STRIP-TILLAGE PRODUCTION SYSTEMS FOR TOBACCO

by

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Abstract

Conservation tillage production systems for flue-cured tobacco (*Nicotiana tabacum* L.) have been studied for many years. Inadequate chemical weed control and lack of acceptable pesticide and fertilizer application resulted in consistently lower yields and inferior cured leaf quality. The development of new conservation tillage equipment, improved methods of fertilizer application, and new herbicides, have resulted in a renewed interest in conservation tillage labeled for tobacco. This research investigated management practices to address slow early season growth characteristic of strip-tillage tobacco production. Objectives of the first study were to evaluate the methods of starter fertilizer application and determine the optimal rate. A transplant water treatment (11 kg ha^{-1}) and 3 rates (11, 22, and 45 kg ha^{-1}) of injected 9-45-15 ($N:P_2O_5:K_2O$) water soluble starter fertilizer were evaluated for early season plant growth and time of topping. Starter fertilizer treatments increased tobacco root weight by 22% and leaf area up to 41%. Earlier topping was observed as a result of starter fertilizer with 23 and 6% more plants topped during the initial topping date in 1999 and 2000, respectively. Starter fertilizer did not consistently increase the yield of either strip-tillage or conventional tillage tobacco.

The objectives of the second study were to compare the use of raised beds with flat-planting and investigate cover crop residue management techniques. Residue management treatments minimized residue within the strip-tilled area with an early hooded spray application (strip-killed) of a burndown herbicide as opposed to the traditional broadcast burndown application. The use of raised beds for strip-tillage production of tobacco showed no clear benefit when compared to flat-planting. Strip-tillage plots were similar to conventional tillage for cured leaf quality and yield. Early season strip-kill burndown herbicide applications proved beneficial in reducing difficulties incorporating residue into the strip-tilled area thus improving the quality of the prepared seed bed.

This research has added to the present knowledge regarding strip-tillage tobacco production, and refined necessary cultural practices. Transplant starter fertilizer is recommended to overcome the typical slow early season growth characteristic of strip-tilled tobacco. However, increased rates (greater than 11 kg ha^{-1}) or under-row injection of the material had no added benefit. The research also demonstrated that the use of raised beds should not be considered a necessary practice with the use of a strip-till implement that incorporates under-row subsoil tillage. This research has demonstrated that tobacco yields and quality comparable to conventional tillage can be realized using strip-tillage production techniques.

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Chapter I

Introduction

Conservation tillage production of tobacco (*Nicotiana tabacum* L.) has been studied for many years in Virginia, and gained interest due to the anticipated reduction of soil loss. Reduced yields averaging 9.3 %, lack of adequate weed and cover crop control, and ineffective methods of fertilizer application were cited as reasons for unsatisfactory results, and the virtual abandonment of conservation tillage efforts (Moschler et al., 1971). Compliance with environmental regulations that limit the amount of accepted soil loss and encourage soil retention on cultivated fields renewed an interest in conservation practices. Advances in tillage implements, improved fertilizer application methods, and labeling of new herbicides for use in tobacco have alleviated problems encountered with previous conservation tillage research. Strip-tillage has especially gained notice due to the distinct advantage of tillage being incorporated into a soil conservation program. The cover crop is established and killed, and the implement tills narrow strips of soil where the projected area of transplanting will occur (Oschwald, 1973). Strip-tillage offers the advantage of a uniform seedbed, aeration of the soil, and an opportunity to utilize soil incorporated chemicals and existing crop residue.

Changes in tillage practices alter ecological factors in the cropped field, which results in plant growth and quality being potentially altered. Soil properties may also be changed with the addition of crop residues (Vitosh et al., 1985; Hanks, 1992). Increased soil moisture, subsoil compaction, and decreased soil temperature may result in insufficient early season transplant root development which decreases uptake and/or immobilization of essential nutrients (Oschwald, 1973; Reicosky et al., 1977; Mellish, 1978; Vepraskas and Miner, 1986; Bockus and Shroyer, 1998). Decreased root development may result in non-uniform transplant growth that potentially affects subsequent crop potential. Consequently, quality and yield of the crop may be jeopardized, and an economic loss to the farmer may be incurred (Reicosky et al., 1977; Lewis, 1973).

Inadequate weed control in conservation tillage also contributes to reduced plant growth (Weise and Staniforth, 1973). Excessive weed growth competes with transplants for water, light, and essential plant nutrients. Pre-transplant herbicides labeled for use in tobacco often require incorporation for maximum control and consequently, weed suppression may not have maximum efficacy for the season (Reed et al., 2000; Rhodes et al., 1997). Post-transplant herbicides are limited in number, and provide only minimal control of commonly occurring weeds in tobacco. Alternative forms of weed control must be sought to reduce the competition for water and nutrients (Oschwald, 1973; Weise and Staniforth, 1973). Research with shallow cultivation has shown that residue is maintained, by exposing the cover crop root system, in quantities necessary to reduce erosion and increase infiltration (Fisher and Lane, 1973; Weise and Staniforth, 1973). Furthermore, recent research has indicated the necessity of cultivation to provide adequate root systems for acceptable growth and yield of no-tillage tobacco production systems (Jones, 1998). Therefore, the use of secondary row cultivation at critical growth periods may result in increased yield, quality, and value of flue-cured tobacco grown under strip-tillage production systems when compared to no-tillage.

Identifying factors that reduce quality and yields of flue-cured tobacco grown under strip-tillage is critical in developing new management practices. By modifying management strategies, strip-tillage may be a feasible alternative to conventionally tilled tobacco in Virginia. Specific information such as soil temperature and moisture throughout the phase of transplant establishment has proven beneficial when identifying factors involved in decreased transplant vigor. Availability of nutrients may be a secondary factor attributed to soil moisture and temperature. Organic matter left on the soil surface to decrease erosion also increases water content of the soil due to lower levels of evaporation. During the spring months, the residue acts as a cooling mechanism and reflects heat, while higher levels of moisture contribute to lower temperatures by increasing the heat capacity of the soil. With lower temperatures, root development is suppressed and nutrients are not adequately utilized.

Objectives of this research were:

1. Evaluate rate and method of transplant starter fertilizer placement on early season flue-cured tobacco transplant growth and vigor under strip-tillage and conventional tillage systems
2. Monitor soil environmental conditions in bedded and flat-planted strip-tillage tobacco receiving strip-killed and broadcast-killed residue management treatments and conventional tillage
3. Study effects of starter fertilizer rate and method of application on Virginia dark fire-cured tobacco and the interaction with cover crop mulches

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Chapter II

Literature Review

Conservation Tillage Terminology

Conservation tillage has been defined as any practice retaining 30 % cover crop mulch or plant residue on the soil surface at the time of transplanting (Amir, 1996; Unger, 1996; Bockus and Shroyer, 1998). Various tillage operations such as no-tillage, ridge-tillage, strip-tillage, mulch-tillage, and reduced-tillage can be incorporated into this definition.

Strip-tillage, a modified form of no-tillage, incorporates sub-soil shanks with fluted coulters and crumbling baskets and offers the combination of deep tillage, with simultaneous transplanting area preparation (Oschwald, 1973). A uniform seedbed is produced and difficulties associated with transplanting into established sod, as in no-till, are minimized (Miller and Donahue, 1995). Tobacco is commonly produced on 122-cm between-row spacing. Areas of soil disturbed by the strip-tillage equipment are approximately 25 to 35-cm wide and 35 to 45-cm deep. That leaves an estimated 70 % of the total soil surface undisturbed. The amount of cover crop biomass present on the soil surface will vary with cover type, seeding rates, and the age of the crop at the time of burn-down herbicide application (Edminsten et al., 1998; Vitosh et al., 1985; Shul'gin, 1965).

Advantages of Strip-tillage

Many potential benefits may be incurred by adapting current flue-cured tobacco production to a conservation tillage system. The most noted advantage is the reduction in soil erosion and run-off, and consequently, nutrient movement (Angle, 1985; Holt, 1979). Partially buried residue increases the roughness of the soil surface and provides an increased opportunity for water to enter the soil profile (Fisher and Lane, 1973; Lewis, 1973; and Oschwald, 1973).

This increased roughness reduces the factors involved with soil displacement and movement by buffering the energy associated with raindrop impact and slowing the speed of water movement across the soil surface (Box and Bruce, 1996; Bradford and Huang, 1996; Stone et al., 1996). The biomass attained from the cover crop forms small dams, which allows surface water to pond and suspended soil particles to settle out of solution, thus reducing the travel of displaced soil particles in the cropped field.

Time and labor involved in preparing land is reduced in conservation tillage (Morrison et al., 1973; Reicosky, 1977). Harman et al. (1989) stated that no-tillage production reduces tractor, labor, and fuel cost of dryland cotton (*Gossypium hirsutum* L.) production in Texas. Increased cost of herbicides were offset by increased yields and reduced depreciation of equipment. This supports the potential for profitability in strip-tillage production systems of flue-cured tobacco. Smart and Bradford (1999) provided data supporting the reduction of input costs in conservation tillage efforts of corn and grain due to the lower amount of field operations. However, research conducted by Jones (1998) showed no significant increase in flue-cured tobacco yields when conventional tillage was compared to no-tillage production that utilized two or three cultivations.

Conventionally produced flue-cured tobacco is an intensively cultivated crop, with as many as six secondary cultivations occurring after transplanting (Hawks and Collins, 1970; Hawks, 1978). When the two tillage systems are compared, conventional tillage shows an almost two fold increase in equipment activity prior to transplanting. The increase in tillage activity is primarily due to land preparation activities and secondary tillage. Machinery traffic through the field for pesticide applications, sucker control, and harvesting is comparable for both production systems.

Crop residue on the soil surface alters physical and chemical properties of the soil, such as retention of soil moisture and decrease in soil surface temperature fluctuation, and must be managed accordingly. Cover crop residues act as a reflector of solar radiation and as an insulator of the soil. Shul'gin (1965) and Hanks (1992) noted that during the day, residues protect the soil from excessive heating, but at night, help retain warmth. This benefits the soil ecosystem by reducing excessive temperature fluctuations in the profile. In addition, an increase in crop residues will help attain and retain soil moisture. Reicosky et al. (1977) stated that cover crop residues will increase surface water infiltration while reducing erosion.

Concerns with Strip-tillage

Additional cover crop residue and changes in production methods cause ecological changes within the soils micro and macroflora to occur. The most noted changes are increased soil moisture and decreased soil temperature. However, the effects of these changes on growth potential of flue-cured tobacco transplants are not well documented. Vitosh et al. (1985) reported that no-tillage fields have increased moisture, due to the presence of surface residue, averaging 15 to 30 % above conventional tillage. Consequently, it is important to consider the adverse effects of excessive moisture. While this increased moisture retention may be beneficial in periods of potential drought, early season establishment of transplants may be hampered by excessive moisture. Excess amounts of water may play a role in reducing soil temperatures and promoting the development of disease (Bockus and Shroyer, 1998). The warming potential of soil slows with increasing amounts of water in the soil. Therefore, wet soils require more energy (in the form of solar radiation) to heat than drier soils. The additional heat potential from the increased moisture adversely affects the soil by prolonging the warming period in the early season. However, the same added heat potential acts as an insulating factor, which will allow soil to remain at a more constant temperature during periods of extreme air temperature fluctuation.

Increased moisture due to flooding may also lead to anaerobic conditions, resulting in deficient aeration, root injury and death (Osmond and Raper, 1981). The initial effect of flooding adversely affects plant growth by depressing ATP production in the roots. Surplus moisture forces plant roots to utilize anaerobic respiration, which is much less efficient than normal aerobic respiration (Nilsen and Orcutt, 1996). Oxidation of glucose is not fully completed and excessive buildup of waste byproducts, specifically ethanol, may accumulate to toxic levels (Mengel and Kirkby, 1987; Nilsen and Orcutt, 1996). Because cellular damage is incurred during the period of flooding, xylem plugging occurs and total root mass is further diminished. This action further limits the plant's ability to acquire nutrients and moisture through the root system and supply the transplant with necessary components for plant development.

These concerns must be individually addressed, and resolved, to provide an alternative production method capable of producing acceptable flue-cured tobacco. Strip-tillage can address these issues and has many advantages over no-tillage. For example, use of the sub-soil shank to break the hard pan allows excessive moisture to drain away from the effective rooting zone. By decreasing the moisture content, aeration is increased, heat requirements are decreased, and the soil should warm more rapidly. Also, by sub-soiling, the warmed topsoil is mixed and allows cooler soils to be brought to the soil surface and warmed creating a more uniform temperature distribution throughout the soil profile.

