (*Sesbania exaltata* (Raf.) Cory), sunn hemp (*Crotolaria juncea* L.), velvet beans (*Mucuna deeringiana* (Bort) Merr.)
Living mulch	Interplant with annual or perennial cash crop, maintained as a living crop	Suppress weeds, reduce erosion, enhance fertility, and improve water infiltration	Typically perennials, such as red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.) and medics (*Medicago* spp.)
Forage Crop	Occupy land for pasture, haying, or as a green manure	Incorporated or killed for no-till mulch, contributes biomass	Alfalfa (*Medicago sativa* L.), sweet clover (*M.officinalis*), red clover (*T. pratense*), white clover (*T. repens*)

(Adapted from: Sullivan, 2003; Hartwig and Ammon, 2002; Bowman et al., 2000)

Table 1b. Principle Uses of Cereal Grains and Grass Cover Crops.

Use		Function	Cereal Grains and Grasses
Winter annual cover crop	Planted late summer into maturing cash crop or fall after harvest	Provide soil cover in winter to prevent erosion, legume is chosen for added benefit of nitrogen fixation	Oats (*Avena* spp. L.), rye (*Secale cereale* L.), wheat (*Triticum aestivum* L.)
Summer green manure crop	Occupies the land for a portion of the summer growing season	Fills a niche in crop rotations, to improve conditions of poor soils, or prepare land for perennial crop	Sorghum-sudangrass (*Sorghum bicolor* x *Sorghum bicolor* var. *sudanese*), millet (*Setaria italica* (L.) Beauv.), buckwheat (*Fagopyrum esculentum* Moench)
Living mulch	Interplant with annual or perennial cash crop, maintained as a living crop	Suppress weeds, reduce erosion, enhance fertility, and improve water infiltration	Ryegrass (*Lolium multiflorum* Lam.)
Catch crop	Established after harvesting cash crop	Reduces nutrient leaching, fills a niche within a crop rotation	Oats (*Avena* spp.), winter rye (*S.cereale*), wheat (*T. aestivum*), ryegrass (*L. multiflorum*)
Forage Crop	Occupy land for pasture, haying, or as a green manure	Incorporated or killed for no-till mulch, contributes biomass	Fescue (*Festuca* spp. L.)

(Adapted from: Sullivan, 2003; Hartwig and Ammon, 2002; Bowman et al., 2000)

Table 2. Analysis of Variance for Sweetpotato Yield Responses for 2004 and 2005 for No. 1, Total Yield, and Total Marketable Yield.

	No.1[x]			**TY[y]**			**TMY[z]**		
Source	**d.f**	**F value**	**P value**	**d.f**	**F value**	**P value**	**d.f**	**F value**	**P value**
Cover Crop	4	1.92	NS	4	1.14	NS	4	1.35	NS
N Rate	1	3.72	NS	1	2.31	NS	1	3.23	NS
Cover Crop x N Rate	4	0.45	NS	4	0.91	NS	4	0.85	NS
Year	1	95.10	**≤0.0001***	1	54.70	**≤0.0001**	1	69.60	**≤0.0001**
Cover Crop x Year	4	2.84	**0.0301**	4	2.87	**0.0288**	4	2.89	**0.0281**
N Rate x Year	1	2.99	NS	1	0.22	NS	1	0.40	NS
Cover Crop x N Rate x Year	4	0.18	NS	4	0.22	NS	4	0.18	NS

[x] No.1= total U.S. No.1 grade sweetpotatoes
[y] TY= total yield of sweetpotatoes
[z] TMY= total marketable yield of sweetpotatoes
NS, * *Non-significant* or *significant* at $P \leq 0.05$, respectively.

Table 3. Analysis of Variance for Sweetpotato Yield Responses for 2004 and 2005 for Culls.

	culls		
Source	**d.f**	**F value**	**P value**
Cover Crop	4	1.85	NS
N Rate	1	2.72	NS
Cover Crop x N Rate	4	1.84	NS
Year	1	25.67	**≤0.0001***
Cover Crop x Year	4	1.07	NS
N Rate x Year	1	1.16	NS
Cover Crop x N Rate x Year	4	0.47	NS

NS, * *Non-significant* or *significant* at p≤0.05, respectively.

Table 4. Average No. 1[w], No. 2[x], Jumbos[y], Culls[z], TY[XX], and TMY[yy] for Sweetpotatoes in 2004 and 2005.

	No.1		No.2	
Cover crop	**2004**	**2005**	**2004**	**2005**
Crimson clover	33,277 a*	16,331 a	5,062 a	5,090 a
Winter rye	28,360 ab	16,771 a	4,924 a	5,728 a
Winter wheat	26,028 ab	16,934 a	6,083 a	5,013 a
Hairy vetch	32,405 a	15,512 a	4,560 a	3,904 a
Bareground	23,126 b	16,767 a	5,154 a	3,767 a
LSD	7,481	NS	NS	NS

	Jumbos		Culls	
Cover crop	**2004**	**2005**	**2004**	**2005**
Crimson clover	2,717 a	2,849 a	736 a	1,477 a
Winter rye	3,516 a	3,721 a	1,601 a	1,937 a
Winter wheat	1,474 a	2,541 a	1,248 a	2,321 a
Hairy vetch	3,193 a	3,342 a	914 a	2,010 a
Bareground	2,450 a	5,412 a	634 a	2,124 a
LSD	NS	NS	NS	NS

	TY		TMY	
Cover crop	**2004**	**2005**	**2004**	**2005**
Crimson clover	41,794 a	25,747 a	41,057 a	24,270 a
Winter rye	38,402 ab	28,157 a	36,801 ab	26,220 a
Winter wheat	34,834 ab	26,809 a	33,585 ab	24,488 a
Hairy vetch	41,074 a	24,768 a	40,160 a	22,758 a
Bareground	31,365 b	28,071 a	30,731 b	25,946 a
LSD	7,984	NS	8,196	NS

[w]No.1 = average U.S No.1 in $kg{\cdot}ha^{-1}$.
[x] No.2 = average U.S. No.2 in $kg{\cdot}ha^{-1}$.
[y] Jumbos = average Jumbos in $kg{\cdot}ha^{-1}$.
[z] Culls = average culls in $kg{\cdot}ha^{-1}$.
[xx] TY = average total yield in $kg{\cdot}ha^{-1}$.
[yy] TMY = average total marketable yield in $kg{\cdot}ha^{-1}$.
*Means within a column followed by a different letter are significantly different according to LSD at $p \leq 0.05$.

Table 5. 2004 and 2005 Average Biomass Yields[x], Nitrogen[x], Carbon[x], and C:N Ratios of Fall Planted Cover Crops

Year	Cover crop	Biomass[y]	N	C	C:N Ratio
	Bareground	1,148 c[z]	21 d	412 c	19:1
2004	Crimson clover	8,788 a	250 a	3,687 a	15:1
	Winter rye 'Elbon'	9,453 a	77 c	4,208 a	55:1
	Winter wheat	8,354 a	95 c	3,626 a	38:1
	Hairy vetch	4,351 b	184 b	1,838 b	10:1
	LSD	2,020	41	894	
	Bareground	2,428 d	56 c	1,018 c	18:1
2005	Crimson clover	10,545 ab	357 a	4,827 ab	13:1
	Winter rye 'Elbon'	12,110 a	103 b	5,950 a	58:1
	Winter wheat	8,759 bc	100 bc	4,275 b	43:1
	Hairy vetch	7,628 c	353 a	3,724 b	11:1
	LSD	2,534	44	1,234	

[x]All yields are in $kg \cdot ha^{-1}$.
[y]Biomass yield calculated from dry weight.
[z]Means within a column followed by a different letter are significantly different according to LSD at $p \leq 0.05$.