Root Regeneration and Development of Transplants

Addition of soil residue may also affect soil temperature (Hanks, 1992). Mulch acts as insulation, allowing heat to be retained in the soil. Conversely, soil warming may be slowed due to mulch reflecting heat energy from sunlight (Shul'gin, 1965; Bockus and Shroyer, 1998). These factors, combined with the increased heat potential due to water, can cause adverse effects on transplants early growth and development. Osmond et al. (1981) described optimal root growth at 22 ^{o}C for flue-cured and cigar type tobaccos. Nilsen and Orcutt (1996) and Shul'gin (1965) stated that plants in early developmental stages are more subject to chilling stress and injury. This is especially true for young tobacco 3 to 4 wk post transplant. During this time, roots damaged in the process of transplanting have desiccated and new root initiation is taking place (Dean et al., 1960). This is the most critical point in the transplants establishment and growth. Low soil and air temperatures may hamper the plants ability to produce necessary hormones required for differentiation of parenchyma cells in the roots, therefore reducing total root mass and distribution.

Barlow et al. (1977), Osmond and Raper (1981 and 1982), and Raper et al. (1975) described the effects of tobacco transplant development when subjected to below optimum temperatures. A drop in temperature from 24 to 18^{o}C significantly reduced whole plant and dry root weight. Research conducted by Kelly and Moser (1983) on root regeneration of tulip tree (*Liriodendron tulipifera* L.) seedlings showed root weight significantly increased as soil temperature was elevated from 10 to 21^{o}C at a constant air temperature of 21^{o}C. Osmond and Raper (1981) also observed significant increases in total plant weight when root temperatures were elevated from 16 to 24^{o}C, but air temperature and nitrate concentration had little effect on the total weight of tobacco transplants. This is especially important due to the uptake of relatively immobile nutrients (such as phosphorus and potassium) being significantly affected by mass and distribution of the root system (Mellish, 1978).

Availability of Essential Plant Nutrients

Assessing the availability of plant nutrients should first be approached in a broad manner, then narrowed to fit specific soil types. By identifying soil types, determining how nutrients are made available, and how nutrients are intercepted by the root system, a management plan can be more easily identified. Most soils in the Southern Piedmont region of Virginia are classified Ultisols. By definition, Ultisols are strongly acid, extensively weathered soils with a low to medium nutrient reserve (Miller and Donahue, 1995). Ultisols are also characterized as having clay B horizons (B_t) that are high in iron and aluminum hydroxides. Phosphorus and potassium are usually less available due to the degree of weathering and high hydrous oxide characteristics (Miller and Donahue, 1995). These soils can be highly productive, but take extensive nutrient management to reach their fullest potential.

Many factors can affect nutrient availability in the soil profile such as moisture extremes, temperature, pH, nutrient competition, aeration, and nutrient content. Understanding how these factors affect nutrient movement and availability to the plant allows a more distinct nutrient management plan to be developed. Water is the main component of nutrient movement within the soil profile. Three mechanisms of nutrient movement to the roots are recognized: root interception, mass flow, and diffusion. Of the three major nutrients (N, P, and K) only mass flow and diffusion are primary factors involved with nutrient availability. Almost all nitrogen is transported to the root system through mass flow, while phosphorus and potassium are transported mainly through diffusion (Foth and Ellis, 1997).

Mass flow is described as nutrients moving through the natural water flow in a soil profile. Mass flow (Q_m), or total solute moved to the root system, can be described as a function of water flow volume (V_m) and the concentration of the solute (C_m), or $Q_m=V_mC_m$ (Foth and Ellis, 1997). Therefore, as nutrients become less available from the soil, due to pH, temperature, or an increase in moisture (dilution factor), the amount of nutrients reaching the roots will decrease. Diffusion is defined as nutrients moving through the soil profile by means of a concentration gradient (Mengel and Kirkby, 1987). This process is more important for nutrients that do not move well by mass flow, such as phosphorus and potassium, and are in the soil volume at low concentrations. Diffusion works as a check and balance system, keeping the soil solution in equilibrium. As nutrients are used by the plant, they are removed from the soil and placed into the soil solution. Nutrients moved by diffusion (Q_d) can be described as an interaction of root surface area (A_d), diffusion coefficient (k_d), and the concentration (change in concentration (dC_d) as related to change in distance moved (dx_d)), or $Q_d=A_dk_d\ dC_d/dx_d$ (Foth and Ellis, 1997). Due to the dependence on roots, diffusion may be influenced by any factor that hampers root growth.

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Chapter III

Starter Fertilizer Use in Strip-tillage Production of Flue-Cured Tobacco

Abstract

Previous research with strip-tillage flue-cured tobacco has resulted in slow early season transplant growth as compared to conventional tillage. Possible causes of this may be lower soil temperatures and increased moisture that inhibit root growth, resulting in lower nutrient uptake and utilization. Research was conducted at the Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia in 1999 and 2000 to determine the most effective rate and application method of starter fertilizer for increased transplant growth. An alternative method of starter fertilizer application, which involved under-row injection during the strip-tillage operation, was compared to traditional methods of dissolving the starter fertilizer in the water applied with the transplanter. Strip-tillage treatments receiving injected 9-45-15 ($N:P_2O_5:K_2O$) starter fertilizer rates of 11, 22, and 45 kg ha^{-1} and a transplant water rate of 11 kg ha^{-1} were compared to conventionally cultivated tobacco with 11 kg ha^{-1} and no starter fertilizer. Treatments were arranged in a randomized complete block design in 1999, with three transplanting dates (May 5, 12, and 19) added in 2000. An average increase of 23% in root weight and 41% in leaf area was obtained for all starter fertilizer treatments compared to control treatments without fertilizer in 1999. All injected starter fertilizer treatments increased root weight by 59 and 38%, and leaf area by 30 and 39% for the first and third transplanting date, respectively, in 2000. At first topping, an average increase of 49% was recorded for topping when starter fertilizer was compared to no starter fertilizer in 1999. Injected starter fertilizer increased topping by 86% for the first transplanting date, while transplant water treatments

increased topping an average of 55% on the third transplanting date for first topping in 2000. Starter fertilizer did not increase yields in 1999, and cured leaf quality reducing sugars, and total alkaloids were not different either year. Yield increases of 6 and 9% were obtained for conventional tillage receiving 11 kg ha^{-1} applied in the transplant water and strip-tillage receiving 22 kg ha^{-1} injected, respectively, in 2000.

Early season transplant growth and uniformity of flowering justifies use of starter fertilizer in strip-tillage production systems. Comparable rates of 11 kg ha^{-1} were not different whether injected or applied in the transplant water for 1999 or the May 5 and 12 transplanting date in 2000. Economically, injected treatments can not be justified therefore 11 kg ha^{-1} applied in the transplant water is suggested.

Introduction

The response of tobacco to transplant starter fertilizers has been studied for many years. Visual early season transplant growth increases have been reported with starter fertilizer, but cured leaf quality and yields were not affected (Whitty et al, 1966). Chen (1968) reported that constant day temperatures of 27^{o}C and 21^{o}C night temperatures were necessary for optimum plant growth, but low soil temperatures more significantly retarded the growth of small plants than larger, established plants. Parups et al. (1960) reported optimal temperature and moisture for tobacco growth is 22^{o}C and 75%, respectively, with lower temperatures resulting in inferior leaf quality and prolonged maturation periods.

Nutrient uptake may be compromised and transplant growth may be affected by temperature and moisture fluctuations (Hanks, 1992). Phosphorous is a critical plant nutrient involved in plant metabolism mechanisms and components, such as RNA, DNA, photosynthesis, phosphorylation, Kreb’s cycle, and nitrogen metabolism, necessary for the establishment of transplants and their consequent growth and development (Terry and Terrill, 1971). Plant uptake of phosphorus is closely linked to soil temperature and moisture, and if either component is less than optimum, plant growth may be decreased (Mellish, 1978; Traynor, 1980).

According to Lolas et al. (1978 and 1979), levels of applied phosphorus directly correlate with concentration levels of N, P, and K in tobacco transplants at an early stage of growth. Furthermore, phosphorus is taken up primarily through diffusion, with mass flow contributing only one percent of the total phosphorus uptake (Nye, 1985). During transplanting, all of the fibrous root system desiccates and a new root system must be regenerated. According to Dean et al. (1960), the more rapidly a functional root system is established, the shorter the period of growth cessation of the plant. With the adverse conditions encountered in conservation tillage, some means of accelerating root growth and plant establishment is critical.

The effects of accelerated establishment and uniform growth of transplants from starter fertilizer can also be observed at topping. Topping, or removal of the apical meristem, is important and necessary for tobacco production. This process diverts energy and resources back into the leaf, instead of into reproduction (Peedin, 1999). Since the value of the crop arises from leaf mass, this reversion back into the vegetative state allows more energy to be diverted to the harvested portion of the plant. Most producers top plants manually, therefore, topping is labor-intensive. However, minimizing the number of times over the field for topping greatly reduces the time and labor needed for topping. In addition, the lack of uniform growth among the plants poses challenges when applying sucker control chemicals. Commonly, the first chemicals applied are contact suckercides, which only control suckers contacted by the product. Decreased uniformity of plant size may compromise the effectiveness of these applications.

Objectives of this study were to evaluate starter fertilizer rates and method of application on early season transplant growth, uniformity of flowering, and agronomic measures of the cured leaf.

Materials and Methods

Research was conducted in 1999 and 2000 at the Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia. The soil in the test area was classified as a complex of Chesterfield (40% Fine-loamy, siliceous, thermic Typic Hapludult), Mayodan (30% Fine, mixed, semiactive, thermic Typic Hapludult), and Bourne (20% Fine-loamy, mixed, semiactive, thermic Typic Fragiudult) with 2-6% slope. Conventional plots were plowed, and wheat cover was no-till drilled the previous November into a non-bedded field with a killed fescue sod cover.

Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) was utilized at 1.4 kg active ingredient (a.i.) ha^{-1} to kill strips in the projected area of transplanting, for residue management, when the cover crop was 15 to 20 cm in height. The above rate of paraquat dichloride was broadcast applied to remaining cover crop prior to inflorescence emergence. Sulfentrazone (N-[2,4-dichloro-5-[4-(difluromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-trizazol-1-yl]phenyl] methanesufonaminde) and clomazone ((2-2-chlorophenyl) methyl-4,4-dimethyl-3-isoxazolidione) were broadcast applied at rates of 0.32 and 8.4 kg a.i. ha^{-1}, respectively, for weed control prior to strip-tillage and starter fertilizer applications. Aldicarb (2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) omine) was applied in a 25 cm band and incorporated with the strip-tillage implement at a 22 kg a.i. ha^{-1} rate during the 2000 season for nematode control.

Three strip-tillage injected starter fertilizer treatments (11,22, and 45 kg ha^{-1}) and one strip-tillage transplant water starter fertilizer treatment (11 kg ha^{-1}) were compared to conventionally cultivated controls (Table 3.1) in 1999. Treatments were arranged in a randomized complete block design with six replications. Similar treatments were utilized in the 2000 season with two additional treatments (strip-tillage control and conventionally cultivated 11 kg ha^{-1} applied through the transplant water). The 2000 test was further expanded to investigate treatment effects with three transplanting dates (May 5,12, and 19) in a split-plot design. Transplant dates were whole-plot factors while transplant starter fertilizer treatments were the sub-plot factors. Flue-cured cultivar 'K-326' was planted both years. Imidacloprid (1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine) was utilized in the transplant water at 0.16 kg a.i. ha^{-1} for flea beetle, aphid, and wireworm control. Base fertilization of 840 kg ha^{-1} 6-12-18 ($N-P_2O_5-K_2$) was applied both years with a combination fertilizer-transplanter. Attached double disk openers placed the fertilizer approximately 5 cm below the soil surface and on both sides approximately 12 cm from the transplant. Additional nitrogen and potassium was supplied by 175 kg ha^{-1} of 15-0-14 applied with double disk openers which placed the fertilizer approximately 5 cm below the soil surface and 12 cm on both sides of the transplant.

Sethoxydim ([2-1-(ethoxymino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one]) was utilized at the rate of 0.21 kg a.i. ha^{-1} as a spot spray for grass control throughout the growing season. Cutworms, hornworms, and budworms were controlled, as necessary, with applications of 0.84 kg a.i. ha^{-1} acephate (O,S-dimethyl acetyl-phosphoramidothioate).

Plants within strip-tillage treatments were cultivated a minimum of two times with the Sukup® High Residue Cultivator (Sukup Manufacturing Company, Sheffield, Iowa) to reduce crusting of the soil and build a row ridge. Plants in conventional treatments received a minimum of three cultivations with rolling spider cultivators. Overhead irrigation was applied both years as necessary to maintain adequate soil water content.

Strip-tillage Equipment and Starter Fertilizer Injection

Strip-tillage was performed by a two-row KMC® (Kelley Manufacturing Company, Tifton, GA) strip-tillage implement with 122 cm between-row spacing. The action of this implement involves both primary and secondary tillage in a single pass by using a single 60 flute coulter and sub-soil shank followed by two pairs of 8 flute coulters and two crumbling baskets on each row.