Table 6. Analysis of Variance of Soil Moisture Levels from 0-15.2 cm Deep Within-rows (**A**) and Between-rows (**B**) and 15.2 cm-30.5 cm Deep Within-rows (**C**) and Between-rows (**D**) from 2004 and 2005.

	0-15.2 cm in row (**A**)			*0-15.2 cm btw-row* (**B**)		
Source	d.f.	F value	P value	d.f.	F value	P value
Cover crop	4	1.9	NS	4	6.99	**≤0.0001**
N rate	1	0.6	NS	1	0.55	NS
Cover crop x N rate	4	0.13	NS	4	0.11	NS
Year	1	16.58	**≤0.0001***	1	26.33	**≤0.0001**
Cover crop x year	4	0.36	NS	4	1.96	NS
N rate x year	1	0.21	NS	1	0.37	NS
Cover crop x N rate x year	4	0.25	NS	4	0.24	NS

	15.2-30.5 cm in-row (**C**)			*15.2-30.5 cm btw-row* (**D**)		
Source	d.f.	F value	P value	d.f.	F value	P value
Cover crop	4	14.17	**≤0.0001**	4	10.31	**≤0.0001**
N rate	1	0.03	NS	1	17.33	**≤0.0001**
Cover crop x N rate	4	0.21	NS	4	4.09	**0.0028**
Year	1	63.33	**≤0.0001**	1	4.08	NS
Cover crop x year	4	1.92	NS	4	1.97	NS
N rate x year	1	2.4	NS	1	0.99	NS
Cover crop x N rate x year	4	3.56	NS	4	6.62	NS

NS,* *Non-significant* or *significant* at p≤0.05, respectively.

Table 7a. Mean Percent Soil Moisture by Cover Crop Treatments and Means Comparisons of 0-15.2 cm Deep Within rows **(A)** and Between-rows **(B)** and 15.2-30.5 cm Deep Within-rows **(C)** by Cover Crop Treatment for 2004 and 2005.

	0-15.2 cm in row	*0-15.2 cm btw-row*
Treatment	**(A)**	**(B)**
Bareground	20.4 a	24.3 c
Crimson clover	21.0 a	25.9 a
Winter rye	21.7 a	26.4 a
Winter wheat	21.5 a	25.5 ab
Hairy vetch	20.7 a	24.7 bc
LSD	NS	0.89

	15.2-30.5 cm in-row
Treatment	**(C)**
Bareground	24.9 c
Crimson clover	28.0 a
Winter rye	27.8 ab
Winter wheat	27.0 b
Hairy vetch	25.7 c
LSD	0.97

*, NS *Significant* or *non-significant* at $p \leq 0.05$, respectively.
Means within a column followed by a different letter are significantly different according to LSD at $p \leq 0.05$.

Table 7b. Mean Percent Soil Moisture of Cover Crop Treatments by Nitrogen Rates and Means Comparisons of 15.2-30.5 cm Deep Between-rows **(D)** for 2004 and 2005.

Treatment	*50 kg·ha^{-1}*	*100 kg·ha^{-1}*
Bareground	30.0 b*	29.0 ab
Crimson clover	34.0 a	31.2 a
Winter rye	30.3 b	30.1 ab
Winter wheat	30.1 b	30.3 ab
Hairy vetch	31.7 ab	28.4 b

* Means within a column followed by a different letter are significantly different according to *Tukey's* ($p \leq 0.001$).

Table 8. 2004-2005 Net Returns Above Fixed and Variable Costs for Sweetpotato.

Cover crop	Nitrogen Rate[z]	Variable Costs	Fixed Costs	Net Returns
Bareground	50	$2,456.72	$90.40	$3,542.88
Bareground	100	$2,470.23	$90.40	$5,439.37
Crimson clover	50	$2,693.43	$85.79	$5,640.78
Crimson clover	100	$2,706.94	$85.79	$6,082.27
Winter rye	50	$2,690.40	$85.79	$4,824.22
Winter rye	100	$2,712.38	$85.79	$5,496.83
Winter wheat	50	$2,681.83	$85.79	$4,337.38
Winter wheat	100	$2,702.38	$85.79	$5,141.83
Hairy vetch	50	$2,696.10	$85.79	$5,488.11
Hairy vetch	100	$2,709.61	$85.79	$5,634.60

[z] Nitrogen rates are in $kg \cdot ha^{-1}$.

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Appendix 1. Alabama Enterprise Budget for Bareground Sweetpotato Production.

This worksheet reflects the estimated cost/returns of sweetpotato production. The worksheet consists of an enterprise budget, machinery section, and sensitivity analysis. The USER can modify the various quantities and prices to best reflect a given set of circumstances (e.g. - county averages, a specific producer, etc.).

Estimated costs and returns per acre
Conventional Sweet Potatoes, No cover crop - 90 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	506.0000	7590.00	_________
Sweet Potato, No. 2	cwt	5.00	38.0000	190.00	_________
Sweet Potato, Jumbos	cwt	5.00	44.0000	220.00	_________

TOTAL INCOME				8000.00	_________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	_________
Amm Nitrate (34%)	cwt	10.65	2.5000	26.63	_________
HERBICIDE					
Command 3ME	pt	10.36	2.0000	20.72	_________
Poast 1.53	pt	8.38	1.0000	8.38	_________
INSECTICIDE					
Lorsban 4E	pt	4.77	4.0000	19.08	_________
Penncap-M	pt	3.47	4.0000	13.88	_________
Imidan 70 WSB	lb	7.45	1.3000	9.69	_________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	_________
OTHER					
Crate Sweetpotato	each	6.00	2.0000	12.00	_________
Bin Sweetpotato	each	50.00	2.0000	100.00	_________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	_________
Clean, grade, pack	box	1.75	330.0000	577.50	_________
Box Sweetpotato	each	1.20	330.0000	396.00	_________
Broker Sweetpotato	box	1.00	330.0000	330.00	_________
OPERATOR LABOR					
Tractors	hour	9.82	5.1011	50.10	_________
Self-Propelled	hour	9.82	3.0000	29.46	_________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	_________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	_________
HAND LABOR					
Implements	hour	6.44	12.7227	81.93	_________
DIESEL FUEL					
Tractors	gal	2.50	17.5141	43.77	_________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	_________
REPAIR & MAINTENANCE					
Implements	acre	14.94	1.0000	14.94	_________
Tractors	acre	3.91	1.0000	3.91	_________
Self-Propelled	acre	5.86	1.0000	5.86	_________
INTEREST ON OP. CAP.	acre	19.61	1.0000	19.61	_________

TOTAL DIRECT EXPENSES				2470.23	_________
RETURNS ABOVE DIRECT EXPENSES				5529.77	_________
FIXED EXPENSES					
Implements	acre	47.53	1.0000	47.53	_________
Tractors	acre	24.26	1.0000	24.26	_________
Self-Propelled	acre	18.61	1.0000	18.61	_________

TOTAL FIXED EXPENSES				90.40	_________

TOTAL SPECIFIED EXPENSES				2560.63	_________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5439.37	_________

Appendix 2. Revised Alabama Enterprise Budget for Bareground Sweetpotato Production Using a Nitrogen Rate of 50 kg·ha^{-1}.