Stainless steel fumigation tubes (15 mm diameter) equipped with a 5 mm diameter hole in the bottom of each tube were mounted behind each sub-soil shank (Figure 3.1). A CO_2-powered sprayer assembly with manifold and pressure regulator was mounted on the strip-tillage tool bar (Figure 3.2). Spray output was 186 liters per hectare for all treatments and separate starter fertilizer solutions of the appropriate concentration (11, 22, and 45 kg ha^{-1}) were made. Starter fertilizer was injected approximately 10 cm below the soil surface within each row. The system was purged with clean water between different fertilizer treatment applications.

Plant Growth Measurements

Transplants were interplanted between plants in rows for each treatment, utilizing the existing randomized complete block design. After four weeks, the plants were extracted from the soil with minimal root disturbance. Leaves were removed, and the sampled plants were separated into roots, stems, and leaves. The line of transition in color was used to differentiate between root and stem portions. Fresh weight was recorded for all plant parts and leaf area was measured with a Li-Cor® LI-3100 area meter (Li-Cor Biosciences, Lincoln, Nebraska). Oven-dried root weights were recorded following overnight drying at 38^{o}C. Analysis of variance was conducted utilizing PROC GLM (SAS Institute, 1989) and treatment differences evaluated using Duncan's multiple range test (α=0.05).

Collection and Analysis of Topping Data

Plants were topped and sucker growth was controlled following Virginia Cooperative Extension recommendations (Reed et al., 2000). Plants in a given treatment were initially topped when at least 50% inflorescence emergence was observed in at least one replicate plot. Remaining plants were topped weekly until all inflorescences were removed. Data were reported as percentages and arcsine transformed (Gomez and Gomez, 1984) prior to analysis of variance by PROC GLM (SAS Institute, 1989) and Duncan's multiple range test (α=0.05).

Agronomic and Chemical Characteristics of the Cured Leaf

Tobacco was harvested five times, beginning at the bottom of the stalk, as the leaves were determined to be mature and ripe. Leaves from individual plots were separated and identified for curing in a bulk tobacco-curing barn. Throughout all phases, treatments within harvest dates were considered individual data. Cured leaves from individual treatments within each harvest were graded by a tobacco inspector from the USDA Tobacco Marketing Service and assigned U. S. government grades. Cured leaves were weighed, and yields calculated for a plant population of 16,055 plants ha^{-1}. Prices were determined by average Type 11A values corresponding with USDA grades. The grade index of Bowman et al. (1988) was used to assign numerical values to the tobacco grades. Cured leaf samples from each plot and harvest were dried and ground to pass through a 1 mm mesh screen for laboratory analysis. Total alkaloid and reducing sugar concentration in the cured leaves were determined by extraction and analysis with a modified version of the autoanalyzer procedure described by Davis (1976). Sulfanillic acid was substituted for buffered analine in the total alkaloids procedure. Data are reported as a composite value calculated on a weighted basis according to the proportion of the total yield from five individual harvests.

Results and Discussion

Effect of Starter Fertilizer on Interplanted Tobacco Growth

Excised shoots from 45 kg ha^{-1} injected treatments increased weight 35 % when compared to the conventional control (Table 3.3) and 16 to 32% over the remaining fertilizer treatments in 1999. Weights from the excised roots showed increases of 7 to 32% for 11 kg ha^{-1} and 45 kg ha^{-1} injected treatments, respectively, when compared to conventional control treatments. All starter fertilizer treatments increased leaf weight by 21 to 46% and leaf area by 33 to 47% over conventional control treatments.

Average increases of 59 and 30% were obtained for green root weight and leaf area, respectively, when starter fertilizer treatments were compared to conventional tillage with no starter fertilizer in 2000 (Table 3.4). Root weights in conventionally cultivated plots receiving 11 kg ha^{-1} starter fertilizer applied through the transplant water were increased 35% when contrasted to conventional tillage with no starter fertilizer for the May 12 transplant date (Table 3.5). Average increases of 43 to 44 % in green root weights and 38 to 39% in leaf area were obtained when strip-tillage injected treatments were contrasted with strip-tillage controls and conventional controls, respectively, for the May 19 transplant date (Table 3.6).

Starter Fertilizer Effects on Flowering and Topping

Topping was initiated on July 16 and completed for all plots on August 4 in 1999. Analysis of topping data indicate a positive influence of starter fertilizer by increasing the uniformity of flowering. After the second topping date (July 26), all treatments receiving starter fertilizer were over 90% topped, while the conventional tillage control plot was significantly less at 73% (Table 3.7).

Differences were observed with the use of transplant starter fertilizer for each of three transplanting dates in 2000. All injected starter fertilizer treatments and conventional 11 kg ha^{-1} transplant water treatments increased the number of plants topped by 33 to 56%, when compared to conventional control treatments for the second topping time (Table 3.8). Results from transplanting date May 12 showed significant increases of up to 55% for conventional plots receiving 11 kg ha^{-1} starter fertilizer in the transplant water when compared to 11 kg ha^{-1} transplant water in strip-tillage, and both conventional and strip-tillage control plots. Flowering increased 33 to 45% when 11 kg ha^{-1} starter fertilizer treatments were compared to control treatments.

Effects of Starter Fertilizer on Yield, Quality, and Cured Leaf Chemistry

No differences for yield, price, grade index, or value were obtained in 1999 (Table 3.9). However, in 2000 (Table 3.10), yield increases ranging 368 to 385 kg ha^{-1} were observed among conventionally cultivated plots receiving 11 kg ha^{-1} applied through the transplant water when compared to strip-tillage check and 11 kg ha^{-1} transplant water treatments. Strip-tillage plots receiving 22 kg ha^{-1} injected starter fertilizer differed from strip-tillage control plots for yield and value. No differences were noted among rates of fertilizer in strip-tillage plots, and strip-tillage plots receiving fertilizer were similar to conventional control plots. Total alkaloid and reducing sugar concentrations were similar for all treatments in both the 1999 and 2000 growing seasons (Table 3.11).

Cooler, wetter soils commonly associated with conservation tillage may result in suppressed root growth and slowed metabolic activity. Lower root mass directly affects the plants ability to absorb necessary plant nutrients but when starter fertilizer was applied to tobacco, total green root weight was increased above those of conventionally cultivated treatments both years. Transplant starter fertilizer effects continued through flower development with earlier topping differences observed with the use of starter fertilizer. However, there were no differences observed between rates of starter fertilizer or application method. Although no cured-leaf yield or quality increases were observed, the use of starter fertilizer increased performance of transplants to the level of conventionally cultivated tobacco. More uniformity in plants at the time of flowering will decrease the amount of time needed for topping and suckercide applications. Uniform plants are also critical if mechanical harvesters are to be utilized (Chen, 1968). This research demonstrated that the manufacturers suggested rate of 11 kg ha^{-1} of starter fertilizer applied through the transplant will sufficiently increase early season growth, produces more uniform flowering at time of topping, and should be used in strip-tillage production of flue-cured tobacco.

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Figure 3.1. A modified sub-soil shank with 0.95 cm stainless steel fumigation tube attached for injection of starter fertilizer.

Figure 3.2. CO_2-powered delivery system for injection of starter fertilizer in strip-tillage.

Table 3.1. 1999 starter fertilizer treatments.

Production Method	Fertilizer Rate	Method
Strip-tillage	11 kg ha^{-1}	Injected
Strip-tillage	22 kg ha^{-1}	Injected
Strip-tillage	44 kg ha^{-1}	Injected
Strip-tillage	11kg ha^{-1}	Transplant Water
Conventional Control	---	---

Table 3.2. 2000 starter fertilizer treatments.†

Production Method	Fertilizer Rate	Method
Strip-tillage	11 kg ha^{-1}	Injected
Strip-tillage	22 kg ha^{-1}	Injected
Strip-tillage	44 kg ha^{-1}	Injected
Strip-tillage	11 kg ha^{-1}	Transplant Water
Strip-tillage	Control	---
Conventional	11 kg ha^{-1}	Transplant Water
Conventional Control	---	---

† All fertilizer treatments transplanted "early" on May 5, "normal" on May 12, and "late" on May 19 for transplanting date and starter fertilizer effect on plant growth and establishment.

Table 3.3. Influence of starter fertilizer rate and method of application on four-week-old seedling growth with comparisons of treatments for May 18, 1999 transplanting date.

Trt	System	Rate kg ha^{-1}	Method†	Shoot Weight (g)	Shoot Height (cm)	Green Root Weight (g)	Leaf Weight (g)	Leaf Area (cm^2)
1	Strip-tillage	11	Injected	1.0 bc‡	5.5 a	1.3 ab	7.1 a	145.2 a
2	Strip-tillage	22	Injected	1.1 b	8.4 a	1.2 bc	7.2 a	142.9 a
3	Strip-tillage	45	Injected	1.3 a	6.2 a	1.5 a	8.0 a	159.3 a
4	Strip-tillage	11	TPW	0.9 cd	6.1 a	1.2 bc	6.3 a	126.7 a
7	Conventional	---	Control	0.7 d	4.8 a	1.0 c	4.3 b	85.0 b
Contrasts						**F – value**		
Treatments 1, 2, 3 vs. 4				9.71 **	0.22	4.08 *	2.07	2.33
Treatments 1, 2, 3 vs. 7				27.28 **	2.00	15.12 **	16.77 **	19.03 **
Treatment 1 vs. 3				8.22 **	0.17	3.89 *	1.08	0.61
Treatment 1 vs. 4				1.73	0.10	1.70	0.62	1.06

*, ** indicates significant differences observed at 0.05 and 0.01 respectively
†TPW signifies transplant water application method
‡ Treatments with same letter indicate no significant differences at α=0.05

Table 3.4. Influence of starter fertilizer rate and method of application on four-week-old seedling growth with comparisons of treatments for May 5, 2000 transplanting date.

Trt	System	Rate kg ha^{-1}	Method †	Shoot Weight (g)	Shoot Height (cm)	Green Root Weight (g)	Dry Root Weight (g)	Leaf Weight (g)	Leaf Area (cm^2)
1	Strip-tillage	11	Injected	3.7 a‡	6.5 a	2.8 a	0.6 a	34.4 a	686 a
2	Strip-tillage	22	Injected	3.3 a	6.6 a	14.0 a	0.6 a	23.4 a	702 a
3	Strip-tillage	45	Injected	8.5 a	9.3 a	5.2 a	1.0 a	71.9 a	1376 a
4	Strip-tillage	11	TPW	5.4 a	8.1 a	3.1 a	0.7 a	46.9 a	970 a
5	Strip-tillage	---	Control	4.7 a	6.9 a	4.0 a	0.9 a	50.2 a	967 a
6	Conventional	11	TPW	4.5 a	7.1 a	3.3 a	0.8 a	40.0 a	798 a
7	Conventional	---	Control	3.3 a	6.0 a	3.0 a	0.6 a	32.9 a	641 a
<u>Contrasts</u>							**<u>F – value</u>**		
Treatments 1, 2, 3 vs. 4				0	0.93	5.00 *	0.45	0.07	0.01
Treatments 1, 2, 3 vs. 7				4.61 **	7.92 **	5.04 *	1.71	2.46	4.92 *
Treatment 1 vs. 3				19.72 *	17.44 **	1.24	8.40 **	21.25 **	19.65 **
Treatment 1 vs. 4				1.80	4.72 *	0.04	0.15	1.49	2.36
Treatment 4 vs. 5				0.71	4.28 *	0	1.64	0.03	0.09
Treatment 6 vs. 7				1.20	3.01	0	1.32	0.76	1.01

*, ** indicates significant differences observed at 0.05 and 0.01 respectively

† TPW signifies transplant water application method

‡ Treatments with same letter indicate no significant differences at α=0.05

Table 3.5. Influence of starter fertilizer rate and method of application on four-week-old seedling growth with comparisons of treatments for May 12, 2000 transplanting date.