Estimated costs and returns per acre
Conventional Sweet Potatoes, No cover crop - 45 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	384.0000	5760.00	
Sweet Potato, No. 2	cwt	5.00	41.0000	205.00	
Sweet Potato, Jumbos	cwt	5.00	25.0000	125.00	
TOTAL INCOME				6090.00	
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	
Amm Nitrate (34%)	cwt	10.65	1.2500	13.31	
HERBICIDE					
Command 3ME	pt	10.36	2.0000	20.72	
Poast 1.53	pt	8.38	1.0000	8.38	
INSECTICIDE					
Lorsban 4E	pt	4.77	4.0000	19.08	
Penncap-M	pt	3.47	4.0000	13.88	
Imidan 70 WSB	lb	7.45	1.3000	9.69	
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	
OTHER					
Crate Sweetpotato	each	6.00	2.0000	12.00	
Bin Sweetpotato	each	50.00	2.0000	100.00	
Storage Sweetpotato	cwt	1.00	112.0000	112.00	
Clean, grade, pack	box	1.75	330.0000	577.50	
Box Sweetpotato	each	1.20	330.0000	396.00	
Broker Sweetpotato	box	1.00	330.0000	330.00	
OPERATOR LABOR					
Tractors	hour	9.82	5.1011	50.10	
Self-Propelled	hour	9.82	3.0000	29.46	
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	
HAND LABOR					
Implements	hour	6.44	12.7227	81.93	
DIESEL FUEL					
Tractors	gal	2.50	17.5141	43.77	
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	
REPAIR & MAINTENANCE					
Implements	acre	14.94	1.0000	14.94	
Tractors	acre	3.91	1.0000	3.91	
Self-Propelled	acre	5.86	1.0000	5.86	
INTEREST ON OP. CAP.	acre	19.42	1.0000	19.42	
TOTAL DIRECT EXPENSES				2456.72	
RETURNS ABOVE DIRECT EXPENSES				3633.28	
FIXED EXPENSES					
Implements	acre	47.53	1.0000	47.53	
Tractors	acre	24.26	1.0000	24.26	
Self-Propelled	acre	18.61	1.0000	18.61	
TOTAL FIXED EXPENSES				90.40	
TOTAL SPECIFIED EXPENSES				2547.12	
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				3542.88	

Appendix 3. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Crimson Clover Cover Crop and a Nitrogen Rate of 100 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Crimson Clover Cover Crop - 90N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	571.0000	8565.00	________
Sweet Potato, No. 2	cwt	5.00	45.0000	225.00	________
Sweet Potato, Jumbos	cwt	5.00	17.0000	85.00	________

TOTAL INCOME				8875.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	2.5000	26.63	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Crimson Clover Cover	1	212.72	1.0000	212.72	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	20.15	1.0000	20.15	________

TOTAL DIRECT EXPENSES				2706.94	________
RETURNS ABOVE DIRECT EXPENSES				6168.06	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2792.73	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				6082.27	________

Appendix 4. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Crimson Clover Cover Crop and a Nitrogen Rate of 50 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Crimson Clover Cover Crop - 45N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	536.0000	8040.00	________
Sweet Potato, No. 2	cwt	5.00	45.0000	225.00	________
Sweet Potato, Jumbos	cwt	5.00	31.0000	155.00	________

TOTAL INCOME				8420.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	1.2500	13.31	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Crimson Clover Cover	1	212.72	1.0000	212.72	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	19.96	1.0000	19.96	________

TOTAL DIRECT EXPENSES				2693.43	________
RETURNS ABOVE DIRECT EXPENSES				5726.57	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2779.22	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5640.78	________

Appendix 5. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Winter Rye Cover Crop and a Nitrogen Rate of 100 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Rye Cover Crop - 90 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	527.0000	7905.00	________
Sweet Potato, No. 2	cwt	5.00	48.0000	240.00	________
Sweet Potato, Jumbos	cwt	5.00	30.0000	150.00	________

TOTAL INCOME				8295.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	2.5000	26.63	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Rye Cover	1	218.16	1.0000	218.16	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	20.15	1.0000	20.15	________

TOTAL DIRECT EXPENSES				2712.38	________
RETURNS ABOVE DIRECT EXPENSES				5582.62	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2798.17	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5496.83	________

Appendix 6. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Winter Rye Cover Crop and a Nitrogen Rate of 50 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Rye Cover Crop - 45 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	480.0000	7200.00	________
Sweet Potato, No. 2	cwt	5.00	46.0000	230.00	________
Sweet Potato, Jumbos	cwt	5.00	34.0000	170.00	________

TOTAL INCOME				7600.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	1.2500	13.31	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	2.0000	6.94	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Rye Cover	1	218.16	1.0000	218.16	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.5516	54.53	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3309	85.85	________
DIESEL FUEL					
Tractors	gal	2.50	17.4612	43.64	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	15.90	1.0000	15.90	________
Tractors	acre	3.89	1.0000	3.89	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	19.84	1.0000	19.84	________

TOTAL DIRECT EXPENSES				2690.40	________
RETURNS ABOVE DIRECT EXPENSES				4909.60	________
FIXED EXPENSES					
Implements	acre	42.66	1.0000	42.66	________
Tractors	acre	24.11	1.0000	24.11	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.38	________

TOTAL SPECIFIED EXPENSES				2775.78	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				4824.22	________

Appendix 7. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Winter Wheat Cover Crop and a Nitrogen Rate of 100 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Wheat Cover Crop - 90 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	506.0000	7590.00	
Sweet Potato, No. 2	cwt	5.00	51.0000	255.00	
Sweet Potato, Jumbos	cwt	5.00	17.0000	85.00	

TOTAL INCOME				7930.00	
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	
Amm Nitrate (34%)	cwt	10.65	2.5000	26.63	
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	
Roundup Ultra	oz	0.36	16.0000	5.76	
Poast 1.53	pt	8.38	2.0000	16.76	
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	
Imidan 70 WSB	lb	7.45	1.3000	9.69	
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	
OTHER					
Wheat Cover	1	208.16	1.0000	208.16	
Crate Sweetpotato	each	6.00	2.0000	12.00	
Bin Sweetpotato	each	50.00	2.0000	100.00	
Storage Sweetpotato	cwt	1.00	112.0000	112.00	
Clean, grade, pack	box	1.75	330.0000	577.50	
Box Sweetpotato	each	1.20	330.0000	396.00	
Broker Sweetpotato	box	1.00	330.0000	330.00	
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	
Self-Propelled	hour	9.82	3.0000	29.46	
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	
Tractors	acre	3.93	1.0000	3.93	
Self-Propelled	acre	5.86	1.0000	5.86	
INTEREST ON OP. CAP.	acre	20.15	1.0000	20.15	

TOTAL DIRECT EXPENSES				2702.38	
RETURNS ABOVE DIRECT EXPENSES				5227.62	
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	
Tractors	acre	24.33	1.0000	24.33	
Self-Propelled	acre	18.61	1.0000	18.61	

TOTAL FIXED EXPENSES				85.79	

TOTAL SPECIFIED EXPENSES				2788.17	
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5141.83	

Appendix 8. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Winter Wheat Cover Crop and a Nitrogen Rate of 50 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Wheat Cover Crop - 45 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	452.0000	6780.00	________
Sweet Potato, No. 2	cwt	5.00	47.0000	235.00	________
Sweet Potato, Jumbos	cwt	5.00	18.0000	90.00	________

TOTAL INCOME				7105.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	1.2500	13.31	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	2.0000	6.94	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Wheat Cover	1	208.16	1.0000	208.16	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	19.86	1.0000	19.86	________

TOTAL DIRECT EXPENSES				2681.83	________
RETURNS ABOVE DIRECT EXPENSES				4423.17	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2767.62	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				4337.38	________

Appendix 9. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Hairy Vetch Cover Crop and a Nitrogen Rate of 100 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Hairy Vetch Cover Crop - 90 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	540.0000	8100.00	________
Sweet Potato, No. 2	cwt	5.00	37.0000	185.00	________
Sweet Potato, Jumbos	cwt	5.00	29.0000	145.00	________

TOTAL INCOME				8430.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	2.5000	26.63	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Hairy Vetch Cover	acre	215.39	1.0000	215.39	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	20.15	1.0000	20.15	________

TOTAL DIRECT EXPENSES				2709.61	________
RETURNS ABOVE DIRECT EXPENSES				5720.39	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2795.40	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5634.60	________

Appendix 10. Revised Alabama Enterprise Budget for No-till Sweetpotato Production Using a Hairy Vetch Cover Crop and a Nitrogen Rate of 50 kg·ha^{-1}.