Trt	System	Rate kg ha^{-1}	Method†	Shoot Weight (g)	Shoot Height (cm)	Green Root Weight (g)	Dry Root Weight (g)	Leaf Weight (g)	Leaf Area (cm^2)
1	Strip-tillage	11	Injected	27.8 a‡	16.3 a	11.2 a	2.5 a	122.4 a	2209 a
2	Strip-tillage	22	Injected	57.2 a	21.3 a	17.3 a	3.6 a	208.5 a	3518 a
3	Strip-tillage	45	Injected	42.9 a	18.3 a	16.8 a	4.9 a	179.7 a	2965 a
4	Strip-tillage	11	TPW	31.7 a	16.4 a	12.9 a	2.5 a	150.1 a	2667 a
5	Strip-tillage	---	Control	40.2 a	17.7 a	16.5 a	3.5 a	177.0 a	3024 a
6	Conventional	11	TPW	51.5 a	22.5 a	21.7 a	5.0 a	208.2 a	3393 a
7	Conventional	---	Control	31.1 a	15.2 a	14.2 a	2.8 a	157.6 a	2620 a
Contrasts							**F – value**		
Treatments 1, 2, 3 vs. 4				3.00	1.98	1.80	3.81	1.36	0.90
Treatments 1, 2, 3 vs. 7				3.09	3.30 *	0.77	2.02	0.87	1.14
Treatment 1 vs. 3				5.41 *	2.23	7.84 **	11.57 **	6.90 **	5.39 *
Treatment 1 vs. 4				0.16	0	0.31	0	0.69	0.73
Treatment 4 vs. 5				1.76	0.26	1.38	1.33	0.66	1.45
Treatment 6 vs. 7				4.21 *	7.26 **	5.73 **	5.21 *	2.30	2.07

*, ** indicates significant differences observed at 0.05 and 0.01 respectively
† TPW signifies transplant water application method
‡ Treatments with same letter indicate no significant differences at α=0.05

Table 3.6. Influence of starter fertilizer rate and method of application on four-week-old seedling growth with comparisons of treatments for May 19, 2000 transplanting date.

Trt	System	Rate kg ha^{-1}	Method †	Shoot Weight (g)	Shoot Height (cm)	Green Root Weight (g)	Dry Root Weight (g)	Leaf Weight (g)	Leaf Area (cm^2)
1	Strip-tillage	11	Injected	70.7 a‡	25.9 a	21.5 a	4.7 a	316.6 a	5460 a
2	Strip-tillage	22	Injected	60.9 a	26.2 a	19.0 a	5.0 a	257.7 a	4620 a
3	Strip-tillage	45	Injected	53.7 a	19.7 ab	17.1 a	4.1 a	227.3 a	3940 a
4	Strip-tillage	11	TPW	38.2 a	18.8 ab	12.9 a	3.5 a	175.5 a	3236 a
5	Strip-tillage	---	Control	27.6 a	15.88 b	10.9 a	3.0 a	145.3 a	2638 a
6	Conventional	11	TPW	43.6 a	21.5 ab	15.2 a	3.4 a	183.6 a	3643 a
7	Conventional	---	Control	28.1 a	15.1 b	12.0 a	2.6 a	155.0 a	2840 a
Contrasts							**F – value**		
Treatments 1, 2, 3 vs. 4				13.21 **	11.52 **	10.75 **	2.45	12.4 **	11.77 **
Treatments 1, 2, 3 vs. 7				27.18 **	35.21 **	13.90 **	7.93 **	18.76 **	19.32 **
Treatment 1 vs. 3				0.77	4.10 *	0.69	0	1.87	2.17
Treatment 1 vs. 4				10.61 **	9.21 **	8.84 **	0.90	12.19 **	11.51 **
Treatment 4 vs. 5				1.93	2.99	0.78	0.35	1.00	1.49
Treatment 6 vs. 7				4.1 *	13.04 **	1.87	0.96	0.89	2.68

*, ** indicates significant differences observed at 0.05 and 0.01 respectively
† TPW signifies transplant water application method
‡ Treatments with same letter indicate no significant differences at α=0.05

Table 3.7. Effects of starter fertilizer on percentage plants topped in 1999.

Treatment			Cumulative percent plants topped	
System	Rate kg ha^{-1}	Method	July 20	July 26
Strip-tillage	11	Injected	76 a†	90 b
Strip-tillage	22	Injected	86 a	98 b
Strip-tillage	45	Injected	91 a	98 b
Strip-tillage	11	Transplant Water	85 a	93 b
Conventional	---	Control	43 b	73 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 3.8. Effects of starter fertilizer and transplanting date on percentage plants topped in 2000

Treatment			Cumulative percent plants topped		
System	Rate kg ha^{-1}	Method	July 10	July 18	July 31
May 5					
Strip-tillage	11	Injected	54 a†	72 a	96 a
Strip-tillage	22	Injected	63 a	83 a	99 a
Strip-tillage	45	Injected	56 a	84 a	97 a
Strip-tillage	11	Transplant Water	31 b	71 a	92 a
Strip-tillage	---	Control	27 b	60 a	93 a
Conventional	11	Transplant Water	21 bc	64 a	99 a
Conventional	---	Control	8 b	28 b	89 a
May 12					
Strip-tillage	11	Injected	---	55 ab	94 a
Strip-tillage	22	Injected	---	57 ab	88 a
Strip-tillage	45	Injected	---	60 ab	99 a
Strip-tillage	11	Transplant Water	---	37 b	88 a
Strip-tillage	---	Control	---	38 b	89 a
Conventional	11	Transplant Water	---	85 a	98 a
Conventional	---	Control	---	30 b	93 a
May 19					
Strip-tillage	11	Injected	---	45 bc	78 a
Strip-tillage	22	Injected	---	51 abc	87 a
Strip-tillage	45	Injected	---	34 c	95 a
Strip-tillage	11	Transplant Water	---	75 a	95 a
Strip-tillage	---	Control	---	30 c	66 a
Conventional	11	Transplant Water	---	67 ab	96 a
Conventional	---	Control	---	34 c	64 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 3.9. Effects of starter fertilizer on yield, market price, grade index, and value in 1999.

Treatment						
System	Rate kg ha^{-1}	Method	Yield kg ha^{-1}	Price \$ kg^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Strip-tillage	11	Injected	3,582 a†	4.42 a	77.3 a	15,832 a
Strip-tillage	22	Injected	3,440 a	4.42 a	77.5 a	15,205 a
Strip-tillage	45	Injected	3,555 a	4.40 a	74.2 a	15,642 a
Strip-tillage	11	Transplant Water	3,543 a	4.44 a	78.3 a	15,731 a
Conventional	---	Control	3,456 a	4.40 a	75.2 a	15,206 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 3.10. Effects of starter fertilizer on yield, market price, grade index, and value combined over three transplanting dates in 2000.

Treatments						
System	Rate kg ha^{-1}	Method	Yield kg ha^{-1}	Price \$ kg^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Strip-tillage	11	Injected	3,976abc †	4.54 a	78.6 a	18,051 abc
Strip-tillage	22	Injected	4,087 ab	4.54 a	78.9 a	18,555 ab
Strip-tillage	45	Injected	3,935 abc	4.54 a	78.8 a	17,865 abc
Strip-tillage	11	Transplant Water	3,837 bc	4.54 a	78.6 a	17,420 bc
Strip-tillage	---	Control	3,854 c	4.54 a	78.4 a	17,497 c
Conventional	11	Transplant Water	4,222 a	4.54 a	76.9 a	19,168 a
Conventional	---	Control	4,049 ab	4.52 a	76.8 a	18,301 abc

† Treatments with same letters indicate no significant differences at α=0.05

Table 3.11. Effects of starter fertilizer on total alkaloid and reducing sugar concentration in the cured leaf for 1999 and 2000. †

Treatment			1999		2000 ‡	
System	Rate kg ha^{-1}	Method	TA	RS	TA	RS
			%		%	
Strip tillage	11	Injected	3.3 a§	15.7 a	3.3 a	13.7 a
Strip-tillage	22	Injected	3.2 a	12.0 a	3.3 a	13.2 a
Strip-tillage	45	Injected	3.2 a	11.5 a	3.3 a	14.2 a
Strip-tillage	11	Transplant Water	3.2 a	12.5 a	3.2 a	13.8 a
Strip-tillage	---	Control	---	---	3.2 a	13.5 a
Conventiona1	11	Transplant Water	---	---	3.3 a	13.8 a
Conventional	---	Control	3.2 a	11.3 a	3.3 a	13.8 a

† Weighted averages calculated from percent total alkaloids or reducing sugar per harvest multiplied by percent of total leaf weight per harvest

‡ No differences were obtained for transplanting date variable

§ Treatments with same letters indicate no significant differences at α=0.05

Chapter IV

Strip-tillage Production Systems for Flue-Cured Tobacco

Abstract

Raised beds have been the traditional method of producing flue-cured tobacco under conventional tillage. Transplanting on pre-formed raised beds was necessary to reduce the potential for drowning, and provide structural support to minimize lodging. However, in strip-tillage, the increased depth of tillage may reduce drowning by allowing excess moisture to drain through the soil profile. Difficulty incorporating excessively lignified or dense residue with the strip-tillage implement has also been observed. Ways to limit the amount of residue in the area to be tilled would increase the performance of the strip-tillage implement in preparing the seed bed. The objective of this research was to compare tobacco planted flat and on raised beds in strip-tillage production systems to conventionally cultivated tobacco on a raised bed. Two residue management options (strip-killed with subsequent broadcast-kill or total broadcast-kill) were also evaluated. A strip-killed treatment was prepared with a hooded sprayer applications of paraquat dichoride (1,1'-dimethyl-4,4'-bipyridinium dichloride) over the row center (30 cm wide) when the cover crop was 15-20 cm in height. Broadcast applications of paraquat dichloride were made to all treatments prior to inflorescence emergence. Soil temperature and moisture were recorded for each treatment throughout the growing season to identify treatment-induced changes in soil environmental conditions. Moisture content in the soil increased an average of 35 % through the 0-15 cm profile when flat-planted and bedded conventional tillage was compared to broadcast-killed flat-planted tobacco on July 6. Increases of 40.5 and 38.5 % were obtained at the same depth on July 12 when conventional treatments were compared to bedded strip-killed and flat-planted broadcast-killed tobacco, respectively. No temperature

increases were observed in 1999, however increases were observed during the first three weeks post-transplant during the 2000 season. Conventionally cultivated flat-transplanted tobacco averaged 59% less accumulated degree-days in the first week following transplanting. Flat-planted strip-killed treatments had 11 to 29 % and 12 to 31% more accumulated degree-days than all other treatments for week 2 and 3, respectively. Percentage of plants topped in all flat-planted strip-killed, flat-planted broadcast-killed, and bedded strip-killed treatments were similar to conventional treatments at each topping in 1999, however no differences were observed in 2000. Temperatures recorded in strip-tillage production systems were not different from conventional tillage in 1999, but flat-planted strip-killed plots were warmer when compared to flat-planted conventional tillage in 2000. No differences were observed among treatments for yield, market price, grade index, or value in 1999. In 2000, bedded broadcast-killed and flat-planted strip-killed were similar to bedded conventionally cultivated tobacco for yield, market price, grade index, and value. However, bedded conventionally cultivated treatments averaged 9 and 10% higher yields and value, respectively, over flat-planted conventionally cultivated, flat-planted broadcast-killed, and bedded strip-killed treatments. This study showed that, contrary to earlier research, flat-planted strip-killed tobacco is equal to bedded conventionally cultivated tobacco. The flat-planted strip-killed method is suggested for strip-tillage production of tobacco.

Introduction

Flue-cured tobacco has traditionally been cultivated on preformed, raised beds (Figure 4.1) used to reduce potential drowning problems early in the season (Hawks, 1978). Subsequent row ridge cultivations direct soil towards the plant base for additional support, thus minimizing lodging potential. However, with strip-tillage as the primary tillage, the depth of tillage is increased and potential threat of drowning is decreased.

By changing the production system to a flat surface, advantages such as less time needed for land preparation may be realized. In addition, tobacco will frequently follow another crop in a rotational program. The existing crop residue can be utilized as mulch cover during the winter, and provide erosion control to the cover crop planted for the upcoming tobacco season.

Excessive residue, which is difficult to incorporate into the soil, poses potential concerns in strip-tillage production. Residue, from roots and shoots of the cover crop, prevent the preparation of a smooth seed bed. Lack of uniformity and increased roughness in the seed bed causes problems when transplanting by allowing large portions of residue to wrap around the transplanting shoe, impede proper function of the fertilizer coulters, and prematurely wear the strip-tillage coulter hubs. In addition, the transplanter press wheels can not function correctly, and a decreased root to soil contact has been observed.

Growing conditions in the early season greatly affects the growth rate and characteristics of the harvested tobacco (Kasperbauer, 1966 and 1970; Raper, 1972; Raper and Thomas, 1972). Kneivel (1972) reported that root temperatures influenced nutrient availability, uptake, and significantly affected plant growth. Phosphorus uptake and activity in the soil was influenced by soil temperatures in the first few weeks of growth, as determined by P content in corn plants (Hunsigi and Ketcheson, 1969; Power et al., 1964). Root temperatures have also been cited as having a greater effect on plant growth than aerial temperatures, or nitrate (NO_3^-) concentrations (Osmond and Raper, 1981). Furthermore, plant growth may be influenced by below optimal soil temperatures when grown under constant ambient air temperatures (Chen et al., 1968). Many factors work in combination to affect soil temperature, but Hanks (1992) stated anything that influences heat availability, or dissipation of available heat, can influence soil temperatures. Soil bulk density, color, soil mulch, water content, and any tillage practices may affect soil temperature. However, soil water content has been recorded as being a main factor in influencing temperature. Due to the high heat capacity of water, most of the heat collected by the soil is used to warm and evaporate the water and dissipation of the heat through the soil is limited (Hanks, 1992). The addition of surface mulch, as in conservation tillage practices, reduces evaporation and results in slower warming of the soil as compared to conventional tillage. Jalota and Prihar (1998) reported that evaporation loss is inversely related to mulch thickness, consequently the more mulch encountered on the soil surface, the slower evaporation and soil warming will occur. Moisture has been linked with root development, and therefore the uptake of nutrients (Osmond and Raper, 1982). Additionally, water content through the growing season potentially influences leaf characteristics, total alkaloids, and reducing sugar concentration, thus affecting cured leaf quality and compromising crop value.

The objectives of this study were to:

1. monitor soil environmental conditions in bedded and flat-planted tobacco in strip-tillage production and conventional tillage and
2. compare strip-killed to broadcast-killed residue management.

Materials and Methods

Research conducted at the Virginia Tech Southern Piedmont Agricultural Research and Extension Center near Blackstone, VA during 1999 compared strip-tillage tobacco production systems variables. Treatments included broadcast killed residue on raised beds and flap-planted, strip-killed residue on raised beds and flat-planted compared to conventional tillage with raised beds (Table 4.1). An additional treatment, flat-planted conventional tillage, was utilized in 2000.

Strip-killed treatments involved a 30 cm band application of a burndown herbicide with two Redball™ (Redball, LLC, Benson, MN) hooded sprayers prior to the normal broadcast herbicide application. A wheat cover crop, that had been established the previous November, was allowed to grow to a height of 15 to 20 cm before 1.4 kg active ingredient (a.i.) ha^{-1} paraquat dichloride was applied with the hooded sprayers to kill areas (Figure 4.2). Strip-kill herbicide applications were intended to minimize crop residue within the area to be strip-tilled while maximizing residue growth over the remaining portion of the field, by delaying broadcast burndown herbicide applications (Figure 4.3). Before the cover crop reached inflorescence emergence (boot stage), a broadcast application of paraquat dichloride at the above rate was applied to the whole field. Aldicarb (2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) omine) was applied in a band and incorporated with the strip-tillage implement at a 22 kg a.i. ha^{-1} rate during the 2000 season for nematode control. Prior to transplanting, 0.32 kg a.i. ha^{-1} sulfentrazone (N-[2,4-dichloro-5-[4-(difluromethyl)-4,5-dihydro-3-methyl-5-oxo-1H-1,2,4-triazol-1-yl]phenyl] methanesulfonamide), and 0.84 kg a.i. ha^{-1} clomazone (2-(2-chlorophenyl)methyl-4,4-dimethyl-3-isoxazolidione) were applied for weed control.

Flue-cured cultivar ‘K-326’ was planted in a Chesterfield (40% Fine-loamy, siliceous, thermic Typic Hapludult), Mayodan (30% Fine, mixed, semiactive, thermic Typic Hapludult,), Bourne (20% Fine-loamy, mixed, semiactive, thermic Tyipic Fragiudult) soil series complex with 2-6% slope each year. Base fertilization of 840 kg ha^{-1} 6-12-18 ($N-P_2O_5-K_2$) was applied both years with a combination fertilizer-transplanter. Attached double disk openers placed the fertilizer approximately 5 cm below the soil surface and 12 cm on both sides of the transplant. Additional side-dress nitrogen and potassium was supplied by 175 kg ha^{-1} of 15-0-14 applied with double disk openers which placed the fertilizer approximately 5 cm below the soil surface and 12 cm on both sides of the transplant. Sethoxydim ([2-1-(ethoxyimino) butyl]) at 0.21 kg a.i.

ha^{-1} was applied as a spot treatment for grass control in both seasons. Cutworms, hornworms, and budworms were controlled, as necessary, with applications of 0.84 kg a.i. ha^{-1} acephate (O,S-dimethyl acetyl-phosphoramidothioate).

Plants within strip-tillage treatments were cultivated a minimum of two times with the Sukup® High Residue Cultivator (Sukup Manufacturing Company, Sheffield, Iowa) to reduce crusting of the soil surface and build a row ridge by layby (last cultivation). Plants in conventional treatments received a minimum of three cultivations with rolling spider cultivators. Overhead irrigation was applied both years as necessary to maintain adequate soil water content.

<u>Temperature and Moisture</u>

Soil temperature was recorded with Tidbit™-XT data loggers (Onset Corporation; Pocasset, MA), on fifteen-minute intervals for 1999 and one-hour intervals for the 2000 growing seasons at a depth of ten centimeters below soil surface. Degree-days were calculated to quantify the accumulation of heat units for each production system treatment. A base temperature of 22^{o}C was utilized based on research by Chen et al. (1968), and Osmond et al. (1981). Degree-days 22 were calculated on an hourly basis as:

$$(((T_i+T_{i+1}) / 2) – 22) * (1/24)$$

where T_I = hourly temperature measurement. A daily accumulated degree-day 22 was calculated by summation of the 24 hourly DD_{22} values.

Soil moisture was measured with a Trime ®-FM3 Time Domain Reflectometry (Mesa Systems, Framingham, MA) soil moisture measurement unit in the 2000 season. The Trime unit utilized 0.5 m tubes placed in the soil at a depth of 0.3 m and located in the center of the row between two tobacco plants. The Trime T3 access probe allowed moisture measurements through the profile at 0-15 and 15-30 cm depths.

Collection and Analysis of Topping Data

Plants were topped and sucker growth controlled following Virginia Cooperative Extension recommendations (Reed et al., 2000). Plants in a given treatment were initially topped when at least 50% inflorescence emergence was observed in at least one replicate plot. Remaining plants were topped weekly until all inflorescences were removed. Data were reported as percentages and arcsine transformed (Gomez and Gomez, 1984) prior to analysis of variance by PROC GLM (SAS Institute, 1989) and Duncan's multiple range test (α=0.05).

Agronomic and Chemical Characteristics of the Cured Leaf

The tobacco was harvested five times, beginning at the bottom of the stalk, as the leaves were determined to be mature and ripe. Leaves from individual plots were separated and identified for curing in a bulk tobacco-curing barn. Throughout all phases, treatments within harvest dates were handled as individual data. Cured leaves from individual treatments within each harvest were graded by a tobacco inspector from the USDA Tobacco Marketing Service and assigned U. S. government grades. Cured leaves were weighed, and yields calculated for a plant population of 16,055 plants ha^{-1}. Prices were determined by average Type 11A values corresponding with USDA grades. The grade index of Bowman et al. (1988) was used to assign numerical values to the tobacco grades. Cured leaf samples from each plot and harvest were dried and ground to pass through a 1 mm mesh screen for laboratory analysis. Total alkaloid and reducing sugar concentration in the cured leaves were determined by extraction and analysis with a modified version of the autoanalyzer procedure described by Davis (1976). Sulfanillic acid was substituted for buffered analine in the total alkaloids procedure. Data are reported as a composite value calculated on a weighted basis according to the proportion of the total yield from five individual harvests.

Results and Discussion

Effects of Production System Management on Temperature and Moisture

Data collected during the 1999 season showed no differences for degree-day temperatures across all treatments (Figure 4.4) however, trends were observed. Strip-killed flat-planted treatments were consistently higher than bedded conventional tillage treatments. An additional treatment that received conventional tillage without bedding (flat-planted conventional tillage) was added in the 2000 season. Results showed similar trends as in 1999, however strip-killed flat-planted treatments accumulated 59% more degree-days in week 1 when compared to flat-planted conventionally cultivated treatments (Figure 4.5). Week 2 and 3 showed strip-killed flat-planted treatments accumulated 11 to 29% and 12 to 31% more degree-days than any other treatments and remaining treatments averaged 19 % more degree days than flat-planted conventional treatments in week 2. All remaining treatments in week 3 averaged 19% more accumulated degree-days when compared to flat-planted conventional treatments.

Moisture content in the soil was increased through the 0-15 cm profile an average of 35% for conventional treatments when compared to flat-planted broadcast-killed treatments on July 6. Increases in soil moisture of 40.5 and 38.5% were measured at the same depth on July 12 when conventional treatments were compared to bedded strip-killed and flat-planted broadcast-killed treatments, respectively. Bedded conventional plots were 20-27% higher in soil moisture than flat-planted treatments and bedded strip-killed treatments on July 19 at the 15-30 cm depth measurements only (Figure 4.6 and 4.7).

Production System Management Effects on Flowering and Topping

Plants were topped on July 16, July 26, and August 4 during the 1999 season. Bedded broadcast-killed treatments averaged 36% fewer plants topped when compared to bedded conventional tillage and bedded strip-killed treatments at first topping. Decreases of 31% were measured when bedded broadcast-killed treatments were compared to bedded conventional, bedded strip-killed, and flat-planted strip-killed treatments at second topping. At both topping dates, all strip-killed and flat broadcast-killed treatments were similar to conventional treatments (Table 4.2). Tobacco was topped on July 13, July 19, and July 28 in 2000. No statistical differences for any treatments were observed (Table 4.3).

Production System Management Effects on Yield, Quality, and Cured Leaf Chemistry

Harvest data from the 1999 season indicated there were no significant treatment effects on tobacco for yield, price, grade index, or value (Table 4.4). Yields decreased an average of 9% for flat-planted conventional, flat-planted broadcast-killed, and bedded strip-killed treatments in 2000 when compared to conventional bedded treatments (Table 4.5). No treatment effects were found for total alkaloid and reducing sugar concentrations in the cured leaf in 1999 and 2000 (Table 4.6).

Higher moisture averages in the conventional plots during the 2000 season may be a result of a semi-permeable hardpan located at plowing depth. Primary tillage operations in conventional plots may limit the travel of water, both downward and upward, through the profile and increase the amounts of water measured. Conversely, the strip-tillage plots may allow excessive moisture to drain away from the root zone, therefore creating a lower moisture environment. Data supports the conclusion that differences occurred between conventional and strip-tillage treatments, however no treatment affects were noted among strip-tillage production practices. Statistical differences noted on the 19th at the 15-30 cm depth may have been a result of 2.5 cm irrigation and 3.8 cm rainfall on the 17th and 19th, respectively.

Warmer temperatures recorded in the flat-planted strip-killed treatments are contrary to previous research reported. However, soil moisture data reported from this research may suggest strip-tillage allows excess soil moisture to drain through the soil profile. Strip-killing residue at a height of 12-15 cm also allows warming to occur more quickly and offers an environment conducive to transplant growth. Lower moisture and less residue would reduce the energy necessary to warm the soil, and increase the amount of solar radiation which reaches the soil surface.

The modest yield differences observed in 2000 may be the result of environmental conditions. Cooler, more wet conditions were encountered early in the 2000 season when compared to the 1999 season (Appendix A). Rainfall was limited in 1999 (Appendix B), and irrigation was relied on to maintain adequate soil moisture. However, in 2000, rainfall was evenly dispersed and adequate throughout the season (Appendix C). Regardless of years, flat-planted strip-killed and bedded broadcast-killed treatments have equaled bedded conventional tillage of flue-cured tobacco.

The use of strip-killed residue management techniques offer the opportunity to maximize total field residue cover for soil erosion, while minimizing residue within the anticipated area of tillage. Minimizing this residue reduces inadequate residue incorporation and improves the action of the strip-tillage implement to prepare a well tilled seed bed. Bedding showed no advantages over flat-planted tobacco, in both years. This study has shown strip-tillage production, with under-row sub-soiling, and flat-planted strip-killed residue management produces tobacco comparable to bedded conventionally cultivated tobacco.

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Figure 4.1. Flue-cured tobacco planted on raised beds with conventional tillage.

Figure 4.2. Additional residue growth by strip-killing cover at a height of 15-20 centimeters with hooded sprayers in the row center

Figure 4.3. Additional cover crop growth at time of broadcast-kill application.

Figure 4.4. Effect of production systems on soil temperature in 1999.

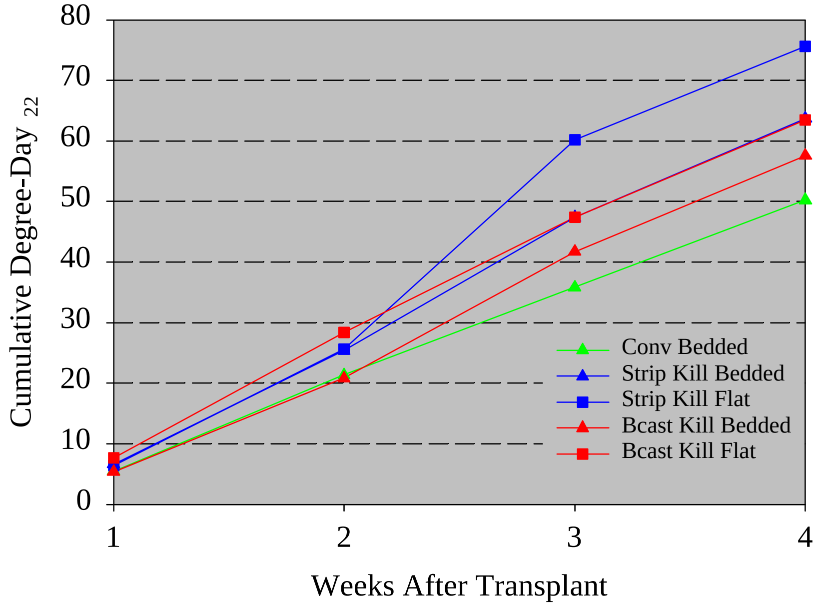

Figure 4.5. Effect of production systems on soil temperature in 2000.