Estimated costs and returns per acre
following recommended management practices; Alabama 2005.

Estimated costs and returns per acre
No-Till Sweet Potatoes, Hairy Vetch Cover Crop - 45 N
North Alabama Research Station, Cullman,Alabama, 2005

ITEM	UNIT	PRICE	QUANTITY	AMOUNT	YOUR FARM
		dollars		dollars	
INCOME					
Sweet Potato, No. 1	40lb	15.00	529.0000	7935.00	________
Sweet Potato, No. 2	cwt	5.00	38.0000	190.00	________
Sweet Potato, Jumbos	cwt	5.00	29.0000	145.00	________

TOTAL INCOME				8270.00	________
DIRECT EXPENSES					
FERTILIZER					
Fert 5-20-30+S+B	cwt	20.42	4.0000	81.68	________
Amm Nitrate (34%)	cwt	10.65	1.2500	13.31	________
HERBICIDE					
Command 3ME	pt	10.36	4.0000	41.44	________
Roundup Ultra	oz	0.36	16.0000	5.76	________
Poast 1.53	pt	8.38	2.0000	16.76	________
INSECTICIDE					
Penncap-M	pt	3.47	4.0000	13.88	________
Imidan 70 WSB	lb	7.45	1.3000	9.69	________
SEED/PLANTS					
Sweetpotato Plants	thous	21.00	11.0000	231.00	________
OTHER					
Hairy Vetch Cover	acre	215.39	1.0000	215.39	________
Crate Sweetpotato	each	6.00	2.0000	12.00	________
Bin Sweetpotato	each	50.00	2.0000	100.00	________
Storage Sweetpotato	cwt	1.00	112.0000	112.00	________
Clean, grade, pack	box	1.75	330.0000	577.50	________
Box Sweetpotato	each	1.20	330.0000	396.00	________
Broker Sweetpotato	box	1.00	330.0000	330.00	________
OPERATOR LABOR					
Tractors	hour	9.82	5.6143	55.15	________
Self-Propelled	hour	9.82	3.0000	29.46	________
Harvest Labor					
Special Labor	hour	6.44	25.0000	161.00	________
PLANTING LABOR					
Special Labor	hour	6.44	15.0000	96.60	________
HAND LABOR					
Implements	hour	6.44	13.3623	86.05	________
DIESEL FUEL					
Tractors	gal	2.50	17.6225	44.04	________
GASOLINE					
Self-Propelled	gal	3.00	8.9000	26.70	________
REPAIR & MAINTENANCE					
Implements	acre	16.05	1.0000	16.05	________
Tractors	acre	3.93	1.0000	3.93	________
Self-Propelled	acre	5.86	1.0000	5.86	________
INTEREST ON OP. CAP.	acre	19.96	1.0000	19.96	________

TOTAL DIRECT EXPENSES				2696.10	________
RETURNS ABOVE DIRECT EXPENSES				5573.90	________
FIXED EXPENSES					
Implements	acre	42.85	1.0000	42.85	________
Tractors	acre	24.33	1.0000	24.33	________
Self-Propelled	acre	18.61	1.0000	18.61	________

TOTAL FIXED EXPENSES				85.79	________

TOTAL SPECIFIED EXPENSES				2781.89	________
RETURNS ABOVE TOTAL SPECIFIED EXPENSES				5488.11	________