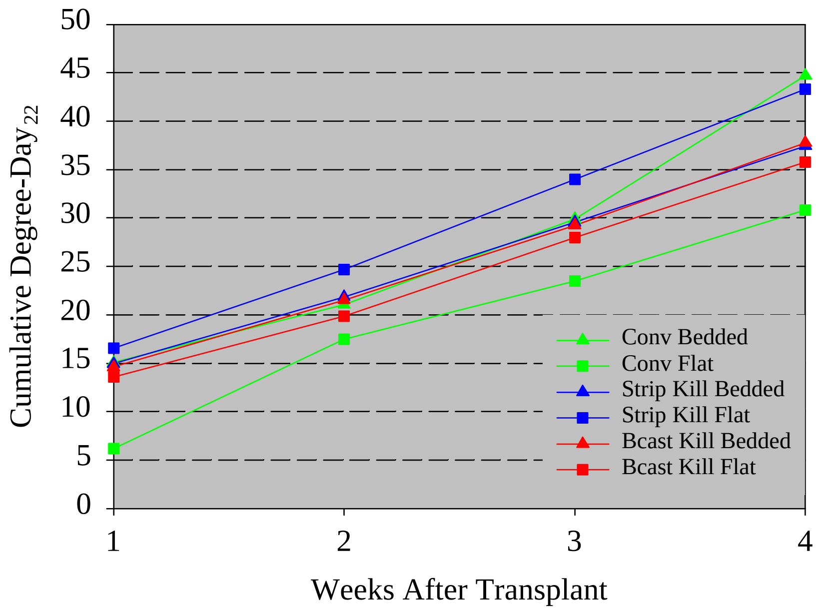

Figure 4.6. Measurements of soil moisture recharge at 0-15 centimeters depth as related to precipitation in 2000.

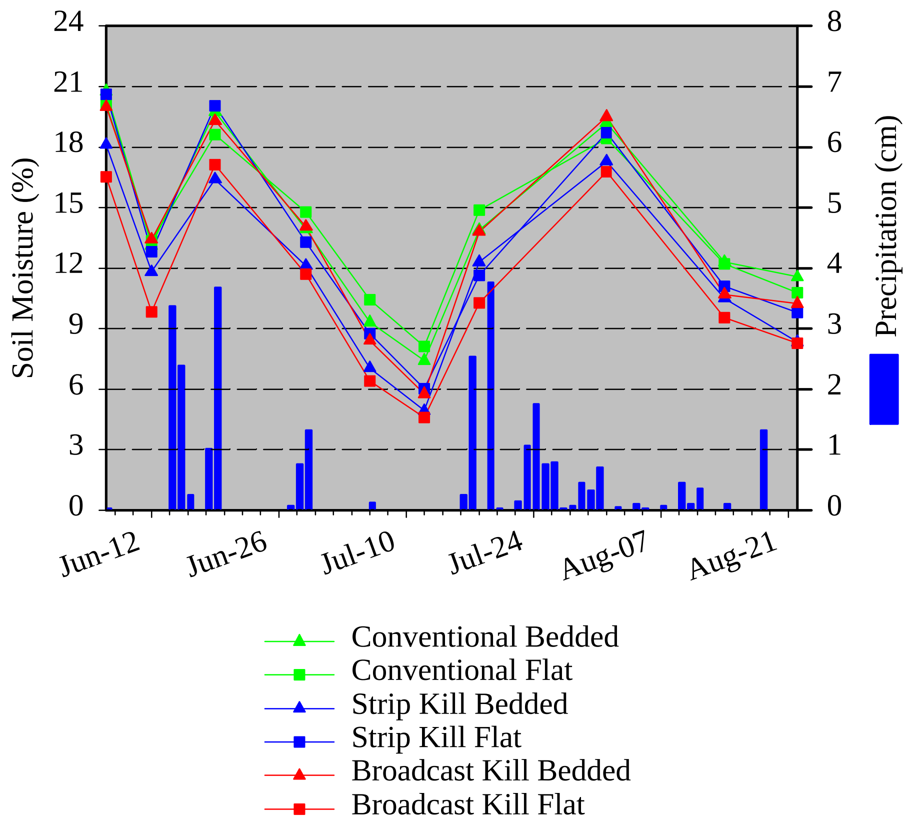

Figure 4.7. Measurements of soil moisture recharge at 15-30 centimeters depth as related to precipitation in 2000.

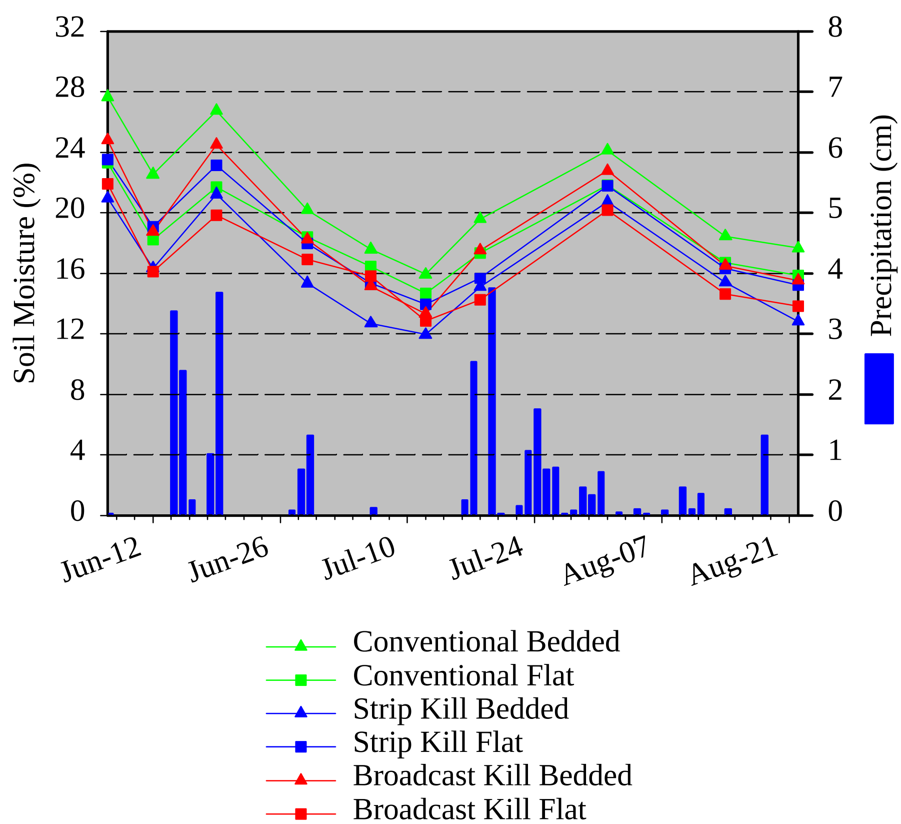

Table 4.1. Production system treatments in 1999 and 2000†.

Production Method	Preparation	Residue Management
Strip-tillage	Bedded	Broadcast-killed
Strip-tillage	Flat	Broadcast-killed
Strip-tillage	Bedded	Strip-killed
Strip-tillage	Flat	Strip-killed
Conventional	Bedded	---
Conventional	Flat	---

† Conventional flat transplanted in 2000 only

Table 4.2. Effects of production systems on percentage plants topped in 1999.

Treatments	Cumulative percent plants topped July 16	Cumulative percent plants topped July 26
Conventional Bedded	48 a†	76 a
Broadcast-killed Bedded	17 b	41 b
Broadcast-killed Flat	28 ab	58 ab
Strip-killed Bedded	57 a	71 a
Strip-killed Flat	42 ab	76 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 4.3. Effects of production systems on percentage plants topped in 2000.

Treatments	Cumulative percent plants topped July 13	Cumulative percent plants topped July 19
Conventional Bedded	56 a†	94 a
Conventional Flat	48 a	92 a
Broadcast-killed Bedded	39 a	92 a
Broadcast-killed Flat	41 a	96 a
Strip-killed Bedded	33 a	94 a
Strip-killed Flat	28 a	89 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 4.4. Effects of production systems on yield, market price, grade index, and value in 1999.

Treatment	Yield kg ha^{-1}	Price \$ ha^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Conventional Bedded	3,755 a†	4.42 a	77.6 a	16,597 a
Broadcast-killed Bedded	3,779 a	4.44 a	79.4 a	16,779 a
Broadcast-killed Flat	3,902 a	4.44 a	77.8 a	17,325 a
Strip-killed Bedded	3,894 a	4.42 a	76.4 a	17,211 a
Strip-killed Flat	3,828 a	4.42 a	76.4 a	16,920 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 4.5. Effects of production systems on yield, market price, grade index, and value in 2000.

Treatment	Yield kg ha^{-1}	Price \$ ha^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Conventional Bedded	3,638 a†	4.57 a	82.2 a	16,626 a
Conventional Flat	3,291 b	4.54 a	81.7 a	14,941 b
Broadcast-killed Bedded	3,502 ab	4.57 a	81.2 a	16,004 ab
Broadcast-killed Flat	3,293 b	4.54 a	81.3 a	14,950 b
Strip-killed Bedded	3,301 b	4.54 a	81.8 a	14,987 b
Strip-killed Flat	3,422 ab	4.54 a	81.2 a	15,536 ab

† Treatments with same letters indicate no significant differences at α=0.05

Table 4.6. Effects of production systems on total alkaloid and reducing sugar concentration in the cured leaf for 1999 and 2000.†

Treatment	1999 Nic	1999 RS	2000 Nic	2000 RS
	——— % ———		——— % ———	
Conventional Bedded	3.5 a‡	10.5 a	3.3 a	11.6 a
Conventional Flat	---	---	3.4 a	10.9 a
Broadcast-killed Bedded	3.4 a	10.0 a	3.4 a	11.2 a
Broadcast-killed Flat	3.5 a	10.8 a	3.3 a	10.3 a
Strip-killed Bedded	3.6 a	9.8 a	3.3 a	10.8 a
Strip-killed Flat	3.6 a	10.2 a	3.2 a	10.8 a

† Weighted averages calculated from percent total alkaloids or reducing sugar per harvest multiplied by percent of total leaf weight per harvest

‡Treatments with same letters indicate no significant differences at α=0.05

Chapter V

Starter Fertilizer and Cover Crop Effects on Virginia Dark Fire-Cured Tobacco

Abstract

Strip-tillage production of dark fire-cured tobacco has shown potential as an alternative production system. Cool, wet soils commonly associated with conservation tillage may result in slow, non-uniform transplant growth, affecting the plants development throughout the season. Starter fertilizer may lessen the effects of the non-uniform growth. The objective of this research was to evaluate rates and method of starter fertilizer application on early-season transplant growth and cured leaf yield, quality, and total alkaloid and reducing sugar concentration. Cover crops were killed in strip 30 cm wide with a 1.4 kg active ingredient (a.i.) ha^{-1} rate of paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) utilizing a hooded sprayer and subsequently broadcast killed with the same rate of paraquat dichloride. Strip-tillage treatments received three rates (11, 22, and 45 kg ha^{-1}) of 9-45-15 ($N:P_2O_5:K_2O$) injected with the strip-tillage implement and a transplant water treatment of 11 kg ha^{-1} in 1999. These treatments were compared to conventionally cultivated treatments receiving no starter fertilizer. Two additional treatments (strip-tillage control and conventional tillage with 11 kg ha^{-1} starter fertilizer applied in the transplant water) were included in 2000. The dark fire-cured cultivar 'VA 359' was transplanted into a two-year old crimson clover cover crop in 1999, with treatments arranged in a randomized complete block design. Cultivar 'Brownleaf JH' was transplanted into wheat and red clover cover crop treatments arranged in a split-plot design with fertilizer treatments arranged within the cover crop treatments as a randomized complete block design in 2000. No differences were observed in 2000 for early season transplant growth when starter fertilizer

treatments were compared to conventionally cultivated tobacco receiving no starter fertilizer. No differences were observed in 1999 for uniformity of flowering. However, in 2000, 11 kg ha^{-1} transplant water treatments and strip-tillage treatments receiving an injected rate of 45 kg ha^{-1} increased topping an average of 29% when compared to conventional tillage receiving no starter fertilizer for the July 17 date. No differences were observed in yield, quality, reducing sugar or total alkaloids for either year. Research showed increased uniformity of topping for all transplant water treatments and strip-tillage treatments receiving 45 kg ha^{-1} in 2000. Economically, injection of starter fertilizer can not be justified and applying 11 kg ha^{-1} through the transplant water is suggested.

Introduction

Lower soil temperature and increased soil moisture, common in conservation tillage, may result in slow early season tobacco growth. Non-uniform growth may impact cured leaf quality through non-uniform topping and resulting effects on tobacco maturity. Temperature and moisture fluctuations may compromise nutrient availability and uptake to the transplant (Hanks, 1992). Phosphorous, a critical nutrient involved in RNA, DNA, photosynthesis, phosphorylation, and other plant metabolism mechanisms, is closely linked to soil temperature and moisture (Terry and Terrill, 1971; Mellish, 1978; Traynor, 1980). Therefore, plant growth may be reduced if soil temperature and moisture are less than optimum. Phosphorous, taken up primarily through diffusion, is also affected by root mass and area. After transplanting, the fibrous root system desiccates and growth cessation must be minimized by rapidly establishing a functional root system (Dean et al, 1960). The use of transplant starter fertilizer may be beneficial in accelerating the establishment of a functional root system, and supplying the young plant with an adequate supply of phosphorous.

Jones (1998) observed potential dark fire-cured tobacco yield reductions resulting from clover cover crops used during the 1996 and 1997 growing seasons. Phenols, from leguminous green manure crops, have been documented as providing allelopathic effect on wild mustard (*Sinapis arvensis* L.) seedling radicle growth 8 days after incorporation of legume residue (Ohno et al., 2000). However, the degree of allelopathic effects and potential for interactions among toxins in the soil, current crop root exudates, pathogens, nutrient levels, and plant densities are still debated (Seigler, 1996; Einhellig, 1996). Objectives of this study were to evaluate rate and application method of starter fertilizer on early season transplant growth, topping, and agronomic measures of the cured leaf and determine potential allelopathic effects of clover on dark fire-cured tobacco.

Materials and Methods

This research was conducted at the Southern Piedmont Agricultural Research and Extension Center near Blackstone, Virginia. Dark fire-cured tobacco cultivar 'VA 359' was transplanted in a field containing a Wedowee soil series (Fine, kaolinitic, thermic Typic Kanhapludult, 2-6% slope) in 1999. Metalaxyl ((r)-2-[2,6-dimethylphenyl)-methoxyacetylamino]-propionic acid methyl ester) was broadcast applied prior to planting and at last cultivation at 0.6 kg active ingredient (a.i.) ha^{-1} to reduce problems with black shank. In 2000, cultivar 'Brownleaf JH' was planted into a Helena soil series (Fine, mixed semiactive, Thermic Aquic Hapludult, 2-6% slope). For both years, paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) was strip-sprayed in 25 cm bands at a rate of 1.4 kg a.i. ha^{-1} with hooded sprayers to burndown the cover crop within the area to be strip-tilled. A subsequent application of paraquat dichloride at the same rate was broadcast to control remaining residue. Sulfentrazone (N-[2,4-dichloro-5-[4-(difluromehtyl)-4,5-dihydro-3-methyl-5-oxo-1h-1,2,4-

triazol-1-yl]phenyl]methanesulfonamide), and clomazone (2-(2-chlorophenyl)methyl-4,4-dimethyl-3-isoxazolidione) were broadcast applied at 0.32 and 0.84 kg a.i. ha^{-1}, respectively, prior to transplanting for weed control.

A two-row KMC® (Kelley Manufacturing Company, Tifton, GA) strip-tillage implement was used for the research. Row spacing was 122 cm. Injected starter fertilizer treatments were applied with stainless steel fumigation tubes equipped with a 5 mm diameter hole mounted behind each sub-soil shank on the strip-tillage unit.

One transplant water rate (11 kg ha^{-1}) and 3 strip-tillage injected rates (11,22, and 45 kg ha^{-1}) of 9-45-15 ($N:P_2O_5:K_2O$) starter fertilizer were compared to conventional tillage with no starter fertilizer (Table 5.1) in 1999. Treatments were replicated six times and transplanted into a two year old crimson clover field on May 20 in a randomized complete block design. The 2000 test was expanded to investigate treatment effects on two cover crop treatments (red clover and wheat) in a split-plot design. Two additional treatments (strip tillage control and conventional tillage receiving 11 kg ha^{-1} starter fertilizer applied with the transplant water) were added in 2000 (Table 5.2). Cover crops were whole-plot factors while transplant starter fertilizer treatments were sub-plot factors.

Base fertilizer, 6-12-18 ($N:P_2O_5:K_2O$), was applied at a rate of 840 kg ha^{-1} with the fertilizer-transplanter both years. Additional nutrients were supplied with side-dress applications of 224 kg ha^{-1} (15-0-14) with double disk openers placing fertilizer in bands 5 cm deep and 12 cm on each side of the plants. Remaining fertilizer (33-0-0) was side-dressed at a rate of 179 kg ha^{-1} with double disk openers. Cutworms, hornworms, and budworms were controlled, as necessary, throughout the season with applications of 0.84 kg a.i. ha^{-1} acephate (O,S-Dimethyl acetyl-phosphoramidothioate).

All plants were cultivated a minimum of two times with the Sukup® High Residue Cultivator (Sukup Manufacturing Company, Sheffield, IO) to reduce crusting of the soil surface and build a ridge of soil in the planted row both years. Sethoxydim ([2-1-(ethoxyimino) butyl]-5-[2-(ethylthio) propyl]-3-hydroxy-2-cyclohexen-1-one) was used as a spot application at 0.21 kg a.i. ha^{-1} for grass control. Irrigation was applied with a travelling gun in 1999 as necessary to maintain adequate soil water content. Plants were stalk cut and cured in a traditional dark fire-cured barn.

Plant Growth Measurements

Transplants were interplanted between plants in rows for each treatment, utilizing the existing randomized complete block design. After four weeks, plants were extracted from the soil with minimal root disturbance. Leaves were removed, and the sampled plants were separated into roots, stems, and leaves. The line of color transition was used to differentiate between root and stem portions. Fresh weight was recorded for all plant parts and leaf area was measured with a Li-Cor® LI-3100 area meter (Li-Cor Biosciences, Lincoln, Nebraska). Oven-dried roots were recorded following overnight drying at 38^{o} C. Analysis of variance was conducted using PROC GLM (SAS Institute, 1989) and treatment differences evaluated using Duncan's multiple range test (α=0.05).

Collection and Analysis of Topping Data

Plants were topped and sucker growth controlled with three applications (4% rate) of a fatty alcohol (0.4% C_6; 46.1% C_8; 53.2% C_{10}; 0.3% C_{12}) suckercide both years and a final application of flumetralin (2-chloro-N-[2,6-dinitro-4-(trifluoromethyl) phenyl]-N-ethyl-6-fluorobenzenemethanamine) applied at the rate of 1.3 kg a.i. ha^{-1} and maleic hydrazide (potassium salt of 1,2-dihydro-3,6-pyradazinedione) at the rate of 3.4 kg a.i. ha^{-1} in 1999 and

2000, respectively. Plants in a given treatment were initially topped when at least 50% of the plants in at least one replicate plot reached button stage (elongation of apical meristem). Remaining plants were topped weekly until all buttons were removed. Data were reported as percentages and arcsine transformed (Gomez and Gomez, 1984) prior to analysis of variance by PROC GLM (SAS Institute, 1989) and Duncan's multiple range test (α=0.05).

Agronomic and Chemical Characteristics of the Cured Leaf

After curing, leaves were removed from the stalk in three stalk positions. Cured leaves from individual treatments were graded by a tobacco inspector from the USDA Tobacco Marketing Service and assigned U. S. government grades. Cured leaves were weighted, and yields calculated for a plant population of 13,457 plants ha^{-1}. Prices were determined by average Type 21 values corresponding with USDA grades. The grade index of Wilkinson and Tilson (1992) was used to assign numerical values to the tobacco grades. Cured leaf samples from each plot were dried and ground to pass through a 1 mm mesh screen for laboratory analysis. Total alkaloid concentration was determined by extraction and analysis as described by Davis (1976). Data are reported as a composite value calculated on a weighted basis according to the proportion of yield from three individual stalk positions.

Results and Discussion

Effect of Starter Fertilizer and Cover Crop on Agronomic Measures

Interplanted tobacco data was collected only in 2000. From these plants, no cover crop effect or fertilizer treatment effect was observed (Table 5.3). Similar topping data trends for all treatments were observed for each year of the study. At first and second topping in 1999 strip-tillage and conventional tillage treatments were statistically similar in percent plants topped (Table 5.4) but an increase in topping was observed for starter fertilizer use. In 2000, at first topping, both conventional 11 kg ha^{-1} transplant water treatments were higher in plants topped than the control treatments, and the lower rates of injected fertilizer (11 and 22 kg ha^{-1}). Strip-tillage treatments receiving 45 kg ha^{-1} injected starter fertilizer had more plants topped than conventional control treatments, but was similar to 11 kg ha^{-1} transplant water treatments, all strip-tillage injected treatments, and strip-tillage control treatments. Conventional tillage receiving no starter fertilizer were 33% less uniform when compared to conventional tillage receiving 11 kg ha^{-1}. At second topping, all treatments were at least 95% topped (Table 5.5).

Starter Fertilizer and Cover Crop Effect on Yield, Quality and Cured Leaf Chemistry

Yield and grade indexes obtained were lower than expected in 1999, however slower growth during the early season may be a result of limited rainfall (Appendix A) and clayey soil. No differences were obtained for yield, grade index, price, and value (Table 5.7). Although yield and grade index in 2000 were higher than those observed in 1999, no differences were obtained among starter fertilizer treatments (Table 5.8). Percent total alkaloid concentrations for both years were statistically non-significant (Table 5.9).

Cover Crop Effects

Differences were not detected between wheat or clover cover crops during the 2000 season, nor were yields different between conventional and clover cover crop treatments in 1999. During the 2000 season, wheat was used as the cover crop for conventional plots, but no differences were obtained for any treatments due to cover crop.

During the early 1999 growing season hot, dry conditions were encountered. Visible stunting was noticed during the first two months of growth, with severe effects still visible at harvest. During the 1999 season, the two-year old cover crop was allowed to grow until mid-spring. Conventional plots were then plowed and the cover crop residue incorporated into the soil. This residue may still have an allelopathic effect on the conventional treatments, although it was a conventionally cultivated. In 2000, stunting was not visible, but abundant rainfall and lower temperatures throughout the early season may have not been conducive for an allelopathic effect. Differences in plant growth between the two years are most likely the result of seasonal differences.

Due to the stresses imposed on the transplants during the 1999 season, plants may have prematurely reverted to the reproductive stage and therefore, data may show more plants flowering earlier in the season. The reliability of data gathered during the 1999 season is questionable, due to the severity of plant stunting, and must be examined with caution. Early season growth increases and uniform flowering was observed in 2000 for treatments receiving 11 kg ha^{-1} applied through transplant water and 45 kg ha^{-1} injected treatments. Economically, injection can not be justified and it is recommended that 11 kg ha^{-1} starter fertilizer be applied through the transplant water.

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Table 5.1. Dark fire-cured tobacco starter fertilizer treatments in 1999 and 2000†

Production Method	Fertilizer Rate	Method
Strip-tillage	11 kg ha^{-1}	Injected
Strip-tillage	22 kg ha^{-1}	Injected
Strip-tillage	45 kg ha^{-1}	Injected
Strip-tillage	11 kg ha^{-1}	Transplant Water
Strip-tillage‡	Control	---
Conventional‡	11 kg ha^{-1}	Transplant Water
Conventional	Control	---

† All treatments randomized in wheat and clover cover crops as a split-plot design
‡ Treatments added in 2000

Table 5.3. Effects of starter fertilizer on early season transplant growth[†]

Treatment			Root Weight		Stem		Leaf	
System	Rate kg ha^{-1}	Method	Green (g)	Dry (g)	Height (cm)	Weight (g)	Area (cm^2)	Weight (g)
Strip-tillage	11	Injected	14.4 a[‡]	2.7 a	24.0 a	60.5 a	3464 a	214 a
Strip-tillage	22	Injected	14.4 a	2.8 a	23.7 a	59.8 a	3425 a	265 a
Strip-tillage	45	Injected	14.4 a	2.9 a	24.3 a	62.5 a	3382 a	221 a
Strip-tillage	11	Transplant Water	13.5 a	2.8 a	24.4 a	60.1 a	3220 a	194 a
Strip-tillage	---	Control	14.3 a	2.6 a	23.4 a	60.1 a	3518 a	225 a
Conventional	11	Transplant Water	15.4 a	2.7 a	25.3 a	58.2 a	3468 a	217 a
Conventional	---	Control	14.8 a	2.8 a	20.8 a	52.9 a	2795 a	198 a

† No cover crop interaction

‡ Treatments with the same letters indicate no significant differences at α=0.05

Table 5.4. Effects of starter fertilizer and cover crops on percentage plants topped in 1999

Treatment			Cumulative percent plants topped	
System	Rate kg ha^{-1}	Method	July 16	July 22
Strip-tillage	11	Injected	79 a†	91 a
Strip-tillage	22	Injected	72 a	89 a
Strip-tillage	45	Injected	74 a	89 a
Strip-tillage	11	Transplant Water	83 a	94 a
Conventional	---	Control	70 a	91 a

† Treatments with the same letters indicate no significant differences at α=0.05

Table 5.5. Effects of starter fertilizer and cover crop on percentage plants topped in 2000.

Treatment			Cumulative percent plants topped	
System	Rate kg ha^{-1}	Method	July 10	July 17
Strip-tillage	11	Injected	28 bc†	99 a
Strip-tillage	22	Injected	28 bc	98 a
Strip-tillage	45	Injected	39 ab	100 a
Strip-tillage	11	Transplant Water	56 a	98 a
Strip-tillage	---	Control	24 bc	97 a
Conventional	11	Transplant Water	52 a	100 a
Conventional	---	Control	19 c	99 a

† Treatments with the same letters indicate no significant differences at α=0.05

Table 5.6. Effects of starter fertilizer and cover crop on yield, market price, grade index, and value in 1999.

Treatment						
System	Rate kg ha^{-1}	Method	Yield kg ha^{-1}	Price \$ kg^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Strip-tillage	11	Injected	2,024 a†	3.46 a	44.6 a	7,003 a
Strip-tillage	22	Injected	1,960 a	3.31 a	42.4 a	6,488 a
Strip-tillage	45	Injected	2,013 a	3.51 a	45.6 a	7,066 a
Strip-tillage	11	Transplant Water	1,919 a	3.43 a	44.0 a	6,582 a
Conventional	---	Control	1,944 a	3.23 a	43.4 a	6,279 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 5.7. Effects of starter fertilizer and cover crop on yield, market price, grade index, and value in 2000.

Treatments System	Rate kg ha^{-1}	Method	Yield kg ha^{-1}	Price \$ kg^{-1}	Grade Index (0-100)	Value \$ ha^{-1}
Strip-tillage	11	Injected	2,567 a†	4.59 a	60.8 a	11,783 a
Strip-tillage	22	Injected	2,523 a	4.59 a	61.9 a	11,581 a
Strip-tillage	45	Injected	2,574 a	4.47 a	60.0 a	11,506 a
Strip-tillage	11	Transplant Water	2,601 a	4.64 a	62.2 a	12,069 a
Strip-tillage	---	Control	2,653 a	4.47 a	59.1 a	11,859 a
Conventional	11	Transplant Water	2,443 a	4.89 a	63.0 a	11,946 a
Conventional	---	Control	2,517 a	4.62 a	61.0 a	11,629 a

† Treatments with same letters indicate no significant differences at α=0.05

Table 5.8. Effects of starter fertilizer and cover crop on percent total alkaloids in the cured leaf for 1999 and 2000.

Treatments				
System	Rate kg ha^{-1}	Method	1999	2000
			%	
Strip-tillage	11	Injected	5.76 a†	6.74 a
Strip-tillage	22	Injected	5.73 a	6.78 a
Strip-tillage	45	Injected	5.75 a	6.86 a
Strip-tillage	11	Transplant Water	5.84 a	6.67 a
Strip-tillage	---	Control	---	6.75 a
Conventional	11	Transplant Water	---	6.65 a
Conventional	---	Control	5.67 a	6.67 a

† Treatments with same letters indicate no significant differences at α=0.05

Chapter VI

CONCLUSIONS AND FUTURE RESEARCH DIRECTION

Earlier research conducted at the Southern Piedmont Agricultural Research and Extension Center resulted in the acceptance of secondary cultivations minimizing the amount of erosion on no-tillage plots. No-till tobacco yields comparable to conventional tillage were possible with the addition of two row-ridge cultivations. However, slow early season growth associated with the conservation tillage practice had not been eliminated. Irregular growth and generalized stunting were proposed to be the result of inadequate root to soil contact during the transplanting process.

Strip-tillage was felt to be a way to overcome problems associated with the transplanting process in no-tillage, but irregular transplant growth was still noticeable. Limited research had been conducted to evaluate changes in the environmental conditions of the soil caused by the change in production practices. In 1999, research was initiated to monitor environmental conditions of the strip-tillage production system. Cooler soil temperatures and increased moisture content were expected, and starter fertilizer evaluation tests were used to overcome potential for lower nutrient availability under these circumstances.

Although yield and cured leaf quality increases were not obtained, root weights increased an average of 23 and 49% and leaf area an average of 41 and 35% by applying starter fertilizer in 1999 and 2000, respectively. Uniformity of plants at topping increased 49% in 1999 and an average increase of 45.5% in 2000 with starter fertilizer applications.

The necessity of a pre-formed bed was questioned due to the increased depth of tillage associated with the sub-soil shank on the strip-tillage cultivator. Temperature and moisture obtained in flat or bedded surface treatments proved beds are not necessary in a strip-tillage production system. Moisture increases averaging 35% was observed at the 0-15 cm depth when conventional tillage was compared to broadcast-killed flat-planted strip-tillage treatments. Increases in moisture at the 15-30 cm depth was also observed on July 12 when conventional tillage was compared to strip-killed bedded and broadcast-killed flat-planted strip-tillage treatments. Temperatures were similar among treatments in 1999, however in 2000, flat-planted conventional tillage treatments were 59% lower in accumulated degree-days in week 1 than all other treatments. All treatments were 21% lower in accumulated degree-days when compared to flat-planted strip-killed treatments in weeks 2 and 3. Lower moisture content, and comparable temperatures between production practices denote an optimum environment for transplant establishment and subsequent growth for tobacco transplants. Due to problems associated with excessive residue incorporation, it is advisable to utilize a 30 cm banded burndown herbicide spray (achieved with hooded sprayers) over the projected area of transplanting with a subsequent broadcast application of a burndown herbicide. This research has concluded flat-planted tobacco utilizing strip-killed residue management and 11 kg ha^{-1} 9-45-15 ($N:P_2O_5:K_2O$) starter fertilizer applied in the transplant water equals the yield and quality of conventionally tilled tobacco, and is the most efficient production method for strip-tillage tobacco.

A need for evaluation of cultivation frequency, chemical applications, and insect control in strip-tillage systems exists. Past research citing an increased yield with secondary cultivation was conducted on no-tillage plots only. However, the incorporation of primary tillage in a conservation tillage regime, as in strip-tillage, may overcome the causal mechanisms of reduced yields in the no-tillage production system. General production methods for disease, nematode, and insect control, in strip-tillage production systems must be evaluated and new methods of applying soil-incorporated pesticides must be sought. Feasibility of utilizing mechanical harvesters should be considered in strip-tillage production systems. The increased residue may prevent harvesters from functioning as anticipated, or damage to leaves may result from residue. Future research interests should also include the combination of flat and bedded production systems into a starter fertilizer program. All research conducted during the 1999 and 2000 seasons for starter fertilizer evaluations were conducted on flat surfaces and a further increase in early season transplant growth may be obtained by applying starter fertilizer to tobacco planted on traditional beds.

Appendix A

Climatic data corresponding to four week growth period of interplanted seedling in 1999 and 2000.

		1999				2000			
		Temperature			Rain	Temperature			Rain
Month	Day	Max	Min	Avg	Total	Max	Min	Avg	Total
5	5	-	-	-	-	82.00	57.00	69.50	0.00
5	6	-	-	-	-	86.00	62.00	74.00	0.00
5	7	-	-	-	-	86.00	66.00	76.00	0.00
5	8	-	-	-	-	86.00	64.00	75.00	0.00
5	9	-	-	-	-	85.00	67.00	76.00	0.00
5	10	-	-	-	-	84.00	68.00	76.00	0.00
5	11	-	-	-	-	80.00	51.00	65.50	0.00
5	12	-	-	-	-	88.00	59.00	73.50	0.00
5	13	-	-	-	-	90.00	70.00	80.00	0.00
5	14	-	-	-	-	78.00	60.00	69.00	0.00
5	15	-	-	-	-	72.00	50.00	61.00	0.00
5	16	-	-	-	-	73.00	47.00	60.00	0.00
5	17	-	-	-	-	82.04	55.94	69.70	0.00
5	18	81.32	52.88	66.40	0.00	86.36	63.68	75.87	0.00
5	19	78.62	55.04	66.04	0.00	88.16	65.84	75.43	0.11
5	20	79.16	51.08	63.72	0.00	90.14	61.88	72.03	0.42
5	21	84.56	47.84	67.74	0.00	69.44	60.44	64.42	0.13
5	22	88.16	57.92	71.52	0.10	78.80	59.00	66.70	0.52
5	23	84.38	62.24	72.79	0.20	78.08	50.00	69.29	0.00
5	24	82.94	57.38	71.41	0.00	89.06	63.68	76.75	0.00
5	25	75.38	50.00	63.19	0.00	80.42	60.26	72.42	0.04
5	26	77.36	54.50	64.99	0.00	82.94	52.88	69.33	0.00
5	27	78.26	49.28	65.51	0.00	84.38	59.90	69.44	1.55
5	28	85.82	50.18	70.19	0.00	63.00	58.00	61.50	0.58
5	29	89.78	58.10	74.04	0.00	62.00	49.10	55.00	0.17
5	30	92.84	59.54	75.72	0.00	63.86	48.38	55.38	0.00
5	31	86.90	61.70	74.17	0.00	80.42	49.10	64.96	0.00
6	1	86.54	60.80	73.05	0.00	91.94	58.46	74.77	0.00
6	2	87.26	61.88	75.95	0.00	93.56	67.64	82.10	0.00
6	3	91.04	69.98	78.35	0.00	82.04	65.30	74.73	0.00
6	4	83.30	58.28	70.05	0.00	76.82	57.56	66.81	0.00
6	5	83.84	53.60	69.17	0.00	73.22	61.70	65.13	0.22
6	6	87.80	53.78	70.47	0.00	75.92	58.10	65.17	0.54
6	7	96.26	61.52	79.33	0.00	78.98	53.06	65.61	0.01
6	8	98.96	69.44	84.33	0.00	80.96	54.14	68.84	0.00
6	9	98.60	68.72	83.63	0.00	88.52	60.62	74.27	0.00
6	10	84.74	66.38	73.99	0.00	90.68	66.20	77.90	0.00
6	11	83.84	57.38	71.10	0.00	91.04	67.28	78.64	0.00
6	12	78.26	52.52	66.27	0.17	96.98	68.90	82.18	0.00
6	13	85.46	65.30	72.22	0.16	93.92	70.88	82.30	0.00
6	14	92.48	65.30	79.33	0.00	89.06	69.80	77.92	1.33
6	15	-	-	-	-	93.02	69.62	82.97	0.94
6	16	-	-	-	-	88.16	69.26	76.99	0.10

Appendix B

Weekly rainfall during the 1999 season

Week of:		Precipitation (cm)
May	2	0.00
May	9	5.03
May	16	0.25
May	23	0.51
May	30	0.00
June	6	0.43
June	13	2.69
June	20	1.37
June	27	1.40
July	4	0.20
July	11	3.99
July	18	1.30
July	25	0.69
August	1	0.61
August	8	1.30
August	15	1.37
August	22	2.03
Total Rainfall		**23.16**

Appendix C

Weekly rainfall during the 2000 season

Week of:		Precipitation (cm)
May	1	0.00
May	8	0.00
May	15	1.68
May	22	6.83
May	29	0.43
June	5	1.96
June	12	7.04
June	19	3.68
June	26	2.16
July	3	0.13
July	10	0.25
July	17	5.00
July	24	4.19
July	31	0.91
August	7	0.99
August	14	1.42
August	21	2.13
Total Rainfall		**38.81**

VITA

Scottie Lee Jerrell, the oldest of three children of Harold Lee and Nancy Leticia Jerrell, was born June 29, 1976. He grew up on the family farm where they raised burley tobacco and beef cattle. He attended Rose Hill Elementary School, and graduated with honors from Thomas Walker High School in 1994. After attending Lincoln Memorial University, Scott fulfilled a life-long dream of attending The University of Tennessee, Knoxville. While at U.T., he interned with the U.T. Agricultural Extension Service and developed a desire to pursue a career in Extension. In 1998, he was awarded a Bachelor's of Science in Agriculture and moved to Blackstone, VA where he started his graduate research at Virginia Tech Southern Piedmont Agricultural Research and Extension Center. Following the completion of his thesis, Scott will start work for Virginia Cooperative Extension as Associate Extension Agent in Crop and Soil Environmental Sciences in Wythe and Bland counties. On June 16, 2001, he will be married to Miss M. Allison Coleburn